Volume 42

Number 3

December 2017

ISSN 2230-9705

Journal of Agriculture Research and Technology

Publication of the

Mahatma Phule Krishi Vidyapeeth, Rahuri,
Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola,
Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani and
Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, M.S. (India)

www.jart.co.in

Published on the Occasion of International Seminar on "Global Climate Change: Implications for agriculture and water sectors" (14-16 December, 2017)

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Journal of Agriculture Research and Technology

Volume 42 **Number 3** **December 2017**

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J. Agric. Res. Technol., 42 (3) : 005-009 (2017)

Broad Bed and Furrow Technique- A Climate Smart Technology for Rainfed Soybean of Marathwada Region

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Abstract

A field experiment was conducted during three consecutive years of 2014 to 2016 with objectives of the studies are to find out the effect of various land configurations and nutrient cum stress management practices on growth and yield of soybean. The experiment was designed in split plot design with three replications. The main plot treatment comprised of three land configuration i.e. BBF, ridges and furrows and flat bed with eight sub plot treatments fertilizer cum stress management practices. The gross and net plot sizes are 5.4 x 6.0m and 4.5 x 5.0m respectively. The soybean variety MAUS-162 was used for sowing with spacing of 45 x 5cm. In case of land configuration, the pooled results revealed that yield attributing parameters like number of pods per plant, seed weight per plant, pod weight and seed index were found highest in soybean sown on Broad bed furrow as compared to flat bed and ridges and furrow. In case of fertilizer cum stress management practices, RDF + KNO_3 @ 1 and 2% and RDF + micronutrient mixture @ 0.5% recorded higher yield attributing characters in pooled analysis. Highest soybean seed yield, GMR, NMR and BC ratio was observed with soybean sown on BBF land configuration in pooled analysis. In case of fertilizer cum stress management practices, RDF + KNO_3 @ 1 & 2% and RDF + micronutrient mixture @ 0.5% recorded higher soybean seed yield, GMR, NMR and BC ration in pooled analysis. Higher rain water use efficiency was recorded in BBF sowing and RDF + KNO_3 spray @ 1 and 2%. Higher moisture content was observed in soybean sown with BBF as compared to flat bed and ridges and furrow method. It is concluded that BBF technique is proved as climate smart technique for growing of soybean under rainfed condition.

Key words : Rainfed soybean, broad bed furrow, stress management, micronutrients.

In Maharashtra and Marathwada the area under rainfed agriculture is to the tune of 80 and 83 per cent respectively. The climate of Marathwada experiences wide district and intra district variability. The annual rainfall in this region ranges from 516.0 mm to 1109 mm. More than 50% talukas receive annual rainfall in the range of 600 to 800 mm. The incidental dry and wet spell lengths pose various problems in the growing field crops. The agricultural production in Marathwada region of Maharashtra State is limited primarily by erratic nature of the monsoon rains. Integrated land and water approach aimed at optimising the use of land, water and vegetation in an area to alleviate drought, moderate floods, improve water availability and increase fuel, fodder and agricultural production on sustained basis.

Majority of population living in Marathwada region depend upon rainfed agriculture. Rainfall is uncertain and erratic in this region and sometimes suffers from severe droughts. The rainfall is one of the most important natural input given to agriculture. The fate of rainfed kharif crops largely depend upon the amount and distribution of rain. The productivity of soybean crop decreases with either insufficient of rainfall and its distribution or due to moisture stress in critical growth period due to dryspells occurred in July and August. Soybean is a major crop cultivated in Maharashtra as well as in Marathwada. The

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area under soybean is 35 lakh ha and 15 lakh ha in Maharashtra and Marathwada region respectively

Although the area under soybean cultivation during the last decade has been expanded continuously, yet its productivity has not followed the same trend due to uncertainty in rainfall. In this context, the experiment was planned to enhance the soybean productivity using various land configurations and stress management practices

Material and Methods

The field experiment was conducted during three consecutive years of 2014 to 2016 at the research farm of AICRP for Dryland Agriculture, VNMKV, Parbhani. The objectives of the studies were to find out the effects of various land configurations and nutrient cum stress management practices on growth and yield of soybean. The experiment was designed in split plot design with three replications. The main plot treatment comprised of three land configuration i.e. Broad bed furrows, ridges and furrows and flat bed with eight sub plot treatments fertilizer cum stress management practices. The fertilizer cum stress management practices were F_1: RDF (30:60:30 NPK kg ha^{-1}), F_2: RDF + Foliar Application of KNO_3 two sprays @ 1% & 2%, F_3: RDF + Foliar Application of NPK (19:19:19) two sprays @ 0.5%, F_4: RDF + Foliar Application of MoP two sprays @ 1% & 2%, F_5: RDF + Foliar Application of micronutrient mixture two sprays @ 0.5%, F_6: RDF + Straw Mulch @ 3 t ha^{-1}, F_7: RDF + Anti-transparent Kaolin two

Table 1. Soybean seed yield (kg ha^{-1}), GMR, NMR, BC ratio and RWUE as influenced by different treatments (2014-2016)

Treatment	Poold mean				
	Soybean yield (kg ha^{-1})	GMR (Rs. ha^{-1})	NMR (Rs. ha^{-1})	B:C ratio	RWUE
Main plots: Land configurations : (03)					
L_1 : Flat Bed	1148	34782	9263	1.36	2.77
L_2 : BBF	1460	44191	18587	1.72	3.50
L_3 : Ridges & Furrow	1321	39984	14232	1.54	3.16
SE ±	45.46	1145	341.6		
CD at 5%	125.8	3168	976.4		
Fertilizer cum stress management practices : (08)					
F_1 : RDF (30:60:30 NPK kg ha^{-1})	1140	34670	11457	1.48	2.81
F_2 : RDF + KNO_3 @ 1 % and 2% (two sprays)	1421	42954	17545	1.68	3.35
F_3 : RDF + (19:19:19) @ 0.5%	1384	41884	16448	1.64	3.31
F_4 : RDF + MoP @ 1% and 2 %	1290	39099	14386	1.57	3.11
F_5 : RDF + Micronutrients mixture @ 0.5%	1440	43329	17624	1.68	3.34
F_6 : RDF + Straw mulch @ 3 t ha^{-1}	1348	40738	13958	1.05	3.21
F_7 : RDF + Anti-transparent Kaolin @ 7%	1224	37735	9105	1.31	2.98
F_8 : RDF + Water sprays	1211	36797	12570	1.52	2.98
SE ±	37.75	1298	856.3		
CD at 5%	104.4	3592	2401.6		
Interaction					
SE ±	65.39	2248	1031.5		
CD at 5%	180.9	6223	1698.5		

sprays @ 7% and F_8: RDF + Water sprays (two sprays).

The gross and net plot sizes were 5.4m x 6.0 m and 4.5 x 5.0 m respectively. The soil of experimental field was clayey with pH 7.80, organic carbon (%)0.40, available N (kg ha^{-1}) 154.2, available P2O5 (kg ha^{-1}) 10.54, available K_2O (kg ha^{-1}) 614, respectively. The soybean variety MAUS-162 was used for sowing with spacing of 45 x 5 cm. The rainfall received during season was 448.3 mm, 336.7 mm and 1130 mm during 2014, 2015 and 2016 respectively. The recommended dose of fertilizer (30:60:30 NPK ha^{-1}) was applied at the time of sowing. The foliar sprays were applied at 35 and 65 days after sowing as per treatments. The ancillary data and yield attributing data were collected and analyzed.

Results and Discussion

Soybean grain yield, GMR and NMR : The pooled data for three years (2014, 2015 and 2016) with respect to soybean seed yield, GMR, NMR, BC ratio and RWUE is presented in Table 1. Data showed that soybean sown on BBF was found to be significantly higher than soybean sown on flat bed (L_1) and soybean sown on ridges and furrow method (L_3) in case of seed yield, GMR, NMR and B:C ratio. The application of RDF + Foliar application of micronutrients mixture recorded the highest soybean yield which was found at par with application of RDF + Foliar Application of KNO_3 i.e. F_2, application of RDF + (19:19:19) @ 0.5 % i.e. F_3 and application of RDF + Straw Mulch @ 3 t ha^{-1} i.e. F_6 and it was found significantly superior over rest of all the treatments. Bandopadhyay *et al*. (2004) and Bothe *et al*. (2000) conducted similar study in vertisol for soybean and similar trend of results were obtained in the present study. Jadhav *et al*., (2012) and Lomte *et al*. (2006) conducted study using various land configurations for soybean and found that various land configurations were beneficial for moisture conservation and thereby yield enhancement of soybean. Similar types of results were obtained in the present study.

The pooled data for GMR and NMR revealed that GMR and NMR were significantly higher with treatment L_2 i.e. soybean planted on BBF which was found to be significantly higher than soybean planted on flat bed (L_1) and soybean planted on ridges and furrow method (L_3). The similar trend was observed in

Table 2. Interaction effect of land configurations and fertilizer cum stress management practices on soybean seed yield (kg ha^{-1})

Land configurations / Fertilizer cum stress management practices	L_1 : Flat Bed	L_2 : BBF	L_3 : Ridges and Furrow
F_1 : RDF (30:60:30 NPK kg ha^{-1})	960	1431	1035
F_2 : RDF + Foliar application of KNO_3	1335	1496	1438
F_3 : RDF + Foliar application of NPK (19:19:19)	1235	1473	1451
F_4 : RDF + Foliar application of MoP	1165	1464	1248
F_5 : RDF + Foliar application of micronutrients mixture	1323	1571	1431
F_6 : RDF + Straw mulch @ t ha^{-1}	1198	1418	1434
F_7 : RDF + Anti-transparent Kaolin	974	1422	1282
F_8 : RDF + Water sprays (two sprays)	989	1401	1249
SE ±	65.39		
CD at 5%	180.9		
Mean	1310		

case of NMR. The highest B:C ratio and RWUE was recorded by L_2. It was also indicated that the GMR and NMR were significantly higher in treatment F5 i.e. RDF + Foliar Application of Micronutrients Mixture which was significantly superior over rest of the treatments but it was found at par with F_2, F_3 and F_6.

Rain water use efficiency : During 2014, the RWUE of the various land layouts was differed. The highest RWUE was recorded (4.16) with L_2 treatment followed by L_3 (3.69) and L_1 (3.22) within the different Fertilizer cum stress management practices F_2 recorded highest RWUE (3.96).

During 2015, the RWUE of the various land configurations was differed. The highest RWUE was also differed 3.58 with L_2 treatment followed by L_3 (3.26) and L_1 (2.93) whereas within the different Fertilizer cum stress management practices F_2 recorded highest RWUE (3.46) followed by F3 (3.40).

During 2016, the RWUE of the various land configurations was differed. The highest RWUE was observed (2.77) with L_2 treatment followed by L_3 (2.53) and L_1 (2.15) whereas within the

Table 3. Interaction effect of land configurations and fertilizer cum stress management practices on GMR (Rs. ha^{-1})

Land configurations / Fertilizer cum stress management practices	L_1 : Flat Bed	L_2 : BBF	L_3 : Ridges and Furrow
F_1 : RDF (30:60:30 NPK Kg ha^{-1})	29696	37802	34108
F_2 : RDF + Foliar application of KNO_3	38714	46731	44092
F_3 : RDF + Foliar application of NPK (19:19:19)	38198	44865	42904
F_4 : RDF + Foliar application of MoP	36022	43751	37613
F_5 : RDF + Foliar application of micronutrients Mixture	38044	47707	44609
F_6 : RDF + Straw mulch @ t ha^{-1}	35916	44329	43098
F_7 : RDF + Anti-transparent Kaolin	31079	43570	37383
F_8 : RDF + Water sprays (35 and 60 DAS)	30589	44774	36066
SE ±	2248.6		
CD at 5%	6223.0		
Mean	39653		

Table 4. Interaction effect of land configurations and fertilizer cum stress management practices on NMR (Rs. ha^{-1})

Land configurations / Fertilizer cum stress management practices	L_1 : Flat Bed	L_2 : BBF	L_3 : Ridges and Furrow
F_1 : RDF (30:60:30 NPK Kg ha^{-1})	6376	16781	10424
F_2 : RDF + Foliar application of KNO^3	11504	21620	18724
F_3 : RDF + Foliar application of NPK (19:19:19)	12114	19829	16615
F_4 : RDF + Foliar application of MoP	10219	18142	14009
F_5 : RDF + Foliar application of micronutrients Mixture	11650	21586	19406
F_6 : RDF + Straw mulch @ 3 t ha^{-1}	8827	17474	15114
F_7 : RDF + Anti-transparent Kaolin	5904	14867	80575
F_8 : RDF + Water sprays(two sprays)	7513	18399	11510
SE ±	2195.7		
CD at 5%	6076.5		
Mean	14028		

different Fertilizer cum stress management practices F_5 recorded highest RWUE (2.94) followed by F_2 (2.74). Nandurkar *et al*, (1997) and Raut and Taware (1997) experimented on various methods of sowing for soybean and similar trend of results were obtained.

Interaction effect (L x FS) of land configurations and fertilizer cum stress management practices on soybean seed yield : The interaction effect (L x FS) of land configurations and fertilizer cum stress management practices on soybean seed yield (Table 2) was found to be significant. The treatment combination of the L_2F_5 i.e. (BBF + RDF plus Foliar Application of Micronutrients Mixture) recorded the highest soybean seed yield which was found at par with treatment combinations of L_2F_2 and L_3F_5, and found significantly superior over rest of the treatment combinations.

Interaction effect (L x FS) of land configurations and fertilizer cum stress management practices on monetary returns : The interaction effect (L x FS) of land configurations and fertilizer cum stress management practices on GMR and NMR (Table 3 and 4) was found to be significant. The treatment combination of L_2F_5 i.e. (BBF + RDF plus foliar application of micronutrients mixture) recorded the highest GMR which was found significantly superior over rest of the treatment combinations but it was found at par with L_3F_5, L_2F_3 and L_2F_2. In case of NMR treatment combination of L_2F_5 i.e. (BBF + RDF plus foliar application of micronutrients mixture) recorded the highest NMR which was found significantly superior over rest of all the treatment combinations. Aggarawal and Narang (1975) & Dikey *et al*. (2013) conducted study on various stress management practices for soybean and found similar results.

Conclusion

Broad bed furrow system (BBF) with RDF plus foliar application of KNO3 micronutrients mixture was proved to be the most significant climate smart technology for rainfed soybean in Marathwada region.

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J. Agric. Res. Technol., 42 (3) : 010-015 (2017)

Assessing Soil and Land Irrigability Classes (SIC and LIC) as One of the Most Reliable Indicator for Irrigation Water Management (IWM) in Command Area to Compensate with Climate Change

Mehraj A. Shaikh*[1], P. B. Gokhale[2], S. K. Sabbinwar[3], H. P. Deshmukh[4]

Abstract

Soil erosion has produced maximum degraded land due to mismanagement and indiscriminate use of land resources such as soils and water. Monitoring the land degradation states required timely soil and water conservation measures. In this study an attempt has been made to describe how SIC and LIC play key role in IWM after compiling the parameters of four different soil survey report from different area in Marathwada region. This study stated that SIC and LIC assist properly for IWM in command area. For this study different soil quality parameters were used which include direct field study, maps, open pits, augur pits, collection of soil and water samples for analyzing in laboratory tests from different depths upto 250 cm and preparation of soil survey report. The results of study from four irrigation projects of different command area include Upper Manar Lift Irrigation Scheme, Latur (UMLSL), Kalyan Medium Irrigation Project, Jalana (KMIPJ), Dheku Medium Irrigation Project, Aurangabad (DMIPA) and Mulzara Minor Irrigation Project, Nanded (MMIPN). Study carried out in UMLSL shows 41% soils were categorized in A&B SIC while remaining were in C&D SIC and LIC of UMLSL reveal IIt 40%, IIIst 48% and remaining were IV2st. In KJMIP project soils were categorized 73% in type A and remaining in type B SIC while LIC were IIt 73% and IIIst were 27%, in DMIPA project include 74% A, 12% B and 13% D type SIC while LIC of this project was 74% IIt 12% IIIst and IVst 13% and MMIPN project of this study include 67% A and B type and remaining were C and D type SIC and LIC of this project include IIt 67%, IIIst 29% and IV2st was remaining soils. The SIC and LIC from A to E and I to VIth, respectively with their sub groups assist as most reliable indicator for proper IWM in respective command area to compensate with changing climate in global warming scenario.

Key words : Auger Pit, Climate Change, Command Area, LIC, Open Pit, Marathwada, SIC, Detailed Soil Survey.

Land is the most finite natural resource as it provides subsistence to the mankind as well as flora and fauna. Now a days this resource is overexploiting for its multipurpose uses due to which land degradation problem is arising (Panhalkar, 2011). Land may deteriorate by its mismanagement, improper use or by indiscriminate cultivation practices. Land is heterogeneous in nature as its quality varies from place to place and hence, it should not be used as per users requirement, but as per its potentials and limitations. (Appala Raju, 2015). Land quality is the capacity of soil to work for a specific use (Karlen et.al., 1997). Proper land use planning is essential for managing land as per its capabilities. Land evaluation is pre-requisite for any kind of land use planning (Oluwatosin *et al*., 2006). It plays a significant role in interpretation of soil survey data for land resource management (Sombroek and Figer, 1996; Verheye, 1996). It is based on various characteristics that influence the use and management of soils and thus determines the suitability of land for agricultural as well as non-agricultural uses. (Beek, 1978) defined physical land evaluation as a technique to evaluate the

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land capabilities on the basis of bio-physical characteristics. Several authors have worked on the quantitative land evaluation for perspective land use (Beek, *et al*., 1997; Merolla *et al*.,1994). The main purpose of Land Irrigability Classification (LIC) and Soil Irrigability Classification (SIC) is to predict the agricultural potentiality of any land class in relation to its resources (Sys *et al*., 1991). Such kind of land assessment, in identifying the major constraints for agricultural production, will help administrators/decision makers to develop sustainable land use plans by overcoming these limitations and thus for increasing the crop productivity.

Soil is an important constituent of land as it plays a vital role in the determination of its capability for different types of land use (Upadhyay et al., 2013). Topography and vegetation contribute significantly in determination of soil development (Gorai *et al*., 2013). So, it is essential to know the nature, extent and characteristics of soils along with their limitations and potentials for optimum land uses. Therefore, a detailed soil survey is necessary for land evaluation and land use planning of any area. This study has been undertaken in Marathwada to carryout detailed soil survey for determination of land irrigability classes and soil irrigability classes and thereafter appropriate management of irrigation water need for sustainable productivity.

Materials and Methods

Detailed soil survey data was used to identify and demarcate the different types of soil series information on the map generated from survey. The soil survey report and map was prepared by incorporating morphological characteristics, studies during ground truthing coupled with laboratory analysis of the soil profiles of the study area as shown in fig. 1, 2, 3 and 4.

Fig. 1. Map of UMLIS, Latur

Fig. 2. Map of KMIP, Jalna

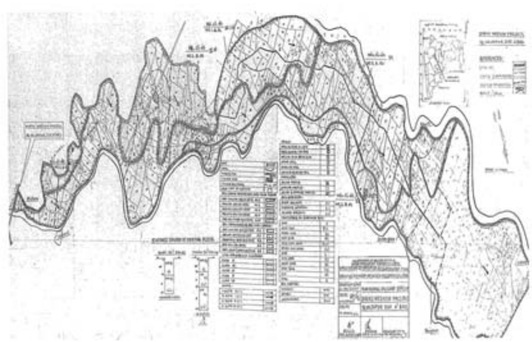

Fig. 3. Map of DMIP, Aurangabad

Soil Survey and land evaluation : Detailed soil survey of the area was carried out according to the procedures outlined in Soil

Survey (Anon, 2014). The cadastral map on 1:10,000 to 1:20,000 scale was used as a base map. During the course of soils survey, different land form units were studied as per broad physiographic position, slope gradients and elevations. Pedons and auger observations were studied as per heterogeneity of the soils in different landform units and morphological features along with site characteristics. Soil samples from each horizon were collected and analyzed for their physio-chemical properties (Black, 1963; Jackson, 1973). Soils were correlated, classified and mapped as phases of soil series on the basis of surface texture, slope and erosion classes (Anon, 1970). Using the assumptions of soil survey manual and considering the rating criteria of land evaluation (Anon, 2014), the lands have been evaluated into different land irrigability classes and subclasses (Mahapatra *et al.*, 1996). The evaluation has been carried out on the basis of potentiality and limitation of lands for sustained production of crops, pasture biomass and forests. It is based on various characteristics that influence the use and management of the soils. The soils that have least limitations or hazards and respond best to management are placed in highest category. The land irrigability classes are the broad groupings indicated by Roman numerals I to VI and show progressive increase of limitation for sustained use of the soils. Land irrigability classes are further subdivided into subclasses on the basis of dominant, kind and degree of limitations / hazards. Four kinds of limitations *viz.*, 'e' for wind and water erosion, 'w' for drainage problems or wetness, 's' for soil limitations affecting plant growth and 'c' for limitations due to climate are recognized.

Soil profiles were studied in different physiographic units, parent material, land use and slope of the area which influences soil information. Representative soil profiles were selected during pre field interpretation. The

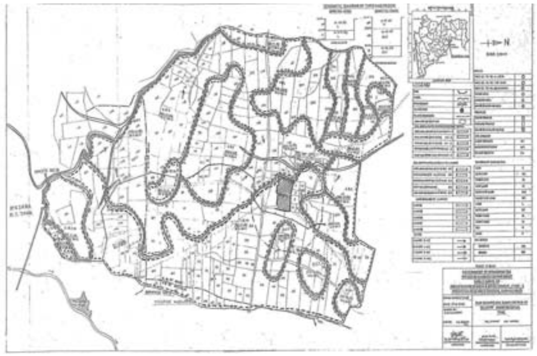

Fig. 4. Map of MMIP, Nanded

soils were studied for their morphological characteristics as per the guidelines developed by DIRD, Pune (Anon, 2014). The present study of Marathwada region include four different projects, 109 profile soils samples were collected in 2009-10 from UMLISL, while from KMIPJ, samples from 46 profile were collected in 2015-16, in DMIPA, 71 profile samples were collected in 2008-09 and in MMIPN, 47 profile samples were collected in 2007-08 for detailed soil survey study.

Field and laboratory works : In detailed soils survey project command was shown on a cadastral map drawn to a scale ranging from 1:10,000 to 1 : 20,000. In this area grid lines laid 400 m (200 m apart in Minor Projects), apart and auger bores were taken at each grid point up to 250cm or hard strata if met first. Soil samples were collected at following depth intervals. 0-20 cm, 20-40 cm, 40-80 cm, 80-120 cm, 120-160 cm, 160-200 cm and 200-250 cm. The intensity and depth of sampling was adjusted to suit the topography and special features. Open profiles were studied as required, at least one profile per square km. In this profiles the soil horizon, colour, structure, texture, consistence, concretions, root distribution, hard pans etc. were studied. Infiltration tests were conducted at suitable depth intervals to study the permeability of different soil horizons. Soil samples were collected from every fourth auger bore on alternate cross section for carrying out following laboratory tests. Mechanical analysis, pH, EC, saturation moisture, free lime etc.

Results and Discussion

The detailed soil survey carried out in UMLIS, Latur (Anonymous, 2012) cover the land of 5328 ha, while KMIP, Jalna (Anonymous, 2017) covered the area of 3744 ha, DMIP, Aurangabad (Anonymous, 2017) include gross command area of 3892 ha and MMIP, Nanded (Anonymous 2009) occupied 800 ha gross command area.

Detailed soil survey of these four projects of Marathawada region classify the soil as per their characteristics ranging in five soil irrigability classes (A to E) and six land irrigability classes (I to VI) as per their sub groups. The similar study also reported by (Singh, 2016).

The brief description of SIC and LIC of these projects are in Table 1.

Soil characteristics and classification : The detailed soil survey of all these four projects were categorized there area into LIC and SIC in percentage. The LIC of these area includes sub classes such as t, st and 2st as suffix to main LIC classification indicates soils having limitations in drainage, soil slope and both respectively. As there are six LIC classes defined, class I soils does not have any limitations for IWM and management purpose and as categorization increasing in order from II, III, IV, V and VI limitations are slightly manageable to extremely limited. In case of SIC A to D, class A have huge potential for IWM such as (net and gross) irrigation requirement interval durations are more because of depth, texture, structure, porosity, infiltration rate etc. These are potentials of soils for example in high temperature evapo-transpiration was high then by calculating (net and gross) irrigation requirement interval durations with available data, it compensate like wise with climate change. Based on soil survey data in four projects of Marathwada region, three soil irrigability classes were found and three land irrigability classes with sub classification were recognized. In detailed study, UMLIS of Latur was disbursed its total area 5328 ha (2160 ha, 2576 ha and 592 ha) in B, C and D SIC followed by IIt, IIIst and IV2st land irrigability classes was recorded. While in KMIP, Jalna total area 3744ha (2752 ha and 992 ha) was grouped SIC wise as A and C followed by IIt and IIIst LIC classes were recorded, in DMIP, Aurangabad the total area 3892ha (2916 ha, 480ha and 496ha) were distributed into A, C

Table 1. SIC and LIC of four different projects in Marathwada region

Project	SIC	LIC	Area (ha)	%
UMLIS Latur	B	IIt	2160	40.54
	C	IIIst	2576	48.35
	D	IV2st	592	11.11
		Total	5328	100.00
KJMIP Jalana	A	IIt	2752	73.50
	C	IIIst	992	26.50
		Total	3744	100.00
DAMIP Aurangabad	A	IIt	2916	74.93
	C	IIIst	480	12.33
	D	IVst	496	12.74
		Total	3892	100.00
MNMIP Nanded	B	IIt	537	67.13
	C	IIIst	232	29.00
	D	IV^{2st}	31	3.87
		Total	800	100.00

When lands are put under any class lower than (I) the reasons are indicated by appending 's' , 't' or 'd' to class number to show whether deficiency is in soils, topography or drainage.

and D SIC followed by IIt, IIIst and IVst LIC and in MMIP, Nanded total area 800ha (537 ha, 232ha and 31ha) had B, C and D SIC and IIt, IIIst and IV2st LIC categorized soil classes was found.

Land evaluation and management needs : Based on their limitations and potentials soil of these four project in Marathwada region have been categorized under SIC and LIC, from A to D and II to IV respectively. The map of project have been shown in figure 1, 2, 3 and 4. The potential and limitations of these soils are useful for proper irrigation water management in changing climate scenario of the world (Gahlod *et al.*, 2017)

Conclusion

In the present study, the criteria followed for land evaluation is based on combination of number and degree of limitations as well as matching of land attributes with the respective requirements. This kind of land categorization will be useful to determine land based on crop suitability and management requirements for enhancing the productivity. The availability of irrigation water and its limitation is also a major constraint for crop productivity, so proper water management conserves soil as well as water and assist for global climate change situation.

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J. Agric. Res. Technol., 42 (3) : 015-022 (2017)

Faster Sugarcane Planter Machine for Shorter Planting Period under Climate Change

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Abstract

The drastic change in the climate especially because of inconsistent rains there is variation in atmospheric and soil conditions. Agriculture in Indian peninsular region is dependent on monsoon rains, all farming operations are related to commencement of monsoon. The delay in rains causes delay in primary field preparation which in turn shortens available time for planting of crops. Faster sugarcane sett planter was developed for covering maximum area under such conditions. The tractor operated automatic sugarcane sett planter was developed to cope up with high demand and faster operational speeds. The planting mechanism for singulation of two budded sugarcane setts loaded in the bulk hopper was designed and tested virtually as well as physically. The planting mechanism was developed with inclined disc and bowl operated with brush less direct current (BLDC) electric motor of 400 W. The developed metering system was capable of singulation and laying setts in furrows with quality of feed index of 72 per cent. The multiple and miss index were recorded 15 to 20 per cent and 7 to 11 percent respectively. The developed machine could be operated with 45 hp tractor at operating speeds of 4.5 km h^{-1} and was able to plant area of 0.57 hectares per hour.

Key words : sugarcane planter, planting, machine, metering mechanism, sett planter.

Sugarcane cultivation thrives well in a tropical climate, with a minimum water requirement of 60 centimetres. The measure sugarcane growing countries are Australia, Bolivia, Brazil, Colombia, Cuba, Ecuador, Hawaii, India, Pakistan, Peru and Philippines. India ranks second in the world in terms of area under sugarcane (4.96 Mha) as well as production with 348 MT in the year 2016. The sugarcane is labour intensive crop, requires huge labour force for various unit operations like planting, weeding, earthing-up, fertilizer application and harvesting. Planting consumes about 16 per cent of the production cost of sugarcane (Yadav *et al.*, 2003;

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Dharmawardene, 2006) also the seed cane is contributing about 25 per cent of cost (Patel and Patel, 2014). The establishment of the crop affects final yield of sugarcane. Poor establishment also encourages weed growth or needs gap filling, which will increase the cost of cultivation (Croft *et al.*, 2000). The germination of the buds on sugarcane sett is affected by temperature that should be more than 8.5°C and optimum range is 32-38°C (Verma, 2004). Moisture in the setts as well as soil, plant hormones and release of reducing sugar in the sett are also measure factors affecting germination. The developing shoot draws nutrients from the sett then from sett roots for about six to seven weeks. Shoot roots develop up to 12 weeks and rotting of setts before that result into death of shoot even after emergence (Croft *et al.*, 2000).

Sugarcane planting requires about 350 man-hour and 30.6 bullock pair-hour per hectare with the cost of operation of Rs. 3987 in conventional system of planting, as against mechanical planting requires Rs. 2200 per hectare with the engagement of 20 man-hours (Yadav *et al.*, 2003). There is urgent need of introduction of modern sugarcane machinery for planting. Although the initial cost of planting machinery is very high but advantages accrued in their use are much more. Planting process is now partially or completely mechanized. In the most part of India and the world tillage operation has been mechanized and remaining operations were done manually to achieve better precision. In the semi-mechanized system harvesting and distribution of seed in the furrow is done manually, maintaining good uniformity of seed spacing. All other operations like transport, furrow opening, covering and the spraying operations are done mechanically. In completely mechanized system the seed cane harvested mechanically using sett harvester and transported to the field and loaded into the planters, and the remaining operations are performed by the planter. There have been several major developments in sugarcane planting techniques. The drop planter only planted and covered the sugarcane setts. This machine required a pre-formed furrow, and operations such as fertilising were undertaken by a separate machine. The mechanical system reduces labour and operational costs significantly. But more seed cane is placed in the furrow, to overcome the lower quality of the seed cane. Cutting the cane into setts presents problem in both, manual (labour availability and cost) as well as harvester method (bud damage). Sugarcane distributors with bulk dropping operates at higher speeds 5.0 to 6.2 km h^{-1} have field capacity of 0.75 to 1.65 ha h^{-1}, but without any control on spacing about 5.7 to 11.2 setts per metre with very high seed rate 8 to 27.7 t ha^{-1} (Janini *et al.*, 2008; Rípoli and Rípoli, 2010; Compagnon *et al.*, 2016; Cortez *et al.*, 2016). In the semi-mechanized system required 4 to 8 t ha^{-1} of seed cane, depending on the variety, the planting period, as well as the soil and climatic conditions of the area. Although a significant improvement on the drop planter, whole stalk planters are now considered by many growers as unacceptable. This is due to the high requirement for labour to cut, haul and plant the cane (Robotham and Croft, 2004). The researchers worked on improvement of machine parameter viz. metering mechanisms, conveyors, cutting and feeding systems, also operating parameters like forward speed, conveyor speeds and angles to achieve maximum efficiency with least costs found that forward speed and conveyor speed are important factors controlling distribution of the seed (Taghinezhad *et al.*, 2014, Compagnon *et al.*, 2016, Singh *et al.*, 2016). Horizontal metering disc was successful in achieving better singulation than other types of singulation mechanisms *viz*., slatted conveyor, external slat drum or internal slat drum (Robotham and Croft, 2004).

Previous efforts in India were concentrated on sugarcane cutter planters (Yadav *et al*. 2003, 2004; Deshmukh, 2009; Singh *et al*., 2009; Kumar and Singh, 2012; Sinha, 2016). But all these planters needed operators to ride on the machine for feeding canes, which may create safety problems. But the as the length of cut was kept constant (30 to 50 mm) without observing bud position; large variation in number of buds per sett from 2 to more than 4 (two bud: 4-7 per cent, three buds: 25 to 35 per cent, four buds: 30 to 45 per cent and > four buds: 13 to 33 per cent) as reported by Yadav *et al*. (2004). The major disadvantage was the chemical treatment was not done properly because those planters used pesticide spray technique instead of the recommended chemical pre-treatment of setts by emersion for 15 to 20 minutes (Verma, 2004). With view of above constraints of present solutions available for planting of sugarcane; the study was undertaken to develop the planting mechanism for sugarcane setts.

Materials and methods

The mechanism was designed for planting of two budded sugarcane setts. The basic design was based on design problem, 'to achieve singulation and metering of sugarcane setts, which were stored in randomized position and was fed in batches without intervention of human'. The design of planting mechanism was based on important factors those affect the performance of the planting mechanism. The most of the researchers recommend use of 2-3 eye bud setts for planting in India (Rott, 2000; Singh *et al*., 2008; Patel and Patel, 2014). The machine development was done for two budded setts, which is prevalent in the most of tropical sugarcane growing area and recommended by the researchers (Kakde, 1985; Yadav, 1991; Patel and Patel, 2014; Sinha, 2016) considering recommended plant to plant spacing of 33 cm in the furrows, 25000 setts ha^{-1} with row to row spacing of 1.2 m in heavy soil (Khade and Pawar, 1998). The machine was having single row mechanism hence the row to row distance could be adjusted as per requirement. The popular varieties CoM0265 popular in Maharashtra, Co86032 popular in southern India and CoS767 popular in Northern India were selected. The physical properties of sugarcane sett viz. length, diameter, weight and bulk-density are important for determining size and shape of machine components. Static coefficients of friction as well as dynamic coefficient of friction between setts and the material of construction of mechanism were important for choosing material, shape and slopes of stationary surfaces and also for calculating the driving forces for operation of mechanism.

Design of components of sugarcane planter : The rotary disc mechanism was designed for singulation of the sugarcane setts stored in bulk hopper. Setts flow under gravity to the auxiliary hopper lifted at 45 by slatted conveyor and fed in batches to rotary disc mechanism. Rotary disc mechanism having inclined disc and outer bowl assembly singulate

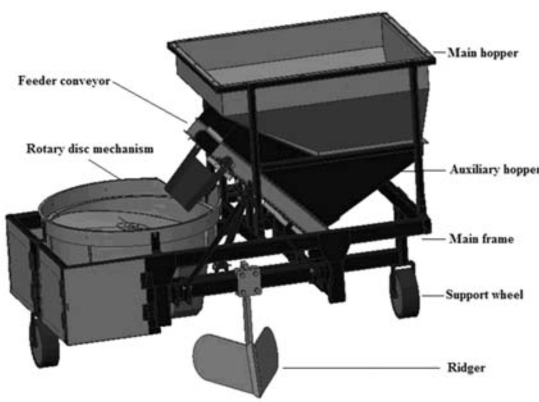

Fig. 1. Isometric view of developed sugarcane sett planter

setts and deliver in chute. Both feeding and singulation mechanism operated by two different DC electric motors. The rotational speeds were controlled by electronic controller. The detailed view of sugarcane sett planter indicating various assemblies is presented in Fig. 1.

Hopper : The hopper was designed to accommodate maximum number of setts with unrestricted movement of setts into auxiliary hopper. The hopper was having one wall was vertical and the opposite side was slanting. The slope of slanting side was kept 30° to achieve uniform flow of sugarcane setts under gravity. The slope was decided on the basis of maximum angle at which two budded setts start sliding, in the experiment of static coefficient of friction with mild steel and painted G.I. sheet i.e. 29.8° (for variety CoM0265 with mild steel). The final overall dimensions of the main hopper were 1295 x 1000 x 585 mm with bottom opening of 628 x 530 mm. The top of the hopper was supported by all around frame of flat sheet with 30 mm width increased upper dimension as 1355 x 1060 mm. The width of hopper and conveyor were decided by the maximum length of the two budded sett observed in experimentation i.e. 424 mm (Co86032). With margin of 50 mm on both sides the bottom width was taken as 530 mm. The final overall dimensions of the useful triangular portion of auxiliary hopper were 650 x 530 x 455 mm with bottom slope 30°. The open portion for slat conveyor was kept with length of 880 mm and 530 mm wide at an angle of 45°. The rubber flap of 90 mm width and 5 mm thickness was attached at bottom of hopper to avoid dropping of setts from the gap generated between slat conveyor and the hopper bottom for passage of slats.

Conveyor : The flat belt with angular slats was designed to collect setts from hopper and feed them to rotary disc. The setts from the hopper were lifted from side of the hopper at an angle of 45° by means of motor driven feeding conveyor. The flat belt drive was designed with fibre reinforced SBR belt of width 500 mm, which was mounted on two pulleys. The height of delivery of the setts was 600 mm from the base of the hopper. Based on angle and the height of delivery the centre distance between pulleys was calculated 800 mm. The BLDC motor was connected to the driver pulley though chain drive. The speed of operation of the pulley was decided by the required quantity of setts per unit time and peripheral speed of conveyor belt. The belt was having 8 slats at spacing of 235 mm and diameter of pulley was 80 mm.

Singulation mechanism : The most important mechanism of the sugarcane planter was singulation mechanism. The major function was to separate sugarcane setts from bulk and deliver individually into chute. The basic principle of centrifugal force acting on the sugarcane setts in combination with friction between sett and the rotary surface was used for designing singulation mechanism. Said mechanism consists of three major components viz. inclined rotary disc, bowl assembly, outer stationary ring and drive system. These components were assembled together to provide singulation of sugarcane setts from bulk and deliver the singulated setts into the chute.

Hypothesis was proposed that the conical angle provided on the disc will assist in outward movement of setts and improve singulation. The diameter of the disc was taken as 1 m after studying combined effect of diameter and rotational speed on the singulation of sugarcane setts through virtual analysis with EDEM version 2.7.3.

Drive mechanism : The driving system of the rotary disc assembly was the important because that has to operate two rotating parts moving at different angle with single drive. The rotary disc and rotary bowl assembly were arranged such that they are moving at the same speed but at different angle. They were connected with each other through universal joint. The single BLDC motor was driving these two assemblies with bevel gear pair with speed ratio of 3:1.

The specifications of the motor were decided by the power requirement for the lifting of sugarcane setts from lower edge of disc to horizontal ring in semicircular path at the height of 200 mm and also the moments of inertia of the components of rotary disc mechanism. The speed of operation of the disc was assumed to be 30 rpm which was decided from the virtual simulation experiments in EDEM software and the angular acceleration of the pulley was assumed 0.93 rad s^{-2}. The weight of the components of the rotary disc mechanism was 42 kg. The number of the setts to be carried by the disc at any instance was assumed 30 having weight of 9 kg.

Functional test of rotary disc mechanism : The mechanism was checked for proper fitment of the components. The dry run was conducted to ensure proper assembly and their functionality. The motor controller was tested for achieving desired speed of rotary disc assembly. The disc speed was measured by using tachometer. The controller knob was set for operating rotary disc assembly the speed of 25, 30, 35 rpm. Similarly the controller of motor driving feeding conveyor was set for operating feeding conveyor driver pulley at different speeds of 25, 30, 35 and 40 rpm. The optimization experiment was designed by using response surface methodology (RSM) with Box-Behnken design (Box and Behnken, 1960). The said design was the combination of two-level factorial and the incomplete block design. This design was suitable for three variables (factors) and three levels. The experiment was designed and data was analyzed with software 'Design expert Ver. 10.0.3.0' (Stat-Ease Inc, Minneapolis, MN).

Results and discussion

The effect of disc cone angle, forward speed and disc speed of the metering mechanism on

Table 1. Effect of independent variables on performance of sugarcane planting mechanism

Std. order	Run order	Disc cone angle (°)	Forward speed (km ha^{-1})	Disc speed (rpm)	Miss index (%)	Multiple index (%)	QFI (%)	PC (%)
1	13	0	3	30	3.84	47.24	48.92	22.68
2	2	10	3	30	3.93	54.39	41.68	23.15
3	1	0	5	30	5.84	40.98	53.19	23.69
4	9	10	5	30	7.94	35.77	56.29	24.32
5	10	0	4	25	14.73	27.40	57.87	25.64
6	7	10	4	25	17.31	19.24	63.45	27.05
7	12	0	4	35	2.48	63.49	34.03	25.25
8	6	10	4	35	1.33	69.80	28.86	22.32
9	15	5	3	25	6.48	41.59	51.93	26.03
10	8	5	5	25	25.00	16.03	58.97	28.65
11	5	5	3	35	3.27	61.83	34.90	23.74
12	14	5	5	35	6.08	46.31	47.62	24.66
13	3	5	4	30	8.26	32.11	59.63	23.89
14	11	5	4	30	3.60	41.73	54.68	25.00
15	4	5	4	30	8.26	37.19	54.55	27.63

the performance of machine was validated in the laboratory and field by observing changes in dependent variables like miss index, multiple index, quality of feed index (QFI) and precision coefficient (PC) which were calculated on the basis of variation in the sett spacing.

The data presented in Table 1 showed that values of dependent variables changed with various combinations of disc cone angle, forward speed and disc speed. The lowest miss index (1.33%), QFI (28.86%), PC (22.32%) and the highest multiple index (69.80%) were recorded at 10, 4 km h^{-1} and 35 rpm disc cone angle, forward speed and disc speed, respectively. The highest miss index (25.00%), PC (28.65%) and the lowest multiple index (16.03%) were recorded at 5, 5 km h^{-1} and 25 rpm disc cone angle, forward speed and disc speed, respectively. But the highest QFI (63.45%) was observed at 10 , 4 km h^{-1} and 25 rpm disc cone angle, forward speed and disc speed, respectively. The miss index and multiple index have opposite trends i.e. when miss index was increasing multiple index was decreasing. Also the higher values of QFI were recorded when multiple index values were lower.

Field validation of mechanism : The field validation testing of the experimental sugarcane planter was done. The machine was prepared for the field test with metering mechanism set at optimized disc cone angle, disc speed and operated at optimum forward speed obtained through the analysis of data observed in optimization experiment. The test was done with disc having cone angle of 0 , disc speed of 28.4 rpm and forward speed of 5 km h^{-1}. Three replication of the test were made to reduce the experimental error. The results of validation test are presented in Table 2 and 3.

Based on analysis of variance indicated very high degree of analytical ability of response surface methodology, with standard error of means (±SE) in the range of 0.01 to 2.79. The effect of the disc cone angle, forward speed and disc speed on the various response variables was validated. The optimum values of independent variables predicted by the software are confirmed by validation test as the mean values of responses showing significant agreement with predicted values.

The actual field capacity was 0.55 ha h^{-1}. The field capacity was much higher than reported field capacity for tractor drawn two

Table 2. Validation test results

Rep. No.	Miss index	Multiple index	QFI	PC
1	10.20	16.33	73.47	26.36
2	16.46	11.39	72.15	24.14
3	7.90	21.05	71.05	22.95
Mean	11.52	16.26	72.23	24.49
SD	4.43	4.83	1.21	1.73
SE	2.56	2.79	0.70	1.00

Table 3. Summarized data sheet for validation field test of sugarcane sett planting mechanism

Particulars	Unit	Mean value
Soil moisture content, db	per cent	8.07
Row spacing	m	1.622
Forward speed	km h^{-1}	4.88
Spacing of setts, SA	mm	305
Multiples, SA < 0.5 times ST	Nos.30 m^{-1}	16
Gaps, SA > 1.5 times ST	Nos.30 m^{-1}	10
Depth of planting	mm	7.0
Area covered	ha	0.1815
Field capacity	ha h^{-1}	0.55
Theoretical field capacity	ha h^{-1}	0.75
Field efficiency	per cent	73.33
Seed rate	kg ha^{-1}	5553
Fuel consumption	l h^{-1}	9.7
Fuel consumption	l ha^{-1}	17.63
Emergence after 30 days	per cent	45
Emergence after 45 days	per cent	68.33

row sugarcane cutter planters 0.2 ha h^{-1} by Mandal and Maji (2008), 0.18 ha h^{-1} by Singh *et al*. (2009), 0.16 ha h^{-1} by Singh and Singh (2016) or 0.127 ha h^{-1} by Gupta *et al*. (2017) and 0.38 ha h^{-1} by Kumar and Singh (2012) for three row planter.

Conclusions

The following conclusions were drawn from the experimentation: Disc speed of Rotary Disc Mechanism was the most significant variable for controlling miss index, multiple index, QFI and PC in planting of two budded setts of sugarcane. While disc cone angle was not affecting any of the dependent variable. The optimized values of disc cone angle, forward speed and disc speed for Rotary Disc Mechanism were 0 , 5 km h^{-1} and 28.4 rpm, respectively. The field capacity of sugarcane sett planter was 0.55 ha h^{-1} with the field efficiency of 73 per cent, when operated at speed of 4.5 to 5 km h^{-1}. The seed rate applied by the sugarcane sett planter was 5550 kg.ha^{-1} with miss index of 7.89 to 16.46 per cent, multiple index of 11.39 to 21.05 per cent, quality of feed index in range of 71.05 to 73.57 per cent and precision coefficient of 22.95 to 26.36 per cent at the optimum disc cone angle, forward speed and disc speed.

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J. Agric. Res. Technol., 42 (3) : 022-029 (2017)

Climate Resilience Through Land Configurations and Nutrient cum Stress Management Practices in Rainfed *Bt* Cotton

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Abstract

The land configuration of broad bed furrow i.e. BBF was found to be significantly superior over rest of the land configurations in respect of various growth and yield attributes of *Bt* cotton *viz*., plant height, number of leaves, leaf area, drymatter plant^{-1}, number of bolls plant^{-1}, boll weight plant^{-1}, seed cotton yield plant^{-1}, seed cotton yield hectare^{-1} and net returns hectare^{-1}. The B:C ratio of rainfed *Bt* cotton and the soil moisture content at various depths of soil profile were also found higher in BBF. In respect of various nutrient cum stress management practices, the application of 75% RDF + green manuring + application of KNO_3 @ 1.0 and 2.0% (at 35 and 75 DAS) and 75% RDF + 25% N through FYM+ KNO_3 @ 1.0 and 2.0% (at 35 and 75 DAS) resulted in higher plant height, number of leaves, leaf area, number of bolls per plant, boll weight, seed cotton yield per plant, seed cotton yield hectare^{-1} and net returns hectare^{-1}. Sowing of *Bt* cotton on BBF and application of 75% RDF + green manuring or application of 75% RDF + 25% N through FYM with the application of KNO_3 (two sprays) @ 1% and 2% (at 35 and 75 DAS) or application of micronutrient mixture (rwo sprays) @ 0.5% (at 35 and 75 DAS) was found more efficient for increasing the seed yield and climate resilience under rainfed condition.

Key words : Btcotton, Land configuration, BBF, Micronutrient, Stress management

Rainfed agriculture is a significant contributor to production of cereals, pulses, oilseeds and cotton which is also characterised by poor natural resource base in terms of low and erratic rainfall, hungry soils and more importantly the poor economic status of farmers. In recent past frequent incidence of droughts has aggravated the situation. About 70 per cent area of the cultivated area in India as well as Maharashtra is under dryland agriculture. Cotton is one of the important cash crop and plays a vital role in the economy of the farmers as well as the country. Marathwada is major cotton growing region in Maharashtra. Cotton is grown predominantly as rainfed crop on black cotton soils having an area of 19 lakh ha with average productivity of 325 kg lint ha^{-1}. The major constraints for low productivity of rainfed cotton in Marathwada are erratic rainfall and imbalanced use of fertilizers. Moreover, the performance of cotton is found to be affected due to its cultivation under rainfed conditions, non adoption of moisture conservation practices and lack of management and nutrient supply during dry spells. Nutrients play a pivotal role in increasing the seed cotton yield. Major and micronutrients should be supplied in a balanced form through integration of inorganic and organic sources of nutrients for achieving crop yields and maintaining soil health.Foliar application of major plant nutrients like nitrogen and potassium was found to be as good as soil application (Kalhapure and Shete, 2013). According to Kalita *et al*., (1984), supplementing urea at the reproductive stage significantly enhanced the crop yield. This practice is more useful under rainfed conditions where moisture is limiting factor.

The research result showed that the yield levels could be increased by adoption of suitable *in-situ* moisture conservation practices and timely supply of nutrients (Redder *et al*., 1991). Assured rainfall situation of Parbhani district is not an exception to vagaries of monsoon. The necessity of proper land configuration for moisture conservation during deficient rainfall years as well as for safe drainage during excess rainfall events and balanced nutrient management is need of the hour. Considering meagre availability of information on land configuration and proper nutrient management for *Bt* cotton, a set of technologies were

Table 1. Plant height (cm) and dry plant per plant (g) as influenced by different treatments in rainfed *Bt* cotton (2014-16)

Treatments	Plant height (cm)				Dry matter platn^{-1} (g)			
	2014-15	2015-16	2016-17	Mean	2014-15	2015-16	2016-17	Mean
Main plots : Land configuration (03)								
L_1 : Flat Bed	139.27	134.73	168.60	147.43	83.35	78.45	118.31	90.71
L_2 : BBF	163.33	157.07	189.53	169.96	112.53	111.29	139.17	118.29
L_3 : Ridges & Furrow	152.97	147.93	180.27	160.29	103.58	99.16	124.86	106.43
SE ±	2.93	4.03	3.25	3.23	6.09	8.13	11.34	3.77
CD at 5%	9.04	12.10	9.28	9.71	18.27	24.34	34.06	11.29
Sub plots : Fertilizer cum stree management practices (07)								
F_1 : RDF	140.13	140.93	169.68	150.66	80.93	68.17	109.93	97.13
F_2 : RDF + Foliar appln of KNO_3	145.24	142.44	174.24	153.52	101.15	91.33	122.19	103.87
F_3 : RDF + Foliar appln micro- nutrient mixture	142.63	142.68	173.28	153.33	100.03	88.20	129.06	104.94
F_4 : 75% RDF + 25% through FYM + KNO_3	160.87	146.12	186.46	165.71	104.33	93.13	136.88	110.41
F_5 : RDF + 25% hrough FYM + M- mix.	150.97	145.37	178.78	158.62	101.40	89.40	130.40	105.93
F_6 : 75% RDF + green manuring + KNO_3	163.03	159.13	188.36	170.50	105.93	96.57	138.93	112.50
F_7 : 75% RDF + 25% NPK throughgreen manuring + micro-nutrient mixture	156.27	147.36	181.46	162.33	102.28	91.90	131.28	107.46
SE ±	4.39	5.71	6.21	7.12	7.86	9.11	12.54	8.93
CD at 5%	13.19	17.16	18.78	21.36	23.58	27.33	37.62	26.79
Interaction effect (L x F)								
SE ±	3.47	4.80	3.97	5.12	5.98	4.62	6.23	6.19
CD at 5%	NS	14.40	11.91	15.36	17.84	13.86	18.69	18.57
GM	151.85	146.57	179.46	159.22	99.82	88.31	127.46	105.19

assessed in AICRP research trial conducted during 2014-15 to 2016-17 at AICRP for Dryalnd Agriculture, VNMKV,Parbhani.

Materials and Methods

A field experiment was conducted during three consecutive years i.e. 2014-15, 2015-16 and 2016-17 at AICRP for Dryland Agriculture, VNMKV, Parbhani having average annual rainfall of 897 mm. The soil of experimental field was medium deep black with 0.43 per cent organic carbon, 234.40 kg available N, 10.04 kg available P, 477.20 kg available K ha^{-1} and soil pH was 7.9. The experiment was laid out in split plot design and replicated three times which consisted of three land configurations as main plots *viz*., Flat Bed (L_1), Broad Bed Furrow (L_2) and Ridges & Furrow (L_3). In the treatment L_1 cotton was sown on flat bed at 120 x 60 cm spacing . In the treatment L_2 i.e. ridges and furrow method cotton was sown at one third height of the ridge at 120 x 60 cm spacing. Whereas, in case of L_3 i.e. BBF method cotton was sown on a broad bed of top width of 90 cm and opened at 120 cm distance maintaining the spacing of 120 x 60 cm. Sub plots consisted of seven nutrient cum stress management practices *viz*. F_1: RDF (120:60: 60 N, P_2O_5, K_2O kg ha^{-1}), F_2 :RDF + Foliar application of KNO_3 two sprays @ 1% and 2%, F_3: RDF + Foliar application of Micronutrients Mixture two sprays @ 0.5%, F_4: RDF 75% + 25% N through FYM (6 t ha^{-1})+ Foliar application of KNO_3 two sprays @ 1 and 2%, F_5: RDF 75% + 25% N through FYM (6 t ha^{-1})+ Foliar application of Micronutrients

Table 2. Number of picked bolls $plant^{-1}$, boll weight $plant^{-1}$ (g) and seed cotton $yield^{-1}$ (g $plant^{-1}$) as influenced by treatments in rainfed *Bt* cotton (2014-16)

Treat-ments	Number of picked bolls $plant^{-1}$				Boll weight $plant^{-1}$ (g)				Seed cotton yield ($plant^{-1}$ g)			
	2014 -15	2015 -16	2016 -17	Mean	2014 -15	2015 -16	2016 -17	Mean	2014 -15	2015 -16	2016 -17	Mean
Main Plots: Land Configurations : (03)												
L_1	18.54	14.46	33.85	22.95	3.09	2.61	3.29	3.00	50.89	42.86	134.13	76.30
L_2	24.56	21.99	44.12	30.22	3.80	3.05	4.10	3.65	72.45	60.02	167.28	99.08
L_3	23.42	18.87	37.85	26.71	3.62	2.94	3.47	3.34	69.48	50.33	151.87	90.29
SE ±	0.31	0.13	0.62	0.35	0.12	0.05	0.10	0.09	3.26	1.35	2.70	2.40
CD at 5%	0.93	0.38	1.73	1.01	0.36	0.14	0.29	0.26	9.78	3.74	7.48	7.0
Fertilizer cum Stress Management Practices : (07)												
F_1	19.28	15.90	28.60	21.26	2.94	2.43	2.67	2.68	46.57	38.39	76	53.7
F_2	24.00	19.40	31.61	25.00	3.36	2.83	3.07	3.09	65.84	55.43	97	72.8
F_3	26.01	20.43	35.60	27.35	3.58	2.89	3.27	3.25	72.45	58.41	115	82.0
F_4	23.89	18.18	38.60	27.10	0.51	1.07	3.18	1.58	70.82	55.43	138	88.1
F_5	21.66	18.20	41.61	27.16	3.91	3.08	3.95	3.65	71.12	55.98	165	97.4
F_6	25.98	21.80	45.61	31.13	3.95	3.32	4.32	3.86	89.43	75.12	198	120.9
F_7	21.93	18.40	42.60	27.64	3.78	2.96	3.57	3.44	70.82	55.43	138	88.1
SE ±	0.85	0.39	0.88	0.71	0.13	0.06	0.13	0.11	3.81	1.74	6.13	3.90
CD at 5%	2.54	1.09	2.45	2.03	0.39	0.17	0.36	0.31	11.35	4.82	16.97	11.0
Interaction												
SE ±	0.71	0.68	1.53	0.97	0.13	0.10	0.23	0.15	8.64	8.35	29.40	15.5
CD at 5%	2.11	1.89	4.24	2.75	0.38	0.29	0.64	0.44	64.27	52.40	144	86.9
GM	22.17	18.11	38.61	26.30	5.61	2.86	3.62	4.03	64.27	52.40	144	86.9

Mixture two sprays @ 0.5%, F_6: RDF 75% + Green Manuring (Sunhemp)+ Foliar application of KNO_3 two sprays @ 1% and 2%, F_7: RDF 75% + Green Manuring (Sunhemp) + Foliar application of Micronutrients Mixture two sprays @ 0.5%. The in situ green manuring of sunhemp was done at 45 DAS in respective treatments (i.e. F_6 and F_7).

I^{st} and II^{nd} foliar application of nutrient cum stress management practices for respective treatments was done at 35 DAS and at 75 DAS. The recommended dose of fertilizers (120:60:60 kg N, P_2O^5, K_2O kg ha^{-1} was applied as per treatments.Net plot size was 4.8 x 4.5 m. The biometric and soil moisture observations were recorded at regular time intervals and data were subjected to the statistical analysis.

Results and Discussion

Various growth and yield attributes of Bt cottonweresignificantly affected with various

Table 3. Cotton seed yield and gross monetary returns as influenced by treatments in rainfed *Bt* cotton (2014-16)

Treatments	**Seed cotton yield (kg ha^{-1})**				**Gross monetary returns (Rs. ha^{-1})**			
	2014-15	**2015-16**	**2016-17**	**Pooled mean**	**2014-15**	**2015-16**	**2016-17**	**Pooled mean**
Main Plots: Land Configurations : (03)								
L_1 : Flat Bed	903	732	1864	1166	-5529	5911	64802	21728
L_2 : BBF	1144	916	2369	1476	3975	7746	86823	32848
L_3 : Ridges & Furrow	1013	853	2147	1339	-1117	5911	76033	26942
SE ±	24.33	10.05	53.77	19.38	871	324	550.2	582
CD at 5%	72.19	27.83	148.8	58.14	2613	898	1522.8	1678
Fertilizer cum Stress Management Practices : (07)								
F_1 : RDF	916	755	1710	1127	-274	3042.1	55462	19410
F_2 : RDF + Foliar application of KNO_3	1046	880	1991	1300	237	5921.7	68067	24742
F_3 : RDF + Foliar application micro-nutrient mixture (two sprays)	1039	837	2055	1310	922	4515.6	72091	25842
F_4 : 75% RDF + 25% N through FYM + KNO_3	1108	867	2190	1388	1939	5852.6	79472	29087
F_5 : RDF + 25% N through FYM +Micro-nutrient mixture (two sprays)	1054	829	2229	1371	1048	5140.7	82558	29582
F_6 : 75% RDF + Green Manuring + KNO_3 (two sprays)	978	820.5	2410	1403	-4994	2730.7	83348	27028
F_7 : 75% RDF + Green Manuring + Micro-nutrient mixture	1006	845	2300	1384	-4913	2474.7	90199	29253
SE ±44.31	20.23	97.89	27.14	249	475	1896	873	
CD at 5%	133.14	56.00	270.9	81.43	749	1316	5247.3	2437
Interaction : (L x F)								
SE ±23.05	35.04	169.5	42.86	659.57	823.7	3284	1589	
CD at 5%	NS	97.00	305.2	128.58	NS	2279	9523	3934

land configurations and nutrient cum stress management practices.

Effect of land configurations : Moisture content (%) in mm in soil: Moisture content in mm of soil was observed varying with the rainfall received in meteorological weeks in different years of experiment. The moisture content of soil at various depths was also affected with different land configurations. Higher soil moisture content was recorded in BBF land configuration at different depths of observation. However, the numerical value of per ecnt moisture content was different in various experimental years due to the variation in rainfall received. The land configuration of flat bed recorded the lowest soil moisture content. Similar results were reported by Kalhapure and Shete (2013). The BBF land configuration conserved 25, 18 and 16 per cent more moisture than that of flat bed during Ist, IInd and IIrd year respectively (Table 7 and 8).

Growth attributes : Treatment L_2 (BBF) produced significantly taller plants and highest dry matter over rest of the land configurations for all the experimental years. However, the land configuration of BBF was found on par with ridges and furrow during later two years of the study i.e. 2015-16 and 2016-17Flat bed method of sowing produced significantly lower plant height and dry matter content of plant. Similar results were reported by Tayade and Meshram (2013).

Table 4. Cotton net monetary returns, B:C ratio and rain water use efficiency as influenced by treatments in rainfed *Bt* cotton (2014-16)

Treat-ments	Net monetary returns (Rs. ha^{-1})				B:C ratio				RWUE (kg ha^{-1} mm^{-1})			
	2014-15	2015-16	2016-17	Pooled mean	2014-15	2015-16	2016-17	Pooled mean	2014-15	2015-16	2016-17	Pooled mean
Main Plots: Land Configurations : (03)												
L_1	-5529	5911	64802	21728	0.75	1.18	2.75	1.56	1.72	2.56	2.37	2.22
L_2	3975	7746	86823	32848	0.87	1.23	3.04	1.71	2.01	3.21	3.01	2.74
L_3	-1117	5911	76033	26942	0.78	1.18	2.85	1.60	1.81	2.99	2.73	2.51
SE ±	871	324	550.2	582	–	–	–	–	–	–	–	–
CD at 5%	2613	898	1522.8	1678	–	–	–	–	–	–	–	–
Fertilizer cum Stress Management Practices : (07)												
F_1	-274	3042.1	55462	19410	0.84	1.10	2.46	1.46	1.85	2.65	2.17	2.22
F_2	237	5921.7	68067	24742	0.73	1.18	2.67	1.52	1.92	3.08	2.53	2.51
F_3	922	4515.6	72091	25842	0.60	1.14	2.80	1.51	1.53	2.93	2.61	2.36
F_4	1939	5852.6	79472	29087	0.89	1.18	2.98	1.68	2.36	3.04	2.78	2.73
F_5	-4994	2730.7	83348	27028	0.65	1.16	3.11	1.64	1.68	2.91	2.83	2.47
F_6	1048	5140.7	82558	29582	0.71	1.08	2.97	1.58	2.10	2.96	2.92	2.66
F_7	-4914	2474	90199	29253	0.51	1.07	3.18	1.58	1.48	2.87	3.07	2.47
SE ±	249	475	1896	873	–	–	–	–	–	–	–	–
CD at 5%	749	1316	5247.3	2437	–	–	–	–	–	–	–	–
Interaction (L x F)												
SE ±	659.57	823.7	3284	1589	–	–	–	–	–	–	–	–
CD at 5%	NS	2279	9523	3934	–	–	–	–	–	–	–	–

Yield attributes, seed cotton yield and economic returns : Significantly higher number of picked bolls, boll weight per plant, seed cotton yield plant^{-1} were observed in BBF land configuration, however it was found at pat with the land configuration of ridges and furrow for boll weight and seed cotton yield during 2014-15. Lowest number of picked bolls, boll weight per plant, seed cotton yield per plant were recorded in flat bed sowing of cotton. These findings are in conformity with the findings reported by Patil and Sheelavantar (2000). Whereas, significantly highest seed yield of *Bt* cotton was observed in BBF land configuration, however it was found at par with the ridges and furrow method of sowing during 2014-15 and 2015-16 whereas it was significantly higher in BBF than both i.e. flat bed and ridges and furrow methods in pooled results. Similar trend of results was observed in net returns hectare^{-1} wherein BBF land configuration recorded significantly higher net returns hectare^{-1} over ridges and furrow and flat bed sowing during all three years of the experimentation. Highest B: C ratio and rain water use efficiency was also observed in BBF land configuration.

Effect of fertilizer cum stress management practices

Growth attributes : Treatment F_6 (75% RDF + green manuring + foliar application of KNO_3) recorded significantly taller plants and highest dry matter than application of RDF and it was found at par with rest of the fertilizer cum stress management practices during 2014 and was found significant over F_1 and F_5 during 2015 and significant over F_1, F_2 and F_3 and it was found at par with rest of the treatments during 2016. However, pooled data showed that, F_6 (75% RDF + green manuring + foliar application of KNO_3) recorded significantly taller plants and highest dry matter except that it was found at par with rest of the fertilizer cum stress management practices except the rest of thr foliar applications coupled with RDF.

Yield attributes, seed cotton yield and economic returns : The pooled results showed that significantly higher number of picked bolls, boll weight plant^{-1}, seed cotton yield plant^{-1} were observed in treatment F_6 (75% RDF + green manuring + foliar application of KNO_3), and it was found at par with F_4 (75% RDF + 25% N through FYM +

Table 5. Interaction Effect (L x FS) of land configurations and fertilizer cum stress management practices on cotton seed yield, gross monetary returns (Rs. ha^{-1}) and net monetary returns (Rs ha^{-1})

Cotton seed yield (kg ha^{-1})				**Net monetary returns (Rs ha^{-1})**			
Land configurations / Fertilizer cum Stress Management Practices	**L_1 : Flat Bed**	**L_2 : BBF**	**L_3 : Ridges & Furrow**	**Land configurations / Fertilizer cum Stress Management Practices**	**L_1 : Flat Bed**	**L_2 : BBF**	**L_3 : Ridges & Furrow**
F_1	967	1367	1046	F_1	14379	26156	20079
F_2	1154	1407	1355	F_2	20166	31133	25312
F_3	1099	1441	1390	F_3	20906	31964	26143
F_4	1243	1540	1394	F_4	24517	35701	29615
F_5	1190	1494	1380	F_5	24976	33429	30112
F_6	1254	1558	1402	F_6	22473	36042	27567
F_7	1255	1526	1395	F_7	24679	35516	29767
SE ±	37			SE ±	1326		
CD at 5%	114			CD at 5%	3982		
Mean	1326			Mean	27173		

foliar application of KNO_3) and significantly superior over rest of the fertilizer cum stress management practices. Whereas, significantly highest seed yield of *Bt* cotton was observed in in treatment F_6 (75% RDF + 25% N though FYM + foliar application of KNO_3), and it was found at par with rest of the fertilizer cum stress managementpractices during 2014 and 2015 except F_1. Whereas during 2018 75% RDF + green manuring + application of KNO_3 gave significantly higher seed cotton yield which was found at par with F_4, F_5 and F_7. However, pooled data showed that, F_6 (75% RDF + green manuring + foliar application of KNO_3) recorded significantly higher seed cotton yield except that it was found at par with F_7, F_5 and F_4 found significant over rest of the fertilizer cum stress managementpractices.

Similar trend of results was observed in net returns hectare^{-1} wherein F_4 (75% RDF + green manuring + foliar application of KNO_3), recorded significantly higher net returns hectare^{-1} during 2014. However, during 2015 highest net monetary returns were recorded by F_2 (RDF + foliar application of KNO_3), and during 2016 significantly higher net returns hectare^{-1} were observed in F_7 (75% RDF + green manuring + foliar application of Micro nutrient mixture) which was found significant over rest of the treatments. The pooled results showed that the significantly higher net returns were observed in F_6 (75% RDF + green manuring + foliar application of KNO_3), which was found at par with F_7 and F_4 during all three years highest B: C ratio was also observed in F_6 (75% RDF + green manuring + foliar application of KNO_3), results were in conformity with the findings of Nehra and Yadav (2013).

Interaction effect : The pooled results showed that, the interaction effect of land configurations and fertilizer cum stress management practices were found to be significant. The treatment combination of L_2F_6 (BBF + 75% RDF + green manuring + foliar application of KNO_3) recoded highest seed cotton yieldwhich was found at par with L_2F_4, L_2F_7 and L_2F_5 and significantly superior over rest of the treatment combinations. In case of net returns hectare^{-1} similar trend was observed wherein, the treatment combination of L_2F_6 (BBf + 75% RDF + green manuring + foliar application of KNO_3) recoded significantly higher net returns hectare^{-1} which was found at par with L_2F_4, L_2F_7 and L_2F_5 and significantly superior over rest of the treatment combinations.

Conclusions : Sowing of *Bt* cotton on BBF land configuration and application of 75% RDF + green manuring + foliar application of KNO_3 (two sprays at 35 and 75 DAS @ 1% and 2% respectively) produced higher seed cotton yield and net returns hectare^{-1} showing climate resilience under rainfed condition.

Table 6. Moisture conservation by various land configurations for Bt -cotton during 2014-15, 2015-16 and 2016-17 (Mean)

Soil depth (60 cm)	Moisture conservation (%)			
	2014-15	**2015-16**	**2016-17**	**Mean**
Moisture conservation (%) in BBF	16% more than Flat bed	24% more than Flat bed	18% more than Flat bed	19% more than Flat bed
Moisture conservation (%) in Ridges and furrow	11% more than Flat bed	14% more than Flat bed	08% more than Flat bed	11% more than Flat bed

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J. Agric. Res. Technol., 42 (3) : 029-035 (2017)

Interrelation of Geomorphological Properties of MPKV Central Campus (West) Watershed Derived From RS and GIS Technique

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Abstract

Geomorphological characteristics of six sub watersheds of MPKV Central Campus (West)Watershed were work out and their interrelation proposed by different research workers were tested. The relationship for the maximum basin length and the area of watershed which developed by Gray (1961) when used for the six sub watersheds of MPKV Central Campus (West) watershed, showed much deviation from the observed value and hence new relation was tried, which matched in the form but the coefficient were found to be different. The computed value of stream frequency from the relation proposed by Melton (1957) differed from the actual stream frequency of watershed and new relationship developed for the stream frequency with drainage density of the watershed was a polynomial function of second order and it differed in the nature proposed by Melton (1957).

Key words : Watershed, Geomorphological characteristics.

Watershed, a hydrogeological entity, is bounded by a ridge line and discharge the water to a common single outlet. The watershed or drainage basin, a system that converts rainfall to runoff, controls the rate at which runoff will occur and the degree to which the runoff water will be concentrated. Characteristics of drainage basin reflect hydrologic behavior and therefore are more useful, when quantified, in evaluating the hydrologic response of the basin. These characteristics relate to the physical drainage basin area, basin shape, ground slope and centroid of basin. Channel characteristics include channel length, channel order, slope, channel profile and drainage density. Topographic map can be digitized these days and the basin characteristics can be conveniently estimated without tedious manual work. Digitizers and simple computer programs are available to determine many of these basin characteristics.

The output of watershed depends on size, shape, slope, orientation, elevation and density of stream. The various morphological characteristics of a watershed can be correlated with each other and can be given in terms of area of watershed. The scientist such as Gray (1961) developed the empirical relationship between maximum basin length and area of watershed and Melton (1957) developed relationship between stream frequency and drainage density. This empirical relationships may be varied for different locations and geomorphology. As such these relationships need to be verified and location specific relationships need to be developed. In view of these, the different geomorphological characteristics of MPKV Central Campus West watershed were worked out and the relationships given by Gray and Melton were verified for the watershed.

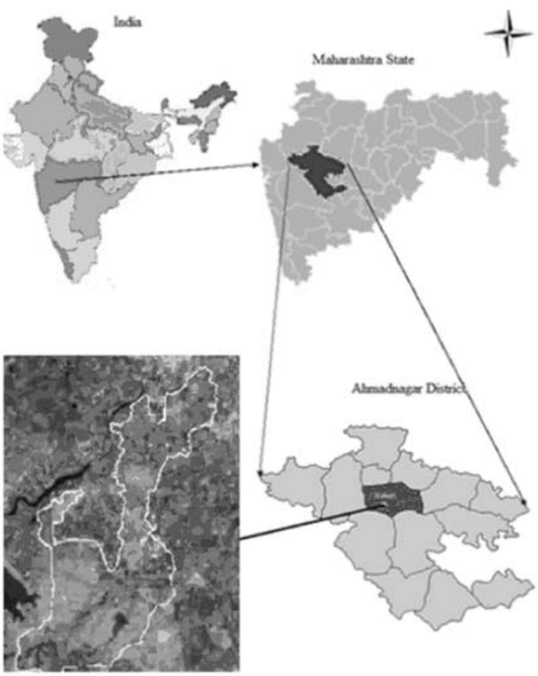

Fig.1. Location of the study area

Materials and Methods

Study area : Study area is located in Ahmednagar district, situated on the AhmednagarManmad highway, 35 km from the district place. The neighbouring districts to Ahmednagar district are Solapur (South-East), Osmanabad (South-East), Beed (South-East), Aurangabad (North-East), Nashik (North-West), Thane (North-West) and Pune (South-West). The study area of the research was Mahatma PhuleKrishiVidyapeeth Central Campus Rahuri in Ahmednagar district, Maharashtra. The area is located between 19o 19' to 19o 22' North latitude and 74° 36´ to 74° 40´ East longitude. The total area of MPKV Central Campus west region is 1528 ha.

Climate : As per the information obtained from the All India Coordinated Research Project on Water Management, area of MPKV receives rainfall between June and September. The area falls in semi-arid subtropical zone, with an average annual rainfall of 520 mm. The

Fig.2. Catchments of MPKV CentralCampus (west)

maximum temperature of the region ranges from 35°C to 43°C and minimum temperature from 4.3°C to 5.4°C. The climate of MPKV is dry except during the south-west monsoon season and winter months; December to February. The mean annual relative humidity at morning and evening is 70% and 40%, respectively (Kanwade. 2016).

Morphological characteristics of MPKV central campus (west) watershed

Morphological analysis is the systematic description of watershed's geometry and its stream system to measure the linear aspects of drainage network, areal aspects of watershed and relief aspects of stream network. The morphological parameters directly or indirectly reflect the entire watershed based on causative factors affecting runoff and sediment loss. The surface features are the fundamental unit of analysis prior to adopting any sophisticated tool to monitor the watershed response in connection to any of the hydrologic process acting on it. Umrikar, et al (2013), Tignath et al (2014) and Waikar (2014) used RS GIS technique to find out the morphological characteristics of watershed. The drainage map of the study area was used for quantitative morphological analysis of both linear and aerial aspects of the drainage basin. The morphological information pertaining to each of the watershed was obtained with reference to its size, shape, slope, relief, stream density, vegetation, and land use and stream network system.

Linear Aspects of Drainage Networks

Stream order : Stream ordering is the first step in evaluation of morphometric parameters, which helps to understand the nature of linear, relief and areal properties of watershed. The concept of stream order in drainage network is introduced by Horton (1932).

Bifurcation ratio (R_b) : It is the ratio of number of stream of any order (Nu) to the number of stream of next higher order (Nu+1). In order to calculate the average value of R_b for a given channel network, the logarithm of number of segments is regressed in order to get the relationship. Horton (1945) proposed the law of stream numbers, which relates the number of stream order u (Nu) to bifurcation ratio (Rb) and the principal order (k).

$$Nu = Rb^{k-u}$$

$$Rb = \text{Antilog}\ (\log Nu/k-u)$$

Stream length ratio : Horton (1945) defined the stream length ratio, RL, as the ratio of mean length, Lu of segments of order u to mean length of segments of the next lower order

Areal aspects of drainage basins : The areal aspects of any watershed have a tremendous response on the hydrologic processes. These aspects of geomorphological study of watershed includes the description of area of the watershed, drainage density, stream frequency, circulatory ratio elongation ratio, basin shape factor, drainage factor, etc.

Drainage density : Drainage density, Dd, is the ratio of total length (L) of all streams of all orders within a watershed to the total area of watershed (A)

$$D_d = \Sigma L_u / A$$

Stream frequency : Stream frequency, Fs, as the number of stream segments of all orders per unit area, or

$$F_s = \Sigma N_u / A$$

Circulatory ratio : Miller (1953) used the circulatory ratio to mark the basin shape. It is the ratio of area of watershed to the area of circle having same perimeter as that of watershed,

Table 1. Geomorphological characteristics of six sub watersheds

Watershed Characteristics	Catchments					
	A	B	C	D	E	F
Drainage area (A), ha	842.20	66.77	162.50	184.57	151.60	93.25
Stream order	3	2	3	3	3	2
Form factor (Rf)	0.43	0.61	0.54	0.53	0.54	0.58
Drainage density (Dd), km km-2	3.15	1.69	2.00	2.41	2.51	2.49
Stream frequency (F), Nos.km-2	7.36	5.99	4.92	7.58	5.93	4.28
Circularity ratio (Rc)	0.53	0.63	0.70	0.47	0.76	0.64
Elongation ratio (Re)	0.74	0.88	0.83	0.82	0.84	0.86
Length of overland flow (Lg), km	0.15	0.29	0.25	0.20	0.20	0.20
Maximum basin length, (Lb) km	4.57	1.06	1.61	1.94	2.15	1.41
Relative relief (RF)	2.61	6.28	3.71	3.41	6.79	1.87
Ruggedness number (RN)	0.12	0.04	0.04	0.06	0.09	0.02
Bifurcation ratio (Rb)	2.77	3	2.15	2.28	1.91	3
Stream length ratio (RL)	2.12	1.12	0.71	3.10	1.56	0.64

$$Re = 3.544 \sqrt{A} / L_p$$

Elongation ratio (Re) : Elongation ratio is the ratio of the diameter of a circle with the same area as the watershed to the maximum length of the watershed (Lb)

Basin shape factor : The basin shape factor (Sb) as defined by Horton (1932), is the ratio between the square of the maximum length of watershed and the area of the watershed.

$$Sb = L_b^2 / A$$

Drainage factor : Drainage factor, Df, is the ratio of stream frequency to the square of drainage density.

$$D_f = F_s / D_d^2$$

Relief aspects of drainage basins : The relief aspect of geomorphological study of watershed includes relief characteristics, Slope of watershed, main stream channel slope and hypsometric analysis of watershed.

Maximum watershed relief : Maximum watershed relief is the elevation difference between basin discharge point and the highest point on the basin perimeter. Maximum watershed relief is obtained from the available contour maps of the watersheds. The speed and extend of runoff.

Relief ratio : Relief ratio (RF)is the maximum watershed relief (H) divided by the maximum watershed length (Lb)

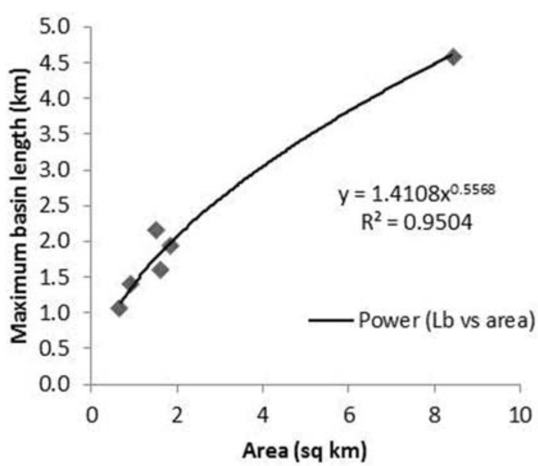

Fig. 3. Maximum basin length Vs area of watershed

$R_F = H / Lb$

Relative relief : Relative relief is the ratio of maximum watershed relief to the perimeter of watershed (Lp).

$R_r = H / L_P$

Ruggedness number : Ruggedness number is the product of drainage density (Dd) and relief (H). It is dimensionless measure of drainage characteristics of basin

It indicates the structural complexity of the terrain in association with relief and drainage density. The high RN value of watershed indicates that watershed is highly susceptible for erosion. It is computed from the following equation:

$R_N = H\ D_d / 1000$

The empirical relationship are proposed by Gray (1961) between maximum basin length and area of watershed as $L_b = 1.312^* A^{0.568}$, where, L_b is in km and A is in sq. km and the relationship proposed by Melton (1957) between stream frequency and drainage density as $S_f = 0.694 * Dd^2$, where, S_f is stream frequency k m^{-2} and D_d Drainage density km k m^{-2}. These relationships were verified for the MPKV Central Campus West watershed.

Results and Discussions

The geomorphological characteristics of all the six sub watersheds of MPKV Central Campus (West) area were determined using RS and GIS and equations given by the various scientists.

Gray (1961) has proposed the relationship between maximum basin length and area of watershed as

$L_b = 1.312^* A^{0.568}$, where, Lb is in km and A is in sq. km. It can be revealed from Table 2 that the observed values of L_b do not match with computed values with Gray method. It was therefore thought to develop relationship between L_b and area. The relationship is shown in Fig 3 and the equation is given as:

$L_b = 1.4108^* A^{0.5568}$ ...(0.6677< A < 8.4220) ----- (1)

The form of developed equation is similar to that proposed by Gray (1961) however it shows some variations as indicated in Table 2.

Absolute % deviation by new equation (eqn 1) for watershed A, D, E, F were less and for watershed B, C were more than the Gray formula.

Melton (1957) proposed an empirical

Table 2. Absolute % deviation of actual watershed basin length and Computed value of maximum basin length from watershed area

Maximum length of basin (Lb)						
Water-shed	Area Sq. km	Actual Lb, km	By Gray formula Lb, km	By new equation Lb, km	Absolute % deviation	
					By Gray formula	By new equation (eq^n.1)
A	8.422	4.573	4.401	4.614	3.757	0.899
B	0.667	1.059	1.042	1.126	1.567	6.357
C	1.625	1.61	1.729	1.848	7.367	14.788
D	1.8457	1.944	1.858	1.984	4.409	2.043
E	1.516	2.154	1.662	1.778	22.852	17.452
F	0.9325	1.412	1.261	1.357	10.698	3.894

Table 3. Absolute % deviation of Actual stream frequency and Computed value of stream frequency from drainage density

		Stream frequency (S_f)				
Water-shed	D_d km km^{-2}	Actual value S_f, km^{-2}	By Melton formula S_f, km^{-2}	By new equation (eq^n 2) S_f, km^{-2}	Absolute % deviation	
					By Melton formula	By new equation
A	3.15	7.36	6.886	7.352	6.437	0.115
B	1.69	5.99	1.982	5.778	66.909	3.544
C	2	4.92	2.776	5.555	43.577	12.915
D	2.41	7.58	4.031	5.722	46.823	24.510
E	2.51	5.93	4.372	5.842	26.269	1.477
F	2.49	4.28	4.303	5.446	0.534	35.885

relation between stream frequency and drainage density as

$S_f = 0.694 * D_d^2$, where, S_f is stream frequency k m^{-2} and D_d Drainage density km k m^{-2}. It can be revealed from Table 3 that the observed value of Sfdo not match with computed values. It was therefore thought to develop some relationship between Sf and Dd. The relationship is shown in Fig 4 and the expression is obtained as

$Sf = 1.561D_d^2 - 6.4773D_d + 12.266$ …(0.6677 < A < 8.4220) -----(2)

The relation observed for the stream

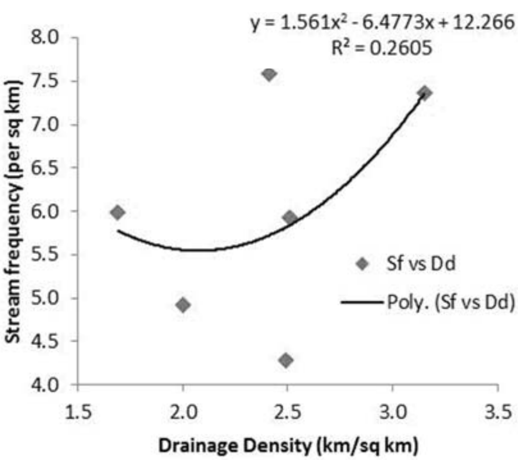

Fig. 4. Stream frequency Vs drainage density

frequency and drainage density was a polynomial function.

Absolute % deviation by new equation for watershed A, B, C, D, E were less and for watershed F were more than the Melton formula.

Conclusions

Gray (1961) overall underestimates the Maximum length of the basin (Lb) as per his equation $L_b = 1.312{*}A^{0.568}$. The new relationship developed for Maximum Basin Length (Lb, in km) and Watershed Area (A, in square km) for MPKV Central Campus (West) Watershed is $Lb = 1.4108{*}A^{0.5568}$ …(0.667 < A < 8.422) can be used for the watershed areas in the range of 6.67 to 842.2 ha for prediction of maximum basin length from the available area. The variation in L_b is ranged from 0.89 to 17.45 per cent for the subwatersheds of MPKV Central Campus (West) Watershed. However the variation is very less (0.89 to 6.35) for A, B, D and F subwatersheds using the newly developed relationship. Melton's (1957) empirical relationship between stream frequency (S_f) and drainage density (D_d); $S_f = 0.694 * D_d^2$, shows much variations and the observed value of $S_f$do not match with computed values. The new relationship developed between stream frequency (S_f) and drainage density (D_d); $S_f = 1.561D_d^2 - 6.4773D_d + 12.266$ …(0.6677 < A < 8.4220) shows less overall variation hence can be used for prediction of Stream frequency from Drainage density.

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J. Agric. Res. Technol., 42 (3) : 036-043 (2017)

Evaluation of DSSAT-CERES Maize Model for Northern Transitional Zone of Karnataka

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Abstract

Two field experiments on maize were conducted during the rainy seasons (Kharif) of 2015 and 2016 at the Main Agricultural Research Station, University of Agricultural Sciences Dharwad, Karnataka, India. One experiment included four hybrids across three levels of nitrogen (Expt-1) and the other experiment included the same four hybrids across three dates of sowing (Expt-2), both the experiments were repeated for two seasons (2015 and 2016). For the calibration of DSSAT-CERES maize model Expt-1 from 2015 and Expt-2 from 2016 seasons were used to optimize four hybrids genetic coefficients observed data on phenology, grain yield, and yield components by employing DSSAT Gencalc software. The calibrated model was further evaluated using another two independent data sets separately; Expt-1 from 2016 and Expt-2 from 2015, hence model performance here is discussed separately for each experiment. During evaluation for Expt-2 from 2015 the model predicted both days to anthesis and maturity of all the four tested hybrids across dates of sowing with the mean RMSE values of ±1.5 and ±5.7 days. Similarly, the index of agreement (d-stat) values for anthesis and maturity were 1.00 and 0.998, respectively, which is categorized as excellent. This is further proved by the very high index of agreement (d-stat) of 0.999 for total above ground biomass, yield traits and grain yield. With regard to second independent data set of Expt-2 from 2015, the model predicted both days to anthesis and maturity with the mean RMSE values of ±2.4 and ±3.7 days, respectively; which is further asserted by very high index of agreements (d-stat) of 0.999 and 0.999 for anthesis and maturity, 0.999 for total above ground biomass, 0.999 for yield traits, and 0.999 for grain yield. On the whole DSSAT-CERES maize model performed exceedingly well for Northern Transitional Zone of Karnataka and can be used as decision support system tool in agriculture and to study the impacts of climate change on maize crop.

Key words : Maize, DSSAT-CERES model, model calibration, model validation, decision support system.

Agronomic research has focused on formalizing and summarizing knowledge of growth and yield of field crops including maize. When mathematical principles are combined to be presented as a cause-effect process, the relationship can be referred as a mechanistic model. Mechanistic representations may be combined in logical segments to provide a simulation of all or part of a complex system (Reckman *et al*., 1996). A crop model can be defined as a quantitative scheme for predicting the growth, development and yield of a crop, given a set of variables (Monteith, 1996).

*Part of the Ph.D. (Agric.) thesis, submitted by the author to the University of Agricultural Sciences, Dharwad - 580 005, Karnataka (India).

Crop simulations are now being used in agronomy for research, education, extension and crop management (Van Evert and Campbell, 1994). A thorough review on potential uses and limitations of crop models was published in Agronomy Journal (1996) by. Whistler *et al*. (1986) and Hoogenboom (2000) described a wide range of major areas in which the application of models is well established. Several maize models such as Hybrid maize, Root Zone Water Quality Model (RZWQM), Agricultural Production Systems Simulator (APSIM), Model for World Food Studies i.e. WOFOST and Agricultural Land Management Alternatives with Numerical Assessment Criteria (ALMANAC) had been used for simulation of crop growth, yield and evaluation of management strategies.

Ritchie *et al.* (1998) studied growth, development and yield of cereal crops included in Decision Support System for Agro-technology Transfer (DSSAT) using CERES Crop simulation model. The CERES model has been tested over a wide range of environments. Results obtained showed that when the weather, cultivar and management information are reasonably quantified, the yield results are usually within acceptable limit.

Simulation models are thought to be an indispensable tool for supporting scientific research, crop management, and policy analysis (Fischer *et al.*, 1999; Hammer *et al.*, 2002; Hansen, 2002). However, validation of such models needs to be conducted because these are developed under very specific edaphic and climatic conditions that do not necessarily prevail in other regions of the world. Therefore, before the model can be adopted or used in other locality, evaluation or validation study must be undertaken to establish its credibility (Balderama and Bareng, 2009).

Soler *et al.* (2007) evaluated the Cropping System Model (CSM)-CERES-Maize for its ability to simulate growth, development, grain yield for four different maturity maize hybrids grown off-season in a subtropical region of Brazil, under rainfed and irrigated conditions. The evaluation of the CSM-CERES-Maize showed that the model was able to simulate phenology and grain yield for the four hybrids accurately, with normalized RMSE (expressed in percentage) less as compared to 15 per cent. Total biomass and LAI were also reasonably well simulated, especially for the hybrids Exceler, DAS CO32, and DKB 333B.

Khaliq (2008) stated that the use of simulation models to predict the likely effects of climate change on crop production is, of necessity, an evolving science. As both general circulation models and crop simulation models become more sophisticated, as more high quality historical weather data for a larger number of sites become available, and as better physiological data become available to model maize responses to climate change variables, predictions will become more accurate.

To study the impact of future climate on the crop productivity models can be used effectively and efficiently. DSSAT-CERES maize model is one of the supportive tools to study the future

Table 1. Optimized genetic coefficients of tested maize hybrids after calibration

Code	Hybrids			
Genetic coefficients	**Nithya-shree**	**NK-6240**	**GH-0727**	**900-M-Gold**
P_1	254.0	250.0	250.0	254.2
P_2	0.270	0.270	0.270	0.270
P_5	880.4	878.7	875.0	863.7
G_2	945.0	950.0	870.0	965.0
G_3	8.00	8.00	8.00	8.00
PHINT	38.70	38.70	38.90	36.01

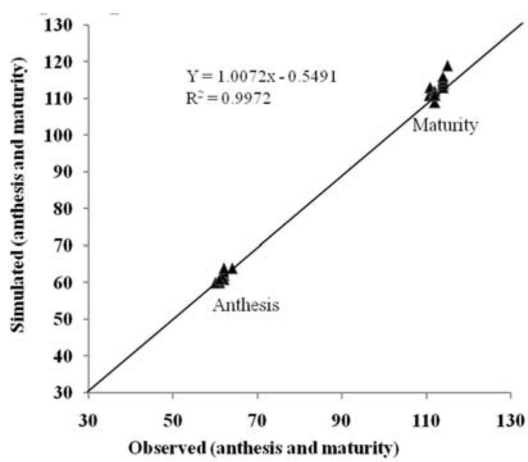

Fig. 1. Observed and simulated days to anthesis and anthesis and maturity DS Vs N (Expt-1) of 2015 after caliberation

crop production and productivity status of the given area, and accordingly devise adaptation strategy. Crop simulation models (viz., DSSAT model) are being used to study and predict the future productivity potential of a crop, cropping systems, for a given area within the shortest possible time. The DSSAT-CERES maize model has not been used for evaluating the currently widely adapted maize hybrids in Northern Transition Zone of Karnataka. Therefore the objective of this work was to evaluate the performance of DSSAT-CERES maize model for the currently ruling maize hybrids.

Materials and Methods

Two field experiments on maize were conducted during the two successive rainy seasons (*Kharif*) of 2015 and 2016 at the Main Agricultural Research Station, University of Agricultural Sciences Dharwad, Karnataka, India. One experiment included four hybrids and three levels of nitrogen (Expt-1) repeated twice (2015 and 2016), and the other experiment included the same four hybrids across three dates of sowing (Expt-2) repeated twice (2015 and 2016). Observations on phenology, total above ground biomass, anthesis and maturity, yield components and yield were collected. The DSSAT-CERES maize model was calibrated using two independent sets of field experiment data i.e. observed data on phenology, grain yield and yield components from Expt-1 of 2015 and Expt-2 from 2016 employing Gencalc software. Here the performance of DSSAT-CERES maize model was discussed separately for both the independent data sets. The calibrated model was evaluated separately for another two independent data sets; Expt-1 from 2016 followed by Expt-2 from 2015.

Result and discussion

The calibration of DSSAT-CERES maize model for the newly tested four hybrids was done using observed data on anthesis, physiological maturity, total above ground biomass, yield component, and grain yield from four hybrids across N levels experiment from 2015 (Expt-1) and hybrids across dates of

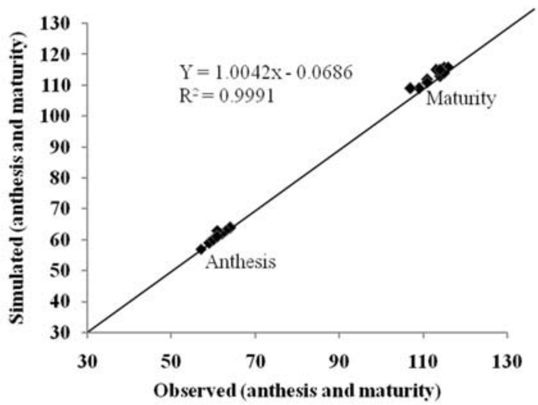

Fig. 1. Observed and simulated days to anthesis and anthesis and maturity DS Vs H (Expt-2) of 2016 after caliberation

Table 2. Observed and simulated values of anthesis and maturity dates for Expt-1 (2016) after evaluation

Treat-ments	Anthesis date (DAS)			Maturity date (DAS)		
	Obs.	Sim.	% deviation	Obs.	Sim.	% deviation
N_1H_1	62	62	0.0	111	119	-7.2
N_1H_2	62	62	0.0	114	119	-4.4
N_1H_3	60	62	-3.3	111	118	-6.3
N_1H_4	61	61	0.0	112	117	-4.5
N_2H_1	62	62	0.0	112	119	-6.3
N_2H_2	62	62	0.0	114	119	-4.4
N_2H_3	61	62	-1.6	112	118	-5.4
N_2H_4	64	61	4.7	115	117	-1.7
N_3H_1	60	62	-3.3	112	119	-6.3
N_3H_2	62	62	0.0	114	119	-4.4
N_3H_3	61	62	-1.6	112	118	-5.4
N_3H_4	64	61	4.7	116	117	-0.9
Mean	62	62	0	113	118	-5
RMSE	1.5			5.7		
d-stat	1.00			0.998		
NRMSE	2.47			5.04		

Table 3. Observed and simulated values of grain yield and total shoot biomass for Expt-1 (2016) after evaluation

Treat-ments	Grain yield ($kg\ ha^{-1}$)			Total shoot biomass ($kg\ ha^{-1}$)		
	Obs.	Sim.	% devi-ation	Obs.	Sim.	% devi-ation
N_1H_1	7500	8332	-11.1	15500	14677	5.3
N_1H_2	9050	8368	7.5	18300	14694	19.7
N_1H_3	7650	7779	-1.7	15300	14332	6.3
N_1H_4	8580	8393	2.2	17200	14503	15.7
N_2H_1	9042	8332	7.9	19450	14677	24.5
N_2H_2	9302	8368	10.0	18210	14694	19.3
N_2H_3	7620	7779	-2.1	14945	14332	4.1
N_2H_4	9070	8393	7.5	18200	14503	20.3
N_3H_1	9080	8332	8.2	18100	14677	18.9
N_3H_2	9310	8368	10.1	18000	14694	18.4
N_3H_3	7600	7779	-2.4	15100	14332	5.1
N_3H_4	9050	8393	7.3	18300	14503	20.7
Mean	8571	8218	4	17217	14552	15
RMSE	644.2			3010.2		
d-stat	0.999			0.986		
NRMSE	7.52			17.5		

sowing experiment from 2016 season (Expt-2) by employing Gencalc software (Table 1).

Where; P1 is thermal time from seedling emergence to the end of the juvenile phase NK-6240 and GH-0727showed the same values, whereas Nithyashree and 900-M-Gold recorded values of 254.0 and 254.2; P2 is extent to which development (expressed in days) is delayed for each hour increase in photoperiod above the longest photoperiod at which development proceeds at a maximum rate all the four tested hybrids showed the same value of 0.270; P5 is thermal time from silking to physiological maturity (expressed in degree days above a base temperature of 8 °C) showed a considerable difference among the tested hybrids; the highest value of 880.4 followed by 863.7 were recorded by Nithyashree and NK-6240, while the lowest value (863.7) was recorded by 900-M-Gold. G2 is maximum possible number of kernels per plant. Among the tested hybrids 900-M-Gold followed by NK-6240 recorded 965 and 950 maximum possible kernel, respectively. The lowest value 870 was recorded by GH-0727; G5 is Kernel filling rate during the linear grain filling stage and under optimum conditions (mg/day) was not varied among the tested hybrids. PHINT is phyllochron interval; the interval in thermal time (degree days) between successive leaf tip appearances there was a slight difference among the hybrids on this trait the highest value was recorded by GH-0727 followed by NK-6240 and Nithyashree.

This was in agreement with Ahmed *et al.* (2017) who worked in Bangladesh on calibration and validation of decision support system for agro-technology transfer model for simulating growth and yield of maize; they used

Table 4. Observed and simulated values of No. of grains m^{-2} and No. of grains per cob for Expt-1 (2016) after evaluation

Treat-ments	No. of grains m^{-2}			No. of grains cob^{-1}		
	Obs.	Sim.	% devi-ation	Obs.	Sim.	% devi-ation
N_1H_1	2586	2422	6.3	323	303	6.2
N_1H_2	2586	2433	5.9	323	304	5.9
N_1H_3	2391	2261	5.4	299	283	5.4
N_1H_4	2524	2498	1.0	315	312	1.0
N_2H_1	2583	2422	6.2	323	303	6.2
N_2H_2	2584	2433	5.8	323	304	5.9
N_2H_3	2485	2261	9.0	307	283	7.8
N_2H_4	2668	2498	6.4	333	312	6.3
N_3H_1	2752	2422	12.0	344	303	11.9
N_3H_2	2660	2433	8.5	333	304	8.7
N_3H_3	2303	2261	1.8	289	283	2.1
N_3H_4	2586	2498	3.4	323	312	3.4
Mean	2559	2404	6	320	301	6
RMSE	174.6			21.4		
d-stat	0.998			0.998		
NRMSE	6.82			6.69		

Table 5. Observed and simulated values of days to anthesis and maturity Expt-2 (2015) after evaluation

Treatments	Anthesis date (DAS)			Maturity date (DAS)		
	Obs.	Sim.	% deviation	Obs.	Sim.	% deviation
DS_1H_1	64	60	6.3	114	111	2.6
DS_1H_2	64	60	6.3	115	111	3.5
DS_1H_3	59	60	-1.7	109	111	-1.8
DS_1H_4	61	59	3.3	114	110	3.5
DS_2H_1	63	59	6.3	116	111	4.3
DS_2H_2	62	59	4.8	115	110	4.3
DS_2H_3	61	59	3.3	109	110	-0.9
DS_2H_4	60	58	3.3	111	109	1.8
DS_3H_1	60	61	-1.7	111	111	0.0
DS_3H_2	61	60	1.6	113	111	1.8
DS_3H_3	57	60	-5.3	107	110	-2.8
DS_3H_4	61	59	3.3	114	109	4.4
Means	61	60	2	112	110	2
RMSE	2.7			3.4		
d-stat	0.999			0.999		
NRMSE	4.36			3.02		

four adapted maize cultivars, BARI Hybrid Maize-7, BARI Hybrid Maize-9, NK-40 and Pioneer. The authors reported that the genotypic coefficient P1 was 225°C day for BARI Hybrid Maize-7 and BARI Hybrid Maize-9, while that was 226°C day for PIONEER and NK-40. The P2 was same for all the varieties and P5 was 956°C day for BARI Hybrid Maize-7 and BARI Hybrid Maize-9, while that was 965 for PIONEER and 964 for NK-40. According to the same authors there was considerable variation among the cultivars in G2 and G3 but PHINT were the same amongst the cultivars.

After caliberation the model predicted both days to anthesis and maturity of all the four tested hybrids across dates of sowing with the mean RMSE values of ±1.5 and ±5.7 days. Similarly the index of agreement (d-stat) values for anthesis and maturity were 1.00 and 0.998; and NRMSE of 2.47, 5.04%, and R2 of 0.999 respectively, which is categorized as excellent (Figure 1 and 2).

On contrary to our work (Ahmed *et al.*, 2017) in Bangladesh reported that validation of simulated days to anthesis was over estimated compared to simulated values irrespective of cultivars where error percentages ranged from 3.75% to 4.94% during the 2015-16, respectively; whereas the days to maturity was in conformity to our work.

The model predicted all the four tested hybrids across the N rates and showed excellent performance with respect to grain yield which is depicted by the highest index of agreement (d-stat) value of 0.999 and NRMSE value of 7.5 %, respectively (Table 3). The evaluation of the model also showed a good agreement in the total above ground biomass which was asserted

Table 6. Observed and Simulated values of grain yield and total shoot biomass for Expt-2 (2015) after evaluation

Treatments	Grain yield (kg ha^{-1})			Total shoot biomass (kg ha^{-1})		
	Obs.	Sim.	% deviation	Obs.	Sim.	% deviation
DS_1H_1	9000	8467	5.9	17350	17049	1.7
DS_1H_2	9167	8505	7.2	20583	17088	17.0
DS_1H_3	7600	7892	-3.8	16200	16457	-1.6
DS_1H_4	9220	8259	10.4	18005	17017	5.5
DS_2H_1	9745	9017	7.5	19191	17974	6.3
DS_2H_2	10050	9058	9.9	19750	18013	8.8
DS_2H_3	8100	8403	-3.7	16500	17639	-6.9
DS_2H_4	10050	8858	11.9	19685	17892	9.1
DS_3H_1	8533	8017	6.0	17772	17481	1.6
DS_3H_2	9250	8053	12.9	18600	17517	5.8
DS_3H_3	8017	7474	6.8	16108	16835	-4.5
DS_3H_4	9533	7564	20.7	19167	16846	12.1
Means	9022	8297	8	18243	17317	5
RMSE	3.4			1568.7		
d-stat	0.999			0.999		
NRMSE	3.02			8.60		

Table 7. Observation and Simulation values of No. of grains m^{-2} and per cob for Expt-2 (2015) after evaluation

Treat-ments	No. of grains m^{-2}			No. of grains cob^{-1}		
	Obs.	Sim.	% deviation	Obs.	Sim.	% deviation
DS_1H_1	2903	2721	6.3	363	340	6.3
DS_1H_2	2619	2733	-4.4	327	342	-4.6
DS_1H_3	2235	2536	-13.5	279	317	-13.6
DS_1H_4	2881	2724	5.4	360	341	5.3
DS_2H_1	3045	2905	4.6	381	363	4.7
DS_2H_2	2956	2919	1.3	369	365	1.1
DS_2H_3	2454	2779	-13.2	306	347	-13.4
DS_2H_4	3140	2999	4.5	392	375	4.3
DS_3H_1	2510	2652	-5.7	314	331	-5.4
DS_3H_2	2721	2663	2.1	340	333	2.1
DS_3H_3	2586	2472	4.4	323	309	4.3
DS_3H_4	2979	2570	13.7	372	321	13.7
Mean	2752	2723	0	344	340	0
RMSE	206.5			25.8		
d-stat	0.999			0.999		
NRMSE	7.50			7.51		

by the highest index of agreement values of 0.986 and NRMSE value of 17.5%, respectively (Table 3). This was in agreement with the work of Balderama *et al*. (2017) who was conducted study in Philippines to estimate the genetic coefficient of hybrid corn cultivar in 2013-2015 using Ceres-Maize Model of DSSAT software. They reported that the validation process was successful as manifested by the goodness of fit between actual and simulated biomass from the five validation sites. The R^2 ranged from 0.86 to 0.97 with d-stat ranging from 0.71 to 0.98 and RMSEs were low which ranged from 1,718 to 5,725 kg ha^{-1} of biomass further the grain yield from the five plots. Actual and simulated yield showed high goodness of fit with R^2, RMSE and d-stat of 0.82, 1,118.40 kg ha^{-1}, and 0.89, respectively.

Soler *et al*. (2007) conducted a research in subtropical environment in Brazil reported that the evaluation of the CSM-CERES-Maize model for simulating the duration from planting to silking revealed similar average values for the four hybrids between observed and predicted values, such as 58 days for observed and 59 days for simulated for irrigated conditions and 59 days for both observed and simulated for the rainfed conditions. The coefficient of determination (r^2) between the simulated and observed duration from planting to anthesis for the four hybrids in the three experiments was 0.96, with the slope of the regression equation not statistically different from one and the intercept not different from zero (P = 0.05). In addition, the normalized RMSE was low (1.6%).

Furthermore according to these authors model for simulating the duration from planting to physiological maturity, showed identical average values for the four hybrids between observed and simulated values, 129 days for irrigated conditions and 128 days for rainfed

Table 8. Observed and Simulated values of single grain weight for Expt-2 (2015) after evaluation

Treatments	Single grain weight (g)		
	Obs.	Sim.	% deviation
DS_1H_1	0.308	0.311	-1.0
DS_1H_2	0.349	0.311	10.9
DS_1H_3	0.340	0.311	8.5
DS_1H_4	0.317	0.303	4.4
DS_2H_1	0.317	0.310	2.2
DS_2H_2	0.338	0.310	8.3
DS_2H_3	0.328	0.302	7.9
DS_2H_4	0.320	0.294	8.1
DS_3H_1	0.342	0.302	11.7
DS_3H_2	0.360	0.302	16.1
DS_3H_3	0.310	0.302	2.6
DS_3H_4	0.320	0.294	8.1
Mean	0.329	0.304	7.32
RMSE	0.03		
d-stat	0.997		
NRMSE	8.94		

conditions. For the four hybrids, the normalized RMSE was low, e.g., 0.7 per cent. Furthermore, the r^2 was high, e.g., 0.99, with a slope of the regression equation that was not statistically different from one and the intercept was not different from zero (P = 0.05), confirming the ability of the CSM-CERES-Maize model for simulating the duration from planting to physiological maturity of maize grown off-season in a subtropical environment.

The model validation outputs were excellent with respect to number of grains m^{-2} and number of grains/cob which was in conformity with the highest index of agreement values (0.998 and 0.998) and NRMSE values (6.82 and 6.69 %), respectively (Table 4).

The model validation result showed that it is highly efficient with respect to the anthesis and maturity of the Expt-2 (2015) which was clearly seen from the very smallest RMSE value (± 2.7 and 3.4), the highest index of agreement values of 0.999 and 0.999, and the smallest NRMSE values of 4.36 and 3.02% which are categorized under excellent category (Table 5).

Evaluation of the performance of the model in prediction of the grain yield and total above ground biomass showed that the grain yield was very much closer to the observed data which is revealed by the lowest RMSE value of (±3.4 kg/ha), index of agreement value of (0.999), and the NRMSE value of (3.02%) which showed the simulation of the parameter fall under excellent category; and also the model was highly effective in predicting the total above ground biomass which can be seen from the statistical parameters; index of agreement value (0.998) and NRMSE value of 8.6%, respectively which are the effective measure of model capability in predicting the parameters (Table 6).

Table 7 shows that the model evaluation was excellent in predicting the parameters with respect to No. of grains m^{-2} and No. of grains/cob which was in a very closer value which can be asserted from the statistical parameters which recorded lowest RMSE values of (±206.5 and 25.8 grains), highest index of agreement values of (0.998 and 0.998), and NRMSE values of (7.50 and 7.51%), respectively.

The evaluation of the DSSAT-CERES-maize model perfectly validates in predicting single grain weight of field data of 2015 season of DS vs. H (Table 8). This can be asserted by the lower value of RMSE (±0.03g), the highest index of agreement value of 0.999 and NRMSE value of (8.94%), respectively showed the highest performance the model in predicting very closely to the observed data. Our work was in agreement with Ahmed *et al*. (2017) who reported the performance of the DSSAT-CERES model after its calibration was satisfactory and the results were within significant limits and also were similar to the results of (Jones and Thornton, 2003) and (Ma *et al*., 2006).

Conclusion

Maize has taken an important place among cereal crops of India after the introduction of hybrid genotypes and its potential to productivity. It is necessary to understand the growth behaviour of hybrid maize in different production environment, especially to address future climate change impacts. Since crop growth model plays an important role in describing variability study performances. The DSSAT CERES maize model was calibrated and validated for Northern Transition Zone of Karnataka environment using field experimental data. The performance of the model was evaluated through phenology, total above ground biomass at harvest, grain yield, and yield components. The simulated results were in close agreement with the observed values and these were within the acceptable statistical significance limit. Simulated and observed phenology and yields were in close agreement with the observed values. It can be inferred that the DSSAT CERES maize model can be successfully employed for simulating the growth and yield of maize hybrids grown under various growth factors, including evaluation of the climate change impact analysis in Northern Transition Zone of Karnataka.

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J. Agric. Res. Technol., 42 (3) : 044-047 (2017)

Response of Public Maize Hybrids to Global Warming and Adaption Strategies: DSSAT Model Based Assessment

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Abstract

A study was conducted at UAS, Dharwad, India during kharif of 2016 to evaluate the performance of public maize hybrids under potential condition for both current and global warming scenarios. A total of 15 hybrids were tested and the detailed observations recorded from the field experiment were used in the DSSAT model to optimize genetic coefficients for each hybrid. The calibrated model was used to quantify the impact of global warming on maturity period and yield of maize hybrids using 32 years historic weather data for seasonal analysis. Temperature scenarios of baseline (current climate), +1°C, and +2°C were used to quantify the effect of rising temperature on crop. Each hybrid's performance varied with respect to yield. Out of 15 hybrids eight were early (< 110 days) and seven were medium (110 to 120 days) maturing type. The results indicated that yield of all hybrids reduced due to rise in temperature. The reduction in mean yield, compared to baseline, was to the tune of 5.77% and 12.08% when temperature was increased by +1°C and +2°C, respectively. To reduce the adverse impact of rising temperature, sowing window was optimized as one of the adaptation strategies for both current and elevated temperature scenarios. Six dates of sowing starting from I FN of June to II FN of August at fortnightly interval were used to simulate the best date of sowing for both current and rising temperature scenarios. Under warmer climates for potential conditions, late sowing is found to be best over planting in June and July under NTZ of Karnataka. The simulation results revealed that under potential condition II FN of August sowing recorded 15.54, 10.87 and 5.14 per cent higher yield for baseline, +1 and +2°C, respectively, over the crop sown during I FN of June.

Key words: Maize, DSSAT-CERES-Maize model, seasonal analysis, temperature scenarios.

Climate change impacts on agricultural crop production vary from place to place and from crop to crop (Tubiello et al. 2002). Higher temperatures can reduce crop production by altering the microclimate required for the crop growth leading to changes in plant physiology. Long-term implications of crop yield reduction are significant for food security, socio-economic stability and ecological integrity. Global general circulation models (GCMs), which are our best tools for predicting future climates, indicate that the earth's surface temperature could rise by an average of 1.5 to 4.5°C over the next 50 to 100 years due to increasing concentrations of greenhouse gases in the atmosphere. Any change in climate will have adverse impact on climate-sensitive systems including agriculture. These impacts are particularly high for the less resilient impoverished countries. A temperature rise by 0.5°C in winter temperature is projected to reduce rainfed wheat yield by 0.45 tonnes per hectare (Walker and Schulze, 2008). For every 1°C increase in the temperature there was a mean yield reduction in the crop to a tune of 5.07 and 11.48 % has been reported by Schlenker and Lobell, (2010).

Climate change will also produce a host of economic effects pertaining to agriculture, including changes in farm profitability, prices, supply, demand, trade, and regional comparative advantage. The agronomic and economic impacts of climate change will depend principally on two factors: (1) the magnitudes of changes in climatic variables, and (2) how well agriculture can adapt to these changes. Maize is a major food crop of the world and provides valuable renewable energy bio-ethanol. Maize is also an important crop in India and it's productivity in Karnataka (3.5 t ha-1) is much better than the national average of (2.54 t ha-1). Therefore, it is important to maintain high yields. Hence we focus on the potential impacts of climate change on regional maize production. In this context, the experiment was carried out to evaluate selected public maize hybrids for their adaptability under future climate (rising temperature scenarios), and to optimize agronomic practice (sowing window) for both current and future climate.

Material and Methods

Study area : The field study was conducted during kharif of 2016 on deep black soils at the University of Agricultural Sciences, Dharwad, Karnataka which is located at 15° 26' N latitude, 75° 07' E longitude and at an altitude of 678 m above mean sea level. The study was carried out under rainfed condition, but irrigation was provided at regular interval to supplement deficit rainfall and nutrients at the rate of 150:65:65 kg N: P: K ha^{-1}, recommended for irrigated maize, were supplied to make sure the crop did not experience moisture and nitrogen stress, thus creating potential growing condition. The experiment was laid out using Randomized Complete Block Design with two replications and with each plot of 4.8 x 3.0 m in size. A total of 15 public maize hybrids were collected from Government Organizations presently operating in Karnataka. The seeds of all the hybrids were sown at a spacing of 60 x 30 cm on 10^{th} of June 2016 and harvested at once on November 5^{th} of 2016, although days to physiological maturity varied by few days. Hand weeding operation was carried out periodically thrice during the crop growth at 20, 35 and 45 DAS to keep the plot weed free.

DSSAT-CERES-Maize model : The Crop Environment Resource Synthesis (CERES) model was designed to describe the system of crops and their environments (Jones *et al*., 2003). The CSM-CERES-Maize model simulates maize phenological stages, growth and development, biomass production, and grain yield based on the information about initial soil conditions, soil profile characteristics, daily weather and other management strategies including cultivar specific coefficients. The models can be used as decision support system (DSS) to estimate crop yield, crop response to management and climate to quantify nutrient and water uptake. Crop simulation models such as CERES-Maize are useful when incorporated into decision support systems which can help determine the best management responses to specific weather conditions, (Jones *et al*., 2003).

Field observation and model simulation : Detailed observation on

Table 1. Effect of rising temperature on the yield of maize hybrids

Hybrids	Yield ($kg\ ha^{-1}$)			% yield loss over baseline	
	Base-line	+1°C	+2°C	at +1°C	at +2°C
GH-150241	7639	7294	6790	4.52	11.11
GH-0727	7383	6599	6154	10.62	16.65
GH-1427	7430	7038	6629	5.28	10.78
GH-1436	7418	7016	6436	5.42	13.24
CAH-1574	7541	7624	7026	-1.10	6.83
GH-1314	7577	6800	6367	10.25	15.97
GH-1316	7614	7339	6815	3.61	10.49
GH-15060	7614	7812	7287	-2.60	4.29
GH-15688	7378	5427	5150	26.44	30.20
GH-15305	7498	7729	7222	-3.08	3.68
BRMH-1	7508	7102	6657	5.41	11.33
H-628	7420	6354	5874	14.37	20.84
DMH-1	7272	6576	6161	9.57	15.28
DMH-3	7416	7930	7441	-6.93	-0.34
DMH-21	7405	7050	6604	4.79	10.82
Mean	7474	7046	6574	5.77	12.08

phenology and grain yield was recorded from the field study, and was used to optimize the genetic coefficients of all the hybrids individually within DSSAT-CERES-Maize model. Soil and weather data of the experimental site were used to create soil profile and weather file and model was calibrated using field data.

The historic daily weather data of 32 years (1985-2016) from the Main Agricultural Research Station, Dharwad was used as baseline weather (current climate) to create future climate scenarios by increasing both the daily maximum and minimum temperature by +1°C and +2°C for all the 32 years, thus a total of three scenarios (Baseline, +1°C and +2°C) were created for 32 years data. The impact of these scenarios on the yield of 15 hybrids was assessed and quantified by running calibrated DSSAT-CERES-Maize model for 32 years. Further, sowing window as an adaptation strategy against rising temperatures was used with six dates of sowing at fortnightly intervals *viz*., I FN and II FN of June, July and August to identify better sowing date for each scenarios.

Result and discussion

Among the 15 hybrids, the highest yield was recorded by the hybrid GH-150241 (7639 kg ha-1) and the lowest was recorded by the hybrid DMH-1 (7272 kg ha^{-1}). The results of per cent yield loss and/or gain for three scenarios over two dates of sowing (I FN of June and II FN of August) are furnished in Table 1 and 2. The yield was reduced, on an average, by 5.77 and 12.08%, respectively, when temperature was increased by 1 and 2°C from the baseline. This result was in close agreement with the findings of Xiao *et al*. (2007), who stated that increase in temperature reduces crop yield by increasing respiration and shortening the crop growth period due to increase in either maximum or minimum temperatures or in both. Rise in temperature influences the crop growth development, crop phenology, duration of crop cycle, which eventually affects the yield. In our study reduction in yield was mainly due to reduced crop duration, especially grain filling

Table 2. Per cent gain in mean yield of hybrids sown in II FN of August over I FN of June across temperature scenarios

Public hybrids	Yield (kg ha^{-1}) (I FN of June)			Yield (kg ha^{-1}) (II FN of August)			% yield gain over I FN of June		
	Baseline	+1°C	+2°C	Baseline	+1°C	+2°C	Baseline	+1°C	+2°C
GH-150241	7639	7294	6790	8894	8099	7103	16.43	11.04	4.61
GH-0727	7383	6599	6154	8057	7244	6372	9.13	9.77	3.54
GH-1427	7430	7038	6629	8629	7818	6883	16.14	11.08	3.83
GH-1436	7418	7016	6436	8520	7687	6767	14.86	9.56	5.14
CAH-1574	7541	7624	7026	9383	8308	7475	24.43	8.97	6.39
GH-1314	7577	6800	6367	8288	7422	6632	9.38	9.15	4.16
GH-1316	7614	7339	6815	8936	8148	7205	17.36	11.02	5.72
GH-15060	7614	7812	7287	9710	8773	7841	27.53	12.30	7.60
GH-15688	7378	5427	5150	6731	6088	5405	-8.77	12.18	4.95
GH-15305	7498	7729	7222	9502	8643	7581	26.73	11.83	4.97
BRMH-1	7508	7102	6657	8731	7866	6973	16.29	10.76	4.75
H-628	7420	6354	5874	7672	7023	6169	3.40	10.53	5.02
DMH-1	7272	6576	6161	8025	7358	6539	10.35	11.89	6.14
DMH-3	7416	7930	7441	9796	8852	7840	32.09	11.63	5.36
DMH-21	7405	7050	6604	8724	7846	6924	17.81	11.29	4.85
Mean	7474	7046	6574	8640	7812	6914	15.54	10.87	5.14

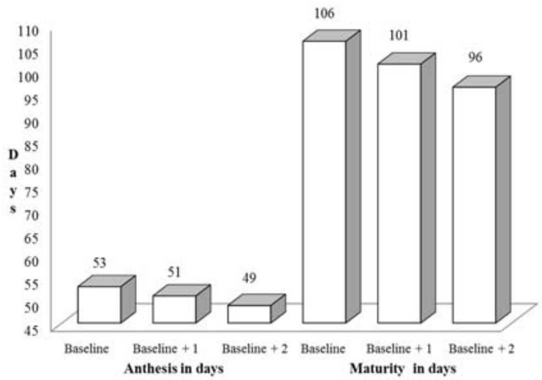

Fig. 1. Number of days taken to anthesis and maturity (mean of 15 hybrids) under different temperature scenarios

period as depicted in Fig. 1. The reduction in days to anthesis was, on average, two days for every 1 °C increase in temperature, and the days to maturity was, on average, reduced by five days. Muller *et al*. (2011) also revealed that the impact of temperature changes on yield of maize are much stronger than changes in rainfall. Further, their study also revealed that duration from sowing until anthesis and maturity were reduced in majority of scenarios as affected by warmer climate. Hence, sowing window was used as adaptation strategy and model simulation showed that varying sowing time help adapting to rising temperature and realize better yield. August II FN proved to be the best date of sowing among all the six dates of sowing tried in this study. The comparison between June I FN and August II FN shows that the yield increase was to an extent of 15.54, 10.87 and 5.14 per cent for baseline, +1°C and +2°C scenarios, respectively. The model simulated outputs in the study was supported by the findings of Andrade (2005) who reported that grain yield varied due to the change in sowing dates.

Conclusion

The study revealed that all the 15 hybrids used in the experiment showed negative response to increasing temperature, when exposed for 32 years of seasonal analysis, with the reduction in mean yield to a tune of 6% for every 1°C increase in the daily mean temperature. Sowing window as an adaptation strategy worked well under the elevated temperature scenarios in controlling the yield loss. For these tested hybrids August II FN sowing was found to be more advantageous over other earlier dates of sowing under rising temperature scenarios, but warming in general across sowing dates reduces maize crop yield, which suggests that development of new maize hybrids for future climate may require certain changes to the current traits to cope with future climate to maintain current yield levels.

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J. Agric. Res. Technol., 42 (3) : 048-058 (2017)

Evaluation of SWAT and WEPP Models for Assessing Soil Conservation Interventions in a Small Watershed

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Abstract

Runoff is a major pathway for transporting sediment and other nonpoint-source pollutants from a watershed to stream systems and other surface water bodies. In this study, the Soil and Water Assessment Tool (SWAT) and Water Erosion Prediction Project (WEPP) models were used to assess sediment transport from the 63.72 ha Maheshgad watershed located in semi-arid region of Maharashtra (India). The soil conservation measures were hypothesised as two different on-stream sediment control structures (check dams and trash barriers). Calibration of models was done with 1997 data and validated with 1998 data. The coefficient of determination (R^2) and Nash-Sutcliffe modeling efficiency (NSE) statistics were found to match with their measured counterparts at 95% significance level as shown by the Student's t-tests. Following calibration and validation, the models simulations were done with and without soil conservation structures to test its capability in visualizing the impacts of sediment control structures in the watershed. The model estimates showed that installation of 07 check dams and 12 trash barriers in the drainage line reduced runoff and sediment yield from the Maheshgad watershed substantially with reduction of 50.34% and 48.61% by SWAT model and 52.27% and 52.16% by WEPP model, respectively. The results of statistical analysis indicated that the simulation of both models were satisfactory though WEPP simulations were found better than SWAT in most of cases, and could be used with a reasonable confidence for soil loss quantification in Maheshgad watershed. Overall, the study showed that the SWAT and WEPP models are useful tools for studying effect of soil conservation interventions on reducing runoff and sediment yield from small watersheds semi-arid conditions of Maharashtra.

Key words: SWAT, WEPP, runoff, sediment yield, check dam.

Land and water are the two most valuable and vital resources essentially required for the sustenance of life and for the economic, social progress as well as sustainability of a region. Therefore an efficient utilization of land and water resources is a most important task. The soil loss and sediment yield problems are serious and important in India, because of varying topographical and geological conditions, the pressure of human and animal population on the land resources and small land holdings. This is further aggravated by improper land use and faulty land management practices being adopted in the upland watersheds (NIH, 1998). Out of the total geographical area of 329 Mha, an estimated 175 Mha of land constituting about 53% of the total geographical area suffers from the adverse effect of soil erosion and other forms of land degradation causing a loss of 5.3 million Mg of soil every year. Active erosion caused by water and wind alone accounts for 150 Mha of land out of which 69 Mha is in the critical stage of deterioration, whereas 25 Mha has been degraded due to ravine/gullies, shifting cultivation, salinity/alkalinity, and water logging (Reddy, 1999; Sharma *et al*., 2014).

To combat the hazards of soil erosion and land degradation, there is a need to understand physical process of erosion in relation to topography, land use, and management. In

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order to develop a comprehensive plan for soil and water conservation, it is essential to estimate runoff and soil loss resulting from different crop and structure-based management practices. At the same time, availability of accurate runoff and sediment yield data is scarcely available at few selected places. Hence, this necessitates the simulation of soil erosion, sediment yield, and processes like runoff as well as transport of sediment from watersheds through hydrological modeling. Among the available tools for soil erosion assessment, simulation models are quite important because appropriate models can be used to evaluate a variety of management scenarios without costly and time-consuming field tests (Pieri *et al*., 2007). In recent years, a trend of testing and using physical process based runoff and soil erosion prediction models both at the field as well as at watershed scales has gained momentum. These physical process based models, often with an explicit attempt to describe runoff and erosion processes, are better equipped to evaluate the impacts of management interventions and help to make management decisions aimed at preserving land productivity and environment quality (Yu and Rosewell, 2001). Before application, such models need to be properly calibrated and validated using measured hydrologic data of the watershed. Lack of reliable field-measured data for calibration and validation of models is the major limitation for their application.

In recent years many numerical models for simulating either the soil erosion or sediment yield have been developed. Researchers have developed hydrological models of empirical or conceptual nature for prediction of hydrological variables. Among these hydrological models, SWAT (Soil and Water Assessment Tool), AGNPS (Agricultural Non-Point Source Pollution), ANSWERS (Areal Non-point Source Watershed Environment Response Simulation) and WEPP (Water Erosion Prediction Project) are the distributed parameters physically based watershed scale models mostly used for low slope conditions and are being extensively used for sustainable development of watersheds (Pandey *et al.*, 2008).

The aim of this study was to evaluate the application of two physically based models, SWAT and WEPP in the small watershed located in semi-arid conditions of Maharashtra. These models have been tested on many agricultural watersheds and were selected for the study based on their wide usability, reputation and use of most up-to-date technology.

SWAT Model Overview : The SWAT is a physical process-based model used to simulate continuous-time landscape processes at watershed scale (Arnold *et al*. 1998; Neitsch *et al*. 2005). The watershed is divided into several hydrological response units (HRUs) based on soil type, land use and slope classes. The eroded sediments at HRUs level are routed along the channels to the outlet of the watershed. The major model components include hydrology, weather, soil erosion, nutrients, soil temperature, crop growth, pesticides agricultural management and stream routing. The model predicts the hydrology at each HRU using the water balance equation, which includes daily precipitation, runoff, evapotranspiration, percolation and return flow components. The surface run-off is estimated in the model using two options; (i) Natural Resources Conservation Service Curve Number method and, (ii) Green and Ampt method. The percolation through each soil layer is predicted using storage routing techniques combined with crack-flow model. The evapotranspiration is estimated in SWAT using three options; (i) Priestley-Taylor (ii) Penman-Monteith and (iii) Hargreaves method.

The SWAT model uses the MUSLE

(Modified Universal Soil Loss Equation) to compute soil erosion at HRU level. The flow routing in the channels is computed using the variable storage coefficient method, Muskingum method or simplified stream power equation of Bagnold's (1977) to route the sediment in the channel. The maximum amount of sediment that can be transported from a reach segment is function of the peak channel velocity. The sediment routing in the channel consists of channel degradation using stream power and deposition in channel using fall velocity.

WEPP model overview : The WEPP is a physically based distributed parameters model. It estimates runoff and soil loss from a watershed using fundamentals of stochastic weather generation, infiltration theory, hydrology, soil physics, plant science, hydraulics, and erosion mechanics. It describes the physical processes of soil particle detachment, transport, and deposition due to hydrologic and mechanical forces acting on hillslope and channel. This model is considered to possess the state-of-the-art knowledge of the erosion science, and has become an important analytical tool for runoff and sediment estimation. The model was initially developed for soil and water conservation planning, and environmental assessment (Singh *et al*. 2011). It has advantage over other existing erosion prediction models as it provides estimate of spatial and temporal distribution of soil loss or deposition in a watershed over a broad range of conditions. The distributed input parameters for the model include rainfall amount and intensity, soil texture, plant growth parameters, residue decomposition parameters, effects of tillage implements on soil properties and residue amount, slope shape, steepness and orientation, and soil erodibiliy.

The WEPP works in continuous as well as single-storm simulation mode. The hillslope version of the model has nine components: climate generation, winter processes, irrigation, hydrology, soil, plant growth, residue decomposition, hydraulics of overland flow, and erosion. Three components: channel hydrology and hydraulics, channel erosion, and impoundments were added in the watershed version. Infiltration is computed using the Green-Ampt Mein-Larson equation. Overland flow is routed using either an analytical solution to the kinematic wave equations or regression equations derived from the kinematic approximation. Peak runoff rate at the channel or watershed outlet is calculated by two methods: (i) the method used in the CREAMS model (Knisel, 1980); and (ii) a modified rational equation. The user has to select the method for the simulations. The model considers interrill and rill erosion process in hillslopes as well as in channels. The movement of suspended sediment in rill, interrill, and channel flow areas is calculated using steady state continuity equation at peak runoff rate. Watershed sediment yield is calculated considering soil detachment from hillslopes and channels, transportation, and deposition of sediment in hillslopes and channels. Sediment deposition and sediment discharge from impoundments is modelled using conservation of mass and overflow rate concepts.

Materials and Methods

Study area description : For hydrological models application, a small watershed was selected based on the availability of rainfall-runoff-sediment yield data of storm events. Maheshgad watershed is located towards the south of central campus of Mahatma Phule Krishi Vidyapeeth Rahuri (Maharashtra) and north east of Maheshgad hill having 63.72 ha area divided into nine sub-watersheds and situated between 19°19' N longitude and 74°38' E latitude (Fig.1).

Fig. 1. Location map of the study area

The topography of the Mahaeshgad watershed is hilly and undulating with an elevation ranging from 531-569 m above mean sea level (MSL). The general slope of the watershed area varies from 1.95 to 21%. And it receives an average annual rainfall of 540 mm and more than 80% of the rainfall occurs during the monsoon season (June-September).

Meteorological and hydrological data : Historical daily rainfall data (1997 and 1998) from the rain gauge station located in the watershed, maximum and minimum air temperature, relative humidity, solar radiation and wind velocity were available from an automatic weather station (AWS) at Mahatma Phule Krishi Vidyapeeth Rahuri, located approximately 3 km away from the research location. Department of Soil and Water Conservation Engineering of Mahatma Phule Krishi Vidyapeeth, Rahuri under Ad-hoc research project, ICAR, New Delhi, India monitored hydrological data of the Maheshgad watershed. Watershed daily sediment yield was collected for the years 1997 and 1998. A set of instruments consisting of continuous recording rain gauge, water level stage recorder, and sediment meter were used to record rainfall, stream flow (seasonal) and sediment flow data, respectively. The sediment yield data were measured by manual sampling using sediment meter, which works on the principle of density of water. The sediment concentration was obtained by filtration and evaporation (oven drying) methods.

Field measurement of soil properties : Soil properties are important factors affecting runoff and soil erosion. Physical and chemical properties of soil at well-distributed locations in the watershed were determined using standard laboratory methods. Cation exchange capacity (CEC) was measured using the method of Sumner and Miller (1996). Organic carbon was determined using Walkley-Black wet oxidation method (Jackson, 1973). Albedo, effective hydraulic conductivity, interrill erodibility, rill erodibility and critical shear were calculated using Eq. 1 to 5.

$$\text{albedo} = 0.6 / e^{(0.4 \times OM)} \quad (1)$$

where, OM = Organic matter (%).

For soils with $\leq$ 40%, clay content, soil effective hydraulic conductivity inputs (Ke) is calculated by,

$$Ke = -0.265 + 0.0086 \times Sand^{1.8} + 11.46 \times CEC\text{-}0.75 \quad (2)$$

where, Sand is sand content in soil (%), CEC is cation exchange capacity (meq/100g).

For soils containing 30% or more sand, the interrill erodibility (Ki), rill erodibility (Kr) and the critical shear stress (τc) equations are,

$$K_i = 2728000 + 192100 \times VFS \quad (3)$$

$$Kr = 0.00197 + 0.00030 \times VFS + 0.03863 \times e^{(-1.4 \times OM)} \quad (4)$$

$$\tau c = 2.67 + 0.065 \times Clay - 0.058 \times VFS \quad (5)$$

where, VFS is percent very fine sand, OM is percent organic matter in the surface soil and Clay is percent clay.

Digital elevation model for watershed characterization : The digital elevation model

(DEM) is quite efficient in extracting the hydrological data by analyzing different topographical attributes like elevation, slope, aspect, relief, curvatures etc. for modeling purpose. In the present study, DEM with cell size 30 x 30 m was used for hydrological evaluation of SWAT and WEPP models. The cloud-free digital satellite data of the study watershed were obtained from the United States Geological Survey (USGS) website https://earthexplorer.usgs.gov/. Landsat 4 (L4-5TM) data (Path: 147 and Row: 046) of 28th April 1999 were used to prepare a land use land cover map of the watershed.

Model evaluation : The model evaluation procedure includes sensitivity analysis, calibration, and validation.

Sensitivity analysis : Sensitivity analysis provides a method for examining the response of a model in a way that eliminates the influence of error related to the natural variation of the model input parameters (McCuen and Snyder, 1983). Input parameters, which were estimated using the recommended equations, and reported in the SWAT and WEPP literature, were considered for sensitivity analysis. To quantify the impact of the change in the values of input parameters on the outputs, the sensitivity ratio, sen (McCuen & Snyder, 1983) was used.

$$sen = \frac{(Y_2 - Y_1) / Y}{(X_2 - X_1) / X} \tag{6}$$

where X_1 and X_2 are the smallest and largest values of the input used, X is the average of X_1 and X_2 whereas, Y_1 and Y_2 are the corresponding outputs for the two input values, and Y is the average of two outputs.

Calibration and validation : Split sample calibration approach was adopted for SWAT and WEPP model's performance evaluation. Two years data set pertaining to 1997 and 1998 was split into two parts. The data of 1997 were used for model calibration and that of 1998 for model validation. The manual calibration based on trial-and-error procedure (Sorooshian and Gupta, 1995) was used in the study. The parameter that produced the maximum sensitivity is adjusted first, followed by the other parameters. The input parameters that showed negligible variation in the sensitivity ratio were not calibrated and were taken as model default values.

Structure-based management scenarios : Considering the cost and availability of local materials for the construction, rock-fill check dam, and trash barrier were considered for simulation of sediment yield from the watershed. Two scenarios were hypothesized to evaluate the structure-based management of the watershed; without impoundment structures (WoIMS) i.e present situation of the watershed and with impoundment structures (WIMS). Hypothesized scenarios were simulated to assess their effects on runoff and sediment yield from the watershed (Fig.2).

Evaluation criteria for the model : In the present study, Coefficient of determination (Santhi *et al.*, 2001), Nash-Sutcliffe coefficient (Nash and Sutcliffe (1970) and percent deviation (Martinec and Rango, 1989) were determined to check the performance of SWAT

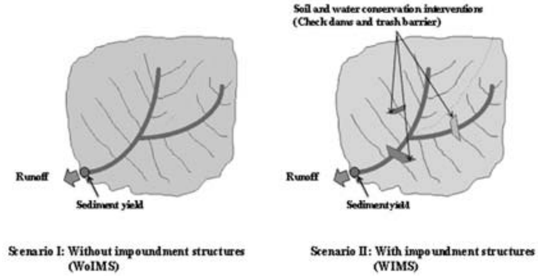

Fig. 2. Schematic of structure-based management scenarios hypnotized

and WEPP models. Also, the Student's t-test at 95% significance level (Gupta and Kapoor, 2002) was performed to compare means of simulated and measured values of daily runoff and sediment yield.

Nash-Sutcliffe coefficient (NSE): The model coefficient is expressed by following formula,

$$NSE = 1 - \frac{\sum_{i=1}^{n} (O_i - P_i)^2}{\sum_{i=1}^{n} (O_i - \bar{O}_i)^2} \quad (7)$$

where $\bar{O}i$ is the mean of observed data for the constituent being evaluated. The NSE values can vary from -∞ to 1, with 1 indicating a perfect fit.

Coefficient of determination (R^2) : It describes the degree of co-linearity between observed and simulated. R^2 describes the proportion of the variance in observed data explained by the model. R^2 ranges from 0 to 1, with higher values indicating less error variance, and typically values greater than 0.5 are considered acceptable (Santhi *et al.*, 2001).

Percent deviation (Dv) : The percent deviation of runoff values, DV given by the following equation is another criterion for evaluation (Martinec and Rango, 1989).

$$Dv\ (\%) = \frac{P_i - O_i}{O_i} \times 100 \quad (8)$$

where Oi is the observed value, Pi is the model computed value. The smaller the value of Dv, the better the model results. Dv should equal to zero for a perfect model.

The student's t-test : It is a statistical method that is used to see if two sets of data differ significantly. The method assumes that the results follow the normal distribution (also called student's t-distribution) if the null hypothesis is true. In the present study, it is used to determine whether there is a difference between two independent sample groups i.e. observed and simulated hydrological data.

Results and Discussion

Sensitivity analysis : For the SWAT model, CN2 (initial SCS runoff curve number for moisture condition II), ESCO (soil evaporation compensation factor), SOL_AWC (available water capacity of the soil layer) and CH_K (effective hydraulic conductivity of channel (mm h^{-1})) were the most sensitive parameters for runoff. Whereas the input parameters, SPCON (linear parameter for calculating the maximum amount of sediment that can be re-entrained during channel sediment routing), CH_EROD (channel erodibility factor), USLE_K (USLE soil erodibility (K) factor), SPEXP (exponent parameter for calculating sediment re-entrained in channel sediment routing) and CN2 were most sensitive for sediment yield.

Table 1. Statistical analysis of runoff and sediment yield during calibrated period

Statistical parameters	SWAT		WEPP	
	Runoff, mm	Sediment yield, t ha^{-1}	Runoff, mm	Sediment yield, t ha^{-1}
R^2	0.99	0.96	0.96	0.87
NSE	0.79	0.89	0.89	0.77
Deviation (%)	11.16	12.18	-5.72	8.31
t Statistical (95% level)	0.60	0.78	0.63	0.70
t Critical two-tail	2.14	2.16	2.33	2.30

t Statistical is the Students t-calculated for equal means at 95% confidence level. R^2 is the coefficient of determination. NSE is the Nash-Sutcliffe efficiency.

Table 2. Statistical analysis of runoff and sediment yield during validation period

Statistical parameters	SWAT		WEPP	
	Runoff, mm	Sediment yield, t ha^{-1}	Runoff, mm	Sediment yield, t ha^{-1}
R^2	0.96	0.95	0.87	0.85
NSE	0.90	0.88	0.81	0.78
Deviation (%)	-7.55	-9.24	-3.08	-3.40
t Statistical (95% level)	-0.23	-0.04	0.75	0.74
t Critical two-tail	2.07	2.07	2.33	2.36

t Statistical is the Students t-calculated for equal means at 95% confidence level. R^2 is the coefficient of determination. NSE is the Nash-Sutcliffe efficiency.

Among the WEPP parameters considered, the change in effective hydraulic conductivity only affected the simulated runoff and sediment yield is sensitive to inter rill erodibility, followed by rill erodibility, effective hydraulic conductivity and critical shear stress of soil in that order.

Calibration : After calibrating above sensitive parameters of SWAT and WEPP models, simulation run was performed for the year 1997. Table 1 shows statistical analysis of runoff and sediment yield by SWAT and WEPP model. During calibration the overall deviations between the observed and simulated values for runoff and sediment yield were minimum. Also, higher values of R^2 and NSE for both models were seen, respectively indicate that the good performance of SWAT and WEPP models. However, student's t-test shows that (t-calculated < t-critical) the means of observed and simulated runoff and sediment yield are not significantly different at the 95% confidence level.

The positive agreement between observed and simulated runoff and sediment yield were found during the SWAT and WEPP model calibration. The predictions are very much close to the observed means indicating good calibration of sensitive parameters which affects runoff and sediment yield to a great extent.

Validation : Validation of SWAT and WEPP models were performed for the year 1998. The descriptive statistics for both the measured and simulated runoff and sediment yield are shown in Table 2. Higher values of R2 and NSE, minimum per cent deviation and non-significant difference between the observed and simulated runoff and sediment yield shows the good performance of SWAT and WEPP models during validation period.

The above reported results by SWAT model are in agreement with Tripathi *et al*. (2003), Kaur *et al*. (2004), Jadhao *et al*. (2010), Jain *et al*. (2010), Ayana *et al*. (2014), Chandra *et al*. (2014) and Panhalkar (2014). Also, the above reported results by WEPP model are in agreement with the explanations given by

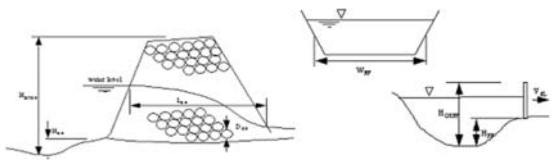

Fig. 3. Definition sketches of rock-fill check dam and trash barrier (Flanagan and Livingston, 1995)

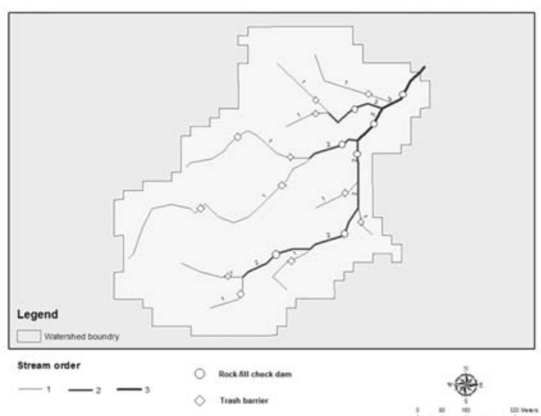

Fig. 4. Schematic of structure-based management scenarios hypnotized

Nearing (1998), Zhang *et al*., 1996; Nearing and Nicks, 1997; Liu *et al*., 1997, Pandey *et al*., 2008 and Singh *et al*., 2011.

Effective watershed management : The sediment yield of the Maheshgad watershed during 1997 and 1998 is quite high (4.22 t ha^{-1}), it falls under permissible limit of soil erosion class (16-20 t ha^{-1}, Singh *et al*., 1992). However, whenever possible it is always better to reduce the sediment yield through the effective watershed management. In present study, two scenarios were hypothesized; without impoundment structures (WoIMS) i.e present situation of the watershed and with impoundment structures (WIMS). Considering the cost and availability of local materials for the construction, rock-fill check dam and trash barrier (Fig. 3) were considered for simulation of sediment yield by SWAT and WEPP models. Database related to these two impoundment structures were modified in the model according to the dimensions of the channels where these structures are considered in the simulations.

The location of structure was considered at the downstream side of the HRU/ hillslope, which were contributing higher sediment yield. At the upstream where runoff flow was low; the structure was considered on the individual channels as well as nearer to the junction of two channels. Location of trash barriers were selected on the 1st order stream and location of rock-feel check dams were considered on 2nd and 3rd order streams (Fig. 4).

The selected structure inputs were modified in the SWAT and WEPP model and the hypothesized scenarios, without impoundment structures (WoIMS) and with impoundment structures (WIMS) were simulated (for 1997 and 1998) to assess their effects on runoff and sediment yield from the watershed.

SWAT Model : The observed and simulated runoff for WoIMS and WIMS scenarios were compared for the year 1997 and 1998 (Table 3). Comparison of simulated runoff for WIMS and WoIMS scenarios revealed that 7 rock-fill check dams and 12 trash barriers resulted in reduction of runoff by 46.86% and 53.82% in 1997 and 1998, respectively.

Similarly, observed and simulated sediment yield for WoIMS and WIMS scenarios were

Table 3. Effect of selected scenarios on runoff using SWAT model

Year	Observed runoff (m^3)	Runoff at the outlet (m^3)		Runoff controlled by the structures (m^3)	Reduction in runoff (%)
		WoIMS	WIMS		
1997	31891.86	28323.54	15050.66	13272.88	46.86
1998	48554.64	38251.12	17663.18	20587.93	53.82

WoIMS: without impoundment structures, WIMS: with impoundment structures.

Table 4. Effect of selected scenarios on sediment yield using SWAT model

Year	Observed soil loss (t)	Sediment at the outlet (t)		Sediment controlled by the structures (t)	Reduction in sediment loss (%)
		WoIMS	WIMS		
1997	194.35	168.86	88.56	80.30	47.55
1998	136.99	135.72	68.31	67.41	49.67

WoIMS: without impoundment structures, WIMS: with impoundment structures.

Table 5. Effect of selected scenarios on runoff using WEPP model

Year	Observed runoff (m^3)	Runoff at the outlet (m^3)		Runoff controlled by the structures (m^3)	Reduction in runoff (%)
		WoIMS	WIMS		
1997	31891.86	33453	15152.62	18300.38	54.70
1998	48554.64	38053.58	19090.51	18963.07	49.83

WoIMS: without impoundment structures, WIMS: with impoundment structures.

Table 6. Effect of selected scenarios on sediment yield using WEPP model

Year	Observed soil loss (t)	Sediment at the outlet (t)		Sediment controlled by the structures (t)	Reduction in sediment loss (%)
		WoIMS	WIMS		
1997	186.89	170.13	78.88	91.26	53.64
1998	142.65	124.89	61.60	63.29	50.68

WoIMS: without impoundment structures, WIMS: with impoundment structures.

compared for the year 1997 and 1998 as shown in Table 4. From the Table 4 it is seen that simulated sediment yield for WIMS and WoIMS scenarios were resulted in reduction of sediment yield by 47.55% and 49.67% in 1997 and 1998, respectively.

WEPP Model : Effect of selected scenarios on runoff and sediment using WEPP model is presented in Table 5 and 6. From the Table 5 it is seen that the comparison of observed and simulated runoff for WIMS and WoIMS scenarios revealed that 07 rock-fill check dams and 12 trash barriers resulted in reduction of runoff by 54.70% and 49.83% in 1997 and 1998, respectively.

Similarly, from the Table 6, it is seen that the simulated sediment yield for WIMS and WoIMS scenarios were resulted in reduction of sediment yield by 53.64 and 50.68% in 1997 and 1998, respectively.

The above results reported in the present study are in agreement with the results of Mishra *et al*. (2007), who executed SWAT model with and without check dams to test its capability in visualizing the impacts of sediment control structures in the watershed. Similarly, Garg *et al*. (2012) applied watershed management interventions like check dams during SWAT simulations, which show reduction in soil loss. The results obtained in present study are in agreement with the related literature of SWAT model. Also, Singh *et al*. (2011) used the calibrated WEPP model to evaluate impacts of different management scenarios on runoff and sediment yield. They found that the sediment yield with reduction of 54.67% and 78.40% due installation of structural measures (check dam and trash barriers) and combination of vegetative and structural measures. Above results for selected scenarios in WEPP model are in agreement with the related literature.

Overall, the study showed that SWAT and WEPP model can be useful tools for studying how watershed management interventions (check dams and trash barrier) can be used to manage and control sediment yield from small watersheds.

Conclusions

In the present study, efficacy of the SWAT and WEPP models were used to test the effect of structural control measures on the runoff and sediment yield generation in Maheshgad watershed. Based on results of the study the following conclusions are drawn: Both SWAT and WEPP models could be validated satisfactorily based on the calibration of these models for one year (1997) for Maheshgad watershed. WEPP model suggested the installation of seven rock-fill check dams and twelve trash barriers in the Maheshgad watershed for about 50% average reduction in runoff and sediment yield. The SWAT and WEPP models identified the zones that are more prone to soil erosion in Maheshgad watershed due to their ability to consider the simulation of the important processes based on hydrological response unit. Hence, hydrological models like SWAT and WEPP need to be considered while planning and implementing soil conservation measures on watershed basis.

Acknowledgements

We are greatful to the Department of Science and Technology (Inspire Fellowship), Government of India and Mahatma Phule Krishi Vidyapeeth, Rahuri (Maharashtra) for supporting the present research.

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J. Agric. Res. Technol., 42 (3) : 059-065 (2017)

Temperature trend analysis at Pune

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Abstract

Climate change became the major discussing point and invariably it poses a significant threat to the humanity. Temperature is one of the most important characteristics of the climate and generally used as a measure of climate change on regional and global scales. In the context of global warming, regional manifestations of temperature variations assume special importance. Greenhouse effect is causing global warming due to increasing concentration of greenhouse gases in the atmosphere after the industrial revolution. As the local changes are contributing to the bigger picture, the objective of the present work is to investigate the annual and seasonal temperature trends at Pune. Monthly maximum and minimum temperature data during the period 1970-2015 were analyzed. Temporal changes in the annual and seasonal values were analyzed by three statistical tests *viz*., Mann-Kendall test, Sphereman test (Non-parametric tests) and Linear regression (Parametric test). The mean annual temperature showed a significant long-term increasing trend. During winter season there was no significant increase in the maximum and minimum temperatures. In the pre-monsoon season, only minimum temperature has shown the significant increase with only Sphereman's Rho test. Monsoon season has shown the significant increase in the minimum temperature. Post-Monsoon season minimum temperature and mean temperature had shown significant increase in the trends. Maximum temperature has shown significant increasing trend in August, November and December months. Minimum temperature from May to December except in June and October, has shown a significant increasing trend. The important finding of the present study is that, there was a significant increasing trend in minimum temperature and mean temperature during the monsoon and post monsoon seasons and it showed that that in the recent period, minimum temperature increased faster than the maximum temperature.

Key words:Climate change, trend analysis, global warming, urbanization.

Climate change became the major discussing point and invariably it poses a significant threat to the humanity. Temperature is one of the most important characteristics of the climate and generally used as a measure of climate change on regional and global scales. Global mean surface air temperature has increased by 0.8°C, in the past century according to Intergovernmental Panel on Climate Change (IPCC) Assessment Report 5 (AR5). Meteorological data over the past centurysuggest significant warming of the earth (Kumar *et al*. 2006). Greenhouse effect is causing global warming due to increasing concentration ofgreenhouse gases in the atmosphere after the industrial revolution. However, in context of global warming, regional manifestations of temperature variations assume special importance as warming is not uniform across the globe. Hence, many researchers have studied temperature variability at regional scales (Kothawale *et al*., 2016). According to the study for Japan by Fujibe (1995, a rising trend of 1°C per 100 years in minimum temperature has been observed at several large cities in Japan. Hingane(1996) estimated rising trends of 0.84 and 1.39 1°C per 100 years in the mean surface temperature calculated for Mumbai and Kolkata, respectively. Dhorde *et*

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al. (2009)studied the trends in annual and seasonal temperatureusing linear regression and the Mann-Kendall test andemphasized the effect of urbanization, leading to a significantshift in temperature during the post-monsoon andwinter seasons at four major Indian cities. As the local changes are contributing to the bigger picture, the objective of the present work is to investigate the annual and seasonal temperature trendsover Pune.

Data and methodology : Monthly maximum and minimum temperature data during the period 1970-2015 were obtained from Department of Agricultural Meteorology, College of Agriculture, Pune and Central Agro Meteorological Observatory, College of Agriculture, India Meteorological Department (IMD), Pune. From the temperature data, mean maximum temperature (T_{max}), mean minimum temperature (T_{min}) and mean minimum temperature (T_{mean}) along with their standard deviation (SD) and coefficient of variation (CV) have been computed for each month and four seasonsviz.,Winter (Jan-Feb), Pre-monsoon (Mar-May), Monsoon (June-Sep) and post-monsoon (Oct-Dec).The datais depicted in Table 1.

A linear trend line was added to the series to simplify the trend. Temporal changes in the annual and seasonal values were also analyzed by three statistical tests, Mann-Kendall test, Sphereman test (Non-parametric test) and Linear regression (Parametric test).

Mann-Kendall test : The Mann-Kendall test used in the present study is based on the test statistic, S, defined as follows;

$$s = \sum_{i=1}^{n-1} \left[\sum_{j=1+1}^{n} \operatorname{sgn}(R_j - R_i) \right]$$

Where, sgn (x) = 1 for x > 0, Sgn (x) = 0 for x = 0, Sgn (x) = -1 for x < 0.

If the null hypothesis Ho is true, then S is approximately normally distributed with:

$$\mu = 0 \qquad \sigma = n\,(n - 1)\,(2n + 5) / 18$$

Therefore, the z-statistic is
$z = | S | / \sigma^{0.5}$

Table 1. Monthly and seasonal temperature means, SD and CV

Month	T_{max}	SD	CV	T_{min}	SD	CV	T_{Mean}	SD	CV
Jan.	29.5	1.21	4.11	11.1	1.85	16.63	20.3	1.16	5.71
Feb.	31.6	0.96	3.04	12.4	1.65	13.37	22.0	0.97	4.42
Mar.	35.5	1.31	3.70	15.8	0.98	6.18	25.6	0.92	3.60
Apr.	37.7	1.29	3.42	19.7	1.43	7.26	28.7	1.26	4.38
May.	37.0	0.93	2.50	22.7	0.70	3.09	29.8	0.60	2.01
June.	31.7	1.39	4.38	22.9	0.47	2.05	27.3	0.87	3.16
July.	28.3	0.89	3.14	22.2	0.38	1.70	25.2	0.54	2.14
Aug.	27.7	0.70	2.53	21.5	0.44	2.06	24.6	0.48	1.93
Sep.	29.5	0.92	3.13	20.8	0.66	3.19	25.1	0.57	2.28
Oct.	31.5	1.16	3.67	18.4	1.04	5.65	25.0	0.63	2.54
Nov.	30.4	0.85	2.81	14.3	2.44	17.01	22.3	1.39	6.24
Dec.	29.1	0.98	3.38	11.3	1.66	14.77	20.2	1.09	5.42
Winter	30.6	0.90	2.94	11.7	1.56	13.30	21.1	0.95	4.48
Pre-.Monsoon	36.7	0.86	2.34	19.4	0.76	3.94	28.1	0.70	2.49
S-W Monsoon	29.3	0.71	2.43	21.9	0.40	1.85	25.6	0.47	1.86
Post-Monsoon	30.3	0.80	2.65	14.7	1.27	8.68	22.5	0.80	3.55

A positive value of S indicates an increasing trend and vice-versa.

Spearman's Rho Test: This is a test that determines whether the correlation between two variables is significant.

$$\rho = S_{xy} / (S_x S_y)^{0.5}$$

Where,

$$S_x = \sum_{i=1}^{n} (x_i - \bar{x})^2$$

$$S_y = \sum_{i=1}^{n} (y_i - \bar{y})^2$$

$$S_{xy} = \sum_{i=1}^{n} (x_i - \bar{x})(y_i - \bar{y})$$

and x_i (time), y_i (variable of interest), $\bar{x}$ and $\bar{y}$ refer to the ranks ($\bar{x}$, $\bar{y}$, s_x and s_y have the same value in a trend analysis).

Linear regression test : This is a parametric test that assumes that the data are normally distributed. With this test we can examine whether there is a linear trend between time (x) and the variable of interest (y). The regression gradient is estimated by,

$$b = \frac{\sum_{i=1}^{n} (x_i - \bar{x})(y_i - \bar{y})}{\sum_{i=1}^{n} (x_i - \bar{x})^2}$$

and the intercept is estimated as:

$$a = \bar{y} - b\bar{x}$$

The test statistic S is:

$$S = b / \sigma$$

Where,

$$\sigma = \sqrt{\frac{12 \sum_{i=1}^{n} (y_i - a - bx_i)}{n(n-2)(n^2-1)}}$$

The test statistic S follows a Student-t distribution with n-2 degrees of freedom. The linear regression test assumes that the data are normally distributed.To find out the trend we have used Trend analysis software (Francis and Lionel, 2005).

Table 2. Yearly temperature trends

Temperature	Mann-Kendall (Non-parametric)	Spearman's Rho (Non-parametric)	Linear regression (Parametric)
Maximum	1.808*	1.859*	1.745*
Minimum	3.02*	2.808*	3.03*
Mean	2.859***	2.86***	3.415***

Note: ***=significant at 0.01, **= significant at 0.05,*= significant at 0.1 level

Table 3. Winter temperature trend

Temperature	Mann-Kendall (Non-parametric)	Spearman's Rho (Non-parametric)	Linear regression (Parametric)
Maximum	1.326	1.457	1.255
Minimum	1.221	1.472	0.497
Mean	1.704*	1.942*	1.016

Table 4. Pre-monsoon temperature trend

Temperature	Mann-Kendall (Non-parametric)	Spearman's Rho (Non-parametric)	Linear regression (Parametric)
Maximum	0.303	0.696	0.704
Minimum	1.25	1.721*	1.465
Mean	0.776	1.217	1.022

Table 5. Monsoon temperature trend

Tempe-rature	Mann-Kendall (Non-parametric)	Spearman's Rho (Non-parametric)	Linear regression (Parametric)
Maximum	0.824	1.139	0.637
Minimum	2.282**	2.763***	2.059**
Mean	1.524	2.045**	1.425

Table 6. Post Monsoon temperature trend

Tempe-rature	Mann-Kendall (Non-parametric)	Spearman's Rho (Non-parametric)	Linear regression (Parametric)
Maximum	1.666*	2.003**	1.795*
Minimum	2.992***	2.91***	3.144***
Mean	2.831***	3.101***	3.461***

Note: ***=significant at 0.01, **= significant at 0.05,*= significant at 0.1 level

Results and Discussions

Annual temperature trends : The mean annual, Tmax and Tmin along with trend line are presented in Fig. 1. The mean annual temperature showed a significant long-term increasing trend Table 2. It could be seen from the figure that there had been a considerable warming after 2000.Maximum and minimum temperatures are significantly increasing but showing significance only at 0.1 level. But annual mean temperature is showing significance at 0.01 level.

Seasonal temperature trends:

Winter season : During winter season there was no significant increase in the maximum and minimum temperatures. But we can see consistent increasing trend in both maximum and minimum temperatures (Fig. 2).It was observed that the mean temperature has shown significance at 90 per cent confidence level in Mann-Kendall and Spearman Rho tests (Table 3).

Pre-Monsoon season : In the pre-monsoon season, only minimum temperature has shown the significant increase with only Sphereman's Rho test (Table 4). But it was observed that there was consistent increase the

Table 7. Monthlytemperature trend

Month	Maximum temperature			Minimum temperature			Mean temperature		
	Mann-Kendall	Spear-man's Rho	Linear regre-ssion	Mann-Kendall	Spear-man's	Linear regre-ssion	Mann-Kendall	Spear-man's	Linear regre-ssion
Jan.	0.625	0.829	0.449	1.221	1.468	0.203	1.231	1.421	0.485
Feb.	1.619	1.823*	1.645	1.307	1.627	0.738	1.752*	2.022**	1.385
Mar.	0.095	0.258	0.372	0.54	0.751	0.708	0.18	0.362	0.488
Apr.	0.862	1.165	0.925	0.265	0.33	0.383	0.473	0.722	0.701
May.	0.454	0.657	0.166	3.087***	3.497***	3.118***	1.117	1.501	1.502
June..	0.312	0.402	0.303	0.776	0.959	0.947	0.862	0.907	0.704
July.	0.227	0.612	-0.293	1.95*	2.292	1.973*	0.757	1.153	0.638
Aug.	2.197**	2.416**	1.887*	2.13**	2.627***	2.315**	2.358**	2.975***	2.298**
Sep.	0.142	0.41	0.231	1.998**	2.427**	2.004*	1.032	1.376	1.284
Oct.	-0.076	0.177	-0.094	1.032	1.344	1.151	1.032	1.376	1.284
Nov.	2.566**	2.85***	2.65**	2.803***	2.641***	2.509***	2.623***	2.519**	3.093***
Dec.	2.452**	2.51**	2.326**	1.486	1.652*	2.388***	2.452**	2.597***	3.06***

Note: ***=significant at 0.01, **= significant at 0.05,*= significant at 0.1 level

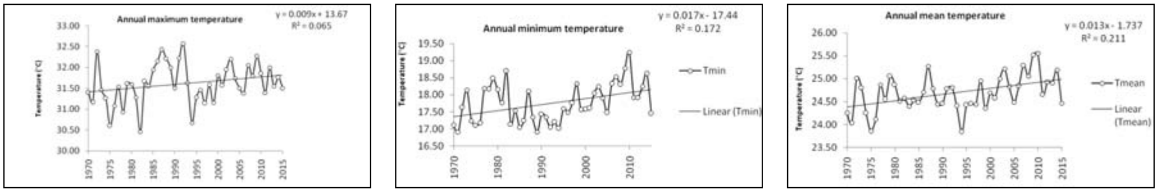

Fig. 1. Annual temperature trends at Pune

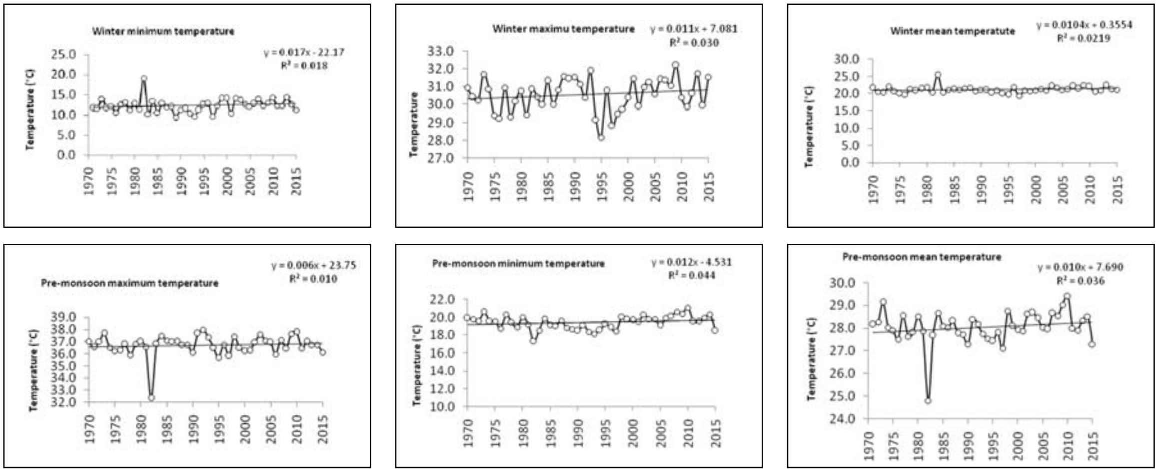

Fig. 2. Winter and Pre monsoon temperature trends at Pune

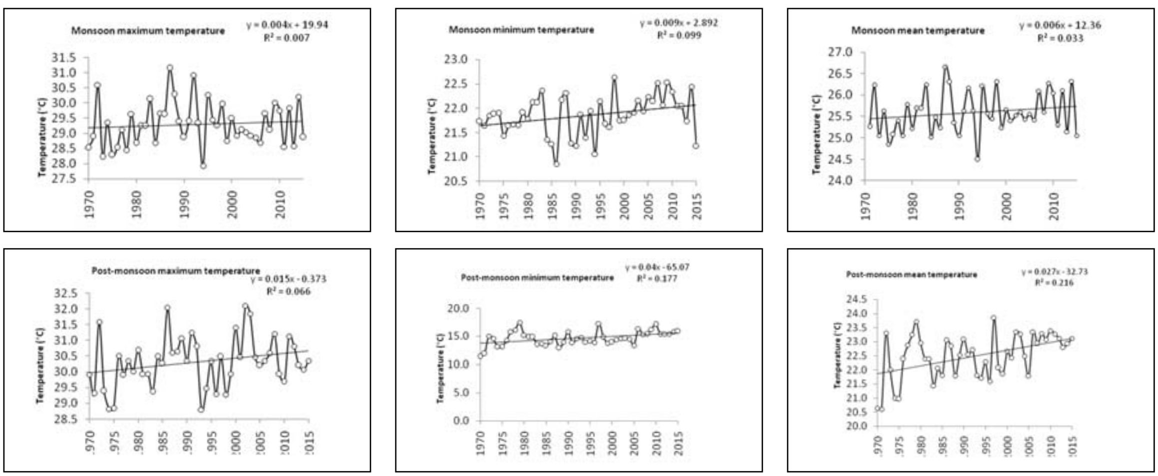

Fig. 3. Monsoon and Post-Monsoon temperature trends at Pune

temperature in the pre-monsoon season (Fig. 2).

Monsoon season : Monsoon season has shown the increase in the minimum temperature significantly (95%) with all the statistical tests (Table 5). Mean temperature has shown significance with only Sphereman's Rho test. From the Fig.3 it was observed that there was a consistent increase in the minimum temperature. With the running mean line, it wasfound that there was considerable increase in the minimum temperature after 2000s. But interestingly, there was a decrease in the maximum temperature during the monsoon season in Pune.

Post-Monsoon season : Minimum temperature and mean temperature had shown significant increase in the trends at 0.01 level in all the statistical tests (Table. 6). Maximum temperature was also increased significantly in the post-mosoon season. There was decrease in the maximum temperature after 2004 (fig. 5).

Monthly temperature trends : Trends of minimum, maximum and mean temperature were studied for individual months by subjecting them to the Mann-Kendall test, Spearman's Rho test and Linear regression.The results are presented in Table 7. Maximum temperature has shown significant increasing trend in August, November and December months. Minimum temperature, from May to December except in June and October has shown a significant increasing trend. It was also observed that there was a significant increase in the minimum temperature during the monsoon season and post monsoon season which is the most important period for the crops.

Conclusion

The important finding of the present study was that, there was a significant increasing trend in minimum temperature and mean temperature during the monsoon and post monsoon seasons. The increase in the mean temperature during the post monsoon may be due to increase in the maximum temperature. Maximum temperature also has shown the significant increase during the post monsoon season. Similar results were reported by Kothawale *et al*. (2016). Gadgil and Dhorde (2005) found that significant cooling trend in mean annual temperature, which is more predominant during winter season and the summer season also showed significant cooling trend in Pune and it was due to increasing Suspended Particulate Matter (SPM) levels in pune. But in this study contrasting results were obtained. Krishnan and Ramanathan(2002) suggested that all-India surface air temperature during the drier part of the year (January-May) has been subjected to a relative cooling by as much as 0.3?C during the last three decades (1968-1997), when the global effects of greenhouse gases and natural variability were filtered out from the temperature series. However, Kothawale and Rupa Kumar (2005) have pointed out that, this was rather a perceived cooling and mentioned that both all-India annual maximum and minimum temperatures have significantly increased during the recent 3 decades (1971-2003) and accelerated warming is observed after 1990.

The present study showed that in the recent period, minimum temperature increased faster than the maximum temperature. It might be due to urbanization. The effects of urbanization are more pronounced on minimum temperature than that of the maximum temperature (Kothawale *et al*. 2016).

Acknowledgements

We are in-debt for support of the India Meteorological Department for providing required data and thankful to http://ewater.org.au/ for providing trend analysis software which was very helpful in this study.

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J. Agric. Res. Technol., 42 (3) : 065-069 (2017)

Delineation of Groundwater Potential zones in Pingalgarh Watershed of Maharashtra State using Geospatial Techniques

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Abstract

Groundwater is the most important natural resource. Over three fourths of food grain production from the irrigated lands, is contributed from lands irrigated by groundwater. With every passing day, our dependence on ground water is increasing and is likely to remain dominant.Groundwater is clearly the preferred source by the farmers. This is one of the reasons why this region has experienced explosive growth in groundwater demand during recent decades. Geospatial technology is a rapid and cost effective tool in producing valuable data on geomorphology, lineaments, slope etc. that helps in delineation of ground water potential zones. The study was conducted in Pingalgarh watershed , a part of Godawari-Purna basin of Marathwada region of Maharashtra state locatedbetween 76°36' to 77°59' E and 19°07' to 19°17'N.The geographical area of the watershed is 34413.87 ha. Most of the area is under cultivation with no forest. Pingalgarh nala, a tributary of Purna River is the main stream of 43.95 km flowing from the watershed The different thematic layers of geomorphology, lineaments, slope, drainage, land use were generated using Resource SAT-2, LISS-IV satellite imaginary. These thematic maps were integrated using Arc-GIS 10.3 software to yield groundwater potential zone map for the study area. Based on the well yield values obtained from the pumping test and integrating the various thematic layers by UNION tool in Arc tools of GIS software, the ground water potential zones were identified.

Key words : Groundwater, GIS, remote sensing, Pingalgarh watershed

Groundwater forms part of the natural water cycle and constitutes a major portion of the cycle. At the national level nearly 60% of all districts have problems related to either the quantitative availability or quality of groundwater or both. Recent research has highlighted the alarmingly high rate at which groundwater levels in various parts of India are falling (CGWB, 2013). Although, groundwater is a renewable resource, it has reached to critical stage of exploitation in many regions. Therefore, its appropriate management has assumed great significance. The groundwater recharge depends not only on location specific geology but also quantum and pattern of precipitation(CGWB,2006). The remote sensing data provides valuable information on various factors like slope, geomorphology, lineaments, drainage and land use which is found to be extremely useful in identifying the groundwater potential zones. Remote sensing and GIS have proved to be cost effective and time saving tools to generate valuable information.

Description of Study Area

Location : Pingalgarh watershed is part of Godavari-Purna Sub basin and comprises three sub watersheds namely GP-59, GP-61 and GP-62 as per GSDA classification of Godavari - Purna basin, located between 76°36' to 77°59' E and 19°07' to 19°17'N. Pingalgarh nala, a tributary of Purna River is the main stream of 43.95 km flowing from the watershed and meets Purna River at Neela village near Purna city. Finally, at a distance of 15 km, the Purna River meets the mighty Godavari river at Katneshwar in Parbhani district. The geographical area of the watershed is 34413.87 ha. Most of the area is under cultivation with no forest cover.

Climate : The watershed area falls under assured rainfall zone of Parbhani Taluka of Marathwada region. Based on analysis of rainfall data of last 30 years, the average annual rainfall of the region is estimated as 875 mm.

Data collection : The toposheet (1:50000 scale) of the study area was collected from Regional Remote Sensing Centre- Central, Nagpur. The basic soil depth, soil texture and hydrological soil group maps on 1 : 250000 scale were procured from National Bureau of Soil Survey and Land Use Planning, Nagpur.

Table1. Area under geomorphologic unit

Geomorphic unit	Area (ha)	Per cent of the total area
Plateau top	10.45	00.03
Plateau slopes	45.78	00.13
Pediments	51.54	00.14
Buried pediments	1480.60	04.30
Shallow pediplain	13789.23	40.08
Moderate pediplain	12242.88	35.57
Deep pediplain	6421.23	18.66
Gullied tract	56.55	00.16
Eroded plains	295.47	00.86
Palaeo channels	20.14	00.05
Total	34413.87	

Table 2. Area under various land use unit

Land use	Area (ha)	Per cent of the total area
Settlements		
City	1136.55	3.30
Village	333.05	0.97
Agriculture		
Crop land	29482.29	85.68
Fallow	1390.50	4.04
plantation	148.00	0.43
Waste land		
Land with scrub	1136.56	3.30
Land without scrub	120.03	0.35
Stony waste	58.63	0.17
Gullied land	136.85	0.40
Others	136.48	0.40
Water body		
Percolation tank lake	118.54	0.35
River	115.86	0.34
Farm pond	28.67	0.08
Abandoned quarry	67.24	0.19
Total	34413.87	

The rainfall data of last 30 years is collected from department of Agricultural Meteorology, VNMKV, Parbhani.

Satellite data procurement : The LANDSAT, CARTOSAT-1 PAN, LISS-IV satellite images were procured from Remote Sensing Centre- Central, Nagpur. Similarly high resolution images, Resource sat-2, LISS-IV data of the study area for 25th March, 2016 and 20th November, 2016 were procured from National Remote Sensing Centre, (NRSC), ISRO, Hyderabad.

Materials and Methods

Delineation of watershed : Initially watershed and sub-watershed boundaries were marked on geometrically rectified toposheet of 1972 on 1:50000 scale and later on it was digitized with the LISS-IV satellite image of 25th March 2016 and 20th November, 2016. The drainage details have been prepared from digitized high resolution satellite data of LISS-IV (Scale 1:10000) and extracted by digitizing boundary of the basin from the geometrically rectified toposheet (Scale 1: 50000). The drainage pattern for delineated watershed was exported to ARC/INFO software. The various thematic maps such as geomorphology, drainage, lineaments, land slope, land use/land cover, hydrologic soil group etc. were generated from the source data and updating it with field observations and overlaying using Arc-GIS 10.3 to find out the groundwater prospects zones in the study area. The long duration pumping tests were conducted on 15 open wells in the watershed area. The aquifer characteristic *viz.*, specific yield and transmissivity were determined using Papadopulos and Cooper method.

Results and Discussion

Geomorphology : Based on the physiographic characteristic, the landforms of the study area have been classified and the area and zone of each category of geomorphic unit of the watershed area is shown in Table 1.

Data presented in Table 1 indicated that majority of the area (80 %) was found to be in shallow, medium and deep pediplain indicating the cultivated land with good vegetative cover. Shallow pediplain is an area comprising of shallow depth of soil and found in scattered portion in the watershed area. Moderate pediplain is an area comprising of moderate depth of soil and found in majority of the area in the watershed. Generally these areas moderate to high productive in respect of crop production. These areas were found to be good for groundwater occurrence. Deep pediplain was an area comprising of deep soil and found in majority of the area in middle and lower reach of the watershed. Generally these areas

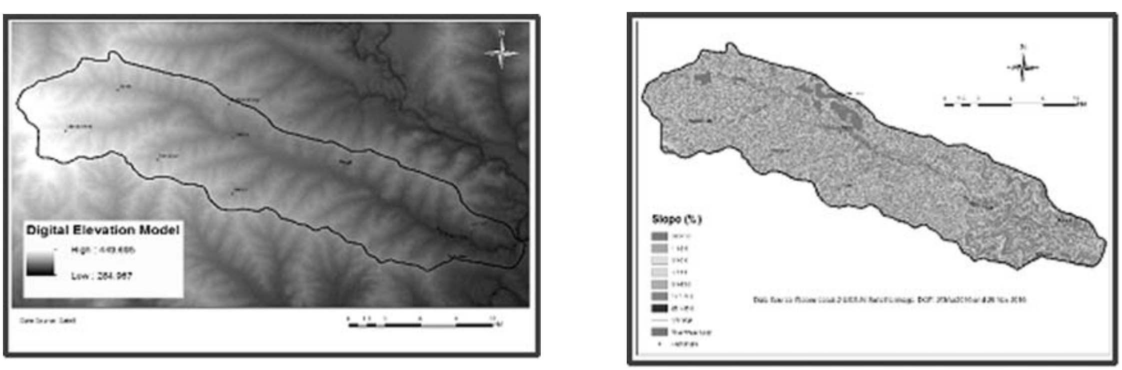

Fig. 1. DEM and thematic map of land slope

are highly productive in respect of crop production. These areas are also found to be very good for groundwater occurrence.

Land use map : The details of the land use in the watershed are presented in Table 2.

Land use pattern indicated that majority of the area i.e. 85.68 per cent is under crop land and 4.04 per cent area in under fallow land. Habitation area in the watershed in recorded as 3.30 per cent. One percolation tank is existed in the watershed near Jamb village with a water ponding area of 118.54 ha. The drainage pattern i.e.. River and streams occupied an area of 115.86 ha and the farm pond occupied an area of 28.67 ha i.e. 0.08 per cent which is very less. The area under waste land is 4.62 per cent.

Using the digital elevation model (DEM), the thematic map for land slope was prepared and shown in Fig.1. The land slope is categorized in 7 sub classes. Majority of the area falls under 0 to 1 per cent and 1 to 3 percent slope category except steep slope in some area at upper catchment. Similarly at confluence point, the slope ranges from 5 to 8 per cent.

Hydrological soil group (HSG) map : The hydrological soil group map was generated and shown in Fig.2. The watershed area is classified in HSG B, HSG-CI and HSG -D group. The majority of the land falls under HSG-D group. In the central upper part of the watershed, the area falls under HSG-C group.

Drainage pattern and Lineaments : The drainage pattern was digitized on the watershed area and stream ordering were given to different streams. Lineaments are the underground fractures in the rocks and drainage channels in the watershed which decides the ground water movement in the watershed area. Using the high resolution satellite data (LISS-IV) of 25th March 2016 and

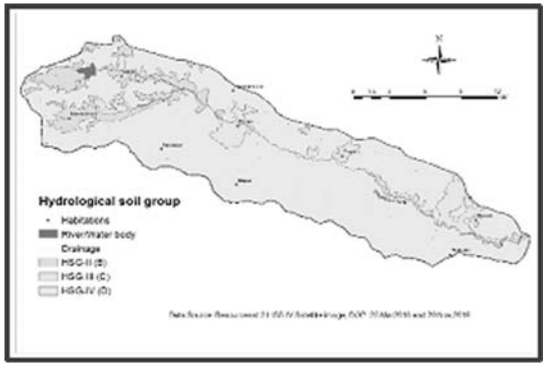

Fig. 2. Thematic map of Hydrological soil group

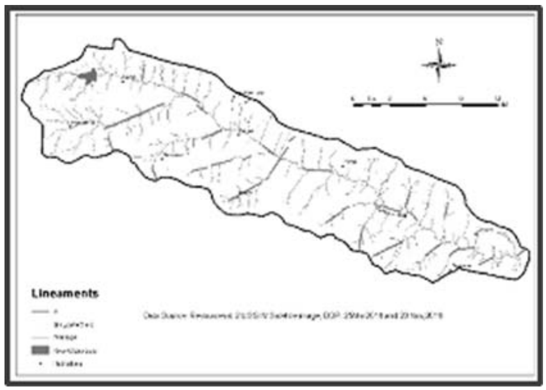

Fig. 3. Thematic map of drainage Pattern and Lineaments

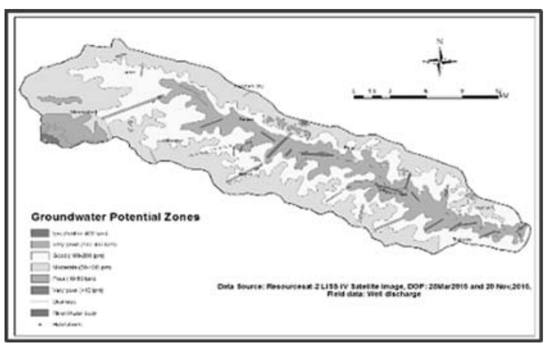

Fig. 4. Groundwater potential zones in Pingalgarh watershed

digital elevation model (DEM) of the study area, the lineaments were demarcated and thematic map was prepared using GIS tools in raster transformation and shown in Fig.3.

Identification of Groundwater potential zones : Pumping test analysis revealed that aquifer transmissivity varied from 318.58 to 801.12 m^2 day^{-1} and the specific yield was found to be in the range of 0.0101 to 0.0238 in the watershed. Based on the well yield values obtained from the pumping test and integrating the various thematic layers by UNION tool in Arc tools of GIS software, the ground water potential zones were identified. According to the well yield potential, the groups of ground water potential zones were identified and groundwater potential zone map was generated in GIS and shown in Fig. 4

Conclusions

Remote sensing and GIS is proved to be an important tool for identification of groundwater potential zones which will help in managing ground water resources on watershed basis. In pingalgarh watershed, the availability of ground water is moderate to good and in central portion of the watershed along the stream course, the groundwater availability is very good. However in some area, the occurrence of ground water is excellent.

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J. Agric. Res. Technol., 42 (3) : 070-074 (2017)

Optimization of water distribution pipe network by Genetic Algorithm

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Abstract

Water is the most essential commodity required to maintain life. Water supplies in general and water distribution networks in particular have been a part of the modern living. Out of the total expenditure incurred on different facilities of water supply system, the expenditure incurred on the distribution network is maximum. Therefore, it is necessary to optimize the water distribution network. Optimization involves the tradeoff between the performance and cost of the network. There are several approaches for optimization of water distribution network. Many researchers have applied genetic algorithm for the optimization of water distribution networks which has proved to be efficient over the conventional optimization techniques. In the present paper, the genetic algorithm model was developed in C#.net to find out optimum cost of the water distributing network. The applicability of the developed genetic algorithm model is discussed in this paper with a case study on water distribution network of Jaragnagar area of Kolhapur city, Maharashtra.

Key words : Water distribution network, pipe network analysis, genetic algorithm.

Next to air, water is the most essential commodity required to maintain life. The present uses of water are varied and may be classified as domestic, public, commercial and industrial. Water is provided to many communities through water distribution pipe networks. Thus, water distribution networks have been a part of the modern living. Out of the total expenditure incurred on different facilities of water supply system, the expenditure incurred on the distribution network is maximum. Therefore, it is necessary to design the water distribution network properly and optimize the water distribution network.

Several researchers have reported conventional algorithms such as linear, non-linear or dynamic programming for optimizing the cost of water distribution through the application of mathematical techniques. The major limitations of these techniques are rigidity, difficulties in representing the heterogeneous systems and their computational in-efficiency when number of variables is more. Also, many conventional optimization techniques result in a local optimum which is dependent on the starting point in the search process. Hence, there is a need to develop appropriate optimization technique which would be applicable for pipe distribution network. Genetic algorithms (GA) are nature based stochastic computational techniques. The major advantages of these algorithms are their broad applicability, flexibility and their ability to find optimal or near optimal solutions with relatively modest computational requirements. Genetic algorithms, pioneered by Holland (1992), have proven useful in a variety of search and optimization problems in engineering, science and commerce (Goldberg, 1989). Chen (1997) investigated the improvement in conventional genetic algorithms for the task of irrigation optimization by introducing two cross over approaches:

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sequence crossover and homo-crossover for the Shijing Irrigation Networks which are located in China. Gupta et.al. (1999) developed the methodology based on genetic algorithm for lower cost design of new and augmentation of existing water distribution networks. Dandy et.al.(1996) developed an improved GA formulation for pipe network optimization. The case study results indicated that the improved GA performs significantly better than the simple GA. Wardlaw and Sharif (1999) demonstrated that GAs provide robust and acceptable solutions to the four-reservoir deterministic finite-horizon problem, and can reproduce the known global optimum. Stewart and Jansson (2004) developed special purpose genetic algorithm for the class of spatial planning problems in which different land uses have to be allocated across a geographical region, subject to a variety of constraints and conflicting management objectives. Ting-chao and Zhang (2005) developed macroscopic nodal pressure model and the model of relationship between supply flow and water source head by using genetic algorithm. Thus, the GAs have wide applications in obtaining the optimum solutions in water related problems.

Materials and Methods

Genetic algorithms are a stochastic heuristic search method whose mechanisms are based upon simplification of evolutionary processes observed in nature as proposed in Darwin's theory of evolution. Genetic algorithms operate on a population of solutions rather than a single solution. Since, they operate on more than one solution at once; genetic algorithms are typically good at both the exploration and exploitation of the search space.

Genetic algorithm search begins with a set of potential solutions and changing them during several iterations. The Genetic algorithm hopes to converge on the most 'fit' solution. The process begins with a set of potential solutions or chromosomes (usually in the form of bit strings of binary numbers) that are randomly generated or selected. The entire set of these chromosomes comprises a population. The chromosomes evolve during several iterations or generations. New generations (offspring) are generated using the crossover and mutation techniques. Crossover involves splitting two chromosomes and then combining randomly selected bits of one chromosome with the other in a pair. Mutation involves flipping a single bit of a chromosome. The chromosomes are then evaluated using a certain fitness criteria and the best ones are kept while others are discarded. This process repeats until one chromosome has the best fitness and thus taken as the best solution of the problem. This process is illustrated in the Figure 1 below. Sensitivity analysis was performed by varying generation number, cross-over probability and mutation

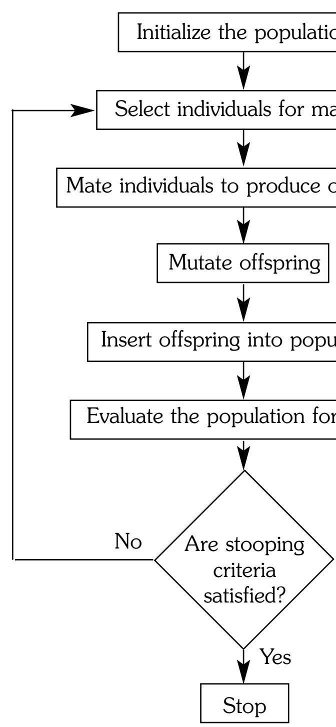

Fig. 1. Flowchart for optimization by GA

probability and optimum parameters were found.

Case study : The genetic algorithm model was developed in C#.net to find out optimum cost of the water distribution sub-network of Jaragnagar area of Kolhapur city (Figure 2). The data of this sub-network are presented in Tables 1 to 3 and the network is presented in Figure 2. Nodal details are given in Table 4. This network consists of 15 pipes and 12 nodes. Constraint on minimum nodal pressure is 10m. Water is supplied through the overhead water tank of 15m height at node No.1. The coefficient of roughness for the pipes is 0.005. The population size of the solutions used for the GA based algorithm is 20. The pipe diameters are the decision variables and form the bits of the string. They have been generated randomly within the range 0.05 to 0.5m.

Table 1. The pipe network details for loop '0'

Loop no.	Pipe no.	Peak flow ($m_3\ s^{-1}$)	Length of the pipe (m)
I	1- 2	92.52	160
	2 -10	3.618	31.5
	10 -3	3.618	150.5
	3 -1	0	31.5

Table 2. The pipe network details for loop '1' and '2'

Loop no.	Pipe no.	Peak flow ($m_3\ s^{-1}$)	Length of the pipe (m)
II	2 - 4	179.952	65
	4 - 5	17.952	30
	5 - 9	1.674	35
	9 -10	0.384	30
	10 -2	3.618	31.5
III	5 - 6	15.894	77
	6 -7	15.894	31
	7- 8	0	21
	8 - 9	0.84	65
	9 - 5	1.674	35

Table 3. The pipe network details for loop '3'

Loop no.	Pipe no.	Peak flow ($m_3\ s^{-1}$)	Length of the pipe (m)
IV	9-8	0.840	65
	8 -7	0	21
	7- 12	15.894	378
	12 -11	0	56
	11- 3	0	168
	3 - 10	3.618	130.5
	10 - 9	0.384	30

Table 4. Node elevations for the pipe network

Node no.	Elevation (m)	Node no.	Elevation (m)
1	593.00	7	584.57
2	591.30	8	589.50
3	593.46	9	589.80
4	589.30	10	590.60
5	589.21	11	596.55
6	583.34	12	597.59

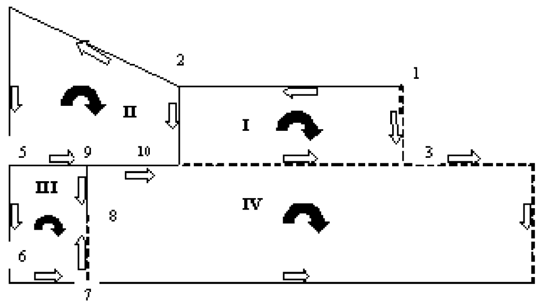

Fig. 2. Network map

Results and Discussions

The genetic algorithm model developed in C#.net was used to find out optimum cost of the water distributing sub-network of Jaragnagar area of Kolhapur city, Maharashtra. Sensitivity analysis was performed by varying generation number, cross-over probability and mutation probability as below.

Generation numbers	:	500 - 1000
Cross-over probability	:	0.5 - 0.8
Mutation probability	:	0.008 - 0.03

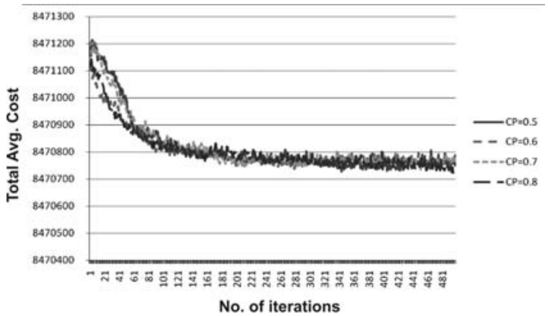

Fig. 3. The variation of the average costs of the network over generations for different crossover probabilities for mutation probability 0.008

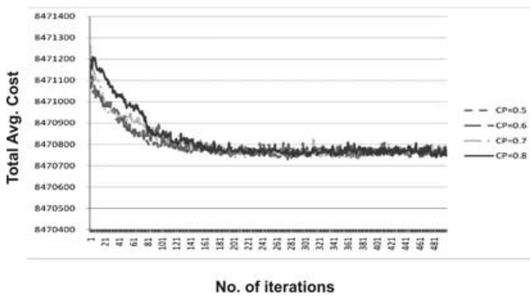

Fig. 4. The variation of the average costs of the network over generations for different crossover probabilities for mutation probability 0.01

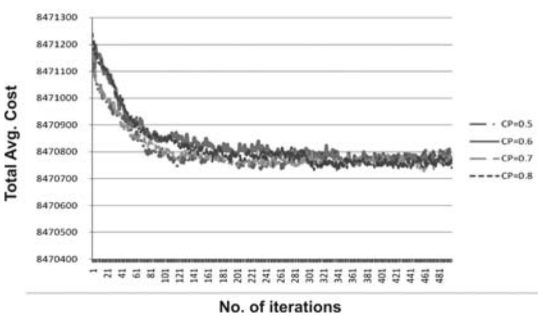

Fig. 5. The variation of the average costs the network over generations different crossover for mutation probability 0.03

The developed model was run for this network using these parameters. The results of

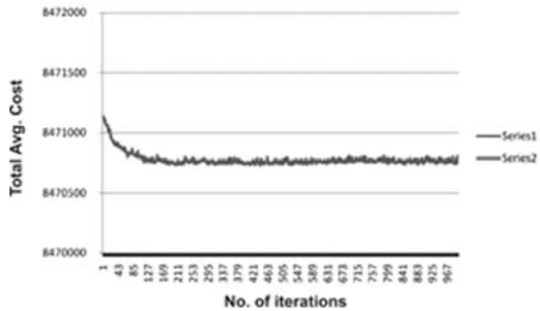

Fig. 6. The average costs vs GA iterations for Cross over probability 0.8 and mutation probability 0.008

the sensitivity analysis are presented in Figures 3 to 6.

It was observed that the optimum solution is obtained for cross over probability of 0.8 and

Table 5. Optimal diameters

Loop no.	Pipe no.	Peak flow ($m^3 s^{-1}$)	Length of the pipe (m)	Diameter (m)
I	1- 2	92.52	160	0.06
	2 -10	3.618	31.5	0.08
	10 -3	3.618	150.5	0.105
	3 -1	0	31.5	0.12
II	2 - 4	179.952	65	0.15
	4 - 5	17.952	30	0.17
	5 - 9	1.674	35	0.205
	9 -10	0.384	30	0.225
	10 -2	3.618	31.5	0.08
III	5 - 6	15.894	77	0.075
	6 -7	15.894	31	0.075
	7- 8	0	21	0.075
	8 - 9	0.84	65	0.075
	9 - 5	1.674	35	0.205
IV	9-8	0.840	65	0.075
	8 -7	0	21	0.075
	7- 12	15.894	378	0.085
	12 -11	0	56	0.19
	11- 3	0	168	0.085
	3 - 10	3.618	130.5	0.105
	10 - 9	0.384	30	0.225

Table 6. Optimal solution

Pipe no.	Peak flow (m^3 s^{-1})	Length of the pipe (m)	Diameter (m)
1- 2	92.52	160	0.06
2 -10	3.618	31.5	0.08
10 -3	3.618	150.5	0.105
3 -1	0	31.5	0.12
2 - 4	179.952	65	0.15
4 - 5	17.952	30	0.17
5 - 9	1.674	35	0.205
9 -10	0.384	30	0.225
5 - 6	15.894	77	0.075
6 -7	15.894	31	0.075
7- 8	0	21	0.075
8 - 9	0.84	65	0.075
7- 12	15.894	378	0.085
12 -11	0	56	0.19
11- 3	0	168	0.085

mutation probability 0.008. Therefore, this combination was tested for the 1000 iterations of GA. The time required to converge the genetic algorithm model after 1000th iterations was 1.07 hrs. The optimum solution was obtained after 1000th generation. The loop wise optimum solution is shown in Table 5. The pipe details of the best solution obtained through GA technique are presented in Table 6.

It was also observed that the model generates desired results for the other sub-networks of the Jaragnagar area of Kolhapur city. It was also observed from the results shown in figures that the average cost decreases as cross over probability increases. The average cost also decreases with the mutation probability.

The optimal cost of the water distribution network with optimal set of diameters was obtained to be Rs. 84,70620.

Conclusion

The genetic algorithm model is developed in C#.net. It generates the optimum cost of the water distribution sub-network of the Jaragnagar area of Kolhapur city for cross over probability of 0.8 and mutation probability 0.008. The model can also be used to find the optimum cost of other looped water distribution networks.

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J. Agric. Res. Technol., 42 (3) : 075-080 (2017)

Trends and Variability of Reference Evapotranspiration (ETo) at Rahuri, Maharashtra

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Abstract

Evapotranspiration demands and trends were analysed for Rahuri region in western Maharashtra by assessing reference evapotranspiration (ETo), energy balance and aerodynamic components for 38 years (1975-2013). Analysis of 38 years of daily meteorological data of Rahuri indicated that energy balance component of ETo has shown increasing trend, while a decreasing trend is seen in the aerodynamic component as well as in the ETo. Seasonal analysis has shown that ETo has an increasing trend during summer season. Mean annual ETo is 1724 mm with 1035 mm for energy balance component and 689 mm for aerodynamic component. Mean annual ETo, energy balance component and aerodynamic components observed maximum in the month of May while lowest in the month of December. Crop water requirement are more during March to June as ETo is observed to be highest during this period. Trend analysis provides indication on patterns in historical data of evapotranspiration. Monthly ETo variation is very useful for analysis of various water requirement of crops, irrigation plans etc. Present study highlights the necessity of ETo trend analysis as it depend on different weather parameters.

Key words : Evapotranspiration, Penman-Monteith, energy balance component, aerodynamic component.

Agricultural sector is one of the vulnerable sectors influenced by the rise in temperature, rainfall variability and climate change. Climate change is likely to alter crop durations, impact pest populations, hasten mineralization in soils, increase evapotranspiration (ET) and bring in more uncertainties in crop yields. Demand for irrigation water is more sensitive to agricultural production as climatic variability increased dryness thereby creating more demand of water to fulfill crop growing period (IPCC, 2001). In addition, change in normal pattern of temperature, precipitation and amount of rainfall also influence soil water content (Mall *et al*., 2006). ET is a major component of hydrological cycle and maximum portion of total rainfall falling on land surface is returned to the atmosphere through ET. Increase in the rate of ET along with temperature causes depletion in soil moisture retention capacity and increase salinity in semi-arid situations (Sankaranarayanan *et al*., 2010).

Contribution of energy balance to the total ETo has shown negative trend while positive trend was seen for aerodynamic component (Rao and Wani, 2011). In the arid region of China, a study with a dataset of 1955-2008 from 23 meteorological stations indicated that ETo has shown a decreasing trend with wind speed as a most sensitive meteorological variable followed by relative humidity, temperature and solar radiation (Huo *et al*., 2013).

The present study is undertaken to estimate ETo and its components and to assess the trends in ETo and climate variability of Rahuri region.

1. Research Scholar (IDE), 2. Assistant Professor (IDE), and 3. Associate Professor (IDE).

Materials and Methods

The study area is located at 19.38 °N latitude and 74.65 °E longitude with 510 m altitude above mean sea level. Daily climate data for Rahuri station with respect to maximum temperature (Tmax, °C), minimum temperature (Tmin, °C), maximum relative humidity (RHmax, %), minimum relative humidity (RHmin, %), pan evaporation (Epan, mm), wind speed at a height of 2.0 m (km h^{-1}), bright sunshine hours (h) were collected for 38 years (1975-2013) from the India Meteorological Department observatory located at Water Management Project, Mahatma Phule Krishi Vidyapeeth, Rahuri. Average monthly climatic parameters at Rahuri are presented in Table 1. Average relative humidity in the morning and evening were observed to be highest in September as it is the rainiest month. Bright sunshine varies from 3 to 11 hours per day over the year with October - May experience above 8 hours of bright sunshine. June - August experience lowest, about 3-6 hours of sunshine due to cloud cover in monsoon season.

Daily evapotranspiration was computed for 38 years using the FAO Penman-Monteith method (Allen *et al.*, 1998). Daily energy balance and aerodynamic component was also computed. Daily Values of ETo and its components were converted into monthly, seasonal and annual values.

The Penman-Monteith method to estimate ETo can be given as presented by equation;

$$ETo = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u(e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)}$$

Where, ETo = Potential evapotranspiration (mm day^{-1}), Rn = Net radiation at the crop surface (MJ m^{-2} day^{-1}), G = Soil heat flux density (MJ m^{-2} day^{-1}), T= Mean daily air temperature at 2 m height (°C), u_2 = Wind speed at 2 m height (m s^{-1}), e_s = Saturation vapour pressure (kPa), e_a = Actual vapour pressure (kPa), e_s - e_a = Saturation vapour pressure deficit (kPa), Δ = Slope vapour pressure curve (kPa $°C^{-1}$), γ = Psychrometric constant (kPa $°C^{-1}$)

Results and Discussion

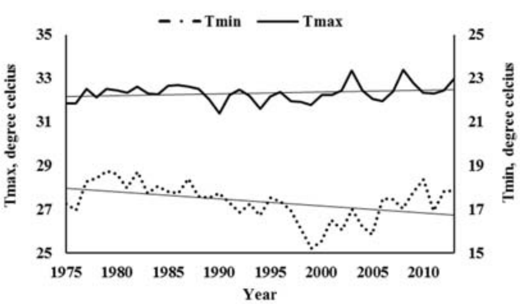
Trend of variation of different climatic parameters, average yearly minimum and maximum temperature (°C), minimum and

Table 1. Average monthly climatic parameters at Rahuri

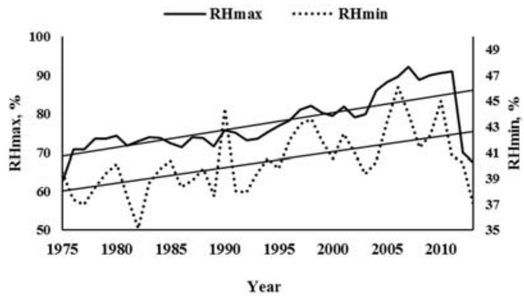
Month	Tmax (°C)	Tmin (°C)	RHmax (%)	RHmin (%)	Wind speed (km hr^{-1})	Bright sunshine (hours day^{-1})
January	28.9	10.6	79	34	3.6	9.0
February	31.2	11.7	74	28	4.2	9.6
March	35.0	15.1	65	23	4.7	9.8
April	38.0	19.0	62	23	6.2	10.8
May	38.6	21.7	69	27	9.1	9.8
June	34.4	22.6	83	50	11.5	5.9
July	30.7	22.2	86	61	12.0	3.7
August	30.0	21.5	88	58	10.5	4.1
September	30.8	20.7	88	63	6.4	5.8
October	31.6	18.0	83	43	4.0	7.9
November	30.0	14.2	80	40	3.8	8.3
December	28.6	10.6	81	36	3.3	8.7

maximum relative humidity (%), bright sunshine hours (hrs) and wind velocity (km hr^{-1}) is shown in Fig.1. Fig.1(a) showed increasing trend of maximum temperature while decreasing trend was observed in minimum temperature. Increasing trend was observed in Relative humidity (Fig.1(b)). No trend was observed in bright sunshine hours (Fig.1(c)). Decreasing trend was observed in wind velocity (Fig.1(d)). ETo showed a decreasing trend in the first of the study period as maximum temperature and sunshine hours also decreased during this period with lowest ETo observed in the year 1994 (Fig. 2). ETo increased in the second period as wind velocity and rainfall also increased during 1999 and 2013 with highest value of 1800 mm observed in the 2003. Thomas (2000) worked on spatial and temporal characteristics of PET trend over china and reported that the wind speed, relative humidity and maximum temperature are the primary factors to be associated with evapotranspiration changes in northwest, central and north-east china.

The energy balance component has shown increasing trend with values ranging from 879 mm to 1222 mm (Fig. 3). There is no trend in ETo during the years 1975 and 1992; after reaching the lowest value of 879 mm in 1993, it increased to reach to 1222 mm in 2001 as sunshine hours also increased continuously during this period.

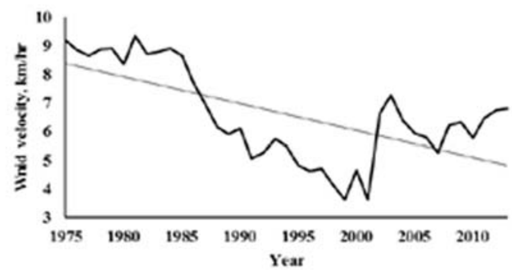


(a) Trend in maximum and minimum temperature (°C) at Rahuri



(b) Trend in maximum and minimum relative humidity (%) at Rahuri

(c) Trend in bright sunshine hours (hrs) at Rahuri



(d) Trend in wind velocity (km hr^{-1}) at Rahuri

Fig. 1. Trend in average yearly climate variables at Rahuri

Similar to the total ETo, aerodynamic component shown decreasing trend with values ranging from 378 mm to 1026 mm (Fig. 4) was observed in the year 1975 and 2001 respectively as wind velocity have the same trend during this period. At Rahuri, energy balance contributes about 60% while areodynamic component by 40% to the total

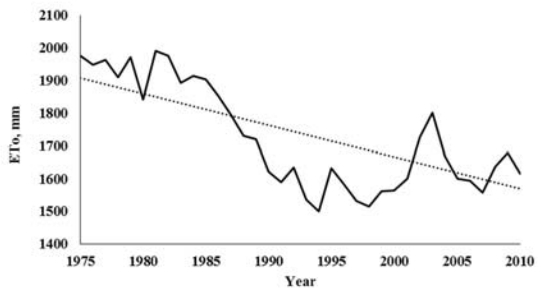


Fig. 2. Trend in reference crop evapotranspiration (ETo) at Rahuri

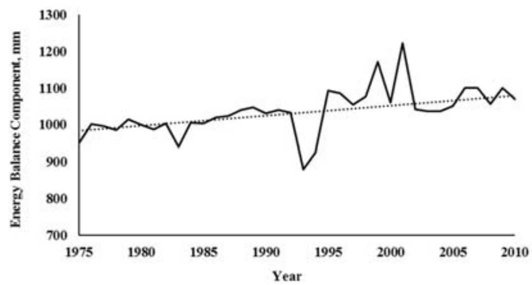


Fig. 3. Trend in energy balance component of ETo at Rahuri

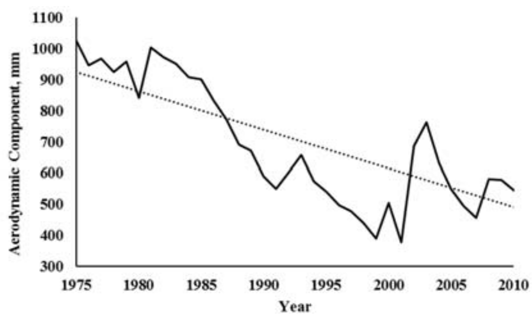


Fig. 4. Trend in aerodynamic component of ETo at Rahuri

ETo. Energy and areodynamic components were observed to contributing 70% and 30% respectively to ETo at ICRISAT, Patancheru (Rao and Wani, 2011). This reported that energy balance component was the dominating factor than areodynamic component to ETo.

Normal values of ETo and its components for *Kharif*, *rabi* and summer season along with monthly and annual mean values over the last 38 years are computed and presented in Table 2. Variation of ETo is an extremely important variable to be considered for agriculture purpose. Mean annual ETo observed 1724 mm while 1035 mm and 689 mm for energy balance component and aerodynamic component, respectively. When comparing *Kharif*, *rabi* and summer season, ETo and aerodynamic components observed minimum in *rabi* season with 547 mm and 186 mm, respectively while maximum in summer season with 612 mm and 274 mm, respectively.

Summer season ETo values observed highest while lowest in winter season among all the season (Rao *et al.*, 2013). In energy balance componet, maximum ETo of 360 mm observed in *rabi* season while lowest in *kharif* season with 337 mm. Mean monthly ETo, energy balance component and aerodynamic component found maximum in the month of May having highest maximum temperature of 39.3 °C with ETo of 238 mm, 120 mm and

Table 2. Average ETo and its components on monthly, seasonal and annual basis

Month/ season	ETo (mm)	Energy balance component (mm)	Aerodynamic component (mm)
Jan	102.9	65.8	37.1
Feb	123.3	75.6	47.8
Mar	168.1	100.4	67.7
Apr	205.9	117.2	88.6
May	238.2	120.2	118.1
Jun	170.6	91.6	79.0
Jul	139.4	77.9	61.5
Aug	130.8	80.0	50.8
Sep	124.4	87.8	36.6
Oct	124.0	88.8	35.2
Nov	102.0	68.2	33.8
Dec	94.3	61.7	32.5
Kharif	565.1	337.3	227.9
Rabi	546.5	360.1	186.4
Summer	612.2	337.8	274.3
Annual	1724	1035	689

Table 3. Temporal changes in ETo, energy balance and aerodynamic component during five year period

Year	ETo			Energy balance			Aerodynamic		
	Kharif	***Rabi***	**Summer**	***Kharif***	***Rabi***	**Summer**	***Kharif***	***Rabi***	**Summer**
1975-79	622.85	628.66	701.95	325.40	354.02	309.62	297.45	274.63	392.33
1980-84	621.23	615.03	686.09	318.17	353.96	315.29	303.06	261.08	370.80
1985-89	586.41	586.33	627.37	339.53	358.99	328.55	246.88	227.34	298.82
1990-94	528.86	498.95	548.90	333.59	326.29	321.56	195.27	172.67	227.35
1995-99	527.97	483.72	553.59	360.31	370.23	365.13	167.66	113.49	188.45
2000-04	545.31	526.21	600.56	338.47	372.34	368.8	206.84	153.87	231.77
2005-09	529.11	512.35	572.46	345.77	384.04	351.97	183.34	128.31	220.50
2010-13	557.82	514.64	605.02	336.67	361.63	342.64	221.15	153.01	262.38

118 mm, respectively. Lowest mean monthly ETo, energy balance component and aerodynamic component observed in the month of December with ETo of 94 mm, 62 mm and 33 mm, respectively.

To evaluate temporal changes in evapotranspiration demands, a five year average ETo of *Kharif* (Jun to Sept), *rabi* (Oct to Feb) and summer (March to May) seasons are computed (Table 3). ETo observed negative trend in *Kharif*, *rabi* and summer seasons with 15% reducion in *Kharif*, 23% reduction in *rabi* and 21% reduction in summer season.

Rao and Wani (2011) analysed ETo at a semi-arid location of southern India and observed a decreasing trend in both *Kharif* and *rabi* seasons, with 10% reduction in *kharif* and 14% in *rabi* seasons.

Conclusion

Analyses of 38 years of daily meteorological data of Rahuri indicated that energy balance component of ETo has shown increasing trend, while a decreasing trend is seen in the aerodynamic component as well as in the ETo. Seasonal analysis has shown that ETo has an increasing trend during summer season. Mean annual ETo is 1724 mm with 1035 mm for energy balance component and 689 mm for aerodynamic component. Mean annual ETo, energy balance component and aerodynamic components observed maximum in the month of May while lowest in the month of December. Crop water requirement are more during March to June as ETo is observed to be highest during this period. Trend analysis provides indication on patterns in historical data of evapotranspiration. Monthly ETo variation is very useful for analysis of various water requirement of crops, irrigation plans etc.

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J. Agric. Res. Technol., 42 (3) : 080-088 (2017)

Analysis of Rainfall and Temperature Trends in Telangana state, India

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Abstract

Evidence from several climate models suggests that the global climate ischanging in an unprecedented manner, mainly due to the rapid increasein the atmospheric concentration of greenhouse gases. However, variations in rainfall andtemperature patterndue to anthropogenic activities have raised theconcern of researchers and apprehensionregarding the presentas well asanticipated future changesat regional scale. Rainfall andtemperature arethe most important climate variables for any climate change study. However, the regional specific study of the major climatic variables is important to reduce the adverse effects of climate change in developingnations like India. In the present study, an attempt has been made to examine thetrends in rainfall and temperature of Telangana state using secondary datafrom 1901 to 2014. The empirical results of the non-parametric tests (Mann-Kendall and Sen's slope tests) have revealed that there is clear evidence of climate change in the Telangana over the study period. The annual rainfall trend of the state has increased at 5.84 mm per year^{-1}. Similarly, all the districts of the state are showing a rising trend in annual rainfall. The mean, maximum and minimum temperatures of the state has increased at 0.013°C, 0.013°C and 0.011°C per year^{-1} respectively. The district level data of temperature has shown a significant increase over the study period. With the changes and variability in the major climatic variables, policymakers should focus on the mitigation and adaptation strategies to overcome adverse impacts of climate change.

Keywords: Climate change, Rainfall, Temperature, Telangana, Mann-Kendall & Sen's test.

Studies to investigate climate change as well as its impact onthe different sectors deserve urgent attention in light ofthe impact of climate change on agricultural output, increasedrisk of hunger and water shortage, hasty melting ofglaciers,decline in river flows and increase in warming (Intergovernmental Panel on Climate Change, (IPCC, 2007). The present investigationaims to examine the trends in the monthly, annual andseasonal total rainfall; maximum, minimum and meantemperatures forthe Telangana state of India.Although climate change is a wide-ranging area of research,the changing trends and pattern of rainfalland temperature deserve urgent

1. Ph.D. Research Scholar.

andeffective attention as it would bedistress for the availabilityoffood security (Dore, 2005).

Data on precipitation, temperature, humidity, sea level and groundwater level are generally used for characterizing the climatic condition of a region. Among these variables, rainfall and temperature are the most important factors to detect or assess the trend or impacts of climate change. Variations in temperature and rainfall magnitudes may also be used as measures ofthe sensitivity of the weather system to external forcing elements such as changes in carbon dioxide (CO_2) concentration. The above factors, in turn, are affected to some extent by the actionsof human beings such as greaterland-use changes, deforestation, the building of highways and bridges, industrialization, growing population and vast urbanization. Over the earlier several decades these actions have occurred at aspeeded-up pace in the country, India.

The precipitation and temperature data are commonly available for greater areas and extendeddurations inIndia(Sarkar and Thapliyal, 1988).Unequal precipitation distribution, abnormalities in pre-monsoon, post-monsoon andmonsoon rainfall etc., seem to bemore common factors to control cyclical water availability in India (Thapliyal and Kulshrestha, 1991).Whether such variations are the outcome of a global climatic change orare adeviation is an unsettled question and is still being argued.Irrespective of the conclusion of thisdebate, the inferences in economic terms of these climate changes are massive, particularly in anemergingnation such as India. Appropriate preparations,planning and strategies are necessary to adapt with the consequences of these changes in weather. The agricultural sector is the most important one for livelihood to majority of Indian population and any change in its climatic system hasfar-reaching implications for the Indian economy.Therefore, the primary preparation will have to be to attain an increased yield from already irrigatedregions. This could be possible by combining climate impact assessments into existing irrigation projects. Theseinitiatives can decrease or eliminate some of the water-related risks challenged by the Indian economy.

In recent several years, there have been voluminous studies investigatingclimate change and itslikely impact onthe agricultural sector, ecology, water resources and health. Most of the studies found that climate is changing in the last several decades due to anthropogenic activities. To understand the possible impacts of climate change on different sectors, we need study the changes in climate-related variables such as rainfall and temperature.Only a lesser number of relevant and important studies are concisely surveyed here.A comprehensive methodology to the simulation of 'Regional Climate Change' is specifiedby Giorgi & Mearns (1991). The 'Intergovernmental Panel on Climate Change' (IPCC) AR-5 reported the annual andseasonal variability in precipitation trends during the earlier several decades all across the world.

Anabundant number of investigations have been carried out inthe Indian context. Further, several researchers and scientists haveconcluded that the trend as well as magnitude of warming up overIndia over the preceding century is mostconsistentwith the global patternand trend (Dash *et al.*, 2007; Arora *et al.*, 2005). Likewise, the diurnal temperature range (DTR) decadal trends over the country are somewhatdifferent from those witnessed over other regions of theworld because of the comparatively greater increase in maximum temperature over a major part of India (Rupa Kumar *et al.*, 1994; Srivastava *et al.*, 1992).

Several investigations relating to

changingtrends and pattern of rainfall over India have observed that there is noparticular trend of decrease orincrease in normal rainfall overthe nation (Mooley & Parthasarathy, 1984; Lal, 2001).However,long-term patterns and trends in monsoon rainfall season havenot been observed on a Pan-India level, variousinvestigationshave found significant trends in precipitation on a regionalor local scale (Koteswaram & Alvi, 1969; Chaudhary &Abhyankar, 1979). Some investigations have presented that,in general, the frequency of extremeprecipitation events inmany areas of Asia has declined, while the number ofrainy days as well as total annual precipitation has declined(Lal, 2003).Literature survey reveals that it is crucial to know the exact trendof precipitationas well as temperature pattern for mitigation of the existingextreme environmental problems and adaptation to climatic impacts and vulnerability.Therefore, the present study empirically examines the trends in rainfall and temperature of Telangana state at the district level.

Materials and Methods

For the study of climate change (rainfall and temperature trends) in the Telangana state of India, data on rainfall and temperature were gathered for the period of 1901-2015. The rainfall as well as temperature data were collected at ten districts,namely, Adilabad, Karimnagar, Nizamabad, Medak, Rangareddy, Warangal, Hyderabad, Mahabubnagar, Nalgonda and Khammam covering the whole state. Similarly, state level data of rainfall and temperature was also gathered. The state level rainfall data collected from Indian Institute of Tropical Meteorology (http://www.tropmet. res.in). The district level data on temperature and rainfall collected from http://www.indiawaterportal.orgbut the district level data is only up to 2002, therefore the study has used supplement data set gathered from Directorate of Economics & Statistics, Hyderabad.

Methodology

A Plethora of investigations revealed rainfall and temperature changes over India and other regions of the country.Results of theseinvestigationshave presented different trends and patterns. In this study, season wise state and district level analysis of temperature and rainfall trend is considered to be important inthe better understanding of the climatic situation of the Telangana state. Two of the mostreferred non-parametric approaches (Mann-Kendall trend test and Sen's slope estimator) have been used in the present investigation to detectnature of the trendin time series data. Mann-Kendall's trend technique is applied to test the presence of a 'monotonic trend' andthe significance of the trend (Mann, 1945; Kendall, 1955).Sen's slope test for estimatingexact change per year in the time series data (Sen, 1968).

Mann-Kendall (MK) Test : The Mann Kendall (MK) trend test is not only used for precipitation trend analysis, but also extensively used for analysing various climate related variablesand also analysis of different environmentalstatistics. 'World Meteorological Organisation' (WMO)suggested M-K test to measure the significant monotonic trends in climatic data series.The less sensitivity in identical timeseries (Jaagus, 2006) and non-requirement of normal distribution data are two importantadvantages of M-K test (Tabari & Talaee, 2011).

The M-K test is suitablein cases when the data values Xi of a time series can be supposed to follow the model:

$$X_i = f(t_i) + \varepsilon_i$$

where $f(t^i)$ is a continuous monotonic decreasing orincreasing function oftime and the residuals ε_i can assumed to be from the same distribution with zero (0) mean. It is thusassuming that the variance of a distribution is constant in time.

The null hypothesis of no trend, H0, assumes that the observations X_i are autonomously distributed in time and the alternative hypothesis, H1, denoted an increasing or decreasing monotonic trend. The number of annual observations in the considered data series is titled by n. Missing values are permitted and n can thus be smaller than the number of years in the time series. The M-K test statistic 'S' is determined using the subsequent formula:

$$S = \sum_{k-}^{n-1} \sum_{j=k+1}^{n} sgn(x_j - x_k),$$

where, X_j and X_k are the annual values in years' j and k, j > k, respectively, and

$$sgn(x_j - x_k) \equiv \begin{cases} 1 \; if \; x_j - x_k > 0 \\ 0 \; if \; x_j - x_k = 0 \\ -1 \; if \; x_j - x_k < 0 \end{cases}$$

The variance of 'S' is calculated by the subsequent equation which takes into account that ties may be present:

$$VAR(S) = \frac{1}{18}\left[n(n-1)(2n+5) - \sum_{p=1}^{q} t_p(t_p - 1)(2t_p + 5)\right] \ldots.(3)$$

where, n is the number of data observations, 'q' is the number of tied groups and tp isthe number of data values in thepthgroup. Z statistics or Normal Approximationtest mostly used when the sample size is bigger than 10. The Z test is developed by both the values of S and VAR(S).

$$Z = \begin{cases} \frac{S-1}{\sqrt{var(S)}} & \ldots \; if \; S > 0 \\ 0 \quad \ldots & if \; S = 0 \\ \frac{S+1}{\sqrt{var(S)}} & \ldots if \; S < 0 \end{cases}$$

The significant (statistically) trend is evaluated by this Z value. The negative andpositive values of 'Z' denote decreasing andincreasing trend respectively. The statistic 'Z' has a normal distribution. To test for either an increasing or decreasingmonotone trend (a two-tailed test) at ? level of significance, H0 is rejected if thetotalvalue of Z is greater than $Z{-}1_{\alpha/2}$, where $Z{-}1_{\alpha/2}$ is attained from thestandard normal cumulative distribution tables.

Sen's Slope Test : To estimate the exact slope of an existing trend (as change per year) the Sen'snon-parametric method is used mostly. It can be in cases where the trend can be supposed to be linear. This means that f (t) in Equation (1) is equal to

$$f_{(t)} = Q_t + B$$

where, Q is the slope and B is a constant.To get the slope estimate Q in above equation, we first calculate the slopes of alldata value pairs:

$$Qi = \frac{x_j - x_k}{j - k}$$

where, xj and xk are the data scores at times j and k (j > k) respectively. If thereare n values xj in the time series, we get as many as N = $n_{(n-1)/2}$ slope estimatesof Q_i. The Sen's estimator of slope is the median of these N values of Q_i. The Nvalues of Qi are ranked from the smallest to the largest and the Sen's slope estimator is

$$Q = Q_{((N+1)/2))} \text{ if N id Odd (or) } Q = \frac{1}{2}\left(Q_{\frac{N}{2}} + Q_{\left(\frac{N+2}{2}\right)}\right) \text{ if N is even.}$$

Q is tested with a two-sided confidence interval at 100(1 α)% and the slopeestimate is obtained by the nonparametric method.The confidence interval at two different confidence levels; α = 0.01 and α =0.05 as follows:

$$C_\alpha = Z_{1-\alpha/2}\sqrt{VAR(S)}$$

where, VAR(S) has been defined in Equation (3), and $Z_{1-\alpha/2}$ is obtained fromthe standard normal distribution.After that, M1 =(N - C_α)/2 and M_2 = (N + C_α)/ 2 are computed. Thelower and upper limits of the confidence interval, Qmin and Qmax, are the M_1^{th} largest and the $(M_2+1)^{th}$ largest of the N ordered slope estimates Q_i. If M_1 is not a whole number, the lower limit is interpolated. Correspondingly, if M_2 is nota whole number the upper limit is interpolated.

Results and Discussion

Analysis of rainfall trends : The empirical results of trend analysis for the rainfall as well as thetemperature data are analysed in the succeeding sections.In this study, we haveexamined the trends in rainfall and temperature patternsfor the 1901-2014 period in the Telangana state. The state is mainly subjected to four seasons; winter (January-February), summer (March-May), southwestmonsoon (June-September), and a post-monsoon period (October-December).The linear trend of annual rainfall in the state is presented in figure1. The trend line of annual rainfall of the state is showing a slightly increasing trend line. The trend analysis of rainfall has explained below in detail.

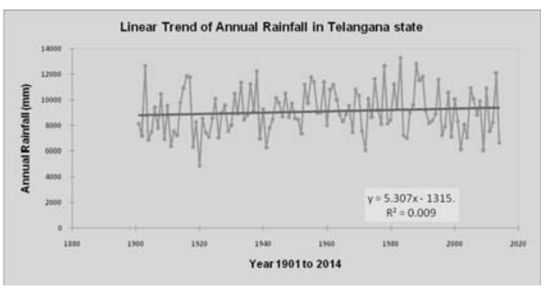

Fig. 1. Annual rainfall trends in Telangana state from 1901 to 2014

After the graphical trend analys is, our results on trend analysis of the state annual rainfall data have been presented in Table1 below. The annual, seasonal and monthly rainfall characteristics of Telangana state has been displayed in the below table.

The results of the non-parametric statistical test for the annual, seasonal and monthly rainfall of Telanganastate has been displayed in the table (1). Except june, august and octoberremaining months are not statistically significant with increasing trend. The annual rainfall for Telangana state displays a long-term increasing trend (0.066) but not statistically significant. The Sen's slope test results for annual rainfall shows that a positive slope (5.84) which means the annual rainfall is increasing 5.84 mm per year. Thus there is an increasing trend in annual rainfall in Telangana state over the study period. Further, except winter season, all the other seasonal rainfall has an increasing trend and the Sen's slope estimator also showing the positive results except winter season.

M-K test results for February, April, June, September and December months have a negative value which means there is a decreasing trend in these months.The Sen's slope for the pre-monsoon and monsoon rainfall data is 0.128 mm/year and 2.813 mm/year respectively, while it is not statistically significant in the Mann-Kendall test. Post-monsoon and Hot weather period also displays an insignificant increasing trend in rainfall. The analysis for rainfall data of Telangana state displays that there is a general increasing trend

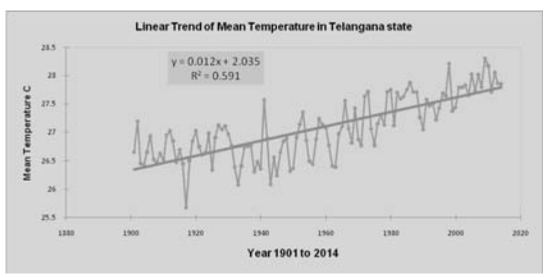

Fig. 2. Annual mean temperature trend in Telangana state from 1901 to 2014

Table 1. Monthly, seasonal and annual rainfall trends in Telangana state from 1901-2014

Time period	MK test	p-value	Sen's slope
Jan	0.016	0.809	0.000
Feb	-0.036	0.585	0.000
March	0.033	0.608	0.010
April	-0.058	0.358	-0.273
May	0.030	0.640	0.224
June	-0.102	0.109*	-2.290
July	0.020	0.756	0.786
Aug	0.182	0.004***	5.429
Sept	-0.062	0.330	-2.200
Oct	0.108	0.088*	2.477
Nov	0.008	0.898	0.000
Dec	-0.040	0.558	0.000
Winter	-0.027	0.675	-0.022
Pre-monsoon	0.010	0.874	0.128
Monsoon	0.036	0.570	2.813
Post-monsoon	0.093	0.145	2.640
Annual	0.066	0.300	5.838

Notes: *, **, ***, Significant at 10%, 5 % and 1% level respectively, Winter: January- February, Pre-monsoon: March to May, Monsoon: June to September, Post-Monsoon: October to December, Source: Author's calculation.

in rainfall data for the annual, pre-monsoon, monsoon and post-monsoon season, although it is not statistically significant. After the analysis of monthly, seasonal and annual rainfall trends of the state, the study analyses the district level rainfall data.

The results of the Mann-Kendall statistical test for the annual rainfall of Telangana state at district level has been displayed in the Table (2). Except forAdilabad, Karimnagar, Medak and Nalgonda remaining districts are showing an increasing trend and also statistically significant. The M-K test results show that the highest trend for Khammam district (0.281) and the lowest trend for Medak district (0.057). Thus, the annual rainfall for all the districts displays a long-term increasing trend over the study period. The Sen's slope test results for annual rainfall at district level shows that a positive slope which means the annual rainfall is increasing certain level per year. Further, the district level annual rainfall has an increasing trend and the Sen's slope estimator also showing the positive results in the state over the study period.

Analysis of Temperature trends in Telangana state : After analysing the trends of rainfall data, we also explored the trend of mean, maximum and minimum temperature data for Telangana state. For Telangana state, we have analysed data for the period of 1901 to 2014. For analysing the trends intemperature data we used both Mann-Kendall and Sen's slope test. Before analysing the trends of temperature data, we have demonstrated the annual meantemperature data for the state in graphic form. Figure (2) displays the trends in annualmean temperature for the state. It can be seenfrom the Figure (2) that there is a clear increasing trend in the annual mean temperature in the state. Further, trend analysis of the temperature data

Table 2. District wise Annual rainfall trends from 1901 to 2014

District	MK test	p-value	Sen's slope
ADB	0.067	0.291	0.671
HYD	0.129	0.043**	1.226
KMM	0.281	0.001***	2.564
KNR	0.098	0.122	0.928
MBNR	0.123	0.052*	0.924
MDK	0.057	0.367	0.444
NLG	0.092	0.149	0.743
NZB	0.132	0.037**	1.166
RR	0.145	0.022**	1.172
WGL	0.207	0.001***	1.595

Notes: *, **, ***, Significant at 10%, 5 % and 1% level respectively.Source: Author's calculation.

Table 3. District wise trendsof Annual mean temperature 1901 to 2014

District	MK test	p-value	Sen's slope
ADB	0.443	0.001***	0.008
HYD	0.538	0.001***	0.014
KMM	0.521	0.001***	0.011
KNR	0.538	0.001***	0.014
MBNR	0.486	0.001***	0.010
MDK	0.482	0.001***	0.011
NLG	0.560	0.001***	0.015
NZB	0.557	0.001***	0.015
RR	0.453	0.001***	0.010
WGL	0.572	0.001***	0.013
TS state	0.561	0.001***	0.013

Notes: *, **, ***, Significant at 10%, 5 % and 1% level respectively.Source: Author's calculation.

infollowing sections will provide a clearer picture.

The results of the 'non-parametric' trend test for the annual mean temperature data of the state at district level has been displayed in the Table 3. The M-K testresult displays that the value is 0.561 which means there is an increasing trend (statistically significant at 1% level) of annual mean temperature in Telangana state. The Sen's slope test gives us the magnitude of the trend of increasing mean annual temperature of the state.The mean annual temperature of the state has increased at the rate of 0.013°C/year during the period 1901- 2014.

Further, the district level mean temperature trend shows astatistically significant increasing trend over the period of time in the state.It can be seen from the table that the results of Mann-Kendall test, the Warangal district has the highest value (0.572) and Adilabad has the lowest value (0.443).The Sen's slope estimate for all the districts shows that there is almost same slope for all the districts of the state. Further, maximum temperature trend analysis of the state at the district level is presentedin the following Table 4.

The results of the Mann-Kendall (M-K)trend test for the annual maximum temperature data of the state at district level has been displayed in the Table 4. The M-K test result for the statedisplays that the value is 0.560 which means there is an increasing trend (statistically significant at 1% level) of annual maximum temperature. The Sen's slope test gives us the magnitude of the trend of increasing maximum temperature of the state. The mean annual temperature of the state has increased at the rate of 0.013°C/year during the period 1901-2014.Further, the district level maximum temperature trend shows an increasing trend over the period of time in the state and also among the districts. And also these trends of all the districts are statistically significant.

The results of the M-K trend test for the annual minimum temperature data of the state at district level has been presented in the table (5). The M-K test result displays that the minimum temperature trend value of the state

Table 4. Trend of Maximum Temperature District wise from 1901 to 2014

District	MK test	p-value	Sen's slope
ADB	0.406	0.0001***	0.008
HYD	0.463	0.0001***	0.011
KMM	0.511	0.0001***	0.011
KNR	0.537	0.0001***	0.014
MBNR	0.479	0.0001***	0.010
MDK	0.565	0.0001***	0.015
NLG	0.539	0.0001***	0.014
NZB	0.552	0.0001***	0.015
RR	0.458	0.0001***	0.011
WGL	0.573	0.0001***	0.015
TS state	0.560	0.0001***	0.013

Notes: *, **, ***, Significant at 10%, 5 % and 1% level respectively.Source: Author's calculation.

Table 5. Trends of Minimum Temperature district wise from 1901 to 2014

District	MK test	p-value	Sen's slope
ADB	0.435	0.0001***	0.009
HYD	0.524	0.0001***	0.013
KMM	0.509	0.0001***	0.011
KNR	0.536	0.0001***	0.013
MBNR	0.469	0.0001***	0.010
MDK	0.324	0.0001***	0.008
NLG	0.562	0.0001***	0.015
NZB	0.555	0.0001***	0.014
RR	0.415	0.0001***	0.010
WGL	0.461	0.0001***	0.010
TS state	0.535	0.0001***	0.011

Notes: *, **, ***, Significant at 10%, 5 % and 1% level respectively.Source: Author's calculation

i.e. 0.535 which means there is an increasing trend (statistically significant at 1 % level). However, the Sen's slope test gives us the magnitude of the trend of increasing minimum temperature of the state. The minimum temperature of the state has increased at the rate of 0.011°C/year during the study period (1901- 2014).

Moreover, the district level minimum temperature trend shows an increasing trend over the period of time in the state. And also these trends of all the districts are statistically significant. It can be seen from the table that the results of Mann-Kendall test, the Nalgondadistrict has the highest value (0.562) and Medak has the lowest value (0.324), however, both the districts are significant at 1 % level. The Sen's slope estimate for all the districts shows that there is almost same slope for all the districts of the state at the range of 0.010 to 0.015°C/per year.

Conclusions

The regional specific study of the major climatic variables is important to reduce the adverse effects of climate change in developingnations like India. The present investigation on district wise rainfall and temperature data of entire Telangana statefrom 1901 to 2015 using Mann-Kendall trend test and Sen's slope testmethodsintendedto have a clear understanding of the rainfall and temperature trends over the state and itsdistricts.The empirical results of the non-parametric tests (M-K and Sen's tests) have shown that there is clear evidence of climate change in the Telangana over the study period. The annual rainfall trend of the state has increased at 5.84mm per/year. Similarly, all the districts of the state are showing a rising trend in annual rainfall. The mean, maximum and minimum temperatures of the state has increased at 0.013 0C, 0.013 0C and 0.011 0C per/ year respectively. The district level data of temperature (mean, maximum and minimum) has shown a rising trend and also statistically significant at 1% level. With the changes and variability in the major climatic variables, policymakers should focus on the mitigation and adaptation strategies to overcome adverse impacts of climate change.So there is need for some districtwise strategies to deal with this climate change condition.

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J. Agric. Res. Technol., 42 (3) : 089-093 (2017)

Validation and Usability of Medium Range Weather Forecast for Parbhani District of Marathwada Region

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Abstract

Weather is an important factor in Agriculture sector and favourable weather is essential for sustainable agriculture which minimizes the weather hazards. Weather forecast related to agriculture is helpful in mitigating the aberrant weather condition thereby reducing the cost of cultivation and increases the crop yield. Reliable and timely weather forecast also provides significant and useful inputs for precise impact assessment for agricultural activities. The attempts were made to verify the medium range weather forecast issued from IMD on every Tuesday and Friday on various weather parameters for the year 2015-2016 on seasonal and yearly basis for Parbhani district of Maharashtra state. The forecast verification comprised of the anticipated weather information on four weather parameters, viz. rainfall, maximum temperature, minimum temperature and wind speed. The validation analysis was carried out on daily basis using various techniques, viz., Ratio Score (RS), Critical Success Index (CSI), Heidke Skill Score (HSS), Hanssen and Kuipers Score (HK), Root Mean Square Error (RMSE) and usability analysis. Results revealed that the Ratio Score for all the seasons ranged from 66 to 90% and HK scores ranged from 0.32 to 0.78. Higher value of ratio score was observed in post monsoon season which indicates higher amount of precision in forecast. The positive values of HK score in all seasons indicate that the reliability of forecast is satisfactory. For rainfall, highest RMSE of 17.08 was recorded in post monsoon season indicating lower accuracy. Lowest RMSE values signifying least error between observed and forecasted data. The qualitative forecast revealed higher reliability compared to quantitative forecast. The CSI values varied from 0.14 to 0.53 and higher value of CSI was found in monsoon season (0.53) which indicates satisfactory forecasts. The HSS value (185.88) was found highest with monsoon season and lowest value (20.34) was calculated with summer season. The forecast of rainfall was 100 percent correct during winter season and 95% percent correct in the summer season. Whereas, the correct forecast for maximum temperature was higher in post monsoon season (73 %) followed by summer season (58%). A higher accuracy of wind speed was obtained when the forecast was validated for post monsoon season (57 %) followed by winter season (31%).

Key words : Weather forecast, Rainfall, Temperature, Wind speed, Validation, Usability.

Agriculture is a major sector of the economy in most countries, especially in the developing world. Inter and intra-seasonal variations in weather/climate carry considerable impact on the timing as well as efficiency of routine agricultural operations such as sowing, weeding and harvesting, and they also determine the efficacy of application of inputs such as fertilisers, insecticides and pesticides. Extreme meteorological events such as droughts and floods, with their potential to increase pest and disease infestations, can cause significant economic losses depending on the stage of crop growth during which they occur. Early forecasts of such events have the potential to help farmers take appropriate remedial measures that could avoid or reduce economic losses. Timely availability of agrometeorological information and services could facilitate both strategic and tactical decisions in increasing and sustaining agricultural production. The main strategic decision for which the information is needed include assessment of crop production potential and identification of appropriate

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region for a specific crop, choice of crops/ cropping systems, management practices and marketing of agricultural products. Weather conditions during cropping periods play a major role in success or failure of agricultural crop production. Weather manifests its influence on agricultural operations and farm production through its effects on soil and plant growth. Out of the total annual crop losses, a substantial portion is because of aberrant weather. The loss could be minimized by making adjustment with coming weather through timely and accurate weather forecasting. Agricultural operations can be advanced or delayed with the help of advanced weather forecast from three to ten days. An agriculturally relevant forecast is not only useful for efficient management of farm inputs but also leads to precise impact assessment (Gadgil, 1989).

The degree of vulnerability of crops to climate variability depends mainly on the developmental stage of the crops at the time of weather aberration (Lansigan et al. 2000). The rainfed agro-ecosystem of the state comprising of varied topographical, altitudinal and agroclimatic elements however, faces several challenges such as temporal and spatial weather variability to realize optimum productivity. Therefore, favourable weather is desired for sustainable agriculture which minimizes the weather hazards. However, weather cannot be modified except on limited scale but agricultural operations can be reoriented to nearly accurate weather forecasts. Under the changed scenario where agriculture has become highly input and cost intensive, today the weather forecasts relating agriculture are indispensable to reduce the cost of cultivation for crops. Agromet advisory services based on medium range weather forecasts have been identified as a micro level management strategy for mitigating the impact of climatic variations on agricultural production and income (Devi and Rao, 2008). Farmers could thereby adjust their cropping patterns and plan agricultural operations in order to obtain maximum production even during adverse weather conditions. In the present study efforts have been made to verify the suitability of the medium range weather forecasts for tropical climate of Marathwada region in relation to its applicability in agricultural management.

Materials and Methods

Medium range weather forecast (forecast given for the period of five days) was given by India Meteorological Department, New Delhi on various weather parameters *viz*., amount of rainfall, cloud cover, maximum and minimum temperature, wind speed and direction for the period from 2015-2016 for Parbhani district. Forecasted data was compared with observed values of the respective weather parameters recorded at the Meteorological Observatory located at VNMKV, Parbhani, selected region for study is located in Marathwada region of Maharashtra state. Medium Range Weather Forecasts (MRWF) on rainfall, wind speed, wind direction, maximum and minimum temperature received from IMD for 2016 for Parbhani were analysed for validation under "Gramin Krishi Mausam Sewa (GKMS) scheme". The forecasts obtained were compared with daily observed weather data for the respective days from the actual data recorded at agro meteorological observatory situated at Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani. The forecast of rainfall, minimum temperature, maximum temperature, wind speed and direction have been verified by calculating the error structure. The location specific medium range weather forecast is received from IMD, Pune on every Tuesday and Friday. Verification is the assessment and quantification of the relation between a matched set of forecasts and observations. Forecast verification was carried out into four seasons as per standards of IMD, i.e., summer season (March-May), monsoon season (June-September), post-monsoon season (October-November) and winter season (December-February). Initially, the error structure was used to categorize the forecast given as correct, usable or unusable based on the per cent deviation in the forecast values as compared to observed values as per the guidelines of National Centre for Medium Range Weather Forecasting (NCMRWF). The correct and usable cases were summed up and the combined values indicates the per cent usability of the forecasts of various parameters to the total events occurred in respective parameter. The forecasts of rainfall, temperature and wind were validated by calculating the error structure. Error structure were calculated as methods suggested by Rana *et al*., (2013).

Error structure

Rainfall : Correct ±10 mm, Usable ± 20 mm, Unusable > ± 20 mm

Temperature : Correct ± 1°C; Usable ± 2°C, Unusable > ± 2°C

Wind speed : Correct ± 3 kmph, Usable ± 6 kmph, Unusable > ± 6 kmph

Similarly, the various skill scores like ratio score (RS), critical success index (CSI), Heidke skill score (HSS) and Hanssen & Kuipers Score (HK) were calculated for rainfall prediction. The accuracy of rain/no-rain is given by ratio score (RS), which measures the proportion of correct forecasts out of all forecasts (Woodcock, 1976). It varies from 0 to 1 with 1 indicating perfect forecast. Hanssen & Kuipers score (HK) is the ratio of economic saving over climatology due to forecaster to that of a hypothetical set of perfect forecasts (Woodcock, 1981) and varies from -1 to +1 with 0 indicating no skill. Heidke skill score (HSS) expresses as decimal fraction the percentage of forecasts that are correct and varies from 1 to minus infinity. Critical success index (CSI) of an event is a measurement of relative forecasting accuracy in a category (Schaefer, 1990) and varies from 0 to 1 with 1 indicating perfect forecast. The root mean square error (RMSE) for all six major weather parameters was worked out for the absolute error between observed and forecasted weather data. The critical values of error structures given by Rathore *et al*., (1999) were followed to consider success and failure cases for analysis. Considering the difficulties in forecasting the exact weather condition, due to difficulties in the observing system, spatial variability in the meteorological elements and precision required for agro meteorological and other applications, numerical thresholds were used.

Observed	Predicted	
	Rain	No Rain
Rain	H (YY)	M (YN)
No Rain	F (NY)	Z (NN)

Where, H = Predicted and observed, M = Observed but not predicted, F = Predicted but not observed, Z = Neither predicted nor observed, N = Total number of observation, fi = Predicted values and oi = Observed values

(i) Ratio Score (RS) = (H + Z)/(H+M+F+Z), (ii) Critical Success Index (CSI) = (H)/(H+M+F), (iii) Heidke Skill Score (HSS) = (ZH-FM)2/[(Z+M)(M+H)+(Z+F)(F+H)], (iv) Hanssen and Kuipers score (HK) = (HZ - MF)/[(Z+F)(H+M)] and (v) Root Mean Square Error (RMSE) = $\{1/N\ \Sigma(fi - oi)^2\}^{1/2}$

Results and Discussion

Rainfall : The forecasted values of weather parameters with actual recorded weather parameters were verified for usability. The rainfall was verified with skill scores and RMSE and results are presented in Table 1 and Table 2. The performance of rainfall was excellent in winter season as it was not rainy season for Parbhani district of Maharashtra. Highest correct rainfall was observed in winter season 100 percent followed by summer season 95.65 percent and lowest correct in monsoon season (72.95 percent). These results are also correlated with Sahu *et al*., (2011) and Lunagaria *et al*., (2008) also recorded lowest percent of rainfall usability during the monsoon season for Gujarat. Yearly correct and usability of forecasted rainfall was 88.77 and 5.75 percent verified.

The skill of forecast (Ratio score) varied between 66 to 90% in all the seasons. The highest value of ratio score was calculated in post monsoon season (90 %) whereas, the lowest value (66%) was observed with monsoon season. Highest values of ratio score indicated a higher amount of precision in forecast. Similar results were observed with Rana et al., (2013). The critical success index (0.53) was highest in monsoon season and lowest CSI (0.14) was in summer season. The HSS value (185.88) was found highest with monsoon season and lowest value (20.34) was calculated with summer season. Similarly HK scores are found positive in all seasons. The lowest HK score 0.32 was observed in monsoon season and highest (0.79) in the summer season. The positive HK scores indicated the reliability of forecast to be satisfactory in all the seasons. RMSE values varied between 6.96 to 17. 08 during different seasons with highest RMSE value observed in the post monsoon season (17.08) corresponding to highest rainfall season indicating high chances of quantitative forecast difference during the season. The lowest RMSE

Table 1. Skill scores of rainfall forecast for Parbhani

Season	Ratio Score	CSI	HSS	HK	RMSE
Summer (March-May)	79.35	0.14	20.34	0.78	6.96
Monsoon (June-September)	66.12	0.53	185.88	0.32	8.43
Post Monsoon (October-November)	90.16	0.33	33.08	0.53	17.08
Winter (December-February)	–	–	–	–	–
Yearly	81.87	0.44	2971.5	0.58	8.35

Table 2. Usability analysis of forecasted rainfall, temperature and wind speed for Parbhani district of Maharashtra

Season	Rainfall			Maximum temp.			Minimum temp.			Wind Speed		
	Usable	Unusable	Cotrrect	Usable	Unusable	Cotrrect	Usable	Unusable	Cotrrect	Usable	Unusable	Cotrrect
Summer (March-May)	95.65	4.35	0.00	58.69	23.91	17.39	27.17	28.26	44.56	2.17	20.65	77.17
Monsoon (June-September)	72.95	13.12	13.93	46.72	23.77	29.51	62.29	25.41	12.29	2.46	13.11	84.43
Post Monsoon (October-November)	93.44	1.64	4.92	73.33	21.66	5.00	34.43	21.31	44.26	57.37	24.59	18.03
Winter (December-February)	100	0.00	0.00	53.85	32.97	13.19	21.11	18.88	60.00	31.11	48.88	20.00
Yearly	88.77	5.75	5.48	55.89	25.75	18.36	38.63	23.84	37.53	18.63	25.75	55.61

values (6.96) were observed in summer season signifying least error between observed and forecasted data.

Temperature : The correct and usability analysis of maximum and minimum temperature forecast was done using error structures (Table 2). The correct forecast for maximum temperature was higher in post monsoon season (73.33) followed by summer season (58.69). Singh and Bhardwaj (2012) observed similar trend for maximum temperature for Kullu valley. Whereas, correct forecast for minimum temperature was higher in monsoon (62.29) followed by post monsoon (34.43) season. The summer and post monsoon season showed high degree of association between the predicted and observed values. Rana *et al*., (2013) also observed similar results.

Wind speed : The wind speed forecast showed maximum usability ranging between 13.11 to 48.88. A higher accuracy was obtained when the forecast was validated for post monsoon season (57.37) followed by winter season (31.11). The usability of forecast was good in winter season (48.88). Khichar *et al*., (2010) analysed the reliability and accuracy of weather forecasts for Haryana and observed similar trends in forecast for wind speed.

Conclusions : Performance of location specific medium range weather forecasts in terms of quality, accuracy, reliability, usability and skill, during 2015-2016 are calculated. The results indicate the variability in accuracy, reliability, usability and skill of weather parameters. The usability of predicted maximum temperature, rainfall and wind speed was highest in post monsoon season whereas for minimum temperature it was highest in monsoon season. Rainfall forecast performance was good with low RMSE considering all seasons but in monsoon season its performance was not so good. The positive HK scores indicated the reliability of forecast to be satisfactory in all the seasons.

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J. Agric. Res. Technol., 42 (3) : 094-098 (2017)

Assessment of Rainfall Variability for Estimating Length of Growing Period in Eastern Talukas of Buldhana District

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Abstract

The uncertainty and variability of rainfall both in space and time are the major constraints affecting agricultural production in rainfed farming. The decision of crop selection and agricultural productivity in rainfed area are highly dependent on the environmental factors, especially rainfall, its distribution and water availability. The present study was carried out in three eastern talukas of Buldhana district namely Nandura, Khamgaon and Shegaon by analyzing 19 years monthly rainfall data (1998-2016). On the basis of monthly rainfall coefficient of variation, rainfall variability during monsoon season was found out and stable rainfall period was estimated. The length of growing period (LGP) was estimated by using the reference method of graphical representation stated in FAO's Soils Bulletin 76-AGRO-ECOLOGICAL ZONING Guidelines. The average seasonal rainfall of three talukas was within the range of 627.9 to 694 mm. The stable rainfall period in Nandura, Khamgaon and Shegaon talukas on eastern side of Buldhana district was found to be 48, 97 and 63 days, respectively. The length of growing period is the total of Moist-I, Humid and Moist-II period which for the study area was found to be 125, 126 and 116 days for Nandura, Khamgaon and Shegaon talukas, respectively. Better selection of crops and their varieties for area under study can be decided using the information generated and assured rainfed crop production can be achieved by optimally utilizing available soil moisture in dryland area.

Key words : Coefficient of variation, length of growing period, stable rainfall period.

Rainfall variability is one of the key factors that affect agricultural production in any region. Rainfall is the most important natural hydrologic event and a unique phenomenon varying both in space and time. The rainfall distribution is very uneven and it not only varied considerably from place to place but also fluctuates from year to year. Crop planning is an important task on the part of the cultivators in rainfed areas, which solely depend on onset of effective monsoon, rainfall amount and its distribution.

The length of the "growing season" or "growing period" (LGS or LGP) is defined as the total period in days during a year when precipitation exceeds half the potential evapotranspiration, which provide guideline to farmer for crop planning. The length of stable rainfall period indicates the period during which crop will not suffer from moisture stress.

Material and Method

The present study was undertaken in Buldhana district which is the part of Amravati division in Vidarbha region of Maharashtra state. It lies between 19°51' to 21°17' North latitudes and 75°57' to 76°59' East longitudes.

The monthly rainfall data for the period of 1998-2016 (19 years) was used for this study. The required rainfall was downloaded from the official website web-portal of Government of Maharashtra http:// www.maharain.gov.

The rainfall data was analysed on seasonal, monthly basis and statistical parameters like average seasonal rainfall, mean, standard deviation (SD), coefficient of variation (CV) were determined.

The stable rainfall period is described as the period of assured rain over the area or the period of low variability for given station (Naitam *et al*. 2015). To estimate the length of stable rainfall period in days, a graphical interpretation technique was used. A line graph of coefficient of variation of monthly rainfall during monsoon season was plotted against corresponding month at each taluka station and by drawing a horizontal line at threshold level of coefficient of variation (CV) for the most stable rainfall month among different rainfall months as followed by Naitam *et al*.,(2015).

The potential evapotranspiration was computed using monthly temperature data according to the concept of Thornthwaite and Mather empirical formula (Gudulas *et al*., 2013).

$$PET = 1.6 \times [\ 10 \times T/I\ ]^a$$

Where,

PET = Potential evapotranspiration in mm, T= Monthly mean temperature in °C and a = Cubic function of I, heat index

$$a = 6.756 \times 10^{-7} \times I^3 - 7.71 \times 10^{-5} \times I^2 + 1.79 \times 10^{-2} \times I + 0.49239$$

Estimation of length of growing period : The length of the growing period (LGP) is defined as the total period in days during a year

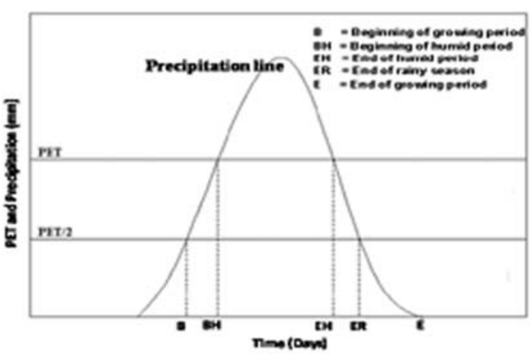

Fig. 1. Graph showing length of growing period (LGP) for various conditions

when precipitation exceeds half the potential evapotranspiration. The reference method to estimate the LGP using graphical technique was adopted from FAO's Soils Bulletin 76-AGRO-ECOLOGICAL ZONING guidelines (Anonymous,1996). The various conditions of LGP over different period are shown in Fig. 1. The length of growing period is the sum of moist-I period, humid period and moist-II period in days.

Moist-I period : The beginning of the growing period occurs when precipitation (P) line graph cross the half PET value i.e. 'B' and it ends when reaches to PET value i.e. 'BH' (Fig. 1).

Humid period : This is the period during which precipitation exceeds potential evapotranspiration (PET). The humid period begin at 'BH' and end at 'EH'. The length in days from 'BH' to 'EH' is the humid period (Fig. 1).

Moist-II period : The end of the growing period occurs at the point where the precipitation curve goes below the value of PET and up to ½ PET curves. The moist-II period is the duration between points EH and ER as shown in Fig. 1.

Result and Discussion

The rainfall analysis was carried out for Nandura, Khamgaon and Shegaon talukas in Buldhana district with the availability of long term rainfall data for 19 years (1998-2016) on seasonal basis. The average seasonal rainfall clearly indicates a variation from 627.9 to 860.7 mm in eastern talukas of Buldhana district with minimum at Nandura (627.9 mm), followed by Khamgaon (669.0 mm) and Shegaon (694 mm) talukas.

After verifying the CV for the monsoon months at different taluka stations in Buldhana district, the threshold level of coefficient of variation for the stable rainfall months (June to September) was decided as 55. It was computed from the two parameter of lowest and highest CV value of monthly rainfall and was worked out by taking average of the sum of lowest monthly CV value and half of highest monthly CV value. The graphical presentation of stable rainfall period for Nandura, Khamgaon and Shegaon is given in Fig. 2, 3 and 4 respectively. The period which falls between a to b and c to d in Fig. 2. combinely represent stable rainfall period for Nandura taluka. This period indicates the period during which crops will not suffer from moisture stress and also indicates the duration of assured rainfall.

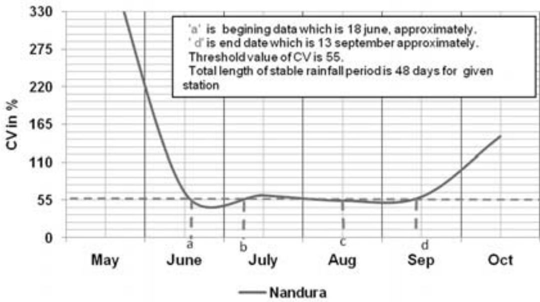

Fig. 2. Estimation of stable rainfall period for Nandura

The beginning date, end date and total duration of stable rainfall period was calculated from the Fig. 2, 3 and 4 for Nandura, Khamgaon and Shegaon taluka respectively and are depicted in Table 1. The stable rainfall period for Nandura, Khamgaon and Shegaon was found to be 48, 97 and 63 days. The monthly rainfall, PET and half of PET value were plotted against respective months on a graph for Nandura, Khamgaon and Shegaon and are shown in Fig. 5, Fig. 6 and Fig. 7 respectively. From these graph the LGP was calculated and presented in Table 2. Moist - I period is the beginning of the growing period which indicates the beginning of rainy season, that starts with land preparation operations. This period varies from 18 to 20 days at different stations. Humid period is the favourable period for plant growth and mostly

Table 1. Duration of stable rainfall period at different study stations

Station name	First phase			Second phase			Total days
	Beginning date	End date	Duration	Beginning date	End date	Duration	
Nandura	18-Jun	07-Jul	19	15-Aug	13-Sep	29	48
Khamgaon	15-Jun	20-Sep	97	–	–	–	97
Shegaon	17-Jun	28-Jul	41	25-Aug	16-Sep	22	63

Table 2. Duration of length of growing period (LGP) at selected station

Station name	Moist-I period			Humid period			Moist-II period			LGP in days
	Start	End	Duration (days)	Start	End	Duration (days)	Start	End	Duration (days)	
Nandura	09-Jun	29-Jun	20	30-Jun	15-Sep	77	16-Sep	14-Oct	28	125
Khamgaon	07-Jun	25-Jun	18	26-Jun	13-Sep	79	14-Sep	13-Oct	29	126
Shegaon	06-Jun	24-Jun	18	25-Jun	15-Sep	82	16-Sep	02-Oct	16	116

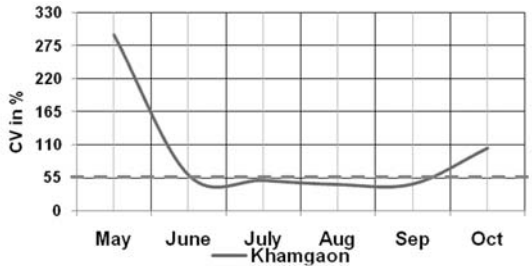

Fig. 3. Estimation of stable rainfall period at Khamgaon

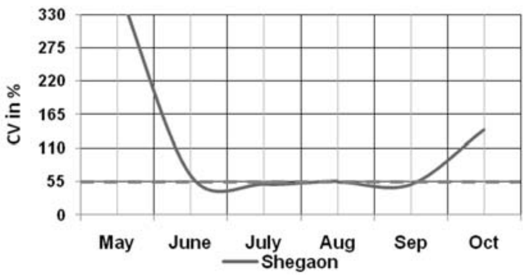

Fig. 4. Estimation of stable rainfall period at Shegaon

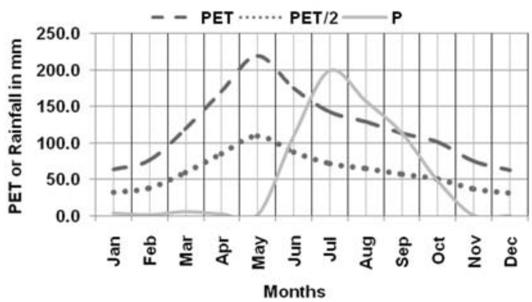

Fig. 5. Estimation of length of growing period for Nandura

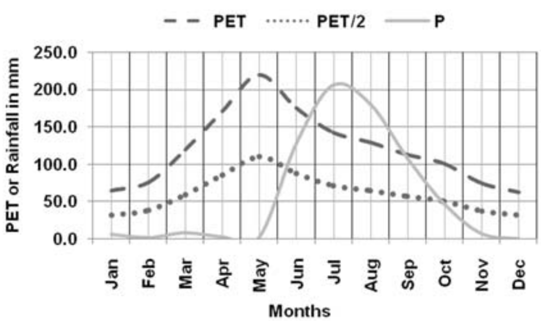

Fig. 6. Estimation of length of growing period for Nandura

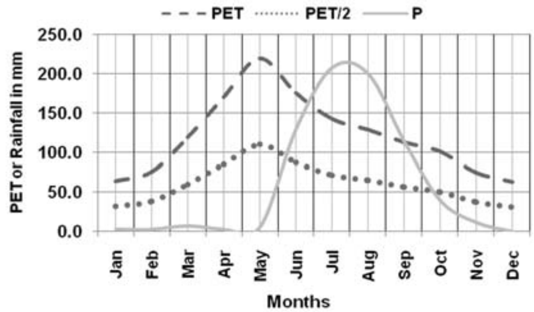

Fig. 7. Estimation of stable rainfall period at Khamgaon

in this period water requirement of crop is fulfilled by monsoon rain water. Moist - II period is the end of the rainfall season so that it is the sensitive stage for crop growth when the crop duration in days is less than LGP then there is no need of additional supply of irrigation but if crop duration is greater than LGP then the need for irrigation facilities arises.

From Table 2, it is revealed that the length of growing period for Nandura, Khamgaon and Shegaon taluka of Buldhana district was found to be 125, 126 and 116 days, respectively. From the above duration of length of growing period, kharif crops like soybean, mung, udid, tur and medium duration of cotton crop can be successfully grown in rainfed area of this region.

Conclusion

The average seasonal rainfall at Nandura, Khamgaon and Shegaon talukas in Buldhana district varied in the range 627.9 to 860.7 mm. Stable rainfall period estimated on the basis of monthly coefficient of variation for the three talukas of Buldhana district varied in the range of 48 to 97 days. The total length of growing period ranges between 116 to 126 days in eastern talukas of Buldhana district. LGP analysis provides useful information for selection of suitable crop variety to study the effect of climate variability and other changes in crop management. This type of study represent the real situation of cropping pattern in Buldhana district and help the planner and agriculture scientist for proper agriculture planning at taluka level. The predominant crops grown are cotton, pigeon pea, green gram and soybean in *kharif* season.

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J. Agric. Res. Technol., 42 (3) : 099-110 (2017)

Application of Statistical Downscaling Model for Long Lead Rainfall Prediction in Ghod Catchment of Upper Bhima River Basin

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Abstract

Climate change is believed to have significant impacts on the water basin and region, such as in a runoff and hydrological system. Prediction of long-term rainfall over a catchment area is a challenge for hydrologists. It is required in many sectors viz. water resources management, hydropower energy forecasting and flood risks assessment in river basins. Several large scale climate phenomena affects the occurrence of rainfall around the world i.e. El Nino Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD) are most famous for their effect on India, North and South America and Australia. However, Global Climate Models (GCMs) which are regarded as the most advanced model yet for estimating the future climate change scenarios areoperated on the coarse spatial resolution and not suitable for climate impact studies.This study is motivated to evaluate the performance of Statistical Downscaling Model (SDSM) developed by monthly, seasonal and annual sub models for downscaling rainfall from Global Climate Models (GCMs) over the Ghod catchment. The study included the calibration and validation with large-scale National Centers for Environmental Prediction (NCEP) reanalysis data, and the projection of future rainfall corresponding to the GCMs-variables (HadCM3 A2 and B2).The study results show that during the calibration and the validation stages, the SDSM model can be well acceptable in regards to its performance in the downscaling of the daily rainfall. The changes in precipitation of Shirur station in study area under scenarios A2 and B2 of HadCM3 model have been presented for future periods: 2020s, 2050s and 2080s. Certain statistical parameters were used to verify the reliability of the simulations. Overall increasing trend was observed in mean precipitation for the Shirur station.

Key words: statistical downscaling, Global Climate Model, Future Emission Scenario, Rainfall, SDSM

In recent years, many studies focused on the effects of climate change on rainfall variability using Global Circulation Models (GCMs) in different parts of the world (Hassan and Harun, 2011). Even through GCMs can be applied directly for climate change assessment, these models have the largest scale resolution and parameters of interest need to be downscaled into a site-scale (smaller scale) (Corzo *et al.*, 2009). Therefore, the statistical methods by using the Regression Models are normally applied by many researchers (Abbasnia and Toros, 2016; Saraf and Regulwar, 2016; Shourav *et al.*, 2016; Vinay *et al.*, 2016). These models generally involve establishing linear or nonlinear relationships between sub grid-scale (e.g. single-site) parameters and coarser-resolution (grid-scale) predictor variables (Wilby and Wigley, 2000). The relationship can be named as 'transfer function' (Mahmood and Babel, 2013). One of the examples of the Statistical Downscaling tools that implement the Regression Models is the Statistical Downscaling Model (SDSM) (Mahmood and Babel, 2014). The SDSM facilities have undergone rapid development of multiple, low cost, single-site scenarios of daily surface weather variables under the present and future climate forcing (Wilby, 1997). As an addition, the tool performs ancillary tasks of

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data quality control and transformation, predictor variable pre-screening, automatic model calibration, basic diagnostic testing, statistical analyses and graphing of climate data (Wilby and Dawson, 2013). Therefore, in this study to downscale current and future rainfall corresponding to GCMs-variables, the SDSM model (Hassan and Harun, 2011) was employed.

Materials and Methods

Description of Study Area : Ghod River is located in Pune District, Maharashtra, western India. It is a tributary of the Bhima River. The Ghod originates on the eastern slopes of the Western Ghats at 1,090 metres (3,580 ft) above sea level. It flows in an east-southeast direction for approximately 200 kilometres before its confluence with the Bhima. Ghod river starts from Sahyadri from about Bhimashankar hill and flows through Pune and Ahmednagar districts and meets Bhima at 32 km downstream of Ghod dam. It flows from the northern side of the Sahyadri hills. The Kukadi river is one of the tributaries of the Ghod. The soil on the upper and lower courses of the river is abundant in paleontological sediments. The river is dammed by the Ghod dam. The study area of the research is catchment of Ghod within the upper Bhima river basin, Maharashtra (Figure 1). The catchment lies between 18° 39' 55.29" N to 19° 15' 52.06" N and 73° 41' 25.27" E to 74° 33' 7.72" E. The catchment covers 2,550 km^2 of area of the upper Bhima basin. Rainfall is the only source of water in Ghod river. The quantity of inflow and flow forecasts depend on the intensity and timeliness of rainfall. Maximum

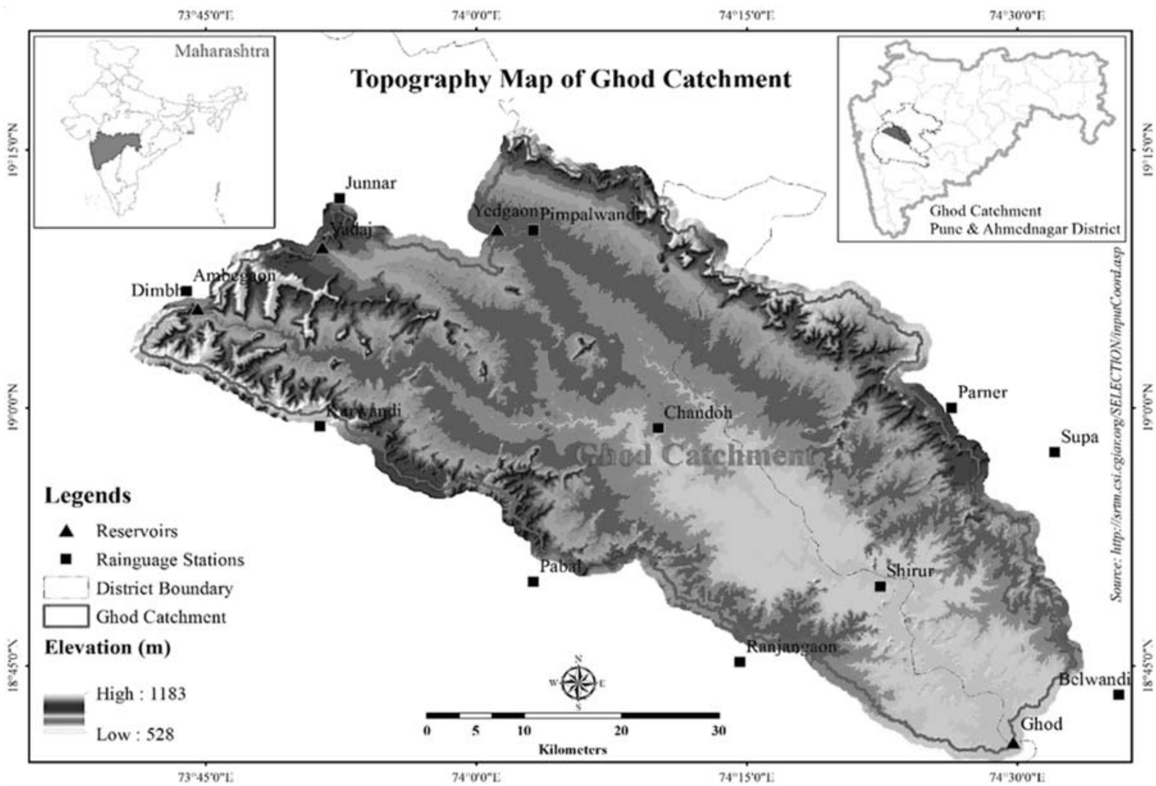

Fig. 1. Topography map of Ghod Catchment

available Rainfall is 5000 mm at Tamhini & minimum is 200 mm at Ghod dam. The mean monthly maximum temperature (Tmax) in the Ghod catchment varies from 29.64 to 38.60° C with mean annual maximum temperature (Tmax) is 32.45° C. The mean monthly minimum temperature (Tmin) ranges from 14.38 to 25.12° C based on decadal (1961-2001) observed values.

HadCM3 : HadCM3 is a coupled atmosphere-ocean GCMs developed at the Hadley Centre of the United Kingdom's National Meteorological Service. HadCM3 was chosen because the model is widely used in many climate-change impact studies. Furthermore, HadCM3 provides daily predictor variables, which can be used for the SDSM model. In addition, HadCM3 has the ability to simulate future climate for a period of thousand years with little drift in its surface climate. Its predictions for temperature change are average whereas for precipitation it is below average (Stott *et al.*, 2000; McCarthy *et al.*, 2001). Among the SRES scenarios, A2 was considered as among the worst case scenarios, projecting high emissions for the future. The GCMs-predictors of Hadley Center's GCM (Hadley Centre 3rd Generation - HadCM3) A2 and B2 future scenarios were run (named as SRES A2 and B2) for 1961-2099. The reanalysis data predictors of National Center of Environmental Prediction (NCEP) on HadCM3 computational grid for 1961-2001 at daily time steps was used in this study.

Statistical DownScaling Model (SDSM) : Statistical Down-Scaling Model (SDSM) which is a decision-support tool for assessing local climate-change impacts using a robust statistical downscaling technique (Liu *et al.*, 2016) developed by Wilby *et al.*, (2002) was used to construct climate change scenarios for the Ghod catchment of Upper Bhima basin in Maharashtra. SDSM as a statistical tool was adopted due to several advantages such as low cost and user friendly over dynami cmethods. There are many researchers who have used SDSM in climate change impact assessments (Ahmadi *et al.*, 2014; Fiseha *et al.*, 2014; Rajabi and Shabanlou, 2013). Regression method establishes a linear or nonlinear regression between predictands and predictors. Therefore, this method highly depends on the empirical statistical relationships. The main advantage of this method is in its simplicity and is less computationally demanding. However it is limited to the locations where good regression results could be found. SDSM was used to obtain downscaled local information for future time period by driving the relationships with GCM derived predictors.

The method consists of two steps. In the first step, it determines whether rainfall occurs on each day or not. This is defined as given in eq^n 1

$$w_t = \alpha_0 + \sum_{j=1}^{n} \alpha_j + \alpha_{t-1} w_{t-1} \quad ......(1)$$

where, t is time (days), Wt is the conditional possibility of rain occurrence on day t, α_j is the regression parameter deduced by an ordinaryleast square method and w_{t-1} and α_{t-1} are the conditional probabilities of rain occurrence on day t-1 and lag-1 day regression parameter, respectively. These two parameters are optional, depending on the study region and predictand. Uniformly distributed random number r_t ($0 \le r_t \le 1$) was used to determine the rain occurrence and supposed the rainwould happen if $w_t \le r_t$.

In the second step, it determines the estimated value of rainfall on each rainy day. It can be defined by a z-score as given in eq^n 2

$$Z_t = \beta_0 + \sum_{j=1}^{n} \beta_j \hat{u}_t^{(j)} + \beta_{t-1} + \varepsilon \quad ..(2)$$

in which Z_t is the z-score on day t, β_j is the calculated regression parameter, $\hat{u}_t^{(j)}$ is the normalized predictor, β_{t-1} and Z_{t-1} are the regression parameters and the z-score on day t-1 respectively. Furthermore, rainfall on day t can be written as given in eq^n 3;

$$y_t = F^{-1}[\emptyset(Z_t)] \quad ..(3)$$

in which ϕ is the normal cumulative distribution function and F is the empirical function of y_t .

During downscaling with the SDSM, a multiple linear regression between a few selected GCM predictors and rainfall were utilised. The operation and structure of the SDSM model during calibration and validation can be summarised as shown in Figure 2.

Preliminary screening of Potential Downscaling Predictor Variables

Several procedures have been suggested to select suitable GCMs-predictor variables, such as partial correlation analysis, step-wise regression, or information criterion. Each statistical analysis can be used to choose a sensible combination of predictors from the available data. However, in SDSM, the task of screening is simple and can be achieved by using linear correlation analysis and scatter plots. The observed daily data of GCMs-predictor variables representing the current climate condition (1961-2001) derived from the NCEP reanalysis data set was used to investigate the percentage of variance explained by each predictand-predictor pairs. The steps to identify predictor variables that were used in this study being recommended by several researchers (Wilby *et al*., 2006); (Mohammed, 2009); (Chu *et al*., 2010) are; (1) Choose all predictors and run the explained variance on a group of eight or ten of predictors at a time; (2) Of each group, pick a high explained variance of predictor(s); (3) Then, perform partial correlation analysis for selected predictors based on correction of each predictor. There could be a predictor with a high explained variance, but it might be very

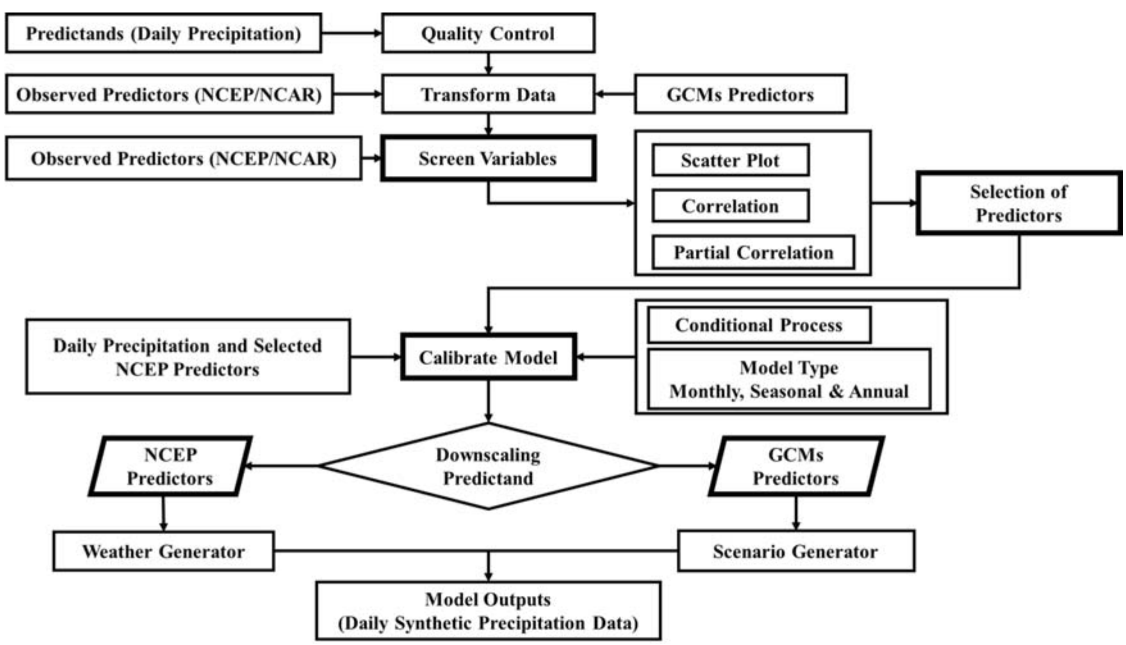

Fig. 2. Flow chart of SDSM (Saraf and Regulwar, 2016; Wilby and Dawson, 2013)

highly correlated with another predictor (Multi-co-linearity). This means that it is difficult to tell that this predictor will add information to the process, and therefore, it will be dropped from the list; (4) finally, the scatter-plot is used to show the relationship between potential predictor and predictand (Mahmood and Babel, 2013).

Calibration and Validation : The calibration model process constructs downscaling models based on multiple regression equations, given a daily weather data (the predictand) and a regional-scale atmospheric (predictor) variables (Wilby *et al.*, 2006). It was carried out based on the selected predictor variables that were derived from the NCEP data set. The temporal resolution of the downscaling model for precipitation downscaling are specified as monthly, seasonal and annual (Hassan and Harun, 2011; Nury and Alam, 2013). Some of the SDSM setup parameters for bias correction and variance inflation were adjusted during calibration to obtain a good statistical agreement between the observed and simulated climate variables. For event threshold, a value of 0.3 was used (Meenu *et al.*, 2013). After the model calibration, validation process is needed. Validation process enables to produce synthetic current daily weather data based on inputs of the observed time series' data, and the multiple linear regression parameters produced using independent observe data, which were neglected during calibration procedure. In this study, daily rainfall from 1961-1990 was used for calibration and the calibrated model was again validated for the data period of 10 years (1991-2001). The choices of the calibration and validation periods was made based on the availability of the rainfall data. Daily precipitation at a station or at a local scale is the pivotal input variable used for validation (Chen *et al.*, 2006). Furthermore, both the calibrated and validated precipitation occurrence were compared with respective NCEP, HadCM3 A2 and B2 scenarios. The precipitation is stochastic process; therefore, the downscaling of precipitation is always a difficult problem (Ramadas *et al.*, 2015). The statistical measures, namely, coefficient of determination (R^2), root mean square error (RMSE), mean absolute percentage error (MAPE), mean (μ),

Table 1. Summary of selected large-scale predictor variables

Stations	predictors	Corr. Coeff.	Partial r	P value
Shirur	r500as	0.361	0.090	0.000
	r850as	0.334	-0.043	0.000
	rhumas	0.359	-0.090	0.000
	shumas	0.385	0.155	0.000

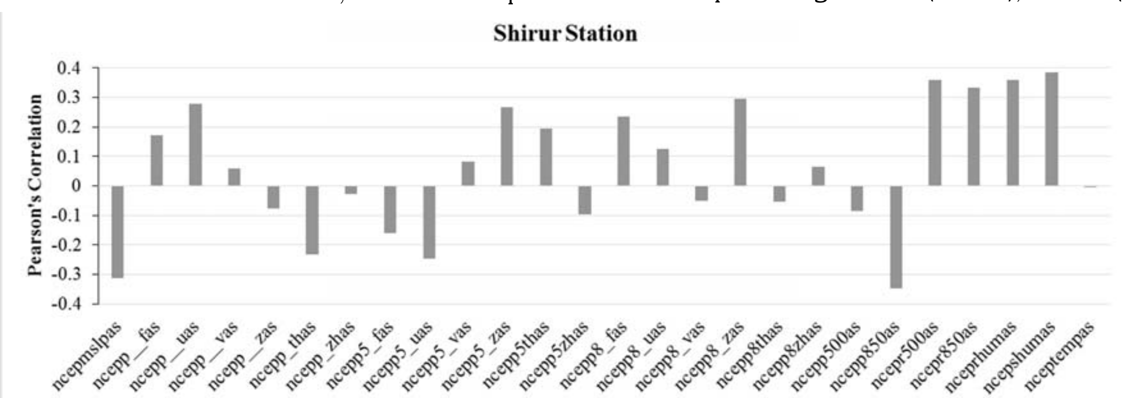

Fig. 3. Pearson's Correlation between predictands with NCEP and GCM predictors

Table 2. Statistical comparison of observed and downscaled mean monthly precipitation during calibration (1961-1990)

Station	Model	Data Type	µ	SD	SE_µ	MAD	R^2	RMSE	MAPE
Shirur	SDSM-M	Obs	2.34	1.04	0.68	–	–	–	–
		NCEP	3.63	1.16	1.05	1.29	0.90	1.34	0.70
	SDSM-S	Obs	2.34	1.04	0.68	–	–	–	—
		NCEP	3.61	0.98	1.04	1.27	0.73	1.37	0.78
	SDSM-A	Obs	2.34	1.04	0.68	–	–	–	–
		NCEP	3.55	0.83	1.02	1.27	0.50	1.40	0.80

standard deviation (SD), standard error of mean (SE_µ) and mean absolute deviation (MAD) were used to compare observed data with downscaled data during calibration and validation period (Saraf and Regulwar, 2016).

Downscaling for Future Emission : The regression weighted produced during the calibration process was applied to generate a future daily weather data. The study assumes that relationship between predictor and predictand under the observed conditions (during calibration) remains valid under the future climate conditions. Maximum hundred ensembles can be produced in SDSM out of which twenty ensembles of synthetic daily rainfall time series were produced for HadCM3 A2 and B2 scenario for a period of 139 years (1961 to 2099). The outcome was averaged and divided by three period of time, which are 2020s (2010-2039), 2050s (2040-2069) and 2080s (2070-2099).

Results and Discussion

Selection of predictors : In all types of statistical down-scaling the screening of large scale variables is the most important process (Wilby *et al.*, 2002 and Huang *et al.*, 2011). Although, there is a screening facility option in the SDSM software, pre-screening is the most time consuming task to identify potential predictor sets for the selected climate variable. Therefore, a more quantitative procedure, also used by Mahmood and Babel (2013) explained in methodology section, was applied for screening the predictors for local climate variable (i.e. precipitation) in this study. The selection of the first and the most appropriate predictor is relatively easy, but the selection of

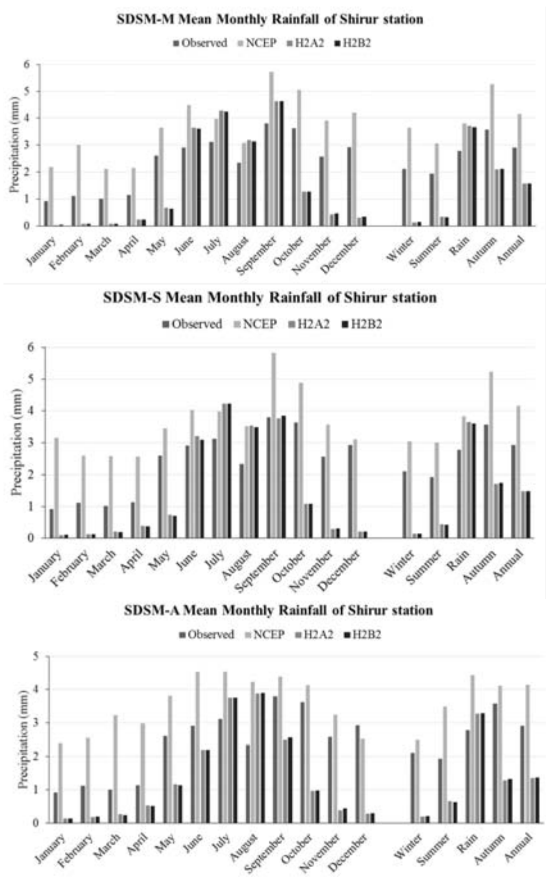

Fig. 4. Observed and downscaled mean monthly precipitation of Shirur station for the calibration period (1961-1990)

Table 3. Statistical comparison of observed and downscaled mean monthly precipitation during validation (1991-2001)

Station	Model	Data Type	μ	SD	SE_μ	MAD	R^2	RMSE	MAPE
Shirur	SDSM-M	Obs	2.65	1.96	0.76	–	–	–	–
		NCEP	1.27	1.85	0.37	1.35	0.77	3.44	0.54
	SDSM-S	Obs	2.65	1.96	0.76	–	–	–	–
		NCEP	1.28	1.38	0.37	1.48	0.80	2.32	0.47
	SDSM-A	Obs	2.65	1.96	0.76	–	–	–	–
		NCEP	1.28	1.35	0.37	1.60	0.86	2.35	0.49

the second, third, fourth and soon is much more subjective. The Pearson's correlation was developed between predictand (precipitation) and 26 NCEP predictors. From Table 1, it is cleared that relative humidity at 500 hpa (r500as), relative humidity at 850 hpa (r850as), near surface relative humidity (rhumas) and surface specific humidity (shumas) have strong correlation with the precipitation of Shirur station. This is also graphically represented in Figure 3.

Calibration and Validation of Models : The calibration model process constructs downscaling models based on multiple regression equations, given the observed daily rainfall and NCEP-reanalysis. The model structures of calibration have been categorized as the condition for rainfall and unconditional for temperature. Table 2 exhibits the performance of statistical Down-scaling model (SDSM) during the calibreatrion of monthly, seasonal and annual submodels. It can be seen that the SDSM model shows a good agreement between the observed and simulated mean daily rainfall (Figure 4). From results, the R2 and RMSE values of predicted monthly mean precipitation by NCEP/NCAR through monthly, seasonal and annual models for Shirur station are during calibrations 0.90, 0.73, 0.50 and 1.34, 1.37, 1.40, respectively. Similar results were obtained by Saraf and Regulwar (2016).

Similarly, results of comparison between observed and downscaled mean monthly precipitation in terms of statistical measures for validation period (1991-2001) are shown in Table 3 that reveals, the value of R^2 (Coefficient of determination) for Shirur station are 0.77, 0.80 and 0.86, respectively. Similarly, the RMSE values of Shirur station for

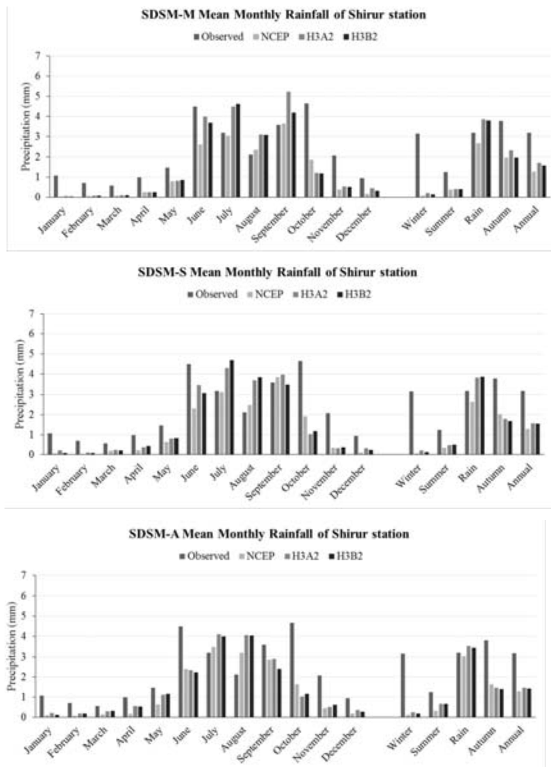

Fig. 5. Observed and downscaled mean precipitation of Shirur station for the validation period (1991-2001)

monthly, seasonal and annual models are during validation 3.44, 2.32 and 2.35, respectively. All values of statistical measures are much closer to the statistics of observed data for precipitation. Other statistical measures of mean (μ), standard deviation (SD), standard error of mean (SE_μ) and mean absolute deviation (MAD) have also shown a good agreement with observed statistics.

Figure 5 represents the comparison between observed and downscaled mean monthly precipitation by NCEP, A2 and B2 scenario of the HadCM3 model during validation period for Shirur station. Monthly model shows decreasing trend in mean monthly precipitation downscaled by NCEP compared to observed data except for August and September rain. A2 scenario shows increasing trend in mean monthly precipitation compared to B2 scenario excluding May, July, August and summer rain. Seasonal model shows decreasing trend in mean monthly precipitation downscaled by NCEP except for August and September rain. Whereas, A2 scenario shows increasing trend in mean monthly precipitation compared to B2 scenario excluding April, May, July, August, October, November, summer and Rainy season rain. Annual model shows decreasing trend in mean monthly precipitation downscaled by NCEP compared to observed data except July and August rain. Whereas, A2 scenario shows increasing trend in mean monthly precipitation compared to B2 scenario except for March, May, October, November and summer rain.

Future Emission Scenario : Figure 6

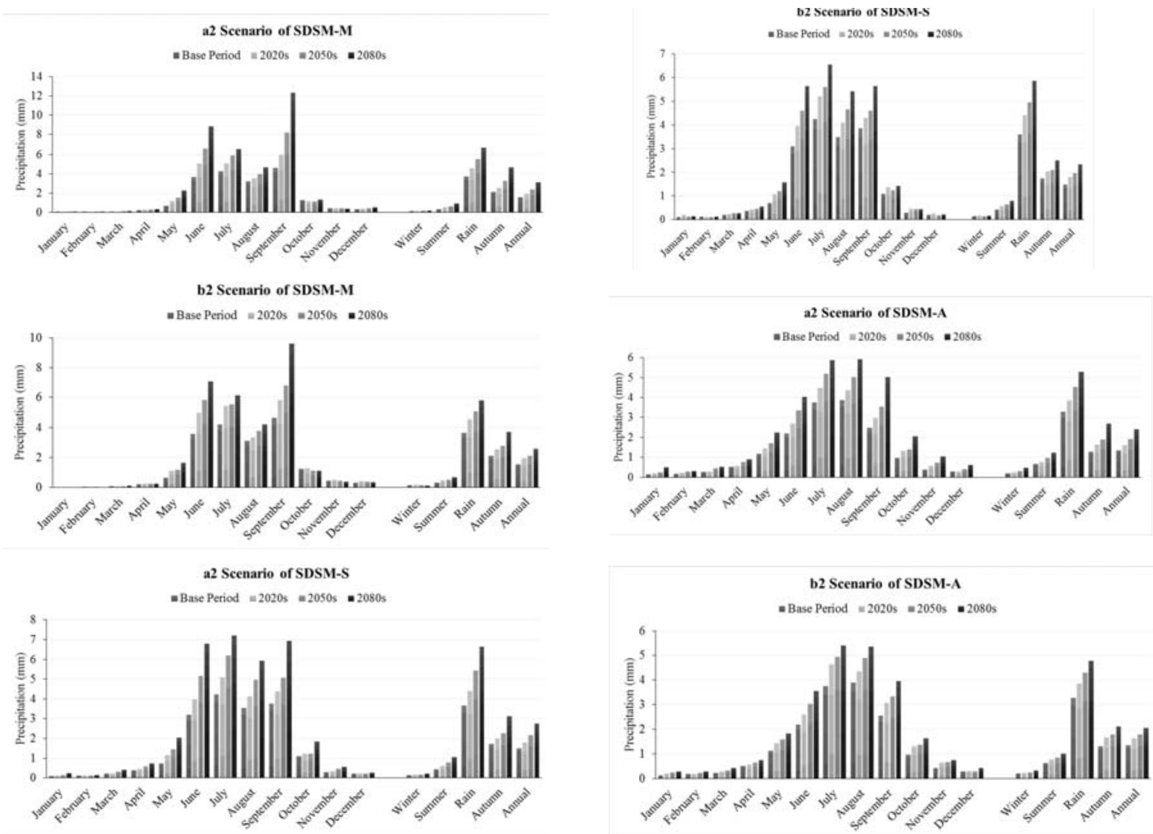

Fig. 6. Mean daily precipitation downscaled from A2 and B2 scenario for Shirur station

depicts downscaled results of the Shirur station of mean daily precipitation for all the models under A2 and B2 scenario. Both the A2 and B2 scenarios show increasing trend in the precipitation for all the individual month rain, seasons and annual rain.

The overall generation of scenario shows wide range of changes in the study area in mean daily precipitation. A2 scenario generates very particular range, either increasing or decreasing trend. The different time windows from B2 scenario follows heterogeneity in the trends for all the stations. Overall results significantly depicts that Shirur station shows increasing trend in the mean daily precipitation under both the A2 and B2 scenario for all the type of the models. Unlike the SDSM, precipitation shows decreasing trends over the study area; which shows an agreement with the findings of Giorgi *et al*., (2012; Fiseha *et al*., (2014) and Saraf and Regulwar, (2016).

IPCC in its fourth assessment report (IPCC) (Solomon, 2007) noted that the GCMs are susceptible to various uncertainties due to model setup in representing the climate system. Despite the progressive advances and use of GCMs to represent land surface processes, the outputs from these GCMs are subjected to various sources of uncertainties while used by end users. The selection of emission scenarios based on the prescribed story lines have their own limitations, as there is no exact rule to predict the global socio-economic systems in the future.

Change in Mean Future Precipitation : Figure 7 depicts the percent change in mean monthly precipitation for Shirur station under both A2 and B2 scenario of HadCM3 model. Under A2 scenario, the annual mean

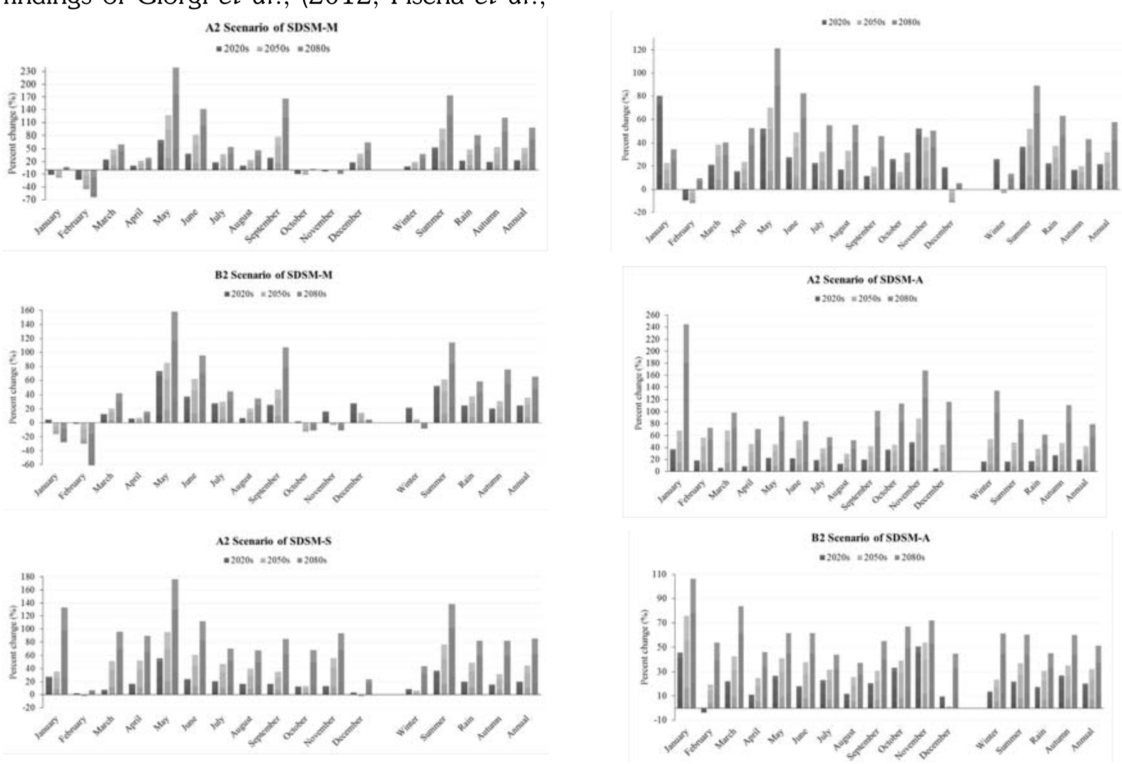

Fig. 7. Mean monthly change in projected precipitation of Shirur station under A2 and B2 scenario of HadCM3 model

precipitation increased by 22.6%, 52.1% and 98.4% in monthly model, 19.9%, 44.9% and 85.2% in seasonal model, 19.5%, 42.2% and 78.9% in annual model, in first, second and third period, respectively, compared to base period. Under B2 scenario, annual mean precipitation found increasedby 24.7%, 36.2% and 65.4% in monthly model, 21.9%, 32.1% and 57.7% in seasonal model, 20.2%, 32.3% and 51.1% in annual model for first, second and third period, respectively compared to base period.

Conclusions

The main fundamental of the SDSM model is the relationships between GCMs-predictor (HadCM3 A2 and B2) and predictand (Precipitation only). Therefore, the selections of GCMs variables are most important parts in the climate change study, and affect the results of climate assessment (Wilby and Wigley, 2000 and Hashmi *et al.*, 2009). The number of GCMs-variables have been chosen in order to show a real condition of climate change in the future. However, the selections of GCMs-variables are difficult and tricky. In addition, the selections of GCMs-variables are still in uncertainty on their methods and there is no standard rule for it. Therefore, in this study, only one of GCMs-variables have been applied. The selections have been tested based on the higher correlation between GCMs-variables and station rainfall data. Furthermore, the selections of GCMs variables have been looked through by the good performance of the SDSM model during the calibration and validation periods. These results have a similar pattern with the patterns from Bothale and Katpatal, (2017); Karamouz *et al.*, (2009) and Mahmood and Babel, (2013), who also used HadCM3 of GCMs-variables. In general, the study showed that the SDSM model was able to capture most of the monthly and annual rainfall with a good agreement between observed and simulated rainfall. However, the study found that the model was poor to average in predicting on a daily rainfall. The results were similar with other studies such as Coulibaly *et al.*, (2005),Hassan and Harun, (2011); Karamouz *et al.*, (2009); and Chu *et al.*, (2010); Mahmood and Babel, (2013); Meenu *et al.*, (2013); Saraf and Regulwar, (2016). Furthermore, adaily rainfall is the most difficult variables for prediction and it is a conditional process which involves an inter-connected with many factors/variables (Mahmood *et al.*, 2016). The future (2011-2099) annual rainfall results showed that there were an increase in the rainfall's intensity (Fowler *et al.*, 2007). For daily rainfall, the results showed that a larger increase of daily rainfall in non-rainy months as compared to rainy months but overall it showed increasing trend.

Acknowledgement

The author's deep gratitude goes to Department of Science and Technology, Government of India for the economic support through Inspire Fellowship during PhD research.

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J. Agric. Res. Technol., 42 (3) : 111-119 (2017)

Effect of Moisture Stress on Root Studies of Sorghum Genotypes

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Abstract

The present study was conducted to evaluate effects of the progressive water deficit on root parameters in *Sorghum bicolor* under pot condition.The pot trial was laid out in Factorial Completely Randomized Design with two replications involving six genotypes *viz.*, Phule Yashoda, Phule Revati, Phule Chitra, Phule Vasudha, Phule Anuradha and Phule Maulee, and four moisture regimes *viz.*, M_1 (25% of Field Capacity.), M_2 (50% of F.C.), M_3 (75% of F.C.) and M_4 (>90% of F.C.). In the present study maximum shoot and root dry matter accumulation, root volume lowest root to shoot ratio was recorded in genotypes PhuleRevati and Phule Yashoda under moisture regime M_1. However, under same moisture regime Phule Anuradha and Phule Maulee recorded significantly higher root length. The major effect of lowest moisture regime was decrease in dry matter accumulation of shoot and root, root to shoot ratio, root volume however increase in root length. In the present study, higher root to shoot ratio (Phule Chitra and Phule Maulee) and increased root length (Phule Anuradha and Phule Maulee) under low moisture regime M_1 indicated adaptability of these sorghum genotypes to water stress condition.Considering all above root parameters it could be inferred that the genotype Phule Chitra and Phule Maulee are more suited under limited soil moisture condition while, the genotype Phule Revati found well suited for medium soil for stress as well as non stress condition.

Key words :Sorghum, moisture regimes, genotypes, root parameters.

Sorghum is the fifth most important world crop grown for food, feed and industrial uses. It is the major crop for millions of people in the semi-arid tropics, and is extensively grown in Africa, China, USA, Mexico and India (Surwenshi *et al.*, 2010), where water availability is a major constraint to crop production. Sorghum (*Sorghum bicolor* (L.) Moench) cultivation has been the heart of dry land agriculture from years together. Though sorghum posses excellent drought resistance, as compared to the most other field crops generally it suffers from severe moisture stress during the stages of growth and development. This situation totally disturbs *Rabi* sorghum production levels especially on light and medium soils where grain and fodder yield get drastically reduced (Pawar and Gadakh, 2016). The main characteristic of the sorghum is drought resistance because of the ability to minimize tissue water loss (Rao and Sinha, 1990). Sorghum has twice the number of secondary roots than maize and also only half the leaf area exposed for evaporation than maize. Being a C_4 plant, it can utilize sunlight and water very efficiently. Sorghum has potential to compete with many types of stresses, including high temperature stress, water stress, salts stress and over irrigation (Ejeta and Knoll, 2007).

Effects of water deficit on plants have been extensively studied and include osmotic, biochemical and physiological effects (Zala*et al.*, 2014). Water deficit affects nearly all growth processes; however, the stress response depends upon intensity, rate and duration of

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the stress phase, as well as plant stage development (Brar *et al*., 1990;Sinaki *et al*., 2007). The major challenge in drought prone areas is to establish ways and means by which reduction in crop yields can be minimized. Genetic improvement for drought tolerance is a long term strategy and hence the selection of drought tolerant genotypes which are either drought escaping or drought avoiding or drought tolerant assumes greater importance (Tuinstra *et al*., 1992). It has been documented that root growth, leaf area development, synthesis of epicuticular wax and osmotic adjustment under stress are some of the guidelines in characterizing the genotypes for stress tolerance in sorghum (Blum, 1987). Despite these mechanisms, limited water availability determines stress, affecting various metabolic processes. Experimental evidence shows that soil moisture deficit causes disturbance in the photosynthetic process, reflecting on growth and final crop yield. Among plant processes, leaf water potential, net photosynthesis and stomatal conductance were shown to be significantly affected by moisture stress in sorghum (Singh and Singh, 1992). Soil moisture deficiency may also affect the growth of the root apparatus, which is responsible for establishing the soil-plant-atmosphere continuum in the flow of water (Kuchenbuch *et al*., 2006).

In view of this, it is necessary to identify the plant factors which extract more moisture and render a genotype more drought tolerance with maximum productivity. Given the uncertainties still surrounding sorghum behavior in response to drought or different moisture regimes especially as it concerns root studies, the present study was planned to investigate root studies of sorghum genotypesunder various water stress conditions.The objective of presented research work was to make a comparison of different sorghum genotypes under various water stress treatments and to studies various root parameters under drought stress condition.

Materials and Methods

Experimental design : The pot culture experiment trials were conducted at Sorghum Improvement Project, Mahatma Phule Krishi Vidyapeeth, Rahuri, Ahmednagar, Maharashtra (India) in *Rabi* season during 2009-2010. The seed material for the present investigation was obtained from the Senior Sorghum Breeder, Sorghum Improvement Project, M.P.K.V., Rahuri. Experiment was laid out in Factorial Completely Randomized Design (FCRD) with two replications. In which first factor was moisture regimes i.e., M_1 (25% of F.C.), M_2 (50% of F.C.) and M_3 (75% of F.C.) and M_4 (> 90% of F.C.) and second factor was genotypes i.e., V_1 (Phule Yashoda), V_2 (RSV-1006), V_3 (Phule Chitra), V_4 (Phule Vasudha), V_5 (Phule Anuradha) and V_6 (Phule Maulee).

Root studies : Root to shoot ratio was calculated by dividing the root length of the observational plants with the shoot length (plant height) of the respective plants in pots. For calculation of root dry matter plant^{-1} (g) and shoot dry matter plant^{-1} (g)roots of the plants were cut and washed properly. The roots were dried in hot air oven at 90°C for one hour and subsequently at 60°C till constant weight were obtained. The dry weight was recorded separately on electronic balance for each plant. Root volume was quantified in terms of ml by water displacement method. Root length was measured as an average maximum length of root. All the above parameters were measured at harvest. The moisture content of soil was measured periodically under pot culture at four days intervals from sowing to harvesting of crop by portable soil moisture meter. The soil moisture (%) depletion pattern as influenced by different moisture regimes at pot cultureis presented in (Table 2).

Statistical Analysis : Fisher's method was used for data analysis and interpretation as suggested by Panse and sukatme (1967). The level of significance used in 'F' and 't' test was p=0.05. Critical difference (CD) values were calculated at 5 per cent probability level, wherever 'F' test was significant.

Results and Discussion

Roots are the primary plant organ affected by drought stress and other environmental stresses of the soil (Prince *et al*., 2002). Under drought conditions change of rooting pattern is one of the discrete mechanism plants employed to avoid low tissue water potentials drought avoidance to increased root growth draws considerable interest since it does not unduly hamper the productive process unlike reduction in leaf area or stomatal closure.Drought stress reduced the phenotypic expression of all the seedling traits starting from germination percentage to other growth parameters as shoot length, number of leaves, leaf area, and total dry matter including both fresh weight and dry weight of the plants till tips of the root systems. All the rapidly growing divisions in different organs are strictly effected by drought stress. The same results have been observed in the present research work where all seedling parameters got negatively affected by water deficit. And the severity of water deficit stress was more in 50% water applied as compare to 75% water stress. The results verified the previous findings as (Meo, 2000, Bibi *et al*. 2010; Ali *et al*. 2011). Bibi *et al*. 2010 observed that most of the morphological and physiological characters at seedling stage were affected by water stress in sorghum. Drought stress suppressed shoot growth more than root growth and in certain cases root growth increased (Salih*et al*. 1999; Bibi *et al*. 2010). Roots are the place where plants first encounter water stress, it is likely that roots may be able

Table 1. Interaction between sorghum genotypes and different moisture regimes in relation to root traits

Moisture regimes	Mean root shoot ratio	Mean root dry matter plant^{-1} (g)	Mean shoot dry matter plant^{-1} (g)	Mean root volume (ml)	Mean root length (ml)
M_1 (25% of F.C.)	0.45	26.81	62.41	18.36	45.26
M_2 (50% of F.C.)	0.51	31.71	65.47	22.47	42.41
M_3 (75% of F.C.)	0.52	35.80	73.02	25.66	41.39
M_4 (>90% of F.C.)	0.55	39.45	73.55	27.58	37.85
SE±	0.015	0.467	1.625	0.22	0.210
CD (p=0.05)	0.045	1.367	4.757	0.64	0.617
Genotypes					
V_1 (PhuleYashoda)	0.42	37.1	88.43	25.46	39.67
V_2 (Phule Revati)	0.43	38.14	89.73	27.2	36.86
V_3 (Phule Chitra)	0.6	27.41	46.13	20.09	46.47
V_4 (Phule Vasudha)	0.49	34.68	69.98	24.44	40.67
V_5 (Phule Anuradha)	0.51	32.33	63.65	23.08	42.1
V_6 (Phule Maulee)	0.57	30.99	53.78	20.84	44.59
SE±	0.019	0.572	1.990	0.27	0.258
CD (p=0.05)	0.055	1.674	5.826	0.79	0.755
Interaction					
SE±	0.037	1.144	3.980	0.27	0.516
CD (p=0.05)	0.143	4.367	9.199	0.79	1.971

first to sense and respond to the stress condition (Xiong*et al*. 2006; Khodarahmpour, 2011). It plays an important role in water stress tolerance by reduction in leaf expansion and promotion of root growth. Water uptake by the root is a complex parameter that depends on root structure, root anatomy, and the pattern. Root length at seedling stage provides a fair estimate about the root growth in field (Ali *et al*., 2011; Rajendran*et al*. 2011).

The data regarding root to shoot ratio, root dry matter plant^{-1} (g), shoot dry matter plant^{-1} (g), root volume plant^{-1}, root length (cm) in different sorghum genotypes used revealed significant differences during Rabi season under pot culture is presented in (Table 1). Root depth, root length density, root distribution were reported as drought tolerance contributing traits (Taiz and Zeiger, 2006). The genotype V3 (PhuleChitra) was found significantly superior in root to shoot ratio (0.60) and root length (46.47 cm) while lowest in root dry matter plant^{-1} (27.41 g), shoot dry matter (46.13 g) and root volume (20.09 ml). The genotype V_1 (Phule Yashoda) registered second highest shoot dry matter and root volume (after RSV-1006) while lowest root to shoot ratio (0.42). Ekanayake *et al*. (1985) indicated that drought stress tolerance was found to be highly associated with root characteristics such as root thickness, root length density, number of thick roots, root volume, and root dry weight. It was also found that number of thick root, root thickness, and root length density were highly associated with leaf water potential and field visual drought scoring using drying leaf.

The sorghum genotype V_2 (RSV-1006) noticed significantly maximum shoot dry matter (89.73 g), root volume (27.20 ml) (Fig 4) and, except Phule Yashoda which was at par with it, root dry matter plant-1 (38.14 g) while lowest root length (36.86 cm). The genotype V_6 (Phule Maulee) was at par with Phule Anuradha in root to shoot ratio and second highest root length (after Phule Chitra).

Genotypes that have large number of seminal roots, large vessel diameter in both seminal and nodal roots showed better survival rate under drought stress conditions. Similarly, Habyarimana *et al*. (2004) found that the

Table 2. Soil moisture (%) depletion pattern as influenced by different moisture regimes at pot culture

Depth	Depth of soil moisture (%)		
	0-15	**15-30**	**Mean**
Soil moisture of 25% F.C.			
M_1V_1	19.33	19.83	19.58
M_1V_2	19.52	20.04	19.78
M_1V_3	18.44	18.86	18.65
M_1V_4	19.12	19.63	19.37
M_1V_5	18.97	19.42	19.20
M_1V_6	18.74	19.28	19.01
Mean	19.02	19.51	
Soil moisture of 50% F.C.			
M_2V_1	25.25	25.63	25.44
M_2V_2	25.41	25.84	25.62
M_2V_3	24.43	24.85	24.64
M_2V_4	25.13	25.44	25.29
M_2V_5	24.84	25.26	25.05
M_2V_6	24.58	25.08	24.83
Mean	24.94	25.35	
Soil moisture of 75% F.C.			
M_3V_1	27.04	27.71	27.38
M_3V_2	27.25	27.88	27.57
M_3V_3	26.22	26.72	26.47
M_3V_4	26.86	27.47	27.17
M_3V_5	26.64	27.21	26.92
M_3V_6	26.41	27.07	26.74
Mean	26.74	27.35	
Soil moisture of 90% F.C.			
M_4V_1	29.50	30.08	29.79
M_4V_2	29.68	30.27	29.97
M_4V_3	28.56	29.17	28.87
M_4V_4	29.35	29.90	29.62
M_4V_5	29.08	29.67	29.38
M_4V_6	28.92	29.50	29.21
Mean	29.18	29.76	

drought tolerance traits displayed by the genotypes were related to drought avoidance mechanisms. These, in turn, are associated with deep root system, which enables plants to exploit moisture from the deeper soil horizons The genotype V_5 (Phule Anuradha) was found second best in root to shoot ratio (after Phule Chitra and Phule Maulee). From the present pot culture studies maximum shoot and root dry matter accumulation and root volume was recorded by the genotypes RSV-1006 and Phule Yashoda under moisture regime M_1 than the rest of the genotypes. However, these varieties showed the lowest root to shoot ratio under low moisture regime M_1. (Fig 1 and 4) The genotype PhuleAnuradha and Phule Maulee recorded highest root length under lowest moisture regime M_1, among the four moisture regimes (Fig 5). Under water deficit conditions, plants urgently need available water in root zone, and tolerant genotypes will extract water from deep layers of soil (Xiong *et al.*, 2006). Generally, it has been observed that drought tolerant crop species has longer roots with more root density (Achakzi, 2009; Kaydan and Yagmur, 2008). The major effect of low moisture regime was decrease in shoot and root dry matter accumulation, root to shoot ratio, root volume however increased root length in the sorghum genotypes studied (Fig 2 and 3). Similar results were obtained by Abdallah (2009) and Seghatoleslami (2008). However, in case of root dry matter accumulation contrasting results were reported by Seghatoleslami (2008). The increase in root length under low moisture regimes indicates that the adaptability of the sorghum genotypes to water stress condition (Reddy *et al.*, 2003). Drought stress suppressed shoot growth more than root growth and in certain cases root growth increased (Salih*et al.*, 1999; Bibi *et al.*, 2010).

The mean root to shoot ratio was influenced significantly due to different moisture regimes.

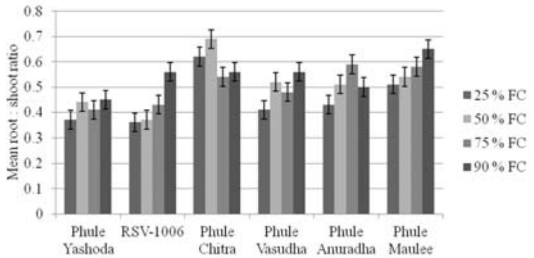

Fig. 1. Effect of different moisture regimes on mean root : shoot ratio (g) in sorghum genotypes

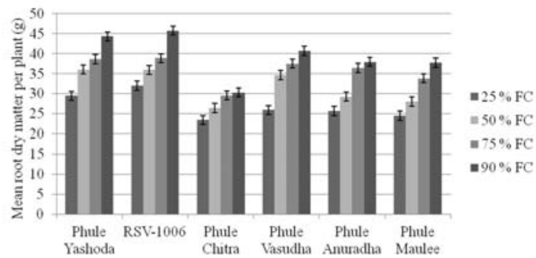

Fig. 2. Effect of different moisture regimes on mean root dry matter per plant (g) in sorghum genotypes

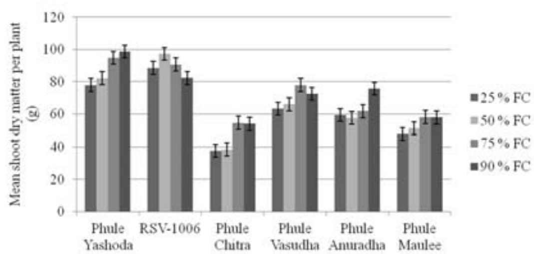

Fig. 3. Effect of different moisture regimes on mean shoot dry matter per plant (g) in sorghum genotypes

The moisture regime M_4 showed significantly highest mean shoot dry matter (73.55), mean root volume (27.58) and minimum mean root length (37.85). The moisture regime M_1 noted the highest root length (45.26), minimum root to shoot ratio (0.45), root dry matter plant^{-1} (26.81), shoot dry matter plant^{-1} (62.41) and root volume (18.36). The moisture regime M3 was found second best in root dry matter plant^{-1}. The moisture regime M_2 was found second best in mean root length. The M_3 and M_2 regimeswere found at par with M_4 in root to shoot ratio. The genotype V_3 (Phule Chitra) registered significantly highest shoot to root ratio (0.69) with moisture regime M_2, except genotypes V_3 (Phule Chitra), V_4 (Phule Vasudha) and V_6 (Phule Maulee) with M_4 and, genotypes V_5 (Phule Anuradha) and V6 (Phule Maulee) with M_3 were found at par with it. However, the genotype V_2 (Phule Revati) with lowest moisture regime M_1 showed minimum root to shoot ratio (0.36). The root:shoot ratio changes with plant growth and development in addition to shifting in response to limiting resources above versus below ground. Therefore, care must be taken to control for plant size and ontology, especially when assessed on young plants (Miller *et al.*, 2000). Dhanda *et al.* (2004) reported that the decrease in water availability affects the crop production at different growth stages but generally resulted in decreased coleoptile length, higher root to shoot ratio and longer roots. In sorghum have shown that total leaf area and specific leaf area decrease under water stress, while the root to shoot ratio increases (Munamava *et al.*, 2001). The genotype V_2 (Phule Revati) recorded significantly highest mean dry matter plant^{-1} (45.75 g) under highest moisture regime M4, shoot dry matter (97.30 g) under M_2, root volume (32.12 ml) under M_4 while significantly minimum root length (33.95 cm) under highest moisture regime M_4. The genotype V_1 (Phule Yashoda) was second best in root dry matter plant^{-1} (after RSV-1006) and at par with genotype V_2 (Phule Revati) with moisture regime M_4 in root volume. The genotype V_3 (Phule Chitra) under lowest moisture regime M_1 showed highest root length (51.78 cm). The genotype V_3 (Phule Chitra) under lowest moisture regime M_1 noted

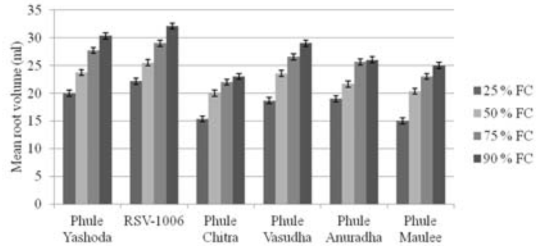

Fig. 4. Effect of different moisture regimes on mean mean root volume (ml) in sorghum genotypes

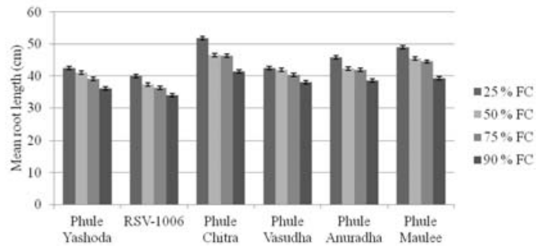

Fig. 5. Effect of different moisture regimes on mean root length (cm) in sorghum genotypes

lowest root dry matter plant^{-1} (23.40 g), shoot dry matter (37.50 g) under lowest moisture regime M1. The genotype V_6 (Phule Maulee) under lowest moisture regime M_1 was second best genotype (after genotype Phule Chitra) in root length. However, it noticed minimum root volume (15.00 ml) under lowest moisture regime M_1. Nour *et al.* (1978) also reported root weight is the best and easiest attribute to determine drought tolerance in grain sorghum. In the present investigation higher root to shoot ratio in Phule Chitra and Phule Maulee under low moisture regime M_1 indicated that it could be due to the shift in photo assimilate partitioning with favour of root growth than shoot (Bota *et al.*, 2004) or it may promote lesser biomass allocation to shoot than root (Salem, 2003).

Conclusion

In present study maximum shoot and root dry matter accumulation and root volume was recorded by sorghum genotypes PhuleYashoda and PhuleRevati while genotypes PhuleChitra and PhuleMaulee recorded significantly higher root lengthat low moisture regime M1. From this study it could be inferred that the sorghum genotypesPhuleChitra and PhuleMaulee are more suited under limited soil moisture condition while genotypes PhuleYashoda and PhuleRevati found well suited for medium soil for stress as well as non stress condition.

Acknowledgement

The author expresses their deep sense of gratitude to Dr. U. D. Chavan, Associate Professor and Senior Cereal Food Technologist, Department of Agril. Botany, Mahatma PhuleKrishiVidyapeeth, Rahuri, District Ahmednagar, Maharashtra, India, for providing lab facilities and timely guidance.

Conflict of interest

The author declares there is no conflict of interests regarding the publications of this paper.

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J. Agric. Res. Technol., 42 (3) : 119-125 (2017)

Phenological studies on Sesamum (*Sesamum indicum* L.) varieties under varied weather condition

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Abstract

An experiment was conducted during *kharif* season 2016 with treatment combination of sowing dates and genotype of sesame replicated thrice in the split spot design (i.e. D_1 (27 MW), D_2 (28 MW), D_3 (29 MW) and D_4 (30 MW) and four genotypes, Phule til -1, Gujarat - 2, JLT - 408 and JLT - 7). The crop was sown with spacing 45 x 15 cm on 5.4 x 4.0 m^2 gross plot size and 4.5 x 3.6 m^2 net plot size. The meteorological parameters (abiotic factor) play an important role in deciding the crop success, because these factors strongly influence the physiological expression of genetic potential of the crops. The results obtained from the study showed that all the biometric observations (plant height, number of leaves, number of branches, leaf area and leaf area index) in *kharif* sesame were significantly highest under D_2 28 MW, (09 to 15 July) sowing date followed by D_1 27 MW, (02 to 08 July). Significantly highest grain yield (227 kg ha^{-1}) was obtained with D_2 (28 MW,) over the rest of treatments followed by first sowing date D_1 (173.71 kg ha^{-1}) and lowest grain yield was observed in fourth sowing D_4 (125 kg ha^{-1}). Hence, sowing of *kharif* sesame should be completed up to 28^{th} MW,. Among the genotypes, JLT - 408 (203 kg ha^{-1})was found significantly superior over the JLT-7 (176 kg ha^{-1}), Phule til - (153 kg ha^{-1}) and Gujarat-2 (123 kg ha^{-1}). However, the interaction between sowing dates and sesame genotypes was found to be non-significant.This indicate that sesame genotypes was equal response to different sowing dates.

Key words : Genotypes

Sesamum [*Sesamum indicum* L.] belongs to the family Pedaliaceae and is one of the most ancient oilseed crop and used in cooking. It is also known as benniseed, ginegelly, simsim, ajonjoli, sesame and til. It was major oilseed crop in the ancient world, great stability and resistance to drought. Sesamum crop cultivated thoughout the year. Crop is also cultivated either as a pure stand or as a mixed crop with aus rice, jute, groundnut, millets and sugarcane. Sesamum is basically considered a crop of warm region of tropics and subtropics. It requires fairly hot condition during growth to produce maximum yield. A temperature of 25-27°C encourage rapid germination , initial growth and flower formation. In India, it is cultivated on an area about 1746.06 thousand hectares with production 827.83 thousand meteric tones and productivity 474 kg ha^{-1} (Anonymous, 2015). In Maharashtra it is cultivated on an area about 204 hundred hectares with production of 42 hundred tones and productivity of 505 kg ha^{-1} and in Marathwada cultivated area about 116 hundred hectares with production of 15 hundred tonnes and productivity of 579 kg ha^{-1} (Anonymous, 2015). It is widely cultivated in the states of Uttar Pradesh, Rajasthan, Orissa, Andhra Pradesh, Tamil Nadu, Karnataka, WestBengal, Bihar and Assam. The success or failure of rainfed crops depends upon the pattern of monsoon rains. The distribution of rainfall in monsoon decides the yield of rainfed crops. To mitigate these losses of *kharif* sesamum, a field experiment was conducted to find out the suitable sowing date for kharifsesamum under rainfed condition or behavior of monsoon.

Material And Methods:A field experiment was conducted during the *kharif* season of 2016-17 under rainfed condition on the experimental farm of the Department of Agricultural Meteorology, College of Agriculture, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani. An experiment was conducted in split plot design with three replications. Treatment under study were four sowing dates in kharif season i.e. D_1 (27^{th} MW,), D_2 (28^{th} MW,), D_3 (29^{th} MW,) and D_4 (30^{th} MW,), and four different varieties Phule til -1, Gujarat - 2, JLT - 408 and JLT - 7 were sown with spacing 45 x 15 cm. The gross plot size was 5.4 x 4.0 m^2 and net plot size was 4.5 x 3.6 m^2. The sowing of seed was done by dibbling method on respective date of sowing. Recommended packaging of practices like thinning, weeding, application of recommended dose of fertilizer and pesticide were uniformly followed for each experiment. Observations were recorded on five plants randomly selected per treatment.

Results and Discussion

Weather conditions during the crop growing season : The total rainfall recorded during growing period (27^{th} MW, to 44^{th} MW,) of sesamum crop was 990.7 mm in 45 rainy days. During the crop growing period the highest maximum temperature (32.5°C) was recorded in 29-MW, and lowest maximum temperature (28.2°C) was recorded in 31-MW, respectively. Whereas the highest minimum temperature (23.9°C) recorded in 27-MW, and lowest minimum temperature (14.4°C) recorded in 44-MW, respectively. The morning time relative humidity ranged between 74 to 96 per cent while evening relative humidity ranged between 31 to 85 per cent during crop growth period. The highest evaporation during the crop growing season (5.9 mm) in 43-MW, and lowest (2.5 mm) was recorded in 31-MW,, respectively. The crop season experienced a very wide range of bright sunshine (BSS) hours ranging from 1.0 hours to 9.6 hours. The highest bright sunshine hours (9.6) was recorded in 42-MW, whereas the lowest sunshine hours recorded (1.0) in 27-MW, The highest wind velocity (6.2 kmph) was recorded in 32-MW, and lowest wind velocity (2.2 kmph) recorded in 42-MW, respectively.

Growth parameters

Plant height : The mean plant height was significantly influenced by different sowing dates. The *kharif* sesamum sown during 28th MW, has recorded significantly more plant height at 90 days after sowing (84.73 cm) over the rest of sowing dates and it was at par with D1 (27 MW,) sowing date. Lowest plant height was recorded in 30th MW, (74.43) during all growth stages of crop. Similar results were reported by Ali *et al.*, (2005) and Nilanthi *et al.*, (2015).Among varieties the maximum plant height was observed at 90 days after sowing with JLT-408 (93.93 cm) over rest of the varieties. The minimum plant height was observed in variety Gujarat-2 (74.28 cm). Similar results were reported by Khairnar *et al.*, (2013) and Phuke (2006) and Gade (2012). The interaction between sowing times and varieties were non-significant at all stages.

Number of functional leaves : The mean number of functional leaves $plant^{-1}$ was significantly influenced by different sowing dates. The *kharif* sesamum sown during 28th MW, produced significantly maximum number of functional leaves $plant^{-1}$ at 60 days after sowing (77.07). It was significantly superior over rest of the sowing dates. While, it was at par with 27 MW, sowing date. The minimum number of functional leaves $plant^{-1}$ was recorded in 30th MW, (61.60) during all growth stages of crop. Similar results were reported by Gade (2012). Among varieties the highest number of functional leaves (71.80) significantly produced by JLT - 408 at 60 days after sowing and drastically reduced at harvest due to senescence. However, it was at par with JLT-7. The minimum number of functional leaves $plant^{-1}$ was observed in variety Gujarat - 2 (4.60). This may occurr due to genetic characteristics of the varieties. The results are in conformity with Phuke (2006), Unde (2015)

Table 1. Different growth attributes influenced by different sowing dates and varietal treatments

Treatments	Plant height (cm) 90 DAS	No. of leaves 60 DAS	Leaf area (dm^2) 60 DAS	Leaf area index 60 DAS	No. of branches at harvest	Days to 50% flowering	Days to capsule formation	Days to maturity
Sowing dates								
D_1 (27th MW)	80.24	71.86	37.97	5.62	5.49	46.33	51.25	89.83
D_2 (28th MW)	84.73	77.07	41.08	6.03	5.92	43.08	48.08	88.42
D_3 (29th MW)	76.11	62.20	32.35	4.53	4.81	41.67	45.92	88.92
D_4 (30th MW)	74.43	61.60	30.43	4.68	4.02	42.67	47.92	88.33
SE ±	1.86	1.71	1.09	0.16	0.10	0.88	0.94	0.10
CD at 5%	6.45	5.93	3.78	0.57	0.37	3.28	3.28	0.36
Varieties								
V_1 (Phule til-1)	81.10	67.10	33.58	4.96	5.65	45.67	50.83	93.67
V_2 (Gujarat-2)	66.21	54.60	29.10	4.21	2.27	44.58	49.42	90.33
V_3 (JLT-408)	93.93	79.23	41.97	6.20	6.02	41.25	46.17	83.17
V_4 (JLT-7)	74.28	71.80	37.20	5.48	5.83	42.25	46.75	88.33
SE ±	2.39	2.35	1.44	0.23	0.11	0.88	1.00	0.30
CD at 5%	8.28	8.14	4.98	0.81	0.39	3.04	3.48	1.06
Interaction								
(D x V)								
SE ±	3.76	4.26	3.01	0.44	0.29	0.88	0.82	0.43
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS
G.M	78.87	68.18	35.45	5.12	5.05	43.43	48.29	88.87

and Gade (2012). The interaction between sowing times and varieties were non-significant at all stages.

Leaf area plant^{-1} : Mean leaf area plant^{-1} was significantly affected due to different sowing dates up to 60 days of crop growth. For the sowing at 28th MW, leaf area (41.08 dm^2) was found significantly superior over rest of the sowing dates. While, it was at par with 27th MW, sowing. Minimum leaf area (30.43 dm^2) was recorded in 30th MW, during all growth stages expect 30 DAS. This might be due to use more light radiation and more number of functional leaves under former sowing date.Similar results were reported by Gade (2012). Among varieties,mean leaf area plant^{-1} was influenced periodically due to different varieties at all the stages of crop growth except at 30 DAS. Variety JLT - 408 (41.97 dm^2) produced significantly more leaf area than rest of the varieties at 60 days after sowing. The minimum leaf area was observed in variety Gujarat - 2 (29.10 cm). This might be due to varietal effect of sesamum. Similar results were reported by Phuke (2006) and Gade (2012). The interaction between sowing times and varieties were non-significant at all stages.

Leaf area index plant^{-1} : Mean leaf area index plant-1 was significantly affected due to different sowing dates up to 60 days of crop growth. The sowing at 28th MW, was found significantly superior in producing maximum leaf area index (6.03) over rest of the sowing dates. While, it was at par with 27th MW, sowing at 60 DAS and at 90 DAS. Whereas minimum leaf area index (4.68) was recorded in 30th MW, at 60 and 90 DAS and was at par with 29 MW,. During reproductive stage sowing at 28th MW,observed more temperature (26.9 to 27.4°C) and BSS (hrs) which help to increase the leaf area index with increase in leaf area. Among varieties Mean leaf area index plant^{-1} was significantly influenced periodically due to different varieties at all the stages of crop growth. Variety JLT - 408 (6.20) produced significantly more leaf area index than rest of the varieties at 60 and 90 days after sowing. The minimum leaf area index was observed in variety Gujarat - 2 (4.21) and statistically at par with Phule til-1.This might be due to varietal performance and more number of functional leaves and profused growth of the plants. Reported by Phuke (2006) and Unde (2015) also observed the similar trend. The interaction between sowing times and varieties were non-significant at all stages.

Number of branches plant^{-1} : Sowing of seasmum at 28th MW, produced significantly maximum number of branches (5.92) than other sowing dates at all growth stages expect 30 DAS while, it was at par with sowing at 27th MW, at 60 DAS. However, minimum number

Table 2. Different Post-harvest parameters and yield attributes influenced by different sowing dates and varietal treatments

Treatments	No. of capsules plant^{-1}	No. of grains row^{-1}	No. of grains capsule^{-1}	Grain yield kg ha^{-1}
Sowing dates				
D_1 (27th MW)	30.64	18.80	75.20	173.71
D_2 (28th MW)	33.59	20.92	83.68	226.55
D_3 (29th MW)	29.50	17.73	70.90	130.33
D_4 (30th MW)	26.42	17.12	68.52	124.98
SE ±	0.86	0.38	1.53	5.34
CD at 5%	0.86	1.31	5.35	18.49
Varieties				
V_1 (Phule til-1)	29.98	18.23	72.93	152.75
V_2 (Gujarat-2)	24.68	17.60	70.42	122.61
V_3 (JLT-408)	34.04	19.78	79.18	203.23
V_4 (JLT-7)	31.45	18.94	75.77	176.98
SE ±	1.01	0.37	1.52	13.04
CD at 5%	3.51	1.31	5.26	45.14
Interaction				
(D x V)				
SE ±	3.11	0.62	2.50	24.34
CD at 5%	NS	NS	NS	NS
G.M	30.03	18.64	74.57	163.88

of branches was recorded in 30th MW, (4.02) at 60 and 90 DAS. Similar results were reported by Ali *et al*., (2005) and Abdel Rahman *et al*., (2007). Sowing of seasmum at 28th MW, received prolonged photoperiod and good rainfall during vegetative as well as reproductive stage as a result of which more assimilates was utilized by plant in producing more branches. Among varieties the mean number of branches plant^{-1} due to varieties were significant at all crop growth stages except 30 days after sowing. The higher number of branches was significantly produced by JLT - 408 (6.05) over the rest of the varieties, however, it was at par with JLT-7 at 90 days after sowing and at harvest. The minimum number of branches for observed with variety Gujarat - 2 (2.7). This might be due to varietal performance. Similar results were reported by Unde (2015) and Monpara *et al*., (2011), Bharathi *et al*., (2014). The interaction between sowing times and varieties were non-significant at all stages.

Phenological parameters

Number of days required for 50 percent flowering : The mean number of days required to 50 per cent flowering was significantly influenced by different sowing times. Sesamum varieties sown during 29th MW, recorded significantly minimum days to 50 per cent flowering (41.67) and maximum for 27th MW, (46.33). The more BSS (hrs) was recorded in 29th MW, than other sowing dates, because this meteorological parameter is very important to sesamum crop for early flowering. A variety JLT-408 recorded significantly minimum days to 50 per cent flowering (41.25) and maximum for variety Phule Til-1 (45.67). This was due to the meteorological conditions prevailing during crop growth period and varietal characters. Similar results were reported by Jadhav *et al*., (2015) and Thorve *et al*., (2011). The interaction between sowing times and varieties were non-significant at all stages.

Number of days required for capsule formation : The mean number of days required to capsule formation was significantly influenced by different sowing times. The crop sown during 29th MW, recorded significantly minimum days to capsule formation (45.92) as compared to other sowing dates and maximum for 27th MW, (51.25), because capsule formation was late in succiding treatment. A variety JLT - 408 recorded significantly minimum days to capsule formation (46.17) and maximum for variety Phule Til- 1 (50.83). This was due to the meteorological conditions at that time and genetic factors of those varieties. Similar results were reported by Gade (2012). After 50 per cent flowering of plant within 3-5 days capsule formation was started.

Number of days required for maturity: The mean number of days required to maturity was significantly influenced by different sowing times. Sowing at 30th MW, recorded significantly minimum days to maturity (88.33) and maximum for 27th MW, (89.83) due to more GDD in 30th MW, during maturity stage than other sowing dates.Similar results were reported by Ali and Jan (2014). Among The variety JLT - 408 recorded significantly minimum days to maturity (83.17) as compared to other sowing dates and maximum for variety Phule Til-1 (93.67). This showed that former variety is earlier than others. Similar results were reported by Jadhav *et al.* (2015) and Thorve *et al.* (2011).

Post-harvest parameters

Number of capsules plant^{-1} : Mean number of capsules plant-1 was significantly influenced by different sowing times. Sowing at 28th MW, recorded significantly higher mean number of capsules plant^{-1} (33.59) than rest of the sowing dates. However, significantly less number of capsules plant^{-1} were observed at 30th MW, (26.42). Due to favourable atmospheric conditions at former treatment, the number of capsules were higher as compared to other treatment. Similar results were reported by Ali *et al*., (2005). Variety JLT - 408 recorded significantly more number of capsules plant-1 (34.04) over rest of the varieties and minimum with Gujarat - 2 (24.68). This was due to the meteorological conditions prevailing during crop growth period and varietal differences. Similar results were reported by Phuke (2006) and Thorve *et al.* (2011). The interaction between sowing times and varieties were non-significant at all stages.

Number of grains row^{-1} : Mean number of grains row^{-1} was significantly influenced by different sowing times. Sesamum varieties sown at 28th MW, produced significantly more number of grains row^{-1} as compared rest of the sowing dates. However, the lowest number of grains row^{-1} found at 30th MW. This might due to favourable climatic condition during former sowing date.The variety JLT - 408 (19.78) found significantly superior than Phule til-1, Gujarat - 2 and JLT-7 in respect of numbers of grains row-1. This might be the genetic potential of the variety JLT - 408.

Number of grains capsules^{-1} : The mean number of grains capsules^{-1} was significantly influenced by different sowing times. The sowing at 28th MW, recorded significantly more number of grains capsules^{-1} (83.68) as compared to other sowing dates. Where as minimum number of grains capsules^{-1} were found at 30th MW, (68.52). The results reported by Ali *et al*.,(2005) werealso in conformity of the present investigation. Variety JLT - 408 found significantly superior in respect of number of grains capsules^{-1} (79.18) than rest of the varieties. But the Gujarat-2 produced lowest number of grains capsules^{-1}. This was due to the meteorological conditions prevailed during crop growth period. Phuke (2006) also observed similar results.

Yield attributes

Grain yield (kg ha^{-1}) : The grain yield of sesamum at harvest was significantly influenced by different sowing times. The crop sown at 28th MW, produced significantly highest seed yield (226.55 kg ha^{-1}) than rest of the sowing dates, where as significantly the lowest seed yield was observed under 30th MW,. This might be the effect of optimum temperature, good rainfall and BSS (hrs) during crop growth period under former sowing date. (Ali *et al*., 2005). The lowest seed yield was observed at 30th MW, because of the terminal drought during reproductive phase. Similar results were reported by Choudhary *et al*., (2015).Variety JLT - 408 recorded significantly higher seed yield (203.23 kg ha^{-1}) than JLT-7 (176.98 kg ha^{-1}), Phule til^{-1} (152.75 kg ha^{-1}) and Gujarat - 2 (122.61 kg ha^{-1}). This might be due to less flower drop, more number of branches and more number of filled capsules plant^{-1} with former variety. The minimum grain yield 122.61 kg ha^{-1} was observed in variety Gujarat - 2. The results are confirmed by Jadhav *et al*., (2015) with their investigation. The interaction between sowing times and varieties were non-significant at all stages.

Conclusion : On the basis of observations and analysis of data i.e. biometric and yield contributing character it was observed that D_2 sowing i.e. 28 MW, (09 to 15 July) was superior over rest of treatments with production of highest grain yield (226.55 kg ha^{-1}) followed by first sowing date D_1 (27 MW, - 02 to 08 July). It is therefore, concluded that sowing may be done in D_2 (09 to 15 July) for highest grain yield, followed by D_1 (27 MW,) (02 to 08 July) and variety V_3 (JLT-408) was superior for sowing in *kharif* season on the basis of highest grain yield at Parbhani location.

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J. Agric. Res. Technol., 42 (3) : 126-131 (2017)

Study of Agrometeorological Indices on Black Gram as Affected by Different Dates of Sowing and Varieties

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Abstract

An experiment was conducted at experimental farm of Department of Agril. Meteorology, College of Agriculture, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, during *Kharif* season 2016 entitled "Performance of black gram (*Vigna mungo* (L.) Hepper) varieties in changing weather condition" to find out most suitable week for sowing of black gram in *kharif* season, and to study the relationship between meteorological parameters and different dates of sowing in black gram. The experiment was conducted in split plot design with three replications. Treatments comprised of four sowing dates in main plot treatment i.e D_1 (25^{th} MW), D_2 (27^{th} MW), D_3 (29^{th} MW) and D_4 (31^{th} MW), with three varieties in sub plot *viz*., TAU-1 , BDU-1 and AKU-15.The experiment was sown with spacing 30 x 10 cm. The results showed that all the biometric observations (plant height (cm) , number of functional leaves, number of pods per plant and yield) in *kharif* black gram were significantly highest in D_2 (27^{th} MW) followed by first sowing date D_1 (25^{th} MW), D_3 (29^{th} MW) and D4 (31th MW). The black gram variety BDU-1 was found to be highly productive as compared to TAU-1 and AKU-15. The highest total GDD was observed during D_1 (MW 25) and it was followed by D_2 (MW 27), D_3 (MW 29) and D4 (MW 31). The total GDD requirement of all the varieties during crop life cycle was TAU-1, BDU-1 and AKU-15 respectively. Total HTU and PTU required during total crop growth period was highest in D_2 (MW 27) as compared to remaining treatments. In case of varieties (BDU-1) required highest total HTU and PTU as compared to other two varieties.

Key words : Black gram, varieties, sowing dates, yield and agrometeorological indices.

Pulses have great importance in Indian agriculture as they are rich source of protein (17 to 25 percent) as compared to that of cereals (6 to 10 percent), their ability to fix atmospheric nitrogen and improve the soil fertility. The pulses are good source of protein which is cheaper than other protein rich food like meat, and fish. They are most useful in solving the protein malnutrition and also used as fodder and concentrates in cattle feeds.

Though India is the largest producer of pulses accounting 22 per cent of the world production, availability of pulses per capita per day in the country is much lesser (30-35 g) than the recommendations of WHO (80 g per capita) and thereby around 80 million children of the country are still protein energy under-nourished Hence, there is a need for increasing average pulse productivity to fulfill protein requirement.

Black gram has been distributed mainly in tropical to subtropical countries where it is grown in Kharif and Summer season. It is grown in India, Pakistan, Srilanka , Burma and some countries of East Asia. In India black gram is very popularly grown in Andhra Pradesh, Bihar, Madhya Pradesh, Maharashtra, Uttar Pradesh, West Bengal, Punjab, Haryana, Tamilnadu and Karnataka.

In India, Black gram is grown on 29 lakh ha area with total production of 15.9 lakh tonnes and productivity of 532 kg ha^{-1}. In Maharashtra it occupies an area of 3.65 lakh ha with total

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production of 2.06 lakh tonnes and the productivity of 299 kg ha^{-1} (Anonymous, 2015).

Material and methods

The experiment was conducted at experimental farm, Department of Agricultural Meteorology, College of Agriculture, Vasantrao Naik Marathwada Krishi Vidyapeeth , Parbhani during *kharif* 2016.

The experiment was conducted in Split plot design with three replications. Treatments comprised of four sowing dates in main plot D_1 (25^{th} MW), D_2 (27^{th} MW), D_3 (29^{th}) and D_4 (31_{th} MW), with three varieties in sub plot viz. TAU-1 , BDU-1 and AKU-15.The experiment was sown with spacing 30 x 10 cm. Gross and net plot size viz., 4.2 x 3.5 m2 and 3.6 x 3.1 m^2 respectively. The periodical observations on growth, micrometeorological parameters and yield contributing characters were recorded to assess the treatment effects.

Growing degree days (GDD) : Temperature is a major environmental factor that determines the rate of plant development. The temperature requirement and range of optimum temperature varied with species and genotype. The thermal response of genotype can be quantified by using the heat unit or thermal time concept. There is high probability of successfully predicting the development of black gram by heat unit.

Thermal time or growing degree days were calculated according to the equation. (Mali *et al*. 2000).

$$G.D.D. = \sum_{i=1}^{n} [(T_{max.} + T_{min.})/2 - Tb]$$

Where, G.D.D. = Growing degree days, $T_{max.}$ = Daily maximum temperature of day i (°C), $T_{min.}$ = Daily minimum temperature of day i (°C) and Tb = Base temperature.

In present study, the base temperature of black gram was taken as 10 °C.

Photo thermal units : The photo thermal units was calculated by multiplying GDD with day length at critical stages of crop.

Photo thermal units = GDD x Day length

Helio-thermal units : The Helio-thermal units was calculated by multiplying GDD with mean BSS at critical stages of crop.

Helio thermal units = GDD x Mean BSS

Helio-thermal units (HTU) and photo thermal units(PTU) were determined by the equation proposed by Singh et al. (1990) and Nuttonson (1948), respectively.

Results and Discussions

Yield : The yield of Black gram cultivars was markedly influenced by sowing time (Table 1). Grain and straw yields of black gram cultivars were significantly higher with D_2 (27^{th} MW) sown crop (1218 kg ha^{-1}) as compared to rest of treatment. Higher seed yield was realized in case of D_2 (27^{th} MW) sown crop because of higher growth and yield attributed which lead to higher yield of the respective treatments. Similar results were reported by Damodaran *et al*. (1989) and Rathore *et al*. (2010).

Grain and stover yield differed significantly among the black gram cultivars. The BDU-1 recorded significantly higher grain yield (1163 kg ha^{-1}) followed by TAU-1 (1081 kg ha^{-1}) and the lowest with AKU-15 (950 kg ha^{-1}). On mean basis, BDU-1 variety produced 9.3 per cent higher grain yield over the varieties. This might be due to more growth attributes like more plant population, no of green leaves, dry matter and leaf area was recorded more with the respective treatments. Similar results were reported by Choulwar *et al.* (1997) and Yadahalli and Palled (2004).

Phenological studies : The sequential study of development stages (i.e. crop growth stages) of the crop is known as phenology. The duration (days) taken for commencement of different phonological events viz., Sowing to Emergence (P_1), Emergence to Branching (P_2), Branching to Flowering (P_3), Flowering to Pod formation (P_4), Pod formation to Dough stage (P_5) and Dough stage to Maturity (P_6) for different date of sowing of the black gram crop is given in Table 2. It is clearly understood from the Table 2. that total days required from sowing to maturity ranged from 68 to 74 days. The duration of the crop was varied in different date of sowing is due to the different weather condition prevailed in different phenophases of black gram.

It was apparent from the results, 25th MW and 27th MW sowing took longer duration to attain maturity as compared to 29th MW and 31th MW sowing and variety BDU-1 taken longer duration to attain maturity as compared to TAU-1 and AKU-15 due to this shorter duration in late sown crop seems to have affected the black gram yield as well as total biomass production and it was reflected in the revealed data.

However, the every crucial and important stage regards to black gram yield is pod formation to dough stage (P5) and it was observed that to attain this stage required near about 16 days.

Agro meteorological indices : Black gram is the short day plant grown in tropical and subtropical regions in which weather play major role in crop production. Among the climatic factors, temperature and humidity plays a key role in determining the sowing time and consequently the duration of different phenophases, which affect the crop productivity. Hence, knowledge of the exact duration of all the developmental phases and their association with yield determinants is essential for achieving high yield. Growing degree (GDD) days , photo thermal units (PTU) and Helio thermal units (HTU) are good estimators of black gram growth stages.

Agro meteorological indices showed the temperature impact on the growth and yield of crop. The data on the agro meteorological indices are given in the Table 1 and 2.

Growing degree days (degree days) : The data given in the Table 2 showed that the number of growing degree days was accumulated during the each phenophase at the base temperature of 10.0 °C and it was obtained 1817.2 °C days and 1823.4 °C days as general mean of sowing dates and varieties

Table 1. Yield of black gram, heat use efficiency and Helio-thermal use efficiency as influenced by various treatments

Treatment	Seed yield (kh ha^{-1})	Straw yield (kh ha^{-1})	Heat use efficiency seed yield	Helio-thermal use efficiency seed yield
Sowing dates (D)				
D_1 (MW 25)	1110	2220	0.58	0.13
D_2 (MW 27)	1218	2448	0.65	0.13
D_3 (MW 29)	1010	1999	0.57	0.12
D_4 (MW 31)	921	1795	0.54	0.11
SE ±	5.34	10.61	–	–
CD at 5 %	18.51	36.72	–	–
Varieties (V)				
V_1 (TAU-1)	1081	2147	0.60	0.13
V_2 (BDU-1)	1163	2312	0.63	0.13
V_3 (AKU-15)	950	1888	0.52	0.11
SE ±	3.47	6.78	–	–
CD at 5 %	10.42	20.33	–	–
Interaction (D x V)				
SE ±	13.91	27.13	–	–
CD at 5 %	NS	NS	–	–
G Mean	1064	2115	0.58	0.12

Table 2. Phenophase wise agrometeorological indices required as influenced by various treatments of black gram during *Kharif* season

Treatments	Days required to phenophases						
	P_1	P_2	P_3	P_4	P_5	P_6	Total
Dates of sowing							
D_1 (MW 25)	4	22	6	16	17	9	74
D_2 (MW 27)	5	21	6	16	16	9	73
D_3 (MW 29)	5	21	6	14	16	8	70
D_4 (MW 31)	6	20	5	14	15	8	68
Varieties							
V_1 TAU-1	5	21	6	14	16	8	70
V_2 BDU-1	5	22	6	16	16	9	74
V_3 AKU-15	5	20	6	15	16	10	72
Growing degree days (degree days)							
Dates of sowing							
D_1 (MW 25)	119.0	562.4	159.4	401.4	437.6	237.2	1917.0
D_2 (MW 27)	116.9	548.4	158.5	402.5	437.1	201.9	1865.3
D_3 (MW 29)	120.2	570.8	143.0	366.6	382.2	203.5	1786.3
D_4 (MW 31)	118.3	521.4	135.0	367.1	361.3	197.1	1700.2
Varieties							
V_1 TAU-1	115.3	567.9	137.4	359.5	415.4	204.5	1800
V_2 BDU-1	120.5	562.7	123.8	425.7	407.2	212.9	1852.8
V_3 AKU-15	120.0	549.5	152.0	389.0	394.6	212.2	1817.3
Photo thermal unit (°C day hours)							
Dates of sowing							
D_1 (MW 25)	1587.5	7502.4	2126.4	5338.6	5820.1	3154.8	25529.7
D_2 (MW 27)	1559.4	7315.7	2114.4	5353.3	5813.4	2685.3	24841.4
D_3 (MW 29)	1603.5	7614.5	1907.6	4875.8	5083.3	2706.6	23791.2
D_4 (MW 31)	1578.1	6955.5	1800.9	4882.4	4805.3	2621.4	22643.6
Varieties							
V_1 TAU-1	1538.1	7575.8	1832.9	4781.4	5524.8	2719.9	23972.8
V_2 BDU-1	1607.5	7506.4	1651.5	5661.8	5415.8	2831.6	24674.5
V_3 AKU-15	1600.8	7330.3	2027.7	5173.7	5248.2	2822.3	24203.0
Helio thermal unit (°C day hours)							
Dates of sowing							
D_1 (MW 25)	725.9	1743.4	350.7	1605.6	3107.0	1233.4	8766.0
D_2 (MW 27)	93.5	1974.2	570.6	2213.8	2841.2	1433.5	9126.8
D_3 (MW 29)	637.1	2283.2	858.0	2566.2	1796.3	468.1	8608.9
D_4 (MW 31)	260.3	3441.2	1053.0	2019.1	650.3	1084.1	8507.9
Varieties							
V_1 TAU-1	415.1	2442.0	673.3	1977.3	2077.0	1022.5	8607.1
V_2 BDU-1	433.8	2419.6	606.6	2341.4	2036.0	1064.5	8901.9
V_3 AKU-15	432.0	2362.9	744.8	2139.5	1973.0	1061.0	8713.2

P_1 : Sowing to Emergence, P_2 : Emergence to Branching, P_3 : Branching to Flowering, P_4 : Flowering to Pod formation, P_5 : pod formation to dough stage P6 :Dough to Maturity respectively. The results showed that the growing degree days was significantly affected by different sowing dates and the highest number of growing degree days recorded in D1 (MW 25) indicated more heat load (i.e. 1917 °C day) than rest of the treatments it may be due to maximum air temperature prevailed at sowing time. Date of sowing D_4 (MW 31) recorded lowest heat load (i.e. 1700.2 °C day) heat unit required for attaining various phenophases in D_4 (MW 31) date of sowing due to effect of temperature and delayed sowing during the crop growing season.

Highest GDD was recorded at (570.8 °C day) was recorded in P_2 stage of date of sowing and lowest GDD recorded at sowing to emergence (P_1) as the less number of days required for complete this phenophase.

The data presented in Table 2 revealed that the total heat unit requirement of all the varieties during crop life cycle was 1800.0 °C, 1852.8 0C, and 1817.30C for TAU-1, BDU-1 and AKU-15 respectively. It might be due to the different crop duration in these four varieties.

Photo thermal unit (°C day hours) : Photo thermal unit is the agro meteorological indices that indicated how much quantity of heat energy is used by the plant during the day. It is calculated by multiplying the daily heat units or GDD with the length of day. The no. of photo thermal units to be accumulated by the crop during it life cycle at different phenophases are given in the Table 2.The photo thermal units were influenced by the number of days required for reaching to each phenophase or to complete life cycle.

The data given in the Table 2 showed that number photothermal units was accumulated during the each phenophase at the base temperature of 10.0 °C was significantly influenced by different sowing dates. The data revealed that average photo thermal units accumulated during different sowing dates was observed 24201.5 °C day hrs. whereas, the highest photo thermal units was recorded in 25^{th} MW sowing (25529.7 °C day hrs) followed by 27^{th} MW sowing (24841.4 °C day hrs) and 29^{th} MW sowing (23791.2 °C day hrs) and the lowest in 31^{st} MW sowing (22643.6 °C day hrs).

While, the highest PTU were recorded in 25^{th} MW sowing at all the phenophases. However, within all crop growth stages the highest PTU were recorded at Pod formation to Dough stage (P_5). The lowest no. of PTU was accumulated from sowing to emergence in all the sowing dates.

The data presented in Table 2 revealed that the total PTU requirement of all the varieties during crop life cycle was 23972.8°C, 24674°C, and 24203.0°C for TAU-1, BDU-1 and AKU-15 respectively. It might be due to the different crop duration in these four varieties.

Helio thermal unit : The variation in mean daily temperature and bright sunshine hour among four sowing dates resulted in varied accumulated helio-thermal units at different phenophases and life cycle of black gram crop. The total helio-thermal units were observed in date of sowing (D_1 to D_4) ranged from 8507.9 to 9126.8 °C day hour. Early sowing dates the highest Helio-thermal units was recorded in 27^{th} MW sowing (9126.8 °C day hrs) followed by 25^{th} MW sowing (8766.0 °C day hrs) and 29^{th} MW sowing (8608.9 °C day hrs) and the lowest in 31^{st} MW sowing (8507.9 °C day hrs).

The data presented in Table 2 showed that total HTU required during total crop growth period was highest in D_2 (MW 27) i.e. 9126.8 °C day hour as compare to remaining treatments. In case of varieties V_2 (BDU-1) required highest total HTU i.e. 8901.9 °C day hour as compare to other three varieties. It might be due to different growth period.

Heat use efficiency and Helio thermal use efficiency : At maturity, HUE for grain was significantly higher (0.65) for D_2 (24^{th} MW) sown crop as compared to rest of treatment. Among cultivars, BDU-1 had significantly higher heat use efficiency (0.63) followed by TAU-1 (0.60) and AKU-15 (0.52) for grain production. Heliothermal use efficiency for grain was found maximum 0.13 for D_1 and D_2 sown crops. In case of cultivars, TAU-1 and BDU-1 had highest helio-thermal use efficiency 0.13 for grain production. The minimum heliothermal use efficiency was found in AKU-15 for grain production. Higher HUE and HTUE in timely sown could be attributed to the highest grain yield. As the temperature was optimum throughout growing period crop utilized heat more efficiently and increased biological activity that confirm higher yield.

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J. Agric. Res. Technol., 42 (3) : 132-141 (2017)

Water Requirement and Crop Coefficient for Sugarcane by Field Water Balance Method in a Semiarid Region, India

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Abstract

Crop evapotranspiration (ETc) estimation is essential for many studies such as irrigation system design and management, crop yield simulation, and water resources planning and management. Field studies were conducted at MPKV Rahuri, Maharashtra from 2015-2016 (2 years) in clay soils to determine crop evapotranspiration and crop coefficients (Kc) of sugarcane crop. The experimental area was cultivated with irrigation applied at 7-10 days interval by a drip irrigation system in addition to rainfall and the irrigation scheduling was based on field water balance approach. The crop evapotranspiration was determined by field water balance, reference evapotranspiration (ETo) by the Penman-Monteith approach while crop coefficient were computed through the standard FAO-56 methodology. On an annual basis, the total reference evapotranspiration (ETo) and crop evapotranspiration (ETc) were in the range 1318-1426 mm and 1291-1388 mm respectively. The peak ET of sugarcane varied from 3.9 mm day^{-1} in the maturity stage to 9.8 mm day^{-1} and it occurred 24 weeks after transplanting at grand growth stage. The two years average sugarcane water consumption was 1414.2 mm year^{-1} and the crop evapotranspiration was 1339.4 mm year-1. Two years results showed that there was a notable symmetry between Kc obtained from soil water balance measurements and FAO-56 reported Kc. However, estimated Kc values found lower as compared to FAO Kc values. The determined Kc values for this region during the tillering, grand growth and maturity stages for sugarcane are 0.70, 1.22 and 0.71, respectively.

Key words: Crop ET, Reference ET, Sugarcane, Crop coefficient, Field water balance.

Sugarcane (*Saccharum officinarum* L.) is one of the most important agro-industrial crops next to cotton grown in subtropical and tropical parts of the world especially in India. India ranks 2nd after Brazil among sugarcane producing countries of the world and contributes 22.5 per cent and 27 per cent in area and production of world, respectively. Sugarcane occupies about 3.40% of the total cultivated area (5.08 million ha) and it is contributing about 7.5 per cent of the gross value of agricultural production in the country with an annual sugarcane production of 348 million tonnes and average productivity of 68.5 t ha^{-1} (Pawar *et al*. 2013).

Yield of sugarcane suffer due to insufficient water supply and improper scheduling of irrigation. Sugarcane being a yearlong crop requires continuous supply of irrigation water throughout its growth cycle with differential phasic water requirement (Ingle, 2007). Available irrigation water has to be utilized in a manner that matches the water needs of this crop. Water requirements of the sugarcane are vary substantially during the growing stages mainly due to variation in crop canopy and climatic conditions (Doorenbose and Pruitt, 1977). The knowledge of crop water requirements is an important practical consideration to improve water use efficiency in irrigated agriculture. Even though India is second of the major sugarcane producing

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countries in the world, studies on water requirements of sugarcane cultivated under subtropical conditions are scarce. There is considerable scope for improving water use efficiency of sugarcane by proper irrigation scheduling which essentially governed by crop evapotranspiration (ETc). Accurate estimation of crop ET is an important factor in efficient water management.

Water resources availability is a crucial limiting factor for sugarcane production in semiarid regions of Godavari basin of western Maharashtra, India, where sugarcane cultivation depends upon irrigation (Anonymous, 2015). The area characterized with water as biggest factor for limiting crop growth and the supplemental irrigation is required to produce acceptable yields. Due to over exploitation of available water resources, water for irrigation is becoming scarce and expensive. In these areas, rainfall is low (520 mm) and erratic. The water availability is the major cause of inter-annual yield variation. It is increasingly important that water carefully used to produce maximum benefit when growing sugarcane. Therefore, the first objective of this study was to estimate crop evapotranspiration of sugarcane grown in semiarid environment of Godavari basin of western Maharashtra.

To extrapolate the measurement of ETc for irrigation planning in regional scale, crop coefficient (Kc), which is the ratio of ETc to grass reference evapotranspiration (PET), is often used. Doorenbos and Pruitt (1977) in FAO-24 and Allen *et al*. (1998) in FAO-56 suggested crop coefficient values for a large number of crops under different climatic conditions that commonly used in places where the local data is not available. However, the value reported by Allen *et al.* (1998) are average values all over the world & they emphasized the strong need to develop crop coefficients under given climatic conditions (Kashyap and Panda, 2001).

The crop coefficients have not been developed for sugarcane crop under semi-arid climatic conditions in India. The second objective of this study is to drive the Kc values for sugarcane by field water balance method for semiarid conditions. The Kc developed in the study will be useful for estimating crop water requirements for sugarcane and for the overall improvement of irrigation water management in the study area.

Materials and Methods

Experimental Site : The field experiment was carried out during the Annual seasons of 2015 and 2016 at Experimental Farm of Department of Irrigation and Drainage Engineering, MPKV, Rahuri located in the western area of Maharashtra state, India (latitude 19o 48' N; longitude 190 57' E; altitude 657 m).

The study crop was sugarcane (*Saccharum* spp.), cultivar CoM-265. The average annual precipitation is 520 mm. Out of total annual rainfall, about 80 percent rains are received from South-West monsoon (June to September), while the rest receives from North-East monsoon (October-November). The distribution of rain is erratic, uneven and is ill distributed over 15 to 37 rainy days. The annual mean maximum and minimum temperature ranges from 33 °C to 43 °C and 3.0 °C to 18 °0C, respectively. The annual mean pan evaporation ranges from 5.3 to 12.1 mm day-1 while, the sunshine hours ranges from 7 to 9 hours days^{-1}. The annual mean wind speed ranges from 3.2 to 13.09 km hr^{-1}. The annual mean maximum and minimum relative humidity range from 59 to 90 % and 21 to 61 %, respectively. Agro-climatically, the area falls under the scarcity zone of Maharashtra state. The local climate is semiarid with subtropical sugarcane cultivation and the soil type is clay.

A trench was opened in the experimental site for extracting soil samples that were used to determine the textural class, bulk density, field capacity and wilting point. The groundwater level at the experimental site dropped down to 2.0 m during the growing season. The experimental area was cultivated with irrigation applied at 7-10 days interval by a drip irrigation system, in addition to rainfall. The physical and chemical properties of main soil at study area are summarized in Table 1.

Measurements

Reference evapotranspiration : Daily measurements of air temperature, wind speed, solar radiation and relative humidity for estimating ETo as well as rainfall were made from automatic weather station observatory, situated at sugarcane experimental field for period from 12th December 2014 to 23rd December 2015 and 24th December 2015 to 31st December 2016. Irrigation scheduling was based on 100 per cent of reference evapotranspiration (ETo) which was obtained by the Penman-Monteith approach (Allen *et al.*, 1998).

$$ETo = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u(e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)}$$

Where, ETo is Reference evapotranspiration (mm day^{-1}); Rn is Net radiation at the crop surface (MJ m^{-2} day^{-1}); G is Soil heat flux density (MJ m^{-2} day^{-1}); T is Mean daily air temperature at 2 m height (°C); u^2 is Wind speed at 2 m height (m s^{-1}); es is Saturation vapour pressure (kPa); ea is actual vapour pressure (kPa); Δ is slope of vapour pressure curve (kPa $°C^{-1}$) and γ is psychrometric constant (kPa $°C^{-1}$).

Soil moisture content : Soil moisture content were measured prior to every irrigation and at midpoint of two irrigations approximately of irrigation interval during the whole crop season. Gravimetric method used for determination of the soil moisture content (Michael, 2010). The soil water content monitored at 0.15 m intervals down 075 m starting at 0.15 m.

Root zone depth : The root depth measured through destructive plant sampling. For each moisture content observation, the effective root zone was determined by carefully uprooting one healthy plant (FAO 24). Doorenbos and Kassam (1979) reported a maximum root penetration of the sugarcane plant of 100 cm, whereas most of the roots were concentrated in the top 75-80 cm of soil with only few roots below 20 cm. Therefore, a root zone depth of 75 cm considered when planning the observations.

Irrigation scheduling : The irrigation scheduling was based on soil moisture content of respective treatments. The irrigation was initiated when soil water in the root zone approached, but never depleted more than 65 per cent (FAO 56) of available soil water and reflling the profle to feld capacity. The depth of irrigation applied was calculated according to the following formula (Michael, 2010).

$$d = \sum_{i=1}^{n} \frac{FC_i - MC_i}{100} X\, BD_i X D_i \qquad (2)$$

Where, FC_i is field capacity, percentage for ith layer; MC_i is moisture content at the time of irrigation, percentage; BD_i is bulk density of soil, for ith layer gm/cc; Di is effective root zone depth, for ith layer cm; N is number of soil layers sampled in the root zone depth.

At transplanting, the common irrigation applied to all treatments that continued upto two weeks until the seedling is established. During nursery, the irrigations applied at 2 days interval as per measured crop evapotranspiration (ETc) values through climatelogical method. The value of crop coefficient for irrigation during nursery period was referred as 0.4 (FAO-56). The irrigation season ended by late November in 2015 and early December in 2016 respectively, allowing late-season soil water drawdown to expedite maturity.

Determination of Soil Water Balance : The soil water balance in the root zone over a given time interval was calculated from the mass conservation equation expressed as:

$$Etc = d + Pe - PO - DP + CE \pm \Delta Sf \pm \Delta SW \quad (4)$$

Where, d is irrigation depth; Pe is the effective rainfall; RO is the runoff from the soil surface; DP is the deep percolation below the root zone, below the root zone; ΔSW is the change in root zone water storage, CR is the capillary rise, ΔSF - Horizontal subsurface flow in or out of the root zone, and ET is the actual evapotranspiration. All the water balance components are in mm. Effective rainfall was computed by Dastane *et al.*, 1972 criteria (FAO 22). Surface runoff was neglected, once the experimental site had flat topography. To overcome runoff problem in irrigation process, drip-irrigation system used which did not produced surface runoff in irrigation process. Similarly, CR was assumed to be zero because the water table was more than about 2 m below the bottom of the root zone at the experimental site. For prevention of subsurface flow a 1 m deep ditch was dug around the periphery of experimental plot and mole drainage at 4.5 m lateral distance were laid. The change in soil water storage (ΔS) was determined as:

$$\Delta S = S_1 - S_2 \quad (5)$$

Where, S_1 and S_2 are the soli water storage at time period beginning and ending respectively. The reliability of ETc- estimates from the soil water balance method depends on the measurement or estimation accuracy of the variables in the right-hand side of the equation 4. The FAO-56 has suggested that soil water balance method can usually only give ET estimates over long periods of the order of weeklong or ten-day periods. Therefore, the interval between two successive soil moisture measurements maintained between 7-10 days excepting rainy conditions.

Computation of crop coefficients : The procedure used to obtain the Kc values was that proposed by Allen *et al*. (1998). The values of crop coefficients computed for Suru sugarcane as the ratio of crop evapotranspiration and reference evapotranspiration for the same period. The growth period divided into three stages: Tillering (development), grand growth (mid season) and maturity (end stage). Tillering stage (development stage) is just after 15 days of transplanting the seedlings when tillers are starts to emerge from mother shoot and ends when tiller starts to elongate at the beginning of grand growth; the grand growth stage is from then upto the timing when cane has achieved

Table 1. Physical and chemical properties of soil

Particulars	Initial
Soil mechanical analysis	
Classification	Sodic calciustert
Sand (%)	7.8
Silt (%)	31.4
Clay (%)	60.8
Textural class	Clay soil
Soil moisture constants	
Field capacity (%)	41.4
Permanent wilting point (%)	17.0
Bulk density (g cm-3)	1.27
Soil chemical analysis	
pH (1:2.5)	8.20
EC (dSm^{-1})	0.40
ESP (%)	14.8
Organic carbon (%)	0.46

its full growth; the maturity stage continues from then until harvest. These three growth stages correspond to those defined in FAO-56 (Allen et al. 1998) respectively as development, mid-season and end season.

The polynomial equation of following orders were fitted with Kc as the dependent variables and (t/T) as the independent variables. These are:

$$Kc_t = a_o\left(\frac{t}{T}\right)^0 + a_1\left(\frac{t}{T}\right)^1 + a_2\left(\frac{t}{T}\right)^2 \qquad (6)$$

Where, Kct is crop coefficient of tth day; a0, a1, a2 are constants of equations; t is day considered; T is total period of crop growth from planting to harvesting (days).

Agronomical practices : The sugarcane seedlings rose in nursery and transplanted in field after 40 days. The plot size was 27 x 6 m.

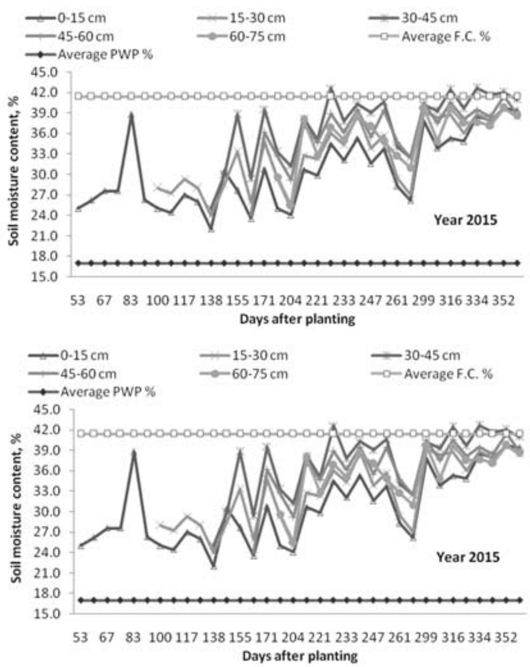

Fig. 1. and 2. Soil layerwise mositure content in 2015 and 2016 season of sugarcane

Table 2. Soil water balance components (mm) during the growth stages for sugarcane observed at the experimental site in a subtropical climate, India

Growth stage	Days	2015						2016						Average of two seasons					
		I	Pe	?S	ETc	TWC, mm	Peak use, mm/d	I	Pe	?S	ETc	TWC, mm	Peak use, mm/d	I	Pe	?S	ETc	TWC, mm	Peak use, mm/d
Initial	55	52.1	–	–	52.1	52.1	3.9	49.3	–	–	49.3	49.3	4	50.7	–	–	50.7	50.7	4.0
Tillering	75	211.1	53.2	4.6	268.9	264.3	4.5	277.6	0	-16.5	261.1	277.6	5.6	244.3	26.6	-6.0	265.0	270.9	5.1
Grand growth	170	799.0	243.8	-104.5	938.2	1042.8	10.5	372.4	534.3	-72.2	834.4	906.7	9.1	585.7	389.1	-88.4	886.3	974.7	9.8
Maturity	65	110.5	16.2	2.0	128.7	126.7	3.2	109.0	0	37.1	146.1	109.0	4.6	109.7	8.1	19.6	137.4	117.8	3.9
Total	365	1172.6	313.2	-97.9	1387.9	1485.8	–	808.3	534.3	-51.7	1290.9	1342.6	–	990.4	423.8	-74.8	1339.4	1414.2	–

Pe = Effective rainfall, I = irrigation, ETc = crop evapotranspiration (I+Pe+ ?S), ?S = water storage change; Total water consumption (TWC) = (I+Pe)

The same plot selected for obtaining soil water content. The transplanting done on 26th January and 1st February of season 2015 and 2016 respectively. Sugarcane seedlings transplanted at the spacing of 1.5 x 0.6 m. The other agronomic practice *viz*., weeding, off barring, earthing up and fertigation schedule were followed as per recommended by parent Agricultural University i.e. MPKV Rahuri.

Results and Discussion

Average soil moisture : The moisture content found increased with increase in soil layer depth upto 45 cm and thereafter it slightly decreased at 60 cm and lowest moisture content observed at 75 cm depth (Fig.1-2). During tillering stage, more soil moisture depletion observed, however, when plant canopy fully developed after earthing up operation, the soil moisture depletion was uniform in all layers (Singh and Mohan, 1994; Raghuvanshi and Wallender, 1998).

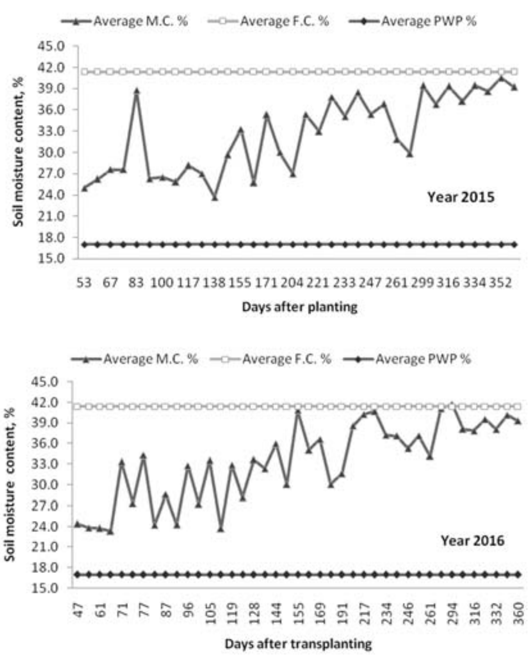

Fig. 3. and 4. Average soil mositure content in 2015 and 2016 season of sugarcane

The average soil moistures during different growth stage of 2015 and 2016 crop season are depicted in Fig. 3 and 4. The Figs. 3 and 4 revealed that particular growth stage and incident of rainfall greatly influenced the average moisture content of soil. Invariably of growth stages and barring rainfall events, the moisture content was closer to field capacity. The soil moisture content increased with increase in crop evapotranspiration during the growth period. In tillering period, the soil moisture content was low and increased with irrigation depth. In 2015, during tillering stage, two intensive rainfall amounting 35 mm shoots up the soil moisture near to field capacity In all treatments. Thereafter with occurrence of rainfall in grand growth stage, the available soil moisture increased and approached to field capacity in most of the observation. However, during maturity stage, the crop water use was largely reduced which resulted in high soil moisture content in soil root zone.

The rainfall events, duration and amount were more in 2016 thus, available moisture increased considerably in soil root zone. In tillering period, soil moisture rapidly increased with rapid increase in crop evapotranspiration mainly due to high temperature and evaporative demand. The beginning of grand growth stage coincided with early monsoon event of 71 mm and further light to moderate rain events contributed to soil moisture during mid to end of grand stage. The monsoon recession also coincided with end of grand growth stage with heavy rainfall event of 63 mm. largely; more soil moisture was available in grand growth stage as compared to 2015. In maturity stage of 2016 season, the soil moisture content was more close to field capacity. This was due to stored soil moisture maintained by monsoon recession and low crop water use in maturity stage.

Soil water balance

Irrigation water applied : The irrigation depth differed for a particular growth stage in a season due to differences in crop water use and duration of stage (Table 2). Total depth of irrigation water applied during nursery period and two weeks period after transplanting was 52.1 mm and 49.3 mm in 2015 and 2016 respectively. The total depths of irrigation water applied during 2015 and 2016 were 1172.6 mm and 808.3 mm, respectively (Table 2).

Invariably in both seasons, grand growth stage identified as high water requirement stage due to its long duration (165-170 days). This followed by tillering stage (75-80 days) and maturity stage (65- 70 days). The irrigation water applied in grand growth stage of 2016 was less half (372.4 mm) than 2015 (799 mm), because of the higher contribution of rainfall in crop water use in 2016. However, irrigation water amount in tillering stage (277.6 mm) was higher in 2016 than in 2015 (211.1 mm); because of the higher evaporative demand. In both seasons, the lowest irrigation water applied for the maturity stage among all stages. This happened because of decline in crop water use with crop maturity. In addition, pushing of sugarcane for lodging prevention at beginning of this stage further reduced evapotranspiration.

Effective rainfall : The effective rainfall during crop growth period of 2015 and 2016 was 313.2. mm in 38 rainy days and 534.3 mm in 40 rainy days, respectively. The occurrence of rainfall affected the depth of irrigation in both the seasons. In 2016, more irrigation amount was applied in tillering stage (February-Mid May) due to high evaporative demand. The respective grand growth stages of crop coincided with South West monsoon, that contributed consumptive use and therefore demand of irrigation water was differed in 2015 and 2016 season. In 2015, the effective rainfall was 40 % less than average rainfall (520 mm) therefore; more irrigation water applied in that season. However, in 2016, effective rainfall (534.3 mm) contributed almost 41 % of crop consumptive use and therefore demands of irrigation water reduced to half in 2016. In maturity stage, no rainfall received in both the season and thus, irrigation amounts for both the seasons were almost same in this stage.

Total water use : The total water consumption calculated by adding the irrigation water and effective rainfall for 2015, 2016 and average of both seasons given in Table 2. The total depths of water consumption during 2015, 2016 and average of two seasons were 1485.8 mm, 1342.6 mm and 1414.2 mm respectively. The total water consumption varies considerably from place to place depending on weather conditions, texture of

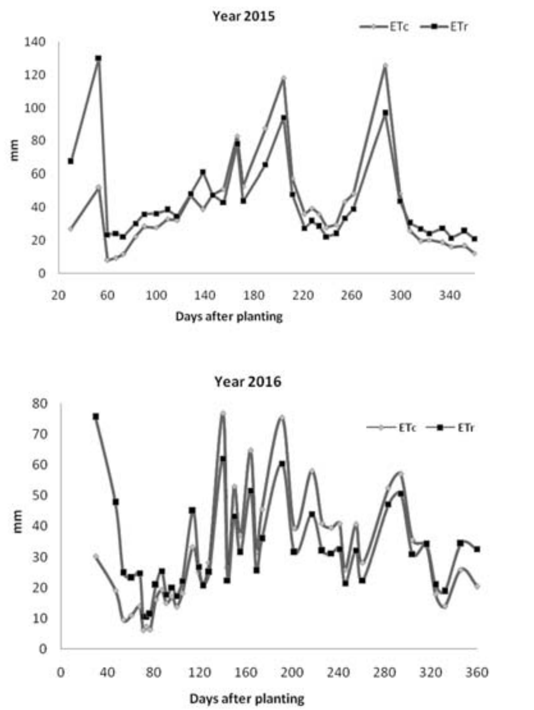

Fig. 5. and 6. Crop evapotranspiration and reference evapotranspiration in season 2015 and 2016

soil and duration of the crop. Earlier, some researchers (Tiwari 2006, Singh *et al.* 2007, Srivastava *et al.* 2011, Bhunia *et al.* 2016, Bhingardeve, 2017) have reported that water consumption of Suru sugarcane for Indian conditions ranged from 1100 to 1800 mm. The water consumption in conventional irrigation in canal command area has reported as 2500 mm for Suru sugarcane crop (Srivastav *et al.* 2011). However, water use largely depends upon type of method used by these researchers to estimate water used. Some researchers used IW/CPE ratio (Tiwari 2006, Singh et al. 2007, Bhunia *et al.* 2016) whereas other have used (Bhingardeve 2017) pan evaporation approach. Most of the researchers followed IW/CPE approach in which 80 mm water depth applied at irrigation interval of 75 mm CPE. This depth usually derived by based on 50 per cent depletion of soil moisture in extended root zone of matured crop. This gives a large irrigation depth at beginning of crop period and smaller depth during the peak use period. Further, the contribution of effective rainfall in crop growth is also not clear from such studies.

In this investigation, the water balance for actual root zone derived. The soil water content taken in this study clearly exhibited the contribution of rainfall in soil. Therefore, the water consumption of this investigation has come out as 1414.2 mm that seems to be appropriate. However, in this investigation nursery planting is encouraged which also saved three irrigations, which amount as 240 mm.

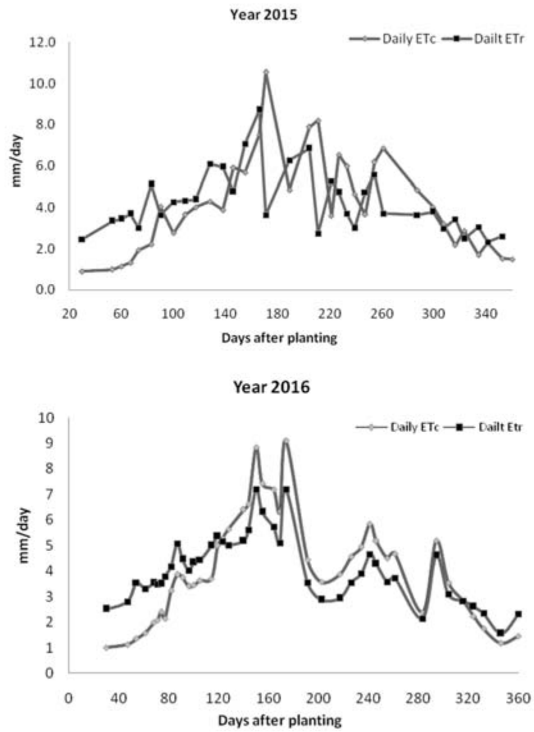

Fig. 7. and 8. Daily crop evapotranspiration and daily reference evapotranspiration in season 2015 and 2016

Crop evapotranspiration : The highest and lowest values of crop evapotranspiration (ETc) occurred in the grand growth (mid-season) and maturity stage (End stage), respectively, as a natural consequence of the lengths of crop development stages. In 2015, irrigation application was high and rainfall amount was

Table 3. Values of crop coefficient for each crop growth stage of sugarcane based on FAO-56 methodology (Allen et al., 1998) and soil water balance (SWB)

Growth stage	FAO Kc	2015	% variation	2016	% variation	Average	% variation
Initial	0.40	0.40	0.0	0.40	0.0	0.40	0.0
Tillering	0.85	0.67	-21.2	0.72	-15.3	0.70	-18.2
Grand growth	1.25	1.20	-4.0	1.23	-1.6	1.22	-2.8
Maturity	0.75	0.68	-9.3	0.74	-1.3	0.71	-5.3
Average	0.81	0.74	-8.6	0.77	-4.6	0.76	-6.6

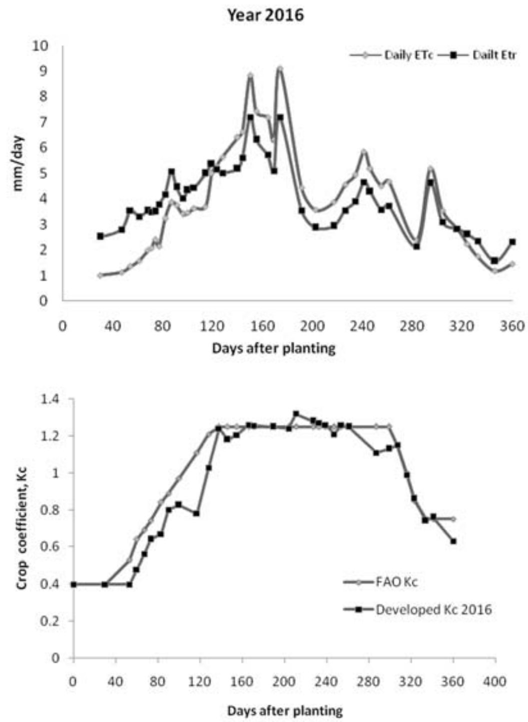

Fig. 9. and 10. FAO-56 Kc (Allen *et al.*, 1998) and Kc developed by soil water balance for sugarcane season 2015 and 2016

low in the grand growth period that resulted in high water use (P and/or I) which had a positive impact on evapotranspiration increase. As can be observed, ΔS also showed a variation in two seasons. Average ΔS varied from Δ6 mm to 19.6 mm from tillering to maturity stage due to the increase in irrigation application.

The crop evapotranspiration (ETc) and reference evapotranspiration (ETr) values for entire crop seasons of 2015 and 2016 are depicted in Fig. 5 & 6. The total ETr estimated over entire crop season was higher as 1425.7 mm in 2015 season over 1317.8 mm in 2016. Because of this, the crop evapotranspiration (ETc) was lower for 2016 (1290.9 mm) than 2015 (1387.9 mm).

The daily crop evapotranspiration (ETc) and reference evapotranspiration (ETr) values for entire crop season of 2015 and 2016 are depicted in Fig. 7 & 8. The highest and lowest values of both daily crop evapotranspiration (ETc) and reference evapotranspiration (ETr) values were observed in grand growth (mid-season) and tillering stage (development stage), respectively.

Crop coefficient of sugarcane : From the comparison, it appears that there was always a good correspondence between Kc-developed and Kc-FAO in the both growing season. However, some variations observed along the growth stages in both seasons (Table 3). The average variation between FAO Kc and developed Kc was about -6.6%. The highest variation between FAO Kc and developed Kc occurred on tillering stage (-18.2%). In practice, results reported here showed that FAO-Kc could lead to over estimation in irrigation scheduling of sugarcane in semiarid conditions, as Kc values based on soil water balance are slightly lower than recommended by FAO- Kc. The crop coefficient values derived from field soil water balance during the tillering, grand growth and maturity stages for sugarcane in a semiarid region are 0.70; 1.22 and 0.71, respectively. The result is consistent with previous studies, that conditions of lower wind speed will have lower values for Kc (Allen et al., 1998). The effect of the difference in aerodynamic properties between the grass reference surface and agricultural crops is not only crop specific but also varies with climatic conditions. This is because the results of these

Table 4. Crop coefficient equations of different orders of polynomials for sugarcane for year 2015, 2016 and average of two season

Season	2nd order polynomial Equation	R^2
2015	$Kct = -5.654(t/T)^2+6.2987(t/T)-0.4869$	0.94
2016	$Kct = -5.2548(t/T)^2+5.8191(t/T)-0.3036$	0.96
Average	$Kct = -5.454(t/T)^2+6.0589(t/T)-0.3953$	0.98

Kct is crop coefficient on tth day; t is number of days since transplanting; and T is total crop period studies obtained either for other climate conditions or for sugarcane/varieties/ transplanted sugarcane.

Kc values are represented in the form of polynomial equation, with respect to the ratio of days to total crop period for season 2015, 2016 and average of 2 seasons in Tables 4.

Conclusion

The study evaluates the crop evapotranspiration and applicability of the crop coefficient for sugarcane in a semiarid region, India, and compares the developed Kc by the field water balance with crop coefficients of FAO-56. The crop evapotranspiration of sugarcane by field soil water balance method for semiarid conditions was estimated as 1339.4 mm. The peak ETc of sugarcane was occurred in the grand stage as 9.8 mm day^{-1} while lowest in maturity stage as 3.9 mm day^{-1}. The estimated Kc values for this region during the tillering, grand growth and maturity stages for sugarcane are 0.70, 1.22 and 0.71, respectively. The calculated values are slightly lesser than those suggested by FAO-56 for sugarcane. However, observed variation between values from the FAO-Kc and Kc calculated by field water balance are not significant. So, these values can be used for irrigation scheduling of sugarcane in semiarid region.

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J. Agric. Res. Technol., 42 (3) : 142-148 (2017)

Development of Deficit Irrigation Practices under Drip for Marigold- Rabi Sorghum Crop Sequence for Varied Planting Techniques in Changing Climate Scenario

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Abstract

A field investigation was conducted at the AICRP on Irrigation Water Management, MPKV, Rahuri (M.S.) during the years 2012-15. The experimental soil was well drained and clayey in texture, low in available nitrogen, medium in available phosphorus and high in potassium. The experiment was laid out in split plot design with three replications having main plots of four irrigation regimes and five Sub plot treatments of planting/sowing methods. The yield and water requirement of summer marigold was significantly higher at 100% PE followed by 80% PE while lowest was at 40% PE irrigation with water saving 61.28% at 40% PE and lowest 10.06% at 100% PE. Marigold planted at 60 x 10 cm with lateral spacing 120 cm recorded highest yield of flowers. Water requirement was higher at 60 x 10 cm planting with lateral spacing 120 cm with the highest water use efficiency at 30-60 x 15 cm planting with 90 cm lateral spacing with maximum water saving 49.53%. The grain yield of sorghum was the highest at 90% ETc. with planting at 45 x 15 cm at 90 cm lateral spacing. The highest grain equivalent yield at 100% ETc was recorded with paired planting of sorghum 30-60 x 15 cm with lateral spacing 90 cm. Water use efficiency was higher at 80% ETc with 30-60 x 15 cm with lateral spacing of 90 cm. Water saving (63.18%) was highest at 70% ETc irrigation alongwith 30-60 x 15 cm planting with lateral spacing 90 cm whereas the lowest (48.12%) was at 45 x 15 cm planting with lateral spacing 90 cm and 60 x 10 cm with lateral spacing 120 cm, respectively. The economics of rabi sorghum-marigold cropping sequence of I_1S_2 i.e. irrigation at 40% PE (marigold) and 70% ETc (*rabi* sorghum) was found superior.

Key words : Irrigation regimes, planting layouts, *rabi* sorghum, marigold, crop sequence.

The marigold (*Tagetes erecta* L.) which occupies a prominent place in ornamental horticulture, is one of the commercially exploited flower crops belonging to the family Asteraceae. Marigold is broadly divided in two groups, viz, African marigold (*Tagetes erecta* L.) and French marigold (*Tagetes putula* L.). The farmers generally grows tall and is known as tall marigold and latter is short called as dwarf marigold. *Tagets erecta* and the *Tagetes patula* L. owe their origin to Mexico and *S. Africa*, respectively. Though, it is an introduction considering its acceptability under Indian conditions, it is presumed that marigold is of Indian origin Desai (1967).

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Considering, its importance in commercial cultivation and as a short duration crop its adaptability under drip irrigation is not so far studied in Maharashtra state. Therefore, the attempt has been made by taking the experiment on marigold followed *rabi* Sorghum to judge its adaptability under drip irrigation to study the irrigation water requirement.

Sorghum or Jowar is a main steple food of Maharashtra state and also due to its excellent fodder quality it is fed to the animals. *Rabi* Jowar is mainly grown on receding soil moisture and in some parts of Maharashtra it is grown on irrigation. Like most other grain crops, grain sorghum responds to irrigation more at certain growth stages (boot, flower and grain fill) when water use is greater than at other stage (early vegetative and dough) when the demand is less. Adequate soil moisture is most important during the booting, heading, flowering and grain filling stages of plant growth. Although sorghum can tolerate short periods of water deficit, extended moisture stress slows plant growth and grain development that can reduce yields, especially if it occurs during critical reproductive stages when water needs are highest. More healthy, functioning leaves typically lead to greater yield. However, day by day due to drought and uneven erratic distribution of rainfall, it is getting very difficult to grow *rabi* sorghum. Some time at peak period of water requirement of crop it suffers from shortage of irrigation. Secondly, crop taken on irrigation water also is in problem due to acute shortage of water since the water table gone down. Hence, its important in human and animal consumption, to get the sustainable grain and fodder yield it is very essential to try this crop under drip irrigation. Therefore, the attempt has been made by taking this crop in sequence of marigold followed by *rabi* sorghum under drip irrigation.

Materials and Methods

The Field experiment was conducted at AICRP on Irrigation Water Management, M.P.K.V., Rahuri during the years 2012-15, laid out in split plot design with three replications as given below. Irrigation at alternate day through drip. Variety Calcutta Gold for marigold and Phule Suchitra for *rabi* sorghum were used. Fertilizer dose for marigold was 100: 50:50 and *rabi* sorghum 80 : 40 : 40 N, P_2O_5, K_2O kg ha^{-1}, respectively alongwith10 tonnes of FYM was used.

The soil clayey in texture with pH 7.80, Ec 0.24 dSm^{-1}, Organic carbon 0.48 per cent, low in available N, moderate in available P and high in available K content with 90 cm depth. The soil had Hydraulic conductivity 0.93 cm hr^{-1}, Bulk density 1.34 Mg m^{-3}. The soil and plant samples were analysed for different parameters before and after the harvest of the crops by using standard methods of analysis as mentioned by Jackson (1973). The biometric and yield observations were recorded. The data generated was analysed and interpreted as per guidelines given by Panse and Sukhatme (1985).

Treatment details of Summer Marigold and *Rabi* Sorghum

Summer Marigold	***Rabi* Sorghum**
A) Irrigation regimes (4)	
I_1 - Irrigation at 40% PE	I_1 - Irrigation at 70% ETc
I_2 - Irrigation at 60% PE	I_2 - Irrigation at 80% ETc
I_3 - Irrigation at 80% PE	I_3 - Irrigation at 90% ETc
I_4 - Irrigation at 100% PE	I_4 - Irrigation at 100% ETc
B) Planting methods	
S_1 : 45 x 15 cm, lateral spacing 90 cm	S_1 : 45 x 15 cm, lateral spacing 90 cm
S_2 : 30-60 x 15 cm, lateral spacing 90 cm	S_2 : 30-60 x 15 cm, lateral spacing 90 cm
S_3 : 60x 10 cm, lateral spacing 120 cm	S_3 : 60x 10 cm, lateral spacing 120 cm
S_4 : 45-75 x10 cm, lateral spacing 120 cm	S_4 : 45-75 x10 cm, lateral spacing 120 cm
Control	
S_5 : 45 x 15 cm row spacing under surface irrigation (Irrigation at 75 mm CPE at 7.5 cm depth)	S5: 45 x 15 cm row spacing under surface irrigation (Irrigation at 75 mm CPE at 7.5 cm depth)

Results and Discussion

Summer Marigold

Effect of irrigation regimes : The irrigation regime of 100% PE recorded higher number of flowers per plant and weight of flowers per plant i.e. 55.81 and 0.26 kg per plant, respectively over 40% PE and 80% PE except the 80% PE irrigation regime recorded at par values of number of flowers per plant and weight of flowers per plant i.e. 55.03 and 0.26 kg respectively (Table 1).

The yield of summer marigold flower (Table 1) as influenced by different irrigation regimes revealed that yield of flower was significantly higher (17.83 t ha^{-1}) when marigold crop was irrigated at 100% PE irrigation over control (11.86 t ha^{-1}) except in order of sequence 80% PE irrigation level (16.91 t ha^{-1}). It was further noticed that as the irrigation applied in deficit the yield of marigold flower was reduced.

Water saving : The maximum total water requirement was noticed (70.26 cm) when marigold was irrigated at 100% PE and the lowest was at 40% PE irrigation 28.11 cm. The water use efficiency was higher at 40% PE irrigation 505.10 kg-ha-cm^{-1} whereas, the lowest under 100% ETc irrigation 61.28 kg-ha-cm^{-1} same trend was noticed in case of water saving, the 40% PE irrigation recorded 63.18% water saving while 100% PE recorded least saving of 10.06%. The above results corroborate with results obtained by Hasan *et al*. (2008) and Limkar (2013).

Effect of planting methods : The number of flowers $plant^{-1}$ (56.35) were significantly higher when marigold was planted

Table 1. Yield contributing characters, yield and water saving of summer marigold as influenced by different treatments (Pooled 2012-2015)

	No. of flowers $plant^{-1}$	Wt. of flower $plant^{-1}$ (kg)	Yield (t ha^{-1})	Total water applied (cm)	Water use efficiency (kg ha-cm^{-1})	Water saving (%)
A) Irrigation regimes (4)						
I_1 - Irrigation at 40% PE	53.58	0.23	15.96	28.11	505.10	61.28
I_2 - Irrigation at 60% PE	53.57	0.23	16.94	42.16	361.64	47.04
I_3 - Irrigation at 80% PE	55.03	0.25	16.91	56.21	275.14	25.30
I_4 - Irrigation at 100% PE	55.81	0.26	17.83	70.26	238.14	10.06
SE ±	0.50	0.05	0.18	–	–	–
CD 5%	1.55	0.02	0.52	–	–	–
B) Planting methods						
S_1 : 45 x 15 cm, lateral spacing 90 cm	53.24	0.21	16.84	51.65	281.83	28.59
S_2 : 30-60 x 15 cm, lateral spacing 90 cm	53.89	0.21	18.07	34.61	434.30	49.53
S_3 : 60x 10 cm, lateral spacing 120 cm	56.35	0.26	18.43	71.74	237.87	11.68
S_4 : 45-75 x10 cm, lateral spacing 120 cm	55.98	0.27	17.54	38.74	395.80	45.96
SE ±	0.48	0.03	0.16	–	–	–
CD 5%	1.45	0.01	0.43	–	–	–
Interaction	NS	NS	NS	–	–	–
Control						
S_5 : 45 x 15 cm row spacing under surface irrigation (Irrigation at 75 mm CPE at 7.5 cm depth)	51.38	0.21	11.86	87.79	141.79	–

at 60 x 10 cm with lateral spacing 120 cm, but was at par with S_4 treatment i.e. 45-75 x 10 cm with lateral spacing 120 cm.(55.98). The weight of flower plant^{-1} was higher (0.27 kg) when marigold planted at 45-75 x 10 cm with lateral spacing 120 cm, however, it was at par with S_3 treatment i.e. 60 x 10 cm with lateral spacing 120 cm (0.26).

Pooled yield data (Table1) showed that, significantly higher yield (18.43 t ha^{-1}) was recorded when marigold was planted at 60 x 10 cm with lateral spacing of 90 cm over control 11.86 t ha^{-1}., but it was at par with the treament S_2 i.e. 30-60 x 15 cm with lateral spacing 90 cm (18.03 t ha^{-1}).

This might be due to optimum moisture and aerated conditions in the soil and this reflected in good physiological activity resulting into increase in yield. In addition to this, the irrigations were scheduled at alternate days maintaining the soil moisture as per the treatments of irrigation regimes. The lowest yield was obtained in 40% PE due to moisture stress during crop growth period. These results are in conformity to the results published by of Samantaray *et al*. (1999), Yadav *et al*. (2004) and Limkar (2013).

Water saving : The maximum total water requirement was noticed at irrigation regime of 100% PE (70.26 cm) whereas, the lowest was

Table 2. Yield contributing character, yield and water saving of *Rabi* Sorghum as influenced by different treatments (Pooled 2012-2015)

Treatments	Grain wt. ear head^{-1} (g)	100 grain weight (g)	Grain yield (q ha^{-1})	Fodder yield (t ha^{-1})	Sorghum equi-valent yield (q ha^{-1})	Total water app-lied (cm)	Water use efficiency (kg ha-cm^{-1})		Water saving over surface (%)
							Grain	Fodder	
A) Irrigation regimes (4)									
I_1 - Irrigation at 70% ETc	106.10	42.33	37.80	12.75	235.22	19.84	189.63	632.18	63.18
I_2 - Irrigation at 80% ETc	110.69	43.60	43.04	12.90	254.76	22.56	189.78	588.15	58.09
I_3 - Irrigation at 90% ETc	112.22	43.77	43.28	14.03	254.62	25.38	168.69	544.29	52.81
I_4 - Irrigation at 100% ETc	110.40	42.49	42.10	14.12	264.73	28.01	149.11	538.65	47.91
SE ±	4.10	0.35	1.65	0.31	5.35	–			
CD 5%	NS	1.05	5.20	0.91	15.29	–			
B) Planting methods									
S_1 : 45 x 15 cm, lateral spacing 90 cm	106.83	42.35	41.35	12.74	248.31	27.91	146.92	467.43	48.12
S_2 : 30-60 x 15 cm, lateral spacing 90 cm	108.33	43.33	42.88	12.90	255.36	19.52	218.81	675.14	63.79
S_3 : 60x 10 cm, lateral spacing 120 cm	114.83	43.75	39.58	14.03	251.69	27.91	140.96	509.37	48.12
S_4 : 45-75 x 10 cm, lateral spacing 120 cm	108.04	43.00	42.24	14.12	253.97	20.64	202.83	690.24	61.54
SE ±	4.33	0.45	0.99	0.38	2.20	–	–	–	–
CD 5%	NS	1.25	2.78	1.06	6.18	–	–	–	–
Interaction	NS	NS	NS	NS	NS	–	–	–	–
Control									
S_5 : 45 x 15 cm row spacing under surface irrigation (Irrigation at 75 mm CPE at 7.5 cm depth)	114.93	41.78	35.91	7.94	35.91	54.91	65.10	141.63	–

noticed at 40% PE of irrigation (28.11 cm). The maximum water use efficiency was recorded at 40% PE of irrigation (505.10 kg-ha-cm^{-1}) and the lowest was recorded (238.14 kg-ha-cm^{-1}) at 100% PE of irrigation. The higher water saving of 61.28% was obtained at 40% PE of irrigation and lower was at 100% PE of irrigation 10.06%.

Among the planting methods, the maximum total water requirement was noticed when marigold was planted at 60 x 10 cm with lateral spacing 120 cm (71.74 cm) while, it was recorded the lowest under 30-60 x 15 cm with lateral spacing 90 cm (34.61 cm). The maximum use efficiency (434.30 kg-ha-cm^{-1}) was noticed when marigold was planted at 30-60 x 15 cm with lateral spacing 90 cm., followed by 45-75 x 10 cm with 120 cm lateral spacing (395.80 kg-ha-cm^{-1}). It was observed that water use efficiency was more in paired planting and the same trend was noticed in water saving i.e. 49.53 per cent at 30-60 x 15 cm lateral spacing 90 cm and 45.96 per cent at 45-75 x 10 cm with 120 cm lateral spacing. Similar results were also reported by Rego *et al*. (2004)

Rabi sorghum

Effect of irrigation regimes : The 1000 grain weight (Table 2) was significantly influenced due to different irrigation regimes. The 90% ETc of irrigation level registered significantly higher 1000 grain weight (43.77 g) over all the other treatments except 80% ETc of irrigation level (43.60 g) was at par with each other.

It was revealed that, significantly higher (43.28 q ha^{-1}) sorghum grain yield was

Table 3. Economics of the *rabi* sorghum-marigold cropping sequence as affected by different treatments (Pooled 2012-15)

Particulars	I_1S_2	I_1S_4	I_2S_4	I_3S_2	I_4S_2	I_4S_3	I_4S_4	C-I
Fix cost (Rs.)	12526	8040	8040	12526	12526	8040	8040	0
Operational Cost (Rs.)	151762	151762	151762	151762	151762	161071	151762	151762
Seasonal Cost (Rs.)	164288	159802	159802	164288	164288	169111	159802	151762
Water used (cm)	32.07	35.90	77.61	52.99	63.44	118.55	71.01	117.38
Grain equavalent yield of Sorghum (q ha^{-1})	241.58	242.79	260.74	254.86	265.41	268.71	259.86	162.09
Fodder yield of Sorghum (t ha^{-1})	11.33	12.50	13.84	13.80	14.43	14.86	15.97	7.03
Selling price of Grain (Rs. q^{-1})	2000	2000	2000	2000	2000	2000	2000	2000
Selling price of Fodder (Rs. t^{-1})	3500	3500	3500	3500	3500	3500	3500	3500
Income from Produce Grain (Rs. ha^{-1})	483160	485580	521480	509720	530820	537420	519720	324180
Income from Produce Fodder (Rs. ha^{-1})	39655	43750	48440	48300	50505	52010	55895	24605
Total Income (Grain + Fodder) (Rs. ha^{-1})	522815	529330	569920	558020	581325	589430	575615	348785
Net seasonal Income (Rs. ha^{-1})	358527	369528	410118	393732	417037	420319	415813	197023
Additional Area (ha)	2.66	2.27	0.51	1.22	0.85	0.00	0.65	0.00
Additional Expenditure (Rs.)	437026	362693	81888	199632	139686	0	104352	0
Additional Income (Rs.)	1390750	1201387	292046	678070	494273	0	375880	0
Additional Net Income (Rs.)	953724	838694	210158	478438	354587	0	271528	0
Gross Cost (Rs.)	601314	522495	241690	363920	303974	169111	264154	151762
Total net income (Rs.)	1312251	1208222	620276	872170	771624	420319	687341	197023
B:C Ratio	2.18	2.31	2.57	2.40	2.54	2.49	2.60	1.30
Net extra income over control (Rs.)	1115228	1011199	423253	675147	574601	223296	490318	0
Net profit (cm water use^{-1})	40918	33655	7992	16459	12163	3545	9680	1679
WUE (kg ha-cm^{-1})	753.29	676.30	335.96	480.96	418.36	226.66	365.95	138.09

recorded at 90% ETc over 70% ETC of irrigation but was at par with 80% ETc of irrigation (43.04 q ha^{-1}) and 100% ETc (42.10 q ha^{-1}). The 100% ETc of irrigation applied to sorghum recorded significantly higher fodder yield 14.12 t ha^{-1} over 70% and 80% ETc of irrigation, but it was at par with irrigation applied at 90% ETc (14.03 t ha^{-1}).

This might be because of the judicious use of water received at all stages of crop growth maintaining proper moisture due to drip irrigation and spacing properly maintained for root proliferation. These results are in conformity to those obtained by Bhakare and Fatkal (2008) and Girase *et al*. (2016)

Water saving : The maximum total water requirement was noticed (28.10 cm) when sorghum was irrigated at 100% ETc and the lowest was at 70% ETc irrigation 19.84 cm. The water use efficiency of grain and fodder was higher at 80% ETc irrigation 184.78 kg-ha-cm^{-1} whereas, in case of fodder it was higher at 70% ETc irrigation 632.18 kg-ha-cm^{-1} same trend was noticed in case of water saving, the 70% ETc irrigation recorded 63.18% water saving while100% ETc recorded least saving of 47.91%. Similar results of water use efficiency are noted by Singh *et al*. (2010)

Effect of planting methods : The data in Table 2 revealed that maximum 1000 grain weight was significantly higher S3: 60 x 10 cm planting with 120 cm (43.75 g) being at par with the treatments S_2: 30-60 x 15 cm with 90 cm lateral spacing (43.33g) and S4 :45-75 x 10 cm with lateral spacing 120 cm (43.00g).

Significantly higher grain yield (42.88 q ha^{-1}) was recorded by S_2:30-60 x 15 cm with 90 cm lateral spacing being at par with the treatment S_4 :45-75 x 10 cm with lateral spacing 120 cm (42.24 q ha^{-1}). The fodder yield (14.12 t ha^{-1}) was significantly higher under the treatment paired planting at 45-75 x 10 cm with lateral spacing 120 cm and was at par with the planting of 60 x 10 cm lateral spacing 120 cm (14.03 t ha^{-1}).

Water saving : Data in respect of water requirement and water use efficiency was presented in (Table 2) which revealed that, in different planting methods water requirement of *rabi* sorghum was different it was maximum (27.91 cm) when *rabi* sorghum planted at 45 x 15 cm and 60 x 10 cm i.e. at sole planting of *rabi* sorghum at lateral spacing of 90 and 120 cm, respectively., but when *rabi* sorghum was planted at paired planting method; the water requirement was lower i.e. 19.52 cm and 20.64 cm at 30-60 x 15 cm at 90 cm lateral spacing and 45-75 x 10 cm lateral spacing of 120 cm, respectively.

The water use efficiency was higher in grain (218.81 kg-ha-cm^{-1}) at 30-60 x 15 cm with lateral spacing 90 cm while for fodder it was higher (690.24 kg-ha-cm^{-1}) at 45-75 x 10 cm with 120 lateral spacing. Water saving was maximum 63.79% at 30-60 x 15 cm and at 45-75 x 10 cm 61.54% with lateral spacing of 90 cm and 120 cm, respectively.

Yield reduction under stress might be due to adverse effect of soil moisture stress on the growth and development of plant. Water stress increase accumulation of compatible solutes like proline, sugar, alcohol, sorbitol and quanternary amine betaine and tries to maintain turgor for stress tolerance and inhibits dehydration of mesophyll cells (Rouphael *et al*.2008).

Sorghum grain equivalent yield : The summer marigold yield as recorded due to different irrigation regimes and different planting methods was converted to sorghum grain equivalent yield and presented in (Table 2). It revealed that; sorghum grain equivalent yield (q ha^{-1}) was significantly differed due different irrigation regimes and was the highest

(264.73 q ha^{-1}) under the treatment 100% ETc of water, however, it was at par with the treatments 80 and 90% ETc i.e. 254.76, 254.62 q ha^{-1}, respectively.

Due to different planting methods it was noticed that; the sorghum equivalent yield was the highest (255.36 q ha^{-1}) under the treatment S_2:30-60 x 15 cm with 90 cm lateral spacing being at par with the treatments S_4 :45-75 x 10 cm with lateral spacing 120 cm (253.97 q ha^{-1}) and S_3: 60 x 10 cm planting with 120 cm (251.69 q ha^{-1}).

Economics of sequence cropping : The economics of summer marigold followed by *rabi* sorghum crop sequence are presented in Table 3. It is revealed from the data that summer marigold followed by *rabi* sorghum cropping sequence recorded the highest net extra income, net profit per cm use of water and water use efficiency (kg ha cm^{-1}) by I_1S_2 combination i.e. 40% PE of irrigation to marigold and 70% ETc of irrigation to rabi sorghum with paired planting of marigold and *rabi* sorghum at 30-60 x 15 cm with lateral spacing of 90 cm i.e. Rs. 11,15,228, 40,918 and 753.29, respectively. However, B:C ratio was higher (2.60) recorded by I_4S_4 combination i.e. 100% PE irrigation to marigold and 100% ETc to *rabi* sorghum with paired planting of 45-75 x 10 cm lateral spacing of 120 cm.

Conclusion

Planting of summer marigold and *rabi* sorghum (Var. Phule Suchitra) in medium deep soils of Western Maharashtra for obtaining higher yield, water saving, net extra income and water use efficiency, marigold and *rabi* sorghum may be planted in sequence under drip irrigation at paired row planting of 30-60 x 15 cm with lateral spacing 90 cm and be irrigated at 40% evaporation to marigold and at 70% ETc to *rabi* sorghum at every alternate day.

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J. Agric. Res. Technol., 42 (3) : 149-153 (2017)

Relationship Between Spectral Reflectance, NDVI and Water Stress Conditions of Soybean (*Glycine max* L.)

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Abstract

The experiment was conducted at the instructional farm of Department of Irrigation and Drainage Engineering, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, during Kharif season of 2015 to study the effect of water stress on spectral reflectance and Normalized Difference Vegetation Index (NDVI) of soybean. The crop was subjected to six different water stress (WS) conditions (I_1 - 0% WS, I_2 - 20% WS, I3 - 40% WS, I_4 - 60% WS, I_5 - 80% WS and I_6 - 100% WS) based on 50 mm cumulative reference evapotranspiration using FAO pan Evaporimeter method. The experiment was laid out in randomized block design with four replications. Spectral reflectances were measured every week for all the treatments using a spectroradiometer in the range of 450-2500 nm at an interval of 1 nm in blue, green, red (IR) and near-infrared (NIR) wavebands. The spectral reflectances increased with water stress from 3.15 to 7.15%, 6.67 to 15.37% and 3.11 to 6.93% in blue, green and IR wavebands, respectively. The spectral reflectances in NIR waveband decreased from 59.83 to 37.13% with increase in water stress from 0% to 100%. The NDVI values estimated on the basis of reflectances in IR and NIR wavebands decreased with increase in water stress. The analysis of spectral reflectances showed that, the water stress could be quantified by using spectral reflectance, especially IR and NIR regions. The overall analysis of experimental data indicated that the spectral reflectance data can be used to assess the water stress conditions of soybean (*Glycine max* L.)

Key words : Water stress, spectral reflectance, NDVI, soybean.

Water stress is one of the most important crop growth limiting factors in crop production. Several methods have been used to detect and evaluate the effect of water stress on plant growth. However, evaluation of water stress level to which crops are subjected to is important for the quantification its effect on crop production. Remote sensing is tool to detect and quantify the effect of water stress (Mirik *et al*. 2012).The remote sensing technique is suitable for assessing water stress and implementing appropriate water management strategies because it presents unique advantage of repeatability, accuracy, synoptic analysis and cost effective over the ground based surveys for water stress detection (Levent Genc *et al* 2013). Hyperspectral remote sensing techniques further allow the early detection of vegetation stress (Panigada *et al*. 2010).

The spectral characteristics of crop are distinctive with low reflectance in blue, high in green, very low in red and very high in NIR. The overall reflectance of water in visible region (400-700 nm) is relatively low and in the NIR (700-900 nm) it is practically zero (Rock *et al* 1986). Extensive research has been conducted to study pigment concentration of plants using spectral reflectance under various environmental conditions and stress (Blackburn, 2007). Numerous spectral vegetation indices have been developed to characterize vegetation canopies. The most common of these indices, which utilize red (0.6-0.7 m) and near infrared (0.7-0.9 m) wavelengths, are the simple ratio and Normalized Difference Vegetation Index (NDVI)

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(Tucker 1979). The NDVI and its various derivatives are most commonly used in estimating the onset of stress (Penulelas et. al 1997). The NDVI has also been used for numerous regional and global applications for studying the distribution and potential photosynthetic activity of vegetation. Bell et.al (2002) reported that NDVI has been used to measure draught stress, turf chlorophyll content and turf quality.

Hence, the research studies were undertaken to know the spectral response of different crop to water stress. In this paper the methodologies used and results obtained for soybean are presented and analysed.

Materials and Methods

Study area : The experiment was conducted at the instructional farm of Department of Irrigation and Drainage Engineering, Dr. Annasaheb Shinde College of Agricultural Engineering and Technology, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, during Kharif season of 2015 to study the effect of water stress on spectral reflectance and NDVI of soybean. Geographically the farm lies at 740 38' 00'' E longitudes and 190 20' 00'' N latitude at 557 m above the mean sea level. The textural class of the soil is clay with field capacity 39 per cent, permanent wilting point 19 per cent and bulk density 1.27 g cc^{-1}.

The experimental farm climatically falls under the semi-arid and sub-tropical zone with average annual rainfall of 566 mm. The distribution of rain is uneven and it is distributed over 15 to 37 rainy days. The annual mean maximum and minimum temperatures range between 28.22 to 39.04°C and 10.10 to 22.9°C, respectively. The annual mean pan evaporation ranges from 3.7 to 12.4 mm day^{-1}. The annual mean wind speed ranges from 3.2 to 13.09 Km hr^{-1}. The annual mean maximum and minimum relative humidity range from 59 to 90 per cent and 21 to 61 per cent, respectively. Monthly averages of metrological data during the study period are presented in Table 1.

Experimental details : The experiment was carried out in randomized block design (RBD) with six water stress treatments (I_1 - 0% water stress, I_2 - 20% water stress, I_3 - 40% water stress, I_4 - 60% water stress, I_5 - 80% water stress and I_6 - 100% water stress) with four replications. The size of each treatment plot was 4 x 3 m. A 1 m wide space was provided between two plots. The soybean crop was sown at the spacing 45 x 10 cm on 7 July, 2015. Pre sowing irrigation of 50 mm was applied after sowing of the crop to ensure the uniform germination of the soybean. The standard cultivation practices were followed to maintain the crop so that there is no other stress except controlled water stress. The quantity of water to be applied was estimated

Table 1. Monthly average values of metrological variables during the study period

Month	Tmax (°C)	Tmin (°C)	RHmax (%)	Rhmin (%)	BSSH (hrs)	Wind speed (km hr^{-1})	Total rainfall (mm)
July	32.42	23.69	70.92	53.04	4.51	8.98	25.80
August	31.90	22.31	73.13	53.35	4.35	4.05	15.40
September	32.24	21.85	76.80	51.50	6.09	2.64	123.60
October	34.00	19.67	64.42	39.26	7.46	0.70	20.60
November	31.69	16.82	61.10	41.97	7.72	1.03	26.00

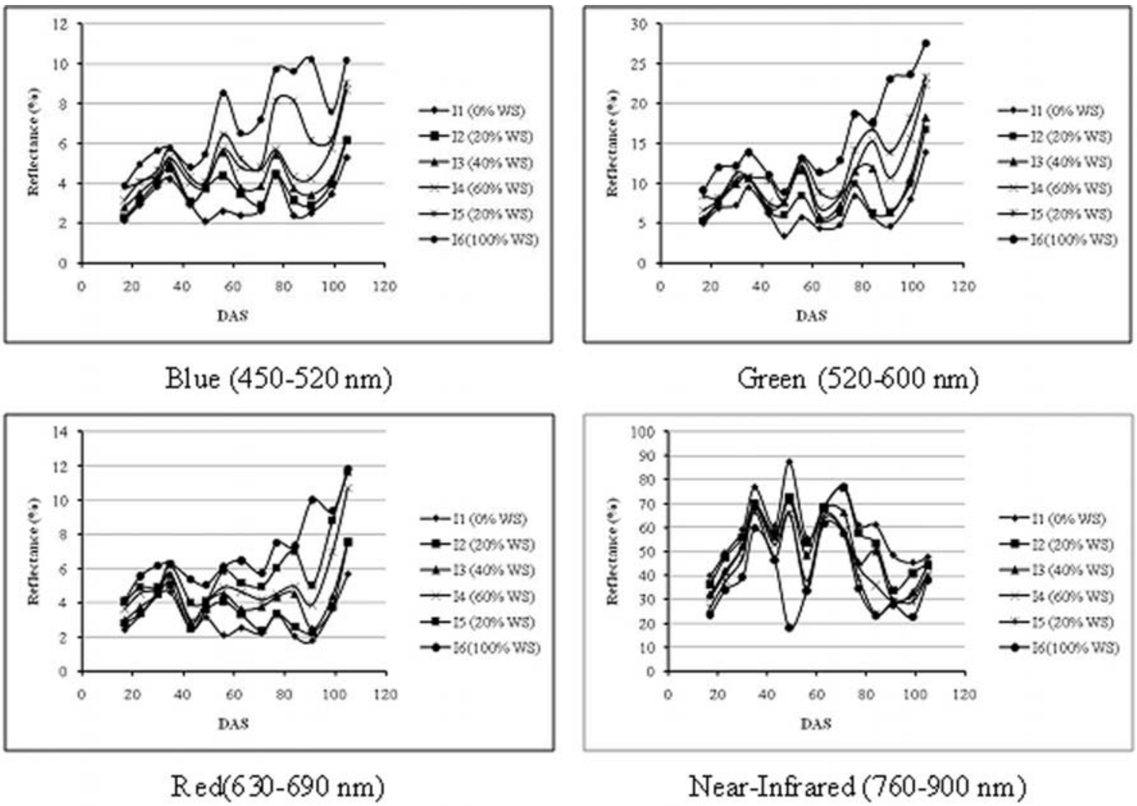

Fig. 1. Spectral reflectance of soybean in blue, green, red (IR) and near-infrared (NIR) wavebands over the growth period for each water stress treatment (I_1-I_6)

for each stress treatment considering the rainfall and evaporation and scheduling the application at 50 mm Cumulative Pan Evaporation. The desired quantity was applied directly at the plot.

Spectral reflectance measurement : Spectroradiometers are widely used to measure spectral reflectance and are designed to match the wavebands of different satellites' sensors (Agapiou *et al*. 2010). In this study field reflectances were measured over soybean plots with the SVC HR-1024i spectroradio-meter in the spectral range of 450-2500 nm during the crop growth periods at an interval of seven days. The spectral reflectances were measured under clear-sky conditions between 12:00 and 14:00 hrs, at 60 to 80 cm above crop canopy, with the 4° field-of-view (FOV). Spectral reflectances were measured at five representative locations from the most central

Table 2. Total amount of irrigation water and seasonal water use of the crop

Treatments	Irrigation water applied (mm)	Effective rainfall (mm)	Seasonal water applied (mm)
T_1 (0% WS)	262	156	418
T_2 (20% WS)	222	156	378
T_3 (40% WS)	183	156	339
T_4 (60% WS)	144	156	300
T_5 (80% WS)	117	156	273
T_6 (100% WS)	–	156	156

part of each plot. A reference calibrated spectralon panel with 100% reflectance was used to measure the incoming solar radiation as a reference, while the measurement over the crops was a target. In order to avoid any errors due to significant changes in the prevailing atmospheric conditions, the measurements over the spectralon panel and the target were taken with the shortest time lag. The reflection of the spectralon panel was recorded for every five measurement to ensure reliable data collection. These spectral reflectance measurements were then used to calculate average in-band spectral reflectance in blue, green, red and near-infrared wavelengths. The same point was visited every week for taking observations over the crop growth period.

Estimation of NDVI : The reflectance measurements were re-sampled to 1 nm wavelength and converted into in-band reflectance: Blue (450-520 nm), Green (520-600 nm), Red (630-690 nm) and NIR (760-900 nm). The NDVI was calculated by using the equation proposed by Rouse *et al*. (1974).

Results and Discussion

Irrigation scheduling : The water to be applied under different water stress conditions was calculated based on 50 mm cumulative reference evapotranspiration using FAO pan Evaporimeter method. The data of water applied, effective rainfall and seasonal water applied for the year 2015 are presented in Table 2. The amount of seasonal water use in I_1, I_2, I_3, I_4, I_5 and I_6 treatments were 418, 378, 339, 300, 273 and 156, respectively.

Spectral reflectance : Spectral reflectance values of soybean obtained by spectroradiometer during the experimentation are shown in Fig.1. Average reflectance values of blue, green, red and near-infrared wavelength are presented in Table 3. The average reflectance values in blue, green, red and near-infrared wavebands for the I_1 treatment were 3.15, 6.67, 3.11 and 59.83 respectively, for the I_2 treatment 3.74, 8.26, 3.66 and 54.97 respectively, for the I_3 treatment 4.22, 9.45, 4.21 and 50.50 respectively, for the I4 treatment 4.91, 11.02, 5.02 and 46.62 respectively, for the I_5 treatment 5.78, 12.39, 5.92 and 43.39 respectively and for I_6 treatment 7.15, 15.37, 6.93 and 37.13 respectively. It was found that for blue, green and red wavebands the spectral reflectance values increase from 0% water stress to 100% water stress, while for near-infrared waveband, the spectral reflectance

Table 3. Average reflectance values of blue, green, red and near-infrared wavelengths and normalized difference vegetation Index (NDVI) for soybean

Treatments	Reflectance (%)				
	Blue (450-520 nm)	Green (520-600 nm)	Red (630-690 nm)	NIR (730-900 nm)	NDVI
I_1 (0% WS)	3.15	6.67	3.11	59.83	0.90
I_2 (20% WS)	3.74	8.26	3.66	54.97	0.88
I_3 (40% WS)	4.22	9.45	4.21	50.50	0.85
I_4 (60% WS)	4.91	11.02	5.02	46.62	0.81
I_5 (20% WS)	5.78	12.39	5.92	43.39	0.76
I_6 (100% WS)	7.15	15.37	6.93	37.13	0.69

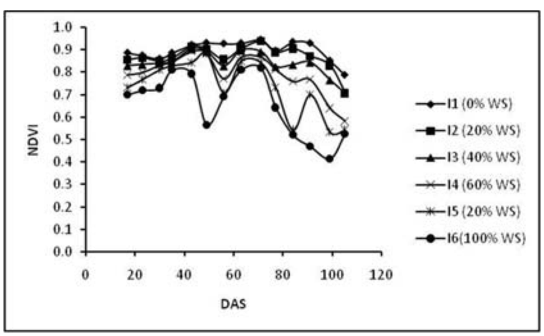

Fig. 2. Time series of Normalized Difference Vegetation Index (NDVI) values during the study period for each water stress treatment (I_1-I_6)

values decrease with increase in water stress. The reflectance values of non irrigated treatment (I_6 - 100% WS) plots in blue, green and red portions were higher and the reflectance value in the near-infrared portion were lower than the values obtained in the other water stress treatments.

Time series of NDVI : The seasonal average NDVI values of the I_1, I_2, I_3, I_4, I_5 and I6 were found 0.90 0.88 0.85 0.81 0.76 and 0.69, respectively. The NDVI values decreased with increasing water stress (Fig. 2).

Conclusions

This study was conducted to investigate the nature of variation of reflectance in the blue, green, red and near-infrared wavebands changes as a function of water stress for soybean. Six different water stress (WS) conditions were examined: I_1 - 0% WS, I_2 - 20% WS, I_3 - 40% WS, I_4 - 60% WS, I_5 - 80% WS and I_6 - 100% WS. Spectral reflectances were measured using spectroradiometer. This investigation showed that in blue, green and red wavebands, the spectral reflectances increased when water stress increased from 0% to 100%. In Near-Infrared waveband the spectral reflectances decreased when water stress increased from 0% to 100%. The NDVI values estimated from the spectral reflectance in IR and NIR region decreased with increase in water stress, this indicated the possibility of quantifying water stress by NDVI. Analysis of the data further indicated that it is possible to use remotely sensed data to develop maps of water stress conditions of soybean.

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J. Agric. Res. Technol., 42 (3) : 154-158 (2017)

Soil-Site Suitability Evaluation for Commonly Growing Crops in Drought Prone Area of Krishna Valley in Marathwada Region of Maharashtra

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Abstract

In the present study, fifteen pedons from different topographic unit of drought prone area of Krishna valley in Marathwada region were evaluated for their soil-site suitability to sorghum, cotton, pigeonpea and soybean crops. The soils of Typic Haplusterts were found as highly suitable (S1); soils of Calcic Haplusterts, Sodic Haplusterts and Vertic Haplustepts as moderately suitable (S2); soils of Typic Haplustepts and Typic Ustorthents as moderately (S2) to marginally (S3) suitable for cultivation of sorghum, cotton, pigeonpea and soybean crops. It was concluded that the Typic Ustorthents and Typic Haplustepts soils are suitable for shallow rooted and short duration crop, whereas Typic Haplusterts, Calcic Haplusterts, Sodic Haplusterts and Vertic Haplustepts soils are suitable for both short and long duration crops as well as shallow and deep rooted crops in study area. For the management of Calcic and Sodic Haplusterts soils improved management practices are required to grow crops successfully on these soils.

Key words : Soil-site suitability,drought prone area, sorghum, cotton, pigeonpea, soybean.

Land resources, particularly soil and water, are limited in extent; their efficient and sustainable utilization is imperative, particularly when the population pressure is increasing alarmingly. For optimum utilization of available land resources on a sustainable basis, timely and reliable information of soil resources regarding their nature, extent and spatial distribution along with their potentials and limitations is important (Shalima Devi and Anil Kumar, 2008). The resource conservation and development programmes are being taken up increasingly on watershed basis and understanding the inter-relationships between land uses, geomorphology, slope and soils qualities in a watershed is very important for their better management (Srinivasa *et al*. 2008). Indiscriminate use of land resources, in general lead to their degradation and in turn decline in productivity. They need to be used according to their capacity to satisfy the needs of its inhabitants. This can be achieved through proper investigation of land resources and their scientific evaluation. Land suitability evaluation is the process of estimating the potential of land for land use planning (Sys *et al*. 1991). The study area is typified by rainfed condition where, sorghum, cotton pigeonpea and soybean are the important kharif and rabi crops grown. The present yield of crops is much below the experimental yield data as observed from yield data collected from farmers.The soil-site suitability evaluation of these soils is of importance for land use planning and soil resource management under the existing climatic conditions. Therefore the present investigation was undertaken to evaluate the soil-site suitability for commonly growing crops in Krishna valley of Marathwada region of Maharashtra.

Materials and Methods

Geographically the North-East part of the Krishna valley in Marathwada region of Maharashtra is located between 180 07' 83" to 180 37' 96" N latitudes and 750 17'14" to 750

49'14" E longitudes. The general elevation of area ranges from 507 to 797 m above mean sea level.The climate of the area is hot, dry, sub humid with mean annual rainfall of 870 mm of which nearly 85 per cent is received during months of June to September. The study area shows different kinds of soils developed on basaltic parent materials on different topographic positions. Based on topographic position fifteen pedonswere selected, exposed and studied morphometrically in year 2013-14 as per guideline given by Soil Survey Staff (1975). The horizonwise soil samples collected from different typifying pedons were analyzed for their physico-chemical properties following the standard analytical techniques and classified as per keys to Soil Taxonomy (Soil Survey Staff, 2014).

The existing soil- site condition were compared with the criteria of each crop and based on the number and intensity of limitations (Sys *et al.* 1991). The criteria of limitation method as given by Sys *et al.* (1991) is slightly modified because of the increased number of parameter in the present study for the suitability evaluation as: Class S1 (Highly suitable)- Land unit with nil or up to 5 slight limitations, Class S2 (Moderately suitable)- Land units with more than 5 slight limitations and or no more than two severe limitations, Class S3 (Marginally suitable)- Land unit with more than 4 moderate limitation or/and no more than two sever limitations, Class N1 (Currently not suitable)- Land unit with more than 2 severe limitations that can be corrected, Class N2 (Unsuitable)- Land units having very severe limitation that cannot be corrected.

In addition, the suitability classes were also derived based on the actual yield as suggested by FAO (1983). This was based on the yield levels for the suitability classes as S1 > 80%, S2 40 to 80%, S3 20 to 40% and N< 20% . The yield reduction levels have been decided on the optimum yield of the crop. The optimum yield was calculated with the help of data collected from 10 farmer's field with similar management practices and the average of 3 to 6 commercial varieties grown in the soils of study region.

Table 1. Site and soil characteristics of soils of Krishna valley in Marathwada (M.S.)

Pedon	Slope (%)	Drainage	Depth (cm)	Tex-ture	PAWC (mm)	CEC [cmol (p+) kg^{-1}]	$CaCO_3$ (%)	B.S. (%)	O.C. (%)	ESP (%)	pH	EC dSm^{-1}
P_1 : Khanapur	3-8	well	29	l	91	30.99	4.20	91.89	0.23	4.79	7.34	0.14
P_2 : Shekapur	1-3	imperfect	64	Sicl	150	54.17	15.83	96.29	0.60	3.15	7.34	0.18
P_3 : Sirsav	0-1	imperfect	150	c	252	64.38	13.18	88.29	0.42	7.27	7.91	0.33
P_4 : Aasu	0-1	imperfect	150	c	277	65.59	15.31	93.39	0.44	6.08	7.68	0.23
P_5 : Dhagpimpri	3-8	well	26	Sicl	111	31.31	1.42	86.26	0.17	2.15	7.42	0.10
P_6 : Khasapur	1-3	mod.well	26	cl	84	45.65	13.85	90.58	0.38	4.96	7.97	0.17
P_7 : Sukta	0-1	mod.well	150	c	265	67.01	14.55	93.54	0.48	1.98	7.74	0.20
P_8 : Pardi	3-8	mod.well	49	l	164	32.46	10.06	90.61	0.57	2.23	7.68	0.13
P_9 : Irachiwadi	1-3	well	33	cl	84	27.99	4.14	90.63	0.39	2.40	7.26	0.12
P_{10} : Walha	3-8	well	24	cl	89	34.78	5.01	65.54	0.33	3.80	7.46	0.14
P_{11} : Pachpimpla	0-1	mod.well	150	c	392	62.71	15.37	104.01	0.41	13.32	7.80	0.51
P_{12} : Watephal	3-8	well	35	cl	111	36.94	3.77	90.55	0.28	2.18	7.73	0.10
P_{13} : Shailgaon	1-3	well	55	Sic	225	60.14	17.93	90.35	0.43	2.72	7.82	0.15
P_{14} : Jejala	1-3	well	27	c	126	56.72	1.71	96.25	0.58	3.15	7.53	0.30
P_{15} : Nali	3-8	well	17	cl	59	43.53	2.45	89.95	0.22	1.70	7.45	0.11

Results and Discussion

Soil-site suitability evaluation for sorghum : Sorghum (Hybrid Jowar) is the important *kharif* crop of the study area. The commercial varieties such as CSH-9, CSH-5, CSH-14 are commonly grown in the study area. According to soil-site suitability criteria given by Sys *et al*. (1991) the soils of Typic (P_7), Calcic (P_3 and P_4) and Sodic (P_{11}) Haplusterts and some soils of Typic (P_{14}) and Vertic (P_{13}) Haplustepts were found to be moderately suitable (S2) for growing sorghum crop (Table 2). These soils possess slight limitations of slope, PAWC, texture and depth with moderate limitations of $CaCO_3$ and drainage (Table 1). Some soils of Typic (P_{12}) and Vertic (P_2) Haplustepts were found to be marginally suitable (S3) for sorghum having moderate to severe limitations of depth, PAWC and $CaCO_3$. The soils of Typic Ustorthents (P_1, P_5, P_8, P_{10} and P_{15}) and some soils of TypicHaplustepts (P_6 and P_9) were found currently not suitable (N1) for growing sorghum as these soils have severe to very severe limitations of depth, PAWC and slope. As per soil-site suitability for sorghum on the basis of optimum yield (FAO, 1983) most of the soils in study area were found to be moderately suitable (S2) for sorghum (Table 2). The soils of pedon P_7 were found highly suitable (S1) whereas soils of pedon P_1 and P_{15} were marginally (S3) suitable for growing sorghum crop.

Soil-site suitability evaluation for cotton : Cotton being a long duration crop with deep rooting system, significant decline in yield in shallow soils with low moisture storage (<100 mm) is reported. The field studies on black soils (NBSS and LUP, 1986; Bhaskar *et al*. 1987; Sehgal, 1991) shows that cotton is successfully grown in deep soils with good drainage. A depth of 100 -120 cm has been observed to be optimum, whereas < 60 cm depth was considered to be uneconomical to grow cotton (Bhaskar *et al*. 1987). Cotton is

Table 2. Soil-site suitability evaluation for commonly growing crops

Pedon	Suitability class for Sorghum		Suitability class for cotton		Suitability class for pigeonpea		Suitability class for soybean	
	A*	B*	A*	B*	A*	B*	A*	B*
P_1 : Khanapur	N1	S3	N1	S3	N1	S3	N2	S2
P_2 : Shekapur	S3	S2	S3	S2	S3	S2	S2	S2
P_3 : Sirsav	S2	S2	S2	S2	S2	S2	S3	S2
P_4 : Aasu	S2	S2	S2	S2	S2	S2	S3	S2
P_5 : Dhagpimpri	N1	S2	N1	S3	N1	S3	N2	S2
P_6 : Khasapur	N1	S2	N1	S3	N1	S3	N2	S2
P_7 : Sukta	S2	S1	S2	S1	S2	S1	S3	S1
P_8 : Pardi	N1	S2	N1	S3	N1	S3	N2	S2
P_9 : Irachiwadi	N1	S2	N1	S3	N1	S3	N2	S2
P_{10} : Walha	N1	S2	N1	S3	N1	S3	N2	S2
P_{11} : Pachpimpla	S2	S2	S2	S2	N1	S2	N1	S2
P_{12} : Watephal	S3	S2	N1	S2	N1	S2	N2	S2
P_{13} : Shailgaon	S2	S2	S2	S2	S2	S2	S2	S2
P_{14} : Jejala	S2	S2	N1	S2	N1	S2	N2	S2
P_{15} : Nali	N1	S3	N1	S3	N1	S3	N2	S3

A*: As per soil suitability criteria given by Sys *et al*. (1991)

B*: As per suitability classes based on the actual yield as suggested by FAO (1983) the main cash crop of the study area. According to soil-site suitability criteria given by Sys *et al*. (1991) the soils of Typic (P_7), Calcic (P_3 and P_4) and Sodic (P_{11}) Haplusterts and some soils of Vertic Haplustepts (P_{13}) were found to be moderately suitable (S2) for growing cotton as these soils have high CEC, base saturation and high clay content (Table 1) with rich in smectite minerals. Whereas some soils of Vertic Haplustepts (P_2) were marginally suitable (S3) as these soils have moderate limitations of PAWC, $CaCO_3$ and severe limitations of depth (Table 1). The soils of Typic Ustorthents (P_1, P_5, P_8, P_{10} and P_{15}) and Typic Haplustepts (P_6, P_9, P_{12} and P_{14}) were currently not suitable (N1) for growing cotton crop as these soils have severe to very severe limitations of depth and PAWC. Kadu and Kharche (2017) also reported that, the PAWC of shallow soils has been considerably low and hence shallow soils are not suitable for cotton owing to the fact that cotton, a long duration crop, needs a deep rooting zone for sufficient soil moisture storage for its proper growth and development. According to the criteria suggested by FAO (1983) the suitability for cotton crop on the basis of optimum yield, the soils of pedon P_7 were found highly suitable (S1), soils of pedon P_2, P_3, P_4, P_{11}, P_{12}, P_{13} and P_{14} were found to be moderately suitable (S2) whereas soils of pedon P_1, P_5, P_6, P_8, P_9, P_{10} and P_{15} were found to be marginally suitable (S3) for growing of cotton crop.

Soil-site suitability evaluation for pigeonpea : Pigeonpea is the most important pulse crop in this area. The commercial varieties grown in this area are BDN-1, BDN-2, BSMR-736, BSMR-853. According to soil site suitability criteria for pigeonpea (Sys, 1991), the soils of Typic (P_7) and Calcic (P_3 and P_4) Haplusterts and some soils of Vertic Haplustepts (P_{13}) were found to be moderately suitable (S2) for growing pigeonpea whereas some soils of Vertic Haplustepts (P_2) were marginally suitable (S3) as these soils have moderate limitations of PAWC, $CaCO_3$ and severe limitations of depth (Table 1 and 2). The soils of Sodic Haplusterts (P_{11}) were currently not suitable (N1) for growing of pigeonpea as these soils have very severe limitations of ESP. The soils of Typic Ustorthents (P_1, P_5, P_8, P_{10} and P_{15}) and Typic Haplustepts (P_6, P_9, P_{12} and P_{14}) were currently not suitable (N1) for growing pigeonpea crop, as these soils have severe to very severe limitations of depth and PAWC. However, according to FAO (1983) suitability based on optimum yield basis (Table 2), the soils of pedon P_7 were found to be highly suitable (S1), the soils of pedon P_2, P_3, P_4, P_{11}, P_{12}, P_{13} and P_{14} were found to be moderately suitable (S2), whereas the soils of pedon P_1, P_5, P_6, P_8, P_9, P_{10} and P_{15} were marginally suitable (S3) for pigeonpea crop.

Soil-site suitability evaluation for soybean : Soybean is an important pulse and oilseed crop of the study region. It is successfully grown under atmospheric temperature ranging between 24 to 28°C and rainfall ranging from 800 to 1200 mm and grown on variety of soils but clay loam, silt loam, silty clay loam and loam soils have been found to be most ideal. Deep soils, having depth of more than 75 cm is ideal and those having the depth less than 30 cm are not suitable to grow soybean. The commercially grown varieties of soybean in the study area are JS-335, MAUS-71. The conditions like soil depth, high PAWC, CEC and base saturation are favourable to soybean crop. According to the soil site requirement criteria for soybean given by Sys *et al*. (1991), some soils of Vertic Haplustepts (P_2 and P_{13}) were found to be moderately suitable (S2) for soybean whereas soils of Typic (P_7) and Calcic (P_3 and P_4) Haplusterts were marginally suitable (S3) for soybean as these soils have moderate limitations of drainage, texture, $CaCO_3$ and pH (Table 1 and 2).

The soils of Sodic Haplusterts (P_{11}) were found currently not suitable (N1) for growing soybean crop as these soils have very severe limitations of ESP. The soils of Typic Ustorthents (P_1, P_5, P_8, P_{10} and P_{15}) and Typic Haplustepts (P_6, P_9, P_{12} and P_{14}) were currently not suitable (N1) for growing soybean crop as these soils have very severe limitations of depth and PAWC. However, according to FAO (1983) the suitability based on the optimum yield basis, most of the soils of study area were moderately suitable (S2) for soybean crop. The soils of pedon P_7 were highly suitable (S1), whereas soils of pedon P_{15} were marginally suitable (S3) for soybean crop.

Conclusions

From the above results however concluded that the soils of Typic Ustorthents and Typic Haplustepts are suitable for short duration and shallow rooted crops, whereas Vertic Haplustepts, Typic Haplusterts, Calcic Haplusterts and Sodic Haplusterts soils are suitable for both short and long duration as well as shallow and deep rooted crops. The Calcic Haplusterts soils have the calcium carbonate ($CaCO_3$) in the profile which adversely affect physical and chemical properties of soil; for management of these soil improved management is required to grow crop successfully on these soils to break down hard pan by deep ploughing, to avoid ammonia volatilization, reducing the formation of insoluble-Ca and Mg phosphate. Using tolerant varieties reduced the severity of lime-induced Fe chlorosis on calcareous soils. Fe, Zn and Mn deficiencies can be corrected by foliar application. The soils of SodicHaplusterts have high ESP in subsurface layer which impair the hydraulic conductivity of soil. The surface application of gypsum coupled with cultivation of crop appears to the promising in restoring the productivity of these soils. The application of organic manures and insitu or exsitugreen manuring may be a sustainable management option to enhance the soil quality and productivity of these soils.

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J. Agric. Res. Technol., 42 (3) : 159-162 (2017)

Multivariate Analysis for Recombinant Inbred Lines of Brassica juncea using D² Analysis under two Environments

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Abstract

Genetic diversity were employed to assess the extent of deviation of sixteen recombinant lines, eight parents along with four checks and to select the best recombinant lines for further use in breeding programme. Sixteen recombinant lines, eight along with four checks were raised during *rabi* 2014-15 and 2015-16 in three replications and data were recorded for days to 50% flowering, days to maturity, plant height at maturity (cm), number of branches plant^{-1}, number of siliquae plant^{-1}, number of seeds siliquae^{-1}, length of siliquae (cm), seed yield plot^{-1} (kg ha^{-1}), seed yield plant^{-1} (g) and 1000 seed weight (g). Considerable variability existed among the genotypes for all characters studied from the significant mean squares due to genotypes. The recombinant lines were grouped into six clusters indicating the presence of wide range of diversity among them. Seed yield plot^{-1}, seed yield plant^{-1}, number of siliquae plant^{-1}, plant height at maturity and days to maturity contributed maximum towards genetic divergence. Sixteen recombinant lines, eight parents and four checks were grouped into six clusters. The grouping of recombinant lines into different clusters clearly showed that many of recombinant lines were highly deviating from the checks. Only five recombinant lines were found promising which had maximum intercluster distance between the clusters and the cluster involving checks, along with high mean performance for seed yield plot^{-1}, seed yield plant^{-1}, number of siliquae plant^{-1} and hence may be promoted for evaluation in trial for further varietal improvement.

Key words : Recombinant lines, inter cluster distance, genetic diversity.

Oilseeds account for about 1.5 per cent of gross domestic product and eight per cent of value of all agricultural products. Among different oilseed crops groundnut, rapeseed-mustard and soybean account for about 80% of oilseeds area and 88% of oilseeds production in the country. They are cultivated particularly in Rajasthan, Uttar Pradesh, Gujarat, Madhya Pradesh and Andhra Pradesh. It is a minor crop of Vidarbha region of Maharashtra, often grown as mixed crop and hence is one of the reasons for lower productivity. In India the average productivity of Indian mustard is low in comparison to the developed countries, especially in Vidarbha it is grown as mixed cropping rather than sole crop. Considering the low productivity in Vidarbha region, there is need of developing high yielding varieties with early maturity and high oil content

Evaluation of genetic divergence among the recombinant lines has significant role in the identification of the superior recombinant lines. The practical significance of grouping the recombinant lines into different clusters and calculating the statistical distance between them and the check varieties are that the recombinant lines selected should be such that they belong to distant clusters and also away from the clusters involving checks. Therefore the clusters having highest average intercluster distance between themselves and the checks are expected to yield better.

Materials and Methods

The experiment was carried out at farm

1. Mustard Breeder, 2. P.G. student and 3. Mustard Agronomist.

Agricultural Botany section, College of Agriculture, Nagpur during *rabi* 2014-15 and 2015-16 ie under two environments. The experimental material comprising of recombinant lines, parents and checks were planted in randomized block design with three replications in plot size of 3 x 1.5 m. the row to row and plant to plant distance was maintained at 45 x 15 cm. Six genotypes of *Brassica juncea* (BIO 902, IC 342718, IC 355314, IC 333199, 355327 and Pusa bold), were crossed amongst themselves as well as with one genotype each from *Brassica carinata* (PC 5), *Brassica rapa* var toria (Bhawani), *Brassica rapa* var yellow sarson (Ragini) and GSL 1 *Brassica napus* to expand the gene sources and to introduce novel genes in these crops (Chaudhary and Joshi (2001). Segrgants of intervarietal crosses as well as interspecific crosses were advanced upto F_6 generation by pedigree method and the promising recombinant inbred lines were used in the study.

Recommended fertilizer doses, cultural practices and all plant protection measures was applied to maintain good crop. The data was recorded on ten characters, *viz*. days to 50% flowering, days to maturity, plant height at maturity (cm), number of branches plant^{-1}, number of siliquae plant^{-1}, number of seeds siliquae^{-1}, length of siliquae (cm), seed yield plot^{-1} (Kg ha^{-1}), seed yield plant^{-1} (g) and 1000 seed weight (g). Mahalanobis (1936) D^2 statistics was used for assessing genetic divergence of the pooled data of 2014-15 and 2015-16 . The clustering of D^2 values was done using Tocher's method as described by Rao (1952), while the intra and inter-cluster distances were calculated using the formula Singh and Choudary (1985).

Results and Discussion

The analysis of variance was highly significant among all the genotypes for all ten characters studied which revealed the presence of considerable genetic variability among the genotypes. The grouping of 28 recombinant lines into different clusters were done by Tocher's method for pooled data are presented in Table 1.

The entire recombinant lines of pooled data were grouped into six clusters. The cluster I was largest comprising of twelve recombinant lines, followed by cluster IV comprising of six recombinant lines, cluster III and V each of comprising of four recombinant lines, cluster II and VI each of comprising of single recombinant lines. The checks Shatabdi, BIO 902, Pusabold and Kranti were grouped into cluster I along with eight recombinant lines. The pooled data revealed that the cluster I had

Table 1. Grouping of recombinant lines into different clusters

Cluster	No. of recombinant lines	Name of recombinant line
I	12	Kranti, Pusabold, Shatabdi, IC 342718, BIO 902, ACN 204, ACN 199, IC333199, ACN193, IC355314, ACN 206, ACN 207
II	1	IC355327
III	4	ACN 202, ACN 208, PC 5, ACN 201
IV	6	ACN 194, ACN 196, ACN 205, ACN 195, ACN 200, ACN 198
V	4	ACN 197, ACN 203, Bhawani, GSL 1
VI	1	Ragini

Table 2. Average intra and inter cluster distance for pooled data

Cluster	I	II	III	IV	V	VI
I	**(2.27)**	3.95	5.61	16.04	6.41	63.02
II		**(0.00)**	4.99	26.28	4.18	63.19
III			**(4.22)**	22.39	9.37	64.50
IV				**(7.65)**	31.04	83.24
V					**(4.14)**	54.20
VI						**(0.00)**

Note : D = 10.91

Bold figures are average intra cluster distance.

maximum number of recombinant inbred lines. Similar to this results, grouping of genotypes into different clusters were done by Pandey *et al*. (2013), Kumar *et al*. (2013) and Budhanwar *et al*. (2010).

Average intra and inter cluster distance among ten characters recorded that the intra cluster distance ranged from 0.00 to 7.65. Cluster IV recorded the highest intra cluster distance (D^2= 7.65) followed by cluster III (D^2= 4.22) and cluster V (D^2=4.14). The average inter cluster-cluster distance was maximum between cluster IV and cluster VI (D^2=83.24) followed by cluster III and VI (D^2=64.50) and cluster II and cluster VI (D^2=63.19). The inter cluster distance was found to be minimum between cluster I and cluster II (D^2=3.95) followed by cluster II and V (D^2=4.18).

Thus, it can be observed that the average intra cluster distance was maximum in cluster II, cluster III and cluster IV where the average inter cluster distance maximum between cluster III and cluster VI and between cluster V and cluster VI. The genotypes in the clusters having maximum inter cluster distance and not belonging to clusters including the checks can be selected.

Selection of recombinant lines based on yield plant^{-1} showing significant superiority over best check BIO 902, and for no. of siliquae plant^{-1},superiority over best checks are presented in Table 3. All possible cluster combinations beyond the mean statistical distance =10.91 have been arranged in descending order in table 3. The data having maximum inter cluster distance (26.28) was recorded between the cluster II and cluster IV, cluster III and IV (D=22.39) and cluster I and IV (D=16.04) the recombinant lines show highest mean significant superiority for seed yield plant^{-1} are ACN 205, ACN 200, ACN 198, ACN 196, ACN 195 and ACN 194 and for no. of siliquae plant^{-1} are ACN 205, ACN 200, ACN 196, ACN 195 and ACN 194.

Selection of recombinant lines was done

Table 3. Average inter cluster distance of recombinant lines

Clusters	Distance between clusters	Recombinant lines (Selection based on)	
		Seed yield plant^{-1}	Number of Siliquae plant^{-1}
II and IV	26.28	ACN 205-, ACN 194-, ACN 196-, ACN 195-, ACN 198-, ACN 200-	ACN 205^, ACN 194^, ACN 196^, ACN 195^, ACN 200^
III and IV	22.39	ACN 205-, ACN 194-, ACN 196-, ACN 195-, ACN 198-, ACN 200-	ACN 205^, ACN 194^, ACN 196^, ACN 195^, ACN 200^
I and IV	16.04	ACN 205-, ACN 194-, ACN 196-, ACN 195-, ACN 198-, ACN 200-	ACN 205^, ACN 194^, ACN 196^, ACN 195^, ACN 200^

Note : - Selection based on best check BIO 902, ^ Selection based on best check Pusabold based on yield plant^{-1} showing significant superiority over best check BIO 902 and for number of siliquae plant^{-1},superiority over best check Pusa bold recombinant lines ACN 205, ACN 198, ACN 196, ACN 195, ACN 194 were significantly superior over the best checks Pusa bold and BIO 902 for number of siliquae plant^{-1} and seed yield plant^{-1}.

On the basis of the present study it will be advisable to evaluate all these five recombinant lines in preliminary yield trial along with standard checks as they have the maximum intercluster distance with those clusters involving checks and also significantly superior mean performance for seed yield plant^{-1} and number of siliquae plant^{-1}. This conclusion is drawn from the fact that clusters containing the recombinant lines are highly divergent from clusters containing the check varieties. These recombinant lines on hybridization with existing check varieties may also be used for improvement of the check varieties.

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J. Agric. Res. Technol., 42 (3) : 163-167 (2017)

Study of genetic variability for agronomic and drought tolerance traits in sorghum [*Sorghum bicolor* (L.) Moench]

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Abstract

The present investigation was undertaken to study genetic variability for grain yield, its attributes and drought tolerance in mapping population of sorghum. The experimental material comprised of two hundred and sixty genotypes (243 RILs + 17 checks). The experiment was conducted in augmented design with three replications at Experimental Farm of Sorghum Research Station, Marathwada Krishi Vidyapeeth, Parbhani during *rabi* 2009-10. RILs and checks were evaluated for different yield and its attributes along with stay green score at flowering and at maturity (1 to 9 score). In Present investigation, it was observed that high heritability was recorded by days to 50% flowering, plant height (cm), visual stay green score at maturity, Panicle length plant^{-1} (cm), Panicle weight plant^{-1} (g), fodder yield (kg plot^{-1} line^{-1}), test weight of 300 seeds (g) and grain yield plant^{-1} (g) having less difference between phenotypic coefficient of variation and genotypic coefficient of variation i.e. less environmental effect. It indicates that those characters are having high heritability and selection will effective for these characters. RILs MB82, MB101 showed maximum visual stay green score at flowering (1 to 9 score) and minimum in MB123, MB7, MB163 while maximum visual stay green score at maturity (1 to 9 score) observed in RIL MB240 & minimum in RIL MB123 and MB112. Therefore, the RILs showing maximum stay green score at flowering and maturity can be used in breeding programme for the development of drought tolerance in sorghum.

Key words : variability, drought, sorghum, stay green.

Sorghum is the fifth most important cereal crop following rice, wheat, maize and barley in world which is grown in semi arid areas of Asia, Africa and USA. It is utilized as food, feed, forage and other alternate uses. Sorghum exhibits various mechanisms either to resists or escape drought stress. Two distinct drought responses *viz*.; pre flowering and post flowering response have been described in sorghum. However, all such desirable traits are needed to be incorporated in high yielding back ground. The present agricultural production can be increased by utilizing variability present among the genotypes for the development of high yielding varieties. In India, the productivity of rabi sorghum is very low, and highly variable from year to year mainly due to post flowering drought which influences the grain filling, grain productivity, quality, storage quality. Delayed senescence or stay green in sorghum is considered to be a valuable trait as it improves genotypes adaptation to post flowering drought stress particularly in environment in which the crop depends largely on stored soil moisture to fill and mature grain. It is often associated with resistance to charcoal rot, lodging and superior ruminant nutritional quality of crop residues due to higher content of basal sugars. Breeding line B-35 is one of the best characterized sources of the stay green component of post flower drought tolerance in sorghum. The present investigation was aimed to study variability for grain yield, its attributes and drought tolerant traits in new recombinant inbred mapping population developed from popular rabi sorghum cultivar M35-1 and stay green donor genotypes B-35.

1. Soybean Breeder; 2. M.Sc Agri. student; 3. Ph.D. Scholar.

Materials and Methods

The material consisted of 260 recombinant inbred lines (243 RILs + 17 checks) derived from cross of M35-1 x B35 of sorghum were evaluated in augmented design with three replications during rabi 2009-10. The data were recorded for days to 50 % flowering, plant height (cm), total leaves per plant, stay green score at flowering (1 to 9 score), stay green score at maturity (1 to 9 score), days to physiological maturity, agronomic acceptability score (1 to 5 score), panicle length (cm), panicle weight (g), fodder yield (kg plot^{-1} genotype^{-1}), test weight of 300 seed (g), grain yield per plant (g) and grain colour. The data collected on individual characters was subjected to the method of analysis of variance (Panse and Sukhatme, 1958). The mean values of all the traits under consideration were used for statistical analysis.

Results and Discussion

The present investigation was undertaken with the object of finding genetic variability for yield and yield components and drought tolerance in mapping population of sorghum. Analysis of variance for various characters are presented in Table 1. It revealed that the differences among the treatments in respective of all the characters studied were significant at 5 and 1 per cent level. Analysis of variance showed significant differences for all the characters. This indicated the existence of sufficient variation for effective selection for these characters in mapping population under study.

In the present investigation, wide range of variability was observed for majority of yield contributing characters viz; range of variation on the basis of mean was more for the character plant height (51.67-177.0), panicle weight (22.06-77.83), grain yield per plant (11.73-65.87), days to 50 per cent flowering (66.33-89.67), panicle length (11.0-28.37), days to physiological maturity (114.33-123.66), test weight of 300 seeds (5.50-12.20), visual stay green score at maturity (2.83-7.33), total number of leaves plant^{-1} (7.07-11.40), agronomic acceptability score (1.00-4.66), fodder yield kg plot^{-1} (1.03-3.00),

Table 1. Analysis of variance (ANOVA) for different characters in *rabi* sorghum

Characters	Mean sum of suqares		
	Replications (2 d.f.)	**Treatments (259 d.f.)**	**Error (518 d.f.)**
Days to 50 % flowering	2.3793	64.0731**	1.2678
Plant height (cm)	161.1571	2291.6462**	12.8129
Total number of leaves	11.4256	12.2593**	10.3472
Visual stay green score at flowering (1-9 score)	0.2359	0.2806**	0.0712
Visual stay green score at maturity (1-9 score)	0.1959	3.4935**	0.1031
Days to physiological maturity	443.2375	10.3923**	4.6202
Agronomic acceptability score (1-5 score)	4.5838	1.1044**	0.2580
Panicle length plant^{-1} (cm)	2.2695	24.4401**	0.6575
Panicle weight plant^{-1} (g)	7.4265	299.2543**	2.8765
Fodder yield (kg plot^{-1} genotype^{-1})	0.0875	0.7051**	0.0149
Test weight of 300 seeds (g)	0.0183	3.4849**	0..0104
Grain yield per plant (g)	28.4379	287.5470**	6.3926

** indicates significant at 1 per cent level and * indicates significant at 5 per cent level visual stay green score at flowering (1.00-2.33) (Table 2). Similar results were reported by several workers including Kumar and Singh (1986), Nimbalkar *et al.* (1988), Berenjii (1990), Malti *et al.* (1990), Veerabadhiran and Kennedy (2001), Prabhakar (2003), Arunkumar *et al.* (2004), Sharma *et al.* (2006).

Genotypic and Phenotypic Coefficient of Variation : The selection under field condition may be strongly influenced by environmental factors affecting progress in the improvement program. In the present study, genotypic coefficient of variation estimates was slightly lower than phenotypic coefficient of variation for all the characters. Although the phenotypic coefficients of variation were greater than genotypic coefficient of variation, the differences between them were of lower magnitude.

In the present study, high estimates of genotypic and phenotypic coefficient of variation were observed from total number of leaves per plant, agronomic acceptability score, grain yield per plant, fodder yield (kg/plot), visual stay green score at flowering, visual stay green score at maturity, panicle weight, plant height, panicle length, test weight of 300 seeds, days to 50 per cent flowering, days to physiological maturity (Table 2). The results are in agreement with those of Singh and Makne (1980), Wankhede *et al.* (1985), Kumar and Singh (1986), Nimbalkar *et al.* (1988), Can and Yoshida (1999), Choudhary *et al.* (2001), Prabhakar (2003), Arunkumar *et al.* (2004), Mallinath *et al.* (2004) and Sharma *et al.* (2006).

Heritability and Genetic Advance : The genotypic coefficient of variation alone does not indicate the proportion of total heritable variation. The heritability estimates are better indicator in this respect. High heritability indicates the effectiveness of selection based on

Table 2. Mean, range, Genotypic coefficient of variation (GCV), Phenotypic coefficient of variation (PCV), heritability and genetic advance for various characters in RILs and checks

Genotypes	Days to 50 % flowering	Plant height (cm)	Total no. of leaves	Visual stay green score at flowering (1-9 score)	Visual stay green score at maturity (1-9 score)	Days to physio-logical maturity	Agronomic acceptability score (1-5 score)	Panicle length plant^{-1} (cm)	Panicle weight plant^{-1} (g)	Fodder yield (kg plot^{-1} line-1)	Test weight of 300 seeds (g)	Grain yield plant^{-1} (g)
Mean	73.24	129.52	8.91	1.49	4.44	119.86	2.4	17.59	44.90	1.75	9.51	33.08
Range	66.33-89.67	51.67-177.00	7.07-11.40	1.00-2.33	2.83-7.33	114.33-123.66	1.00-4.66	11.00-28.37	22.06-77.83	1.03-3.00	5.50-12.20	11.73-65.87
GCV (%)	6.24	21.28	8.96	17.69	23.94	1.16	22.09	16	22.13	27.34	11.32	29.26
PCV (%)	6.43	21.46	37.19	25.14	25	2.13	30.58	16.65	22.45	28.21	11.37	30.24
Heritability (%)	94	98	5	49	91	29	52	92	97	93	99	93
Genetic advance	12.49	43.47	4.45	25.64	47.20	1.29	32.89	31.68	44.94	54.59	23.20	58.31

phenotypic performance but does not necessarily mean a high genetic gain for particular character. The heritability estimates along with expected genetic advance are more useful for predicting yield under phenotypic selection than heritability estimates alone. High heritability accompanied with high genetic advance indicates preponderance of additive gene effect, in such case selection may be effective high heritability with low genetic advance reveals preponderance of non additive gene action.

In the present investigation, heritability was ranged from 5 per cent to 99 per cent. The character test weight of 300 seeds (99.0%), plant height (98.0%), panicle weight (97.0%), days to 50 per cent flowering (94.0%), grain yield (93.0%), fodder yield (93.0%), panicle length (92.0%), visual stay green score at maturity (91.0%), agronomic acceptability score (52.0%), visual stay green score at flowering (49.0%), days to physiological maturity (29.0%), total number of leaves (5.00%).

Kumar and Singh (1986) reported high heritability for plant height, panicle weight, 1000 grain weight. Rao and Patil (1996) reported high heritability for days to 50 per cent flowering and earhead weight. Ambekar *et al.* (2000), Date (2002), Mallinath *et al.* (2004) and Anas and Yoshida (2004) have also reported similar results. Crasta *et al.* (1999) reported that heritability estimates of 0.72 for stay green and 0.90 for maturity.

Higher values of genetic advance was reported for the characters grain yield per plant (58.31), fodder yield (54.59), visual stay green score at maturity (47.20), panicle weight (44.94), plant height (43.47), agronomic acceptability score (32.89), panicle length (31.68), visual stay green score at flowering (25.64), test weight of 300 seeds (23.20), days to 50 per cent flowering (12.49), days to physiological maturity (1.29) (Table 2).

The characters viz; grain yield per plant, fodder yield, visual stay green score at flowering, visual stay green score at maturity, panicle weight, panicle length, plant height, agronomic acceptability score and test weight reported high heritability and genetic advance these traits can be improved by selection.

Cheralu and Rao (1989) observed that genetic advance was more for grain yield, earhead weight. Rao and Patil (1996) for grain per panicle and panicle weight. Prabhakar (2003) for grain yield per plant. Mallinath *et al.* (2004) fodder yield per plant and grain yield per plant. Anas and Yoshida (2004) for 1000 grain weight and plant height. Sharma *et al.* (2006) for grain yield. Hausman *et al.* (2003) the mode of gene action for stay green in their investigation ranged from purely additive to over-dominance. Three QTLs on linkage group LGA, E, G were common to both (RIP1 & RIP2) so these QTL could be potential candidates for transfer of stay green into locally adopted material.

The character days to 50 per cent flowering and grain yield per panicle had medium heritability with low genetic advance suggesting the variability for these characters is governed by non additive gene action indicating the limited scope for improving these characters through phenotypic selection. Similar reports were reported by Prabhakar (2003) for 50 per cent flowering.

Thus, from this it is clear that the characters viz; panicle length, panicle weight, visual stay green core at maturity, plant height, fodder yield per plant, grain per panicle, yield per plant recorded high heritability and high expected genetic advance indicating involvement of additive gene action. Such high estimates were indicative of the fact that these traits were less affected by the environment and thus while expecting genetic variability due to emphasis should be given to those characters (Rao and Patil, 1996).

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J. Agric. Res. Technol., 42 (3) : 168-172 (2017)

Identification of Soil Nutritional Constraints and Land use Planning of UPRS Farm of VNMKV, Parbhani

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Abstract

The present investigation was carried out for assessment of available macro nutrient and micro nutrient status of soil and their relation with soil chemical properties of UPRS (upland paddy research station) farm of VNMKV, Parbhani. Total 80 surface soil samples were collected and analyzed for chemical properties and fertility status of soil. The data revealed that the soils of UPRS Farm of VNMKV, Parbhani were moderately alkaline (pH 7.38 to 8.49) in soil reaction, having safe electrical conductivity (EC 0.21 to 1.21 dSm^{-1}), low to high in organic carbon content (3.1 to 7.7 g kg^{-1}) and non-calcareous to calcareous (43 to 98 g kg^{-1}) in nature. According to the concept of soil nutrient index values the availability of available N (NIV 1.25), S (NIV 1) and Zn (NIV 1) nutrients was in low range and soils were medium in available P (NIV 1.8) and high in available K (NIV 3), DTPA- Fe (NIV 3), DTPA- Mn (NIV 3), and DTPA- Cu (NIV 3). Further, the organic carbon content showed positive and significant correlation with available Nitrogen (0.210*), Phosphorus (0.205*), Sulphur (0.218*) as well as micronutrients like, Mn (0.265*) and Zn (0.310*) in the soils of UPRS farm. Thus, deficiencies of N, S and Zn were the soil nutritional constraints identified and according to soil site suitability characteristics, land use planning may be done for production of soybean, pigeon pea and cotton crops at UPRS farm of VNMKV, Parbhani.

Key words : Macro Nutrients, Micro Nutrients, Correlation, Parbhani.

Soil quality mainly depends on the response of soil to different land use systems and management practices, which may often modify the soil properties and soil productivity (Saqeebulla *et al*., 2012). The major and micro nutrients govern the fertility of the soils and control the yield of crops. With the introduction of high yielding crop varieties and intensive agriculture with modern agro-techniques and less use of on farm organic manures, most soils becoming deficient in major and micro nutrients. Such deficiencies of major and micro nutrients affect the growth, yield and nutrition of crops to great extent (Biswas *et al*., 2011). Therefore, it is important to know the availability of nutrients in soil as influenced by various factors for the efficient management through external application. Soil fertility evaluation of an area or region is an important aspect in context of sustainable agricultural production.

Land is finite natural resource and there is no scope to increase area under cultivation. The food production in India can only be increased by increasing the crop productivity. The higher productivity can only achieved with better information of land and its use. In present dynamic situation accurate, meaningful, current data on land use are essential. Thus, it is necessary to have information on availability of major and micro nutrients of the study area. Hence, a comprehensive study was undertaken to know the fertility status of soils of Upland paddy research station (UPRS) farm of Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani.

Material and Methods

Study area : The present study was carried out in year 2012-13. The upland paddy research station (UPRS) farm of Vasantrao Naik

Marathwada Krishi Vidyapeeth, Parbhani cover an area of 80 ha and consist of seven blocks. The UPRS farm is located 190 20'N, 190 23' N latitude and 76 0 79' E, 760 78' E longitude, respectively. The soils are developed on basaltic and metamorphic rocks of varying age and also on alluvium derived from such rocks. These soils are scientifically known as "Mixed Montmorillonitic Hyperthermic Typic Chromostert". The study area comes under assured rainfall zone where tropical climatic conditions often exist.

Collection of soil samples : Eighty surface soil samples were collected from seven different blocks of UPRS farm, air dried completely, passed through 2 mm sieve and stored in properly labeled plastic bags. The soil pH, EC, organic carbon, available K was estimated by the standard procedures as described by Jackson (1973). The available N was analyzed by using alkaline potassium permanganate (Subbaiah and Asija, 1956). Available S was determined by using 0.15 per cent $CaCl_2$ solution (Willams and Steinberg, 1969). The micronutrients in soil samples were extracted with DTPA solution (Lindsey and Norvell, 1978). The soil nutrient index was calculated according to the procedure given by Ramamoorthy and Bajaj (1969). Correlation between available nutrients and soil physico-chemical properties was also worked out (Panse and Sukhatme, 1985). On the basis of soil site characteristics suitability criteria given by NBSS

Table 1. Fertility status of UPRS farm

Block No.	Average and range	pH	EC dS m^{-1}	OC (g kg^{-1})	Free $CaCO_3$ (g kg^{-1})	N (kg ha^{-1})	P_2O_5 (kg ha^{-1})	K (kg ha^{-1})	S (mg kg^{-1})	Cu (mg kg^{-1})	Fe (mg kg^{-1})	Mn (mg kg^{-1})	Zn (mg kg^{-1})
2	Average	8.29	0.56	6.0	84.9	227.73	12.98	646.24	5.50	4.07	6.37	13.09	1.08
	Range	7.86-8.49	0.25-1.21	5.3-7.3	65.0-98.0	213.24-240.31	9.30-17.40	468.10-834.40	4.10-6.60	3.80-4.50	5.24-8.74	12.20-14.10	0.98-1.26
18	Average	7.83	0.30	5.5	83.8	227.26	13.41	735.09	3.84	1.10	7.37	11.58	0.82
	Range	7.66-8.08	0.24-0.36	3.9-7.1	72.0-93.0	185.02-260.28	10.70-15.50	562.20-864.70	2.50-4.70	0.86-3.02	5.12-9.08	9.78-13.10	0.77-0.88
19	Average	7.57	0.31	5.7	70.6	268.34	11.27	616.18	4.71	2.95	7.82	11.87	0.78
	Range	7.38-7.73	0.25-0.37	4.9-7.0	43.0-90.0	257.15-285.37	8.70-13.70	436.80-808.64	3.40-6.10	0.98-3.88	6.08-8.82	10.50-12.96	0.63-0.88
20	Average	7.93	0.27	5.5	70.4	160.63	12.23	822.33	4.70	2.40	7.55	11.78	0.75
	Range	7.84-8.10	0.21-0.33	3.6-7.3	57.0-86.0	134.84-188.16	7.90-16.40	576.34-893.70	3.20-5.90	1.90-2.94	6.84-8.48	10.34-13.06	0.65-0.82
21	Average	7.98	0.31	4.7	82.6	243.52	18.59	569.76	5.45	2.32	7.54	9.35	0.73
	Range	7.80-8.35	0.25-0.34	3.4-6.1	51.0-91.0	219.52-263.42	10.60-23.80	434.18-704.40	4.80-6.60	2.08-2.56	6.38-8.60	8.24-10.20	0.60-0.91
38	Average	8.14	0.30	5.6	74.3	188.94	11.70	546.86	4.06	2.65	7.23	11.95	0.82
	Range	7.94-8.35	0.25-0.37	3.4-7.6	57.0-90.0	153.66-222.60	8.90-16.00	425.48-648.57	3.20-5.70	1.72-3.54	5.86-8.23	11.42-12.78	0.73-1.04
39	Average	8.12	0.30	5.5	69.1	165.68	11.68	546.33	3.50	3.22	7.62	8.82	0.84
	Range	7.96-8.36	0.25-0.37	3.1-7.7	50.0-85.0	144.25-200.70	8.90-15.10	442.39-612.64	2.30-4.00	2.92-3.62	6.48-8.64	7.92-9.76	0.60-1.06
UPRS farm	Average	7.96	0.32	5.48	76	214.25	13.05	634.81	4.49	2.64	7.93	11.16	0.83
	Range	7.38-8.49	0.21-1.21	3.1-7.7	43-98	138.84-285.37	7.9-23.8	425.80-893.70	2.30-6.60	0.86-4.50	5.12-9.08	7.92-14.10	0.60-1.26

and LUP (1994) suitability of various crops was determined.

Result and Discussion

The results of study presented in Table 1 indicated that all the soil samples from UPRS were moderately alkaline in soil reaction (100%) and within safe limit of electrical conductivity (100%). The pH of soil varied from 7.38 to 8.49. Moderately alkaline nature of soil may be due to formation of these soils from basaltic parent material rich in basic cations. Similar findings were reported by Jibhkate *et al*. (2009). Electrical conductivity (EC) of soil varied from 0.21 to 1.21 dSm^{-1}. The organic carbon content varied from 3.1 to 7.7 g kg^{-1}. It indicates that majority of these soils were low to moderately high in organic carbon content. This might be due to increased rate of decomposition of organic matter as reported by Rashmi *et al*. (2009).The free $CaCO_3$ content varied from 43 to 98 g kg^{-1} indicating calcareous nature of these soils.

The available N was found low to moderate in soils of UPRS (134.84 to 285.37 kg ha^{-1}) farm of Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani. It may be due low organic matter content of soil (Vineetha and Malewar, 2009) as well as rapid loss of applied N in soil (Tur *et al*., 2008). The available P content varied from 7.9 to 23.8 kg ha^{-1} in soils of UPRS was categorized as low to moderate range. As per the findings of Tur *et al*. (2008), the low amount of available P may be due to application of lower doses of P fertilizer, fixation of P on clay minerals or $CaCO_3$ surfaces with the time elapsed between fertilizer application and crop uptake. All soil samples were found high with respect to available K content which ranged from 425.80 to 893.70 kg ha^{-1}. This may be due to occurrence of potash rich minerals like mica and feldspar in parent material of the soils (Tur *et al*., 2008). The available S was found deficient in all the samples from UPRS (2.30 to 6.60 mg kg^{-1}) farm. The availability of S in soil depends on the combined action of factors like nature of parent material, rain fall, clay and organic matter content in soil (Saqeebulla *et al*., 2012). The continued soybean cultivation over a long period for seed production might also be a reason for low available S status. The DTPA-extractable micronutrients Cu (0.86-4.50 mg kg^{-1}), Fe (5.12-9.08 mg kg^{-1}), Mn (7.92-14.10 mg kg^{-1}) were found sufficient and Zn (0.60-1.26 mg kg^{-1}) was found deficient in soils of UPRS farm. Similar results were reported by Kumar *et al*. (2011) and Murthy *et al*. (2005).

Table 2. Nutrient Index values of UPRS Farm, VNMKV, Parbhani

Available nutrients	NIV	Category
Nitrogen	1.2	Low
Phosphorus	1.8	Medium
Potassium	3.0	High
Sulphur	1 .0	Low
Iron	3.0	High
Zinc	1.0	Low
Manganese	3.0	High
Copper	3.0	High

Table 3. Correlation between the physico-chemical properties and available nutrients

Available nutrients	Physico-chemical properties			
	pH	EC	O.C.	$CaCO_3$
N	0.156	0.097	0.210*	0.190
P	0.007	0.027	0.205*	-0.235*
K	0.147	-0.024	0.114	0.056
S	-0.052	0.201	0.218*	0.203
Cu	-0.033	0.124	0.146	-0.074
Fe	-0.246*	-0.037	0.114	-0.185
Mn	-0.064	0.032	0.265*	0.153
Zn	-0.042	0.304*	0.310**	0.211

* Significant at 5% level and ** Significant at 1% level

Table 4. Soil site suitability characteristics oF soils of UPRS Farm of VNMKV, Parbhani

Block no.	Soil site characteristics		Soil characteristics		Soil properties			
	Slope %	Drain-age	Texture	Depth (cm)	pH	EC (dSm^{-1})	OC ($g\ kg^{-1}$)	CaCO3 ($g\ kg^{-1}$)
2	1-3	WMD	Cl	45	8.29	0.56	6.0	8.49
18	1-3	WMD	Cl	55	7.83	0.30	5.5	8.38
19	1-3	WMD	Cl	55	7.57	0.31	5.7	7.06
20	1-3	WMD	Cl	45	7.93	0.27	5.5	7.04
21	1-3	WMD	Cl	45	7.98	0.31	4.7	8.26
38	1-3	WMD	Cl	55	8.14	0.30	5.6	7.43
39	1-3	WMD	Cl	55	8.12	0.30	5.5	6.91

Soil nutrient index value : As per the NIV developed by the Ramamoorthy and Bajaj (1969) the nutrient index value for (Table 2) soils of UPRS farm of Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani represents low fertility status for nitrogen (1.25), sulphur (1), zinc (1), medium for phosphorus (1.8) and high fertility status for available K (3), Fe (3), Mn (3) and Cu (3), respectively.

Correlation studies : The correlations between available nutrients and soil properties (Table 3) of soils of UPRS farm showed that the organic carbon content of soil was significantly positive with soil available N (0.210*), P (0.205*), S (0.218*), Mn (0.265*) and Zn (0.310*). According to Biswas *et al*. (2011), significant positive relation between organic carbon and available N may be due to strong association of N with soil organic matter, it also indicates importance of organic matter in promoting the availability of micronutrients (Kumar *et al*., 2011). Negative but significant correlations between soil pH and DTPA- Fe (–0.246*) indicated decreasing iron availability with increasing alkalinity. Similarly, negative but significant correlations between $CaCO_3$ and available P (-0.235*) indicated decreasing phosphorus availability with increasing calcareousness.

Soil site suitability : The data on soil site suitability characteristics of various blocks of UPRS farm is given in Table 4. On the basis of the analyzed soil properties and the criteria given by NBSS and LUP (1994), the suitability of various crops was determined. The soil site suitability characteristics of UPRS farm showed that these soils were highly suitable for growing soybean, pigeon pea and moderately suitable for growing cotton crop.

Conclusions

It can be concluded that soils of UPRS farm of Vasantrao Naik Marathwada Krishi Vidypeeth, Parbhani were moderately alkaline in soil reaction, safe in electrical conductivity, low to moderately high in organic carbon content and calcareous in nature. According to the concept of soil nutrient index soils were low in the available N, S and Zn, medium in P and high in K, Fe, Mn and Cu. Thus, deficiencies of N, S and Zn were the soil nutritional constraints identified and according to soil site suitability characteristics the land use planning may be done for production of soybean, pigeon pea and cotton crops at UPRS farm of VNMKV, Parbhani.

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J. Agric. Res. Technol., 42 (3) : 173-178 (2017)

Correlation and Path Analysis for Grain Yield, its Components and Drought Tolerance in Sorghum [*Sorghum bicolor* (L.) Moench]

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Abstract

In present investigation, total 260 (243 RILs + 17 checks) entries were evaluated in augmented design to analyzed correlation and path analysis for grain yield, its attributes and drought tolerance. The present investigation revealed that, among RILs *viz*.; MB123, MB163, MB7, MB112, MB97 showed promising performance for nearly all the characters under water stress conditions. MB123, MB163, MB7 showed significantly higher panicle length, panicle weight and lowest stay green score at flowering as well as at maturity. The character panicle weight, panicle length, total number of leaves, fodder yield, test weight of 300 seed, visual stay green score at flowering (1 to 9 score), agronomic acceptability score (1 to 5 score) and visual stay green score at maturity showed positive correlation with grain yield per plant through their direct and indirect effects. Direct selection for these characters will increase the breeding efficiency of the mapping population under stress. Visual stay green score at maturity showed positive correlation with grain yield per plant. 99 RILs were visual stay green score at maturity ranged from 2.5-4.0. These RILs showed drought tolerance at moisture stress (physiological maturity) of the crop.

Key words : Correlation, path analysis, stay green, drought.

India is a major sorghum growing country in the world. It stood second largest crop till green revolution but after green revolution, it occupies third place among food grains after rice and wheat. India covers 34 per cent of total sorghum area in the world and produces 17 per cent of world production. The sorghum productivity in India is less (0.876 kg ha^{-1}) as compared to other countries viz; Argentina (5.09 t ha^{-1}), China (3.6 t ha^{-1}) and Mexico (3.47 t ha^{-1}) (www.agricoop.in). Grain sorghum [Sorghum bicolor (L.) Moench] is a major dryland crop and one of the most important dietary sources of calories for the world's population. In India, the major sorghum growing states are Maharashtra, Karnataka and Andhra Pradesh which contributes nearly 93 per cent of area and production. Remaining area is distributes in states of Tamil Nadu, Gujarat, Madhya Pradesh and Rajasthan. Sorghum is unique to adopt environmental extremes abiotic and biotic stress. This makes the crop to minimize the risks and enables to fit to sustainable and economically profitable dryland production system. In-spite of this, average yield of sorghum is much below the yield potential of this crop. The efficiency of selection depends upon the direction and magnitude of association between yield and its component. As more and more characters are included in path analysis, direct and indirect effects of different characters on a complex trait like yield become increasingly improvement. Correlation and path analysis thus helps lot in plant breeding Programs. The present investigation has been undertaken to assess the correlation and path analysis in mapping population of sorghum (M35-1 x B35).

Materials and Methods

The material consisted of 260 recombinant inbred lines (243 RILs + 17 checks) derived

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from cross of M35-1 x B35 of sorghum were evaluated in augmented design with three replications during rabi 2009-10. The data were recorded for days to 50 per cent flowering, plant height (cm), total leaves per plant, stay green score at flowering (1 to 9 score), stay green score at maturity (1 to 9 score), days to physiological maturity, agronomic acceptability score (1 to 5 score), panicle length (cm), panicle weight (g), fodder yield (kg $plot^{-1}$ $genotype^{-1}$), test weight of 300 seed (g), grain yield per plant (g) and grain colour. The mean values of all the traits under consideration were used for statistical analysis. In order to study the extent of association between different traits the genotypic and phenotypic simple correlation coefficient were worked out from the respective variances and co-variances. The formula as suggested by Johnson *et al.* (1955) were used for calculating correlation from the recorded observations. Significance of correlation coefficient was determined form the Fisher and Yates table at 5 and 1 per cent level of significance. The 'r' values were compared against (n-2) degrees of freedom. The genotypic correlation coefficient between yield and its components were further partitioned into direct and indirect effects with the help of path coefficient analysis originally suggested by Sewall Wright (1921) and further outlined by Dewey and Lu (1959).

Results and Discussion

The present investigation was undertaken with the object of finding genetic variability for yield and yield components and drought tolerance in mapping population of sorghum. Analysis of variance for various characters are presented in Table 1. It revealed that the differences among the treatments in respective of all the characters studied were significant at 5 and 1 per cent level. Analysis of variance showed significant differences for all the characters. This indicated the existence of sufficient variation for effective selection for these characters in mapping population under study.

Correlation : Correlation coefficient is an important statistical constant, which indicates the degree of association among the various characters. The genotypic correlation was

Table 1. Analysis of variance (ANOVA) for different characters in *rabi* sorghum

Characters	Mean sum of suqares		
	Replications (2 d.f.)	Treatments (259 d.f.)	Error (518 d.f.)
Days to 50 % flowering	2.3793	64.0731**	1.2678
Plant height (cm)	161.1571	2291.6462**	12.8129
Total number of leaves	11.4256	12.2593**	10.3472
Visual stay green score at flowering (1-9 score)	0.2359	0.2806**	0.0712
Visual stay green score at maturity (1-9 score)	0.1959	3.4935**	0.1031
Days to physiological maturity	443.2375	10.3923**	4.6202
Agronomic acceptability score (1-5 score)	4.5838	1.1044**	0.2580
Panicle length $plant^{-1}$ (cm)	2.2695	24.4401**	0.6575
Panicle weight $plant^{-1}$ (g)	7.4265	299.2543**	2.8765
Fodder yield (kg $plot^{-1}$ $genotype^{-1}$)	0.0875	0.7051**	0.0149
Test weight of 300 seeds (g)	0.0183	3.4849**	0..0104
Grain yield $plant^{-1}$ (g)	28.4379	287.5470**	6.3926

** indicates significant at 1 per cent level, * indicates significant at 5 per cent level generally higher than phenotypic correlation indicating the inherent association between various traits. Grain yield is an complex character and is dependent on number of component characters. Therefore, study of the relationship of character with each other and with grain yield becomes more important in crop improvement programs. It is essential to find out the relative contribution of each of the component character in relation to yield so as give weightage during selection.

In present investigation, the genotypic and phenotypic correlation of grain yield plant^{-1} with test weight, fodder yield, panicle weight and plant height was positive and highly significant. Whereas agronomic acceptability score, panicle length showed positive and highly significant at genotypic level and positive and significant at phenotypic level indicating that increase in grain yield is because of increase in one or more of the above characters.

Similar results were reported by Bohra *et al.* (1986) for panicle length, Plant height, 1000 grain weight, Giriraj and Goud (1983) for plant height, 1000 grain weight, Potdukhe *et al.* (1994) for panicle length, 1000 grain weight, panicle weight, Umakant *et al.* (2004) for panicle weight, plant height, Panicle length and Iyanar *et al.* (2001) for panicle weight and panicle length.

The character days to 50 per cent flowering showed positive and non significant correlation with grain yield. The similar results has been reported by Nimbalkar *et al.* (1988) for days to 50 per cent flowering. The character days to physiological maturity showed positive and non significant association with grain yield similar results were recorded by Borell *et al.* (2000a). Inter characters correlation at genotypic and phenotypic level was positive and highly significant with fodder yield, test weight, panicle weight, similar results were recorded by Patil and Thombare (1985), Wankhede *et al.* (1985) and Thorat *et al.* (2004).

The character panicle length at genotypic and phenotypic was positive level and highly significant correlation with grain yield per plant. Similar results were recorded by Ambekar *et al.* (2000). The character visual stay green score at maturity showed positive and highly significant correlation with grain yield. Similar results were recorded by Henzell *et al.* (1992). It is important to note that the characters *viz.*; panicle weight, panicle length, test weight, agronomic acceptability score, plant height, fodder yield were positively correlated with grain yield plant^{-1}. These traits could be considered as an important trait for improving grain yield plant^{-1}.

Path Analysis : Genotypic path coefficient analysis outlined by Dewey and Lu (1959) was carried out to find out the direct and indirect effect of various components on grain yield. Direct effect of any component characters on grain yield gives an idea about reliability of indirect selections to be made through that character to bring about improvement in grain yield. If both correlation and the direct effect are high and positive then correlation explains its true relationship and selection for the character will be effective. If the correlation coefficient is positive, but the direct effect is negative or negligible, in such relations the indirect caused factors are to be considered simultaneously for selection. When correlation coefficient is negative but the direct effect is positive and high in such cases direct selection for such traits should be practiced to reduce the undesirable indirect effect.The residual effect determines how best the causal factors account for variability of the dependent factor (grain yield). If the value of residual factors is moderate or high, it indicates that besides the character studied there are some other attributes which

Table 2. Genotypic and Phenotypic correlation coefficient matrix in RILs and Checks for various traits

Genotype		**Days to 50% flower-eing**	**Plant height (cm)**	**Total no. of leaves**	**Visual stay green score at flowering (1-9 score)**	**Visual stay green score at maturity (1-9 score)**	**Days to physio-logical maturity**	**Agro-nomic accepta-bility score (1-5 score)**	**Panical length plant^{-1} (cm)**	**Panical weight plant^{-1} (g)**	**Fodder yield (kg plot^{-1} line^{-1})**	**Test weight of 300 seeds (g)**	**Grain yield plant^{-1} (g)**
Days to 50 % flowering	G	1.000	0.094	0.381**	-0.074	-0.067	0.134	-0.016	-0.076	0.129	-0.016	-0.041	0.131
	P	1.000	0.090	0.096	-0.047	-0.065	0.077	-0.009	-0.065	0.123	-0.013	-0.040	0.122
Plant height (cm)	G		1.000	0.147**	-0.033	-0.081	0.015	0.221**	0.087	0.294**	0.362**	0.374**	0.294**
	P		1.000	0.039	-0.025	-0.077	0.014	0.161*	0.083	0.288**	0.349**	0.369**	0.283**
Total number of leaves	G			1.000	-0.278**	-0.066	0.018	-0.020	0.269**	-0.016	0.009	0.086	-0.012
	P			1.000	-0.073	-0.015	-0.052	0.006	0.046	-0.003	0.006	0.019	-0.006
Visual stay green score at flowering (1-9 score)	G				1.000	0.152*	0.089	0.023	-0.063	0.070	0.051	0.090	0.077
	P				1.000	0.108	0.028	0.014	-0.038	0.051	0.042	0.062	0.056
Visual stay green score at maturity (1-9 score)	G					1.000	-0.056	0.279**	-0.036	0.072	-0.086	0.092	0.056
	P					1.000	-0.016	0.209**	-0.031	0.067	-0.081	0.088	0.053
Days to physiological maturity	G						1.000	-0.251**	0.073	0.108	0.027	0.096	0.098
	P						1.000	-0.122	0.045	0.067	0.016	0.051	0.056
Agronomic acceptability score (1-5 score)	G							1.000	-0.086	0.262**	0.118	0.321**	0.262**
	P							1.000	-0.055	0.181**	0.073	0.229**	0.173*
Panicle length plant^{-1} (cm)	G								1.000	0.203**	0.033	0.047	0.190**
	P								1.000	0.196**	0.028	0.043	0.175*
Panicle weight plant^{-1}	G									1.000	0.191**	0.188**	0.995**
	P									1.000	0.183**	0.186**	0.968**
Fodder yield (kg plot^{-1} line^{-1})	G										1.000	0.211**	0.194**
	P										1.000	0.204**	0.186**
Test weight of 300 seeds (g)	G											1.000	0.183**
	P											1.000	0.178*
Grain yield plant^{-1} (g)	G												1.000
	P												1.000

** indicates significant at 1 per cent level, * indicates significant at 5 per cent level contributes for yield. In the present investigation, panicle weight, panicle length, total number of leaves, test weight, agronomic acceptability score and fodder yield had positive direct effect on grain yield. Similar results were reported by Shahane and Borikar (1982), Potdukhe *et al.* (1992), Patil *et al.* (1993), Veerabadhiran *et al.* (1994), Iyanar *et al.* (2001) and Bidve (2008). Panicle length showed maximum positive direct effect on grain yield. Similar results were reported by Nimbalkar *et al.* (1988) in sorghum, Bakheit (1990).

Test weight had positive correlation and direct effect on grain yield and indirect positive effect through days to 50 per cent flowering. Patel *et al.* (1993) reported that test weight had positive direct effect on grain yield. Similar results found by Potdukhe *et al.* (1994), Iyanar *et al.* (2001), Veerabadhiran and Kennedy (2001), Hemlata *et al.* (2006). Total number of leaves had positive correlation and direct effect on grain yield. Similar results were found by Jayamani and Dorairaj (1993), Awari *et al.* (2003). Grain yield was positively associated with total number of leaves, test weight of 300 seeds. Similar results were found by Giriraj and Goud (1983).

Panicle weight showed maximum positive direct effect on grain yield, similar results were reported by Sriram and Rao (1983). Visual stay green score at maturity had positive correlation and direct effect on grain yield. Similar results reported by Henzell *et al.* (1992). Panicle weight had highly significant and positive correlation with grain yield and had indirect positive effect through plant height, agronomic acceptability score, panicle length, fodder yield, test weight, days to 50 per cent flowering, days to physiological maturity. Similar results were found by Wankhede *et al.* (1985) and Rao *et al.* (1992). Days to 50 per cent flowering and plant height had negative direct correlation with grain yield. Similar results were reported by Nimbalkar *et al.* (1988).

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J. Agric. Res. Technol., 42 (3) : 179-183 (2017)

Influence of Climate Change on Woolly Aphids in Sugarcane in Maharashtra

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Abstract

Insect pest problems in agriculture have shown a considerable shift during first decade of twenty-first century due to ecosystem and technological changes. The incidence of several insect pests like sugarcane woolly aphid, mealy bugs, early shoot borer, internode borer and top shoot borer markedly affected the percentage of sucrose, glucose, commercial cane sugar, brix and purity in canes. The experiment was conducted at State Research Scheme of Entomology section, Central Sugarcane Research Station, Padegaon (M.S.) during the 2009-10 and 2010-11 to study influence of climate change on woolly aphids in sugarcane in Maharashtra. The results revealed that the correlation analysis between woolly aphids incidence with various climatic factors showed that only rainfall was negatively and significantly correlated (r = 0.36* and 0.55*). Hence, rainfall has a negative effect on the population of woolly aphids. The maximum and minimum temperature as well as evening relative humidity has positive correlation during the year 2009-10, Whereas, in the year 2010-11, the correlation between woolly aphids has significant and negative correlation with rainfall and maximum temperature (r = -0.55*). The positive correlation was observed between woolly aphids and minimum temperature, morning and evening relative humidity. The simple linear regression between climatic factors and woolly aphids incidence has showed that 0.438* and 0.653* per cent variation in woolly aphid infestation was due to minimum temperature during 2009-10 and 2010-11 respectively. Similarly, the R2 values showed that 0.678* and 0.693* per cent variation in infestation was due to evening relative humidity during 2009-10 and 2010-11, respectively whereas remaining was caused due to other factors.

Key words : Climate change, woolly aphids, sugarcane.

Sugarcane (*Saccharum officinarum* L.) is one of the most important commercial crops of the tropical countries and is the main source of sugar in the world. Woolly aphid *Ceratovacuna lanigera* Zehntner (Hemiptera: Aphididae) had been a pest of sugarcane in India in the states of West Bengal, Assam, Sikkim, Tripura and Uttar Pradesh. The aphid invaded the tropical Indian states of Maharashtra and Karnataka in 2002 and later spread to Tamil Nadu, Andhra Pradesh, and parts of Kerala and Bihar States (Patil *et al*. 2004b, Srikanth 2007). In recent years, with the changing climate situation and agricultural practices, the pest damage to sugarcane crop from the time of planting till harvest has been quite pronounced and varies according to ecological conditions. This has resulted in highly fluctuating trends in sugarcane production.

It is expected that due to climate change, humidity, wind flow and temperature in India may cause an increase in insects, pests, diseases and microorganisms in agriculture, and accordingly, crop production may be decreased. Insects generally grow rapidly in warmer conditions. About 125 species of insects are known to infest the sugarcane as major pests in various parts of the world. In India, nearly 228 insect and non-insect pests are attacking the crop. Economical loss in sugarcane has been estimated to the extent of 20 per cent in cane yield and 15 per cent in sugar recover due to the ravages of the insect pests.

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Among them, the Sugarcane Woolly Aphid (SWA), *Ceratovacuna lanigera* Zehntner has been the latest threat to sugarcane crop as well as sugar industry in the country (Patil *et al.*, 2004b). In India during 1958, the occurrence of *C. lanigera* was first time reported from Coochebahar in West Bengal. Later, in 1971 from Uttar Pradesh. Although, the SWA has been reported in India as back as 1958, but its epidemics was noticed in Sangli district of Maharashtra during July 2002. Thereafter, it was noticed in severe form in Kolhapur and Satara districts and started spreading to other parts of Maharashtra and created havoc in the country. In Maharashtra, 7 to 39 per cent reduction in cane yield and 1.2 to 3.43 unit reduction in sugar recovery has been recorded. A total loss of about Rs. 874 crores has been estimated in India due to damage caused by SWA (Patil *et al.*, 2004b). Hence, the present investigation on influence of climate change on woolly aphids in sugarcane in Maharashtra was carried out.

Materials and Methods

Trials under field conditions were conducted to gather information pertaining to incidence of woolly aphids, Ceratovacuna lanigera Zehntner in sugarcane planted crop, With a view to find out the population fluctuation of woolly aphids in relation to minimum temperature, maximum temperature, rainfall, morning relative humidity and evening maximum relative humidity. The experiment was carried out at Entomology Section, Central Sugarcane Research Station, Padegaon during the year 2009-10 and 2010-11. Geographically, Padegaon is situated at elevation of 556 meters above mean sea level, it is located at 18°12' North latitude and 74°10' East longitude. A field having sugarcane crop planted with most popular commercial cane cultivar Co 86032 was selected for the study and the area was earmarked with flags. All the agronomic practices were followed as per recommendation. The crops were kept free from insecticidal application. The elevation of plot was such that water could conveniently be taken in and drained out as and when desired. The arrangements were made throughout the period of experimentation for supplement irrigation as and when required through tube wells. The experimental plots were well protected and properly leveled. The recommended dose of fertilizer were applied. The plot was well drained, soils having sandy loam in texture. Observations pertaining to woolly aphid damage were recorded at weekly intervals from first germination up to 12 weeks after planting. Data thus, obtained were computed to work out the percentage incidence of the pest to get an estimate for its population fluctuation during the crop.

For ascertaining the influence of some abiotic factors *viz*., the maximum temperature and minimum temperature, rainfall, morning relative humidity and evening relative humidity on the incidence of *C. lanigera* Zehntner, the meteorological data on weekly averages of maximum and minimum temperature, morning and evening relative humidity and rainfall were collected from the meteorological observatory of this station. Correlation and regression co-

Table1. Correlation between weather parameters with woolly aphids incidence

Year	Climatic Factors	Woolly aphids
2009-10	Maximum temperature	0.02
	Minimum temperature	0.29
	Morning relative humidity	-0.021
	Evening relative humidity	0.28
	Rainfall	-0.36*
2010-11	Maximum temperature	-0.55*
	Minimum temperature	0.17
	Morning relative humidity	0.27
	Evening relative humidity	0.12
	Rainfall	-0.55*

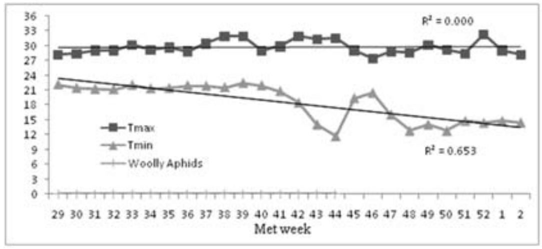
*Significant at 5% level, ** Significant at 1% level efficients were determined to establish relationship between infestation and meteorological parameters. The weather factors (maximum temperature, minimum temperature, rainfall, morning relative humidity and evening relative humidity) and woolly aphids were arranged as a weekly interval. The data obtained were analyzed statistically following the Fisher's method of analysis of variance as recommended by Cochran and Cox (1950). Simple and linear regression analysis between percent incidence and weather conditions were worked out by the methods out lined by Snedecor *et al*. (1967).

Results and Discussion

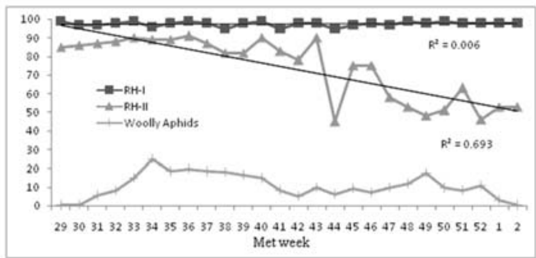
The effect of climate change could be positive or negative on insect and pests depending upon the environmental condition. In most of the agricultural crops, increase in temperature manifested the increase in insect and pests. Different weather parameters played important role in woolly aphid development and spread.

Correlation of weather parameters with woolly aphid : The Correlation between the weather parameters and insect development presented in Table 1. Maximum temperature had a non significant positive correlation r= 0.02 with woolly aphid which implies that increase in maximum temperature had a positive influence on progress of the insect and vice versa. With the progressive increase in maximum temperature from 28.3°C to 31.9°C the incidence of woolly aphids was maximum (24.67 per cent) in recorded on 34th SMW with a maximum temperature of 29.2°C in the year 2009-10 (Fig 1). On the contrary, with the progressive increase in maximum temperature from 27.4°C to 30.6°C the incidence of woolly aphids was maximum (13.14 per cent) was recorded on 33rd SMW with a maximum temperature of 30.4°C in the year 2010-11 (Fig.2).

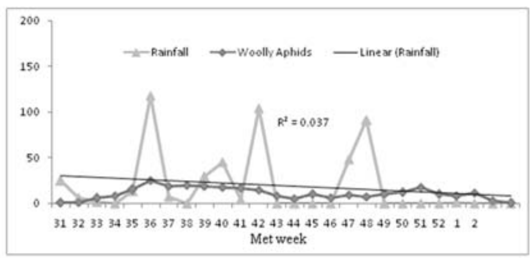
A non significant positive correlation r= 0.29 and 0.17 was observed between minimum temperature and woolly aphids in the year 2009-10 and 2010-11, respectively.



Relation between maximum and minimum temperature with wolly aphids (2009-10)



Relation between Relative humidity and wolly aphids (2009-10)



Relation between Rainfall and wolly aphids (2009-10)

Fig. 1. Relation between different weather parameters and woolly aphids

Table 2. Linear regression between climatic factors and woolly aphid

Year	Woolly aphids
2009-10	Y= 22.58 - 0.168 Tmin (R2= 0.438*)
	Y= 95.9 -1.128 RH-II (R2= 0.678*)
2010-11	Y= 23.86 - 0.398 Tmin (R2= 0.653*)
	Y= 98.42 -1.829 RH-II (R2= 0.693*)

* Tmin: Minimum Temperature and RH-II: Relative Humidity (Evening), Y= Cumulative woolly aphids, *Significant at 5% level, ** Significant at 1% level;

The relationship of morning relative humidity with woolly aphids (r= -0.021) in 2009-10 was found negative and non significant and r= 0.17 in 2010-11 was found positive and non significant (Table 1).

Evening relative humidity was found to have a non significant positive correlation r = 0.28 and r=0.02 in the year 2009-10 and 2010-11, respectively (Table 1).

Rainfall was an important factor for woolly aphids development. A significant negative correlation (r=-0.36* and r = -0.55*) was observed between total rainfall which implies that the cumulative and periodical increment in insect was not increased with the proportion of rainfall. It seems that other weather parameters were also simultaneously responsible for insect progress (Table 1).

Regression analysis : To develop a quantitative relationship between different weather variables and development of woolly aphids and coefficient of determination (R^2) was worked out through linear regression analysis.

Linear correlation coefficients indicated strong relationship between insect and different weather variables. Linear regression analysis was performed to handle seven independent weather variables and to identify critical and most contributing weather variable (s) separately towards the dependent variable of woolly aphids.

Combined effect of weather variables was found significantly favourable for woolly aphids development and spread as indicated by the significant coefficient values of multiple determination. The results of linear regression analysis for prediction of woolly aphids severity was accounted for the linear function involving a negative correlation with minimum temperature and evening humidity.

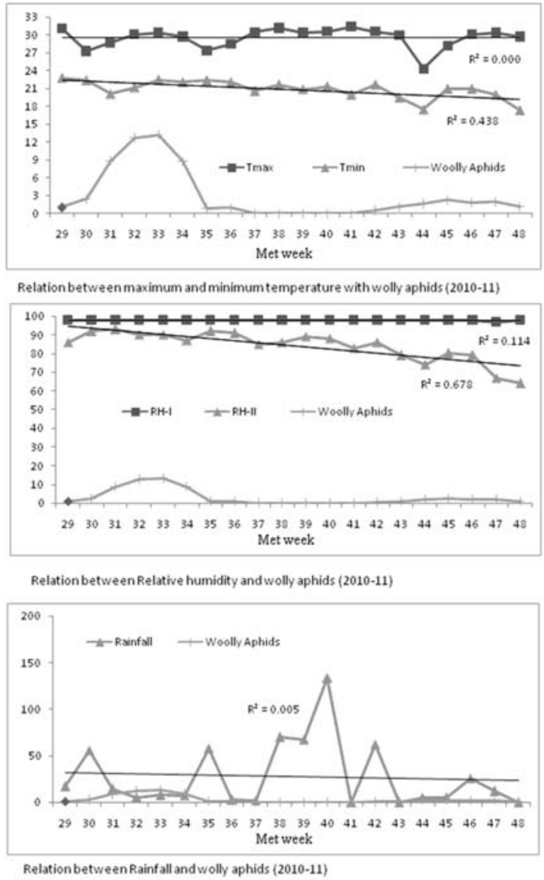


Fig. 2. Relation between different weather parameters and woolly aphids

The simple linear regression between climatic factors and wooly aphid incidence was developed during 2009-10 and 2010-11 and presented in Table 2.

The result of linear regression analysis indicated that a R^2 values showed 0.438* and 0.678* per cent variation in wooly aphid infestation was due to minimum temperature and evening relative humidity during 2009-10. Whereas, in the year 2010-11, The R^2 values showed 0.653* and 0.693* per cent variation in infestation due to minimum temperature and evening relative humidity and remaining was caused due to other factors. It is clearly indicated that the minimum temperature and evening relative humidity was found favourable for insect development and spread. The result is in conformity with Thind et.al (2008) and Tiwari and Chaure (1997) who reported maximum disease development at a temperature range of 25°C to 30°C and relative humidity of more than 80 per cent. The best regression equation for Ceratovacuna lanigera is as below (Table 2).

Conclusion

From the present studies, it could be concluded that aphid, *C. lanigera* population on sugarcane showed negative correlation with morning humidity and rainfall. However, positive correlation was observed with maximum and minimum temperatures and evening relative humidity during 2009-10, Whereas, *C. lanigera* showed positive correlation with minimum temperatures and morning as well as evening relative humidity and negative correlation with maximum temperature and rainfall during 2010-11. Based on regression study, minimum temperature and evening relative humidity played a significant role in inducing significant variation in woolly aphids population.

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J. Agric. Res. Technol., 42 (3) : 184-190 (2017)

Evaluation of *Rabi* Sorghum Generations for Biochemical Alterations under Moisture Stress

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Abstract

The present investigation was aimed to study the osmolyte accumulation in six different generations of rabi sorghum *viz*., P_1 (SPV 1830), P2 (RSLG2332), F_1, F_2, B_1 and B_2 during anthesis stage. The experiment was conducted at All India Coordinated Sorghum Improvement Project, MPKV, Rahuri during 2013. Total sugar, proline, glycine betaine and SOD were increased in moisture stress condition while ascorbic acid was decreased. On the basis of this, the generation response towards osmolytes accumulation to moisture stress was as like $P_2 > B_2 > F_1 > B_1 > F_2 > P_1$. Considering overall results, the promising parent P_2 and generation B_2 can be designated as drought tolerant and the generations F_1 and F_2 as moderately drought tolerant while the parent P_1 and generation B_1 can be considered as drought susceptible.

Key words : Sorghum bicolor, moisture stress, non stress, osmolyte, proline, glyceine betaine, SOD. total sugar and ascorbic acid.

Sorghum bicolor (L) Moench is the most popular *rabi* cereal crop and economical suitable for poor people in rainfed conditions. Globally, it is cultivated on 38.16 million ha of land with an annual production of 57.01 million tons (FAO 2013). India ranks first in terms of area under sorghum (5.90 M ha), representing over 17.2 per cent of world area, while it ranks second after the United States of America in production (5.39 MT) contributing 11.42 per cent of world production. The productivity of sorghum in India (963 kg ha^{-1}) is much less than the world average of 1395 kg ha^{-1} (Rakshit *et al*. 2014).Sorghum bicolor is mainly cultivated in rainfed condition for food, fodder and many other uses. Indian agriculture even today is a gamble in the monsoon (Swaminathan, 2004), because two third of its cultivable area is rainfed. The adequate production of staple grains in India and even in many other countries is mainly threatened by water stress, which reduces the crop productivity up to 50 per cent or more.

Pawar and Chett (1997) observed that the genotypes RS 29, 9-13, A 1, and M 35-1 accumulated more total sugars under moisture stress which also have higher grain yields than others. Yang *et al*. (2003) analyzed 240 sorghum genotypes at the post-flowering stage, glycine betaine fraction of the flag leaves were found in the range of 0.1 µmol g^{-1} fresh weight to 33.0 µmol g^{-1} fresh weights in the leaves of sorghum genotypes under moisture stress. Sharada and Naik (2011) revealed that drought stress increase the activity of superoxide dismutase (SOD) in groundnut. The water deficit condition increased the superoxide dismutase activity in horse gram. The drought tolerant genotype HPK4 showed higher superoxide dismutase activity than the drought susceptible genotype HPKC-2 under drought stress (Bhardwaj and Yadav, 2012). Ascorbic acid is the most abundant, powerful and highly water soluble antioxidant which acts to prevent or minimize the damage caused by reactive oxygen species (ROS) in the plant. Patel *et al*. (2011) reported that the lower decrease in ascorbic acid content in response to drought in drought tolerant variety of chickpea (Tyson and ICC-4958) than drought susceptible variety of chickpea (JG 315 and DCP-92-3).

Materials and Methods

The experimental material for this study was obtained from Senior Sorghum Breeder, Sorghum Improvement Project, MPKV, Rahuri. Two field trials comprising of six different generations of one cross, replicated thrice were conducted under non stress (Normal) and moisture stress (rainout shelter) conditions during *rabi* season.

Salient features of parents used for study

Genotypes	Pedigree	Salient features
SPV 1830	CSV216x SPV 502	High yielding, irrigation responsive, non tan, tall, good grain and fodder quality.
RSLG 2332	Local land race (Karnataka Local)	Drought tolerant, early maturing, medium tall, pearly white bold grain.

The experiment was laid out in a randomized block design with three replications under rainout condition and osmolytes investigation were carried out by using randomly selected third leaf from top of five plants from parents and F_1s; 10 plants from back crosses and 20 plants from F2s were selected at 50 per cent flowering from sorghum plants grown under stress and non stress condition. The methodology used for such analysis is briefly described below.

Proline was estimated by using Bates *et al.*(1973) method. Glycine betaine was estimated by using Stumf (1984) method. SOD activity was estimated by using Costa *et al.*, (2002) method. Total soluble sugar was estimated by using Anthrone method (Dubois *et al.*, 1956 and Yoshida *et al.*, 1972) and ascorbic acid was estimated as per the method of Mukharjee and Choudhari 1983.

Results and Discussion

The results on proline content presented in Table 1 revealed that under moisture stress condition, the accumulation of proline increased. The mean proline accumulation in leaves of different generations under non stress condition was 0.80 µmoles g^{-1} FW and was increased to 3.07 µmoles g^{-1} FW under moisture stress condition, i.e 2.84 fold over the non stress condition. Amongst the parents and generations, the percent increase in proline accumulation varied from as low as 2.16 fold in P_1 (SPV 1830) to as high as 3.26 fold in F_1 generation. In case of proline activity, the B_2 generation recorded significantly higher increase (3.81 µmoles g^{-1} FW) in proline accumulation under moisture stress condition followed by the parent P2 (RSLG 2332)(3.42 µmoles g^{-1} FW).

Many higher plants accumulate free proline in response to osmotic stress and proline accumulation has been correlated with

Table 1. Proline content in the leaves of different generations of *rabi* sorghum cross SPV 1830 x RSLG 2332 under non stress and moisture stress condition

Generations	Proline content (µmoles g^{-1} FW)		
	Non stress	Moisture stress	Fold increase
P_1 (SPV 1830)	0.77	2.45	2.16
P_2 (RSLG2332)	0.84	3.42*	3.06
F_1	0.72	3.09	3.26
F_2	0.63	2.52	3.03
B_1	0.89*	3.14	2.53
B_2	0.95*	3.81*	3.02
Mean	0.80	3.07	2.84
SE±	0.02	0.13	
CD at 5%	0.07	0.40	

* Significant at 5% level

tolerance to drought stress (Kavi Kishor *et al*., 1995). In plants, there is a dramatic accumulation of proline due to increased synthesis and decreased degradation under a variety of stress conditions such as salt or drought (Kavi Kishor *et al*., 2005). In a number of crop plants, it has been shown that proline increases proportionately faster than any other amino acid in plants under water stress and is an evaluating parameter for selecting for drought tolerance (Bates *et al*., 1973). The accumulation of proline was helpful to recover the sorghum plants from water stress (Blum and Ebercon, 1976). The proline contents in various genotypes of sorghum were accumulated at 50 per cent anthesis under drought stress (Yadav *et al*., 1991).

The proline concentration was higher in stressed plants in contrast to all other solutes and higher proline was noticed in drought tolerant sorghum (CS-3541) than in susceptible line (K-886) (Premchandra *et al*., 1995). Similarly, the genotypes Lakadi and Jeur 2TE have recorded the increased proline content by 6- to 8-fold as against 4-fold increase in Swati (SPV-504) (Satbhai *et al*., 1997). Furthermore, comparison of proline accumulation indicated that RSLG-262 accumulated high proline as against moderate and lower levels in M-35-1 and Swati, respectively under moisture stress (Deshmukh *et al*., 2001). The proline content was increased in promising cultivars of sorghum under water deficit condition at anthesis stage (Deshmukh and Dhumal, 2005).

The moisture stress condition reflected in an increase in glycine betaine accumulation in all the generations under estimation (Table 2). Further, the drought tolerant parent i.e P_2 (RSLG 2332) accumulated comparatively higher glycine betaine (45.5 percent) than susceptible parents P_1 (28.6 percent) under stress over control condition (non stress). The mean glycine betaine content under moisture stress condition in B_2 generation was significantly higher with 6.66 µmoles g^{-1} FW, followed by drought tolerant parent (P_2) with 6.33 µmoles g^{-1} FW and F_1 with 6.21 µmoles g^{-1} FW.

Glycine betaine (GB) and proline are the two major organic osmolytes that accumulate in a

Table 2. Glycine betaine content in the leaves of different generations of *rabi* sorghum cross SPV 1830 x RSLG 2332 under non stress and stress condition

Generations	Proline content (µmoles g^{-1} FW)		
	Non stress	Moisture stress	Fold increase
P_1 (SPV 1830)	4.07	5.24	28.64
P_2 (RSLG2332)	4.35	6.33*	45.52
F_1	4.51*	6.21*	37.85
F_2	4.42	5.91	33.64
B_1	4.54*	5.79	27.53
B_2	4.88*	6.66*	36.34
Mean	4.46	6.02	35.00
SE±	0.14	0.18	
CD at 5%	0.45	0.59	

* Significant at 5% level

Table 3. SOD activity in the leaves of different generations of *rabi* sorghum cross SPV 1830 x RSLG 2332 under non stress and moisture stress condition

Generations	SOD activity (units mg^{-1} protein)		
	Non stress	Moisture stress	Per cent increase
P_1 (SPV 1830)	165	199	20.40
P_2 (RSLG2332)	177*	233*	31.39
F_1	178*	224	25.84
F_2	170	210	23.33
B_1	173*	212	22.97
B_2	175*	222	26.86
Mean	173	217	25.40
SE±	2.09	1.67	
CD at 5%	6.58	5.25	

* Significant at 5% level

variety of plant species in response to environmental stresses such as drought, salinity and extreme temperatures, UV radiations and heavy metals. Betaines are quaternary ammonium compounds in which the nitrogen atom is fully methylated. The most common betaines in plants include glycine betaine. Several taxonomically distant species are accumulators of GB, others such as Arabidopsis, rice (*Oryza sativa*) and tobacco (*Nicotiana tabacum*) are considered to be non-accumulators (Rhodes and Hanson, 1993). The introduction of a pathway for the biosynthesis of GB into non-accumulators of GB has proved to be effective in increasing their tolerance to various abiotic stresses (Sakamoto and Murata, 2002).

Yang (1990) reported that almost all the cereal crops including sorghum accumulate GB under stress except rice and its levels vary both among and within species. Wood *et al*., (1996) also reported that sorghum genotypes differ in the amount of GB under water stress conditions. The results of present investigation on GB accumulation are also indicating similar trend, because the content of GB was different in all the six different generations of sorghum under study.

Micklbart *et al*., (1999) stated that among the various osmolytes synthesized in response to stress, the QAC and GB has very important role in retaining water within the cells, to protect the cellular components from injury caused by dehydration. They further explained that the drought tolerant nature of sorghum is because of its specific mechanism for accumulation of GB.

Deshmukh and Dhumal (2005) reported that the content of GB was increased under water deficit condition and PEG- 6000 induced water stress at anthesis stage and seedling in all the promising cultivars of sorghum.

The stressed parents and different generations showed increase in SOD activity over non stress condition (Table 3). Among the parents and generations, the increase in SOD activity was higher in P_2 parent and F_1 generation. The mean SOD activity in leaves of the control parents and different generations was 173 units mg^{-1} protein and was increased to 217 units mg^{-1} protein under moisture stress, an increase of 25.40 per cent over the control condition. Amongst the parents, the

Table 4. Total sugar and ascorbic acid content in the leaves of different generations of *rabi* sorghum cross SPV 1830 x RSLG 2332 under non stress and moisture stress condition

Generations	Total sugar (mg g^{-1} FW)			Ascorbic acid (µmoles g^{-1} FW)		
	Non stress	Moisture stress	Per cent increase	Non stress	Moisture stress	Per cent increase
P_1 (SPV 1830)	1.60	2.14	33.82	8.72	7.25	16.82
P_2 (RSLG2332)	1.72*	2.93*	70.16	7.10*	6.36*	10.39
F_1	1.50	2.49	65.85	7.90	6.84	13.51
F_2	1.38	2.14	55.21	7.25*	6.44*	11.17
B_1	1.72*	2.45	41.97	8.89	7.55	15.16
B_2	1.65*	2.95*	79.35	7.36*	6.62	10.02
Mean	1.59	2.52	58.50	7.87	6.84	15.10
SE±	0.03	0.04		0.10	0.05	
CD at 5%	0.10	0.12		0.30	0.15	

* Significant at 5% level

percent increase in SOD activity varied from as low as 20.4 per cent in P_1 (SPV 1830) to as high as 31.39 per cent in P_2 (RSLG 2332). Among the different generations, F_1 and B_2 generations recorded higher increase in SOD activity of 26.86 and 25.84 per cent, respectively.

Sharada and Naik (2011) revealed that drought stress increase the activity of superoxide dismutase in groundnut. The water deficit condition increased the activity of superoxide dismutase activity in horse gram. The HPK4 (drought tolerant) showed higher superoxide dismutase activity than (HPKC-2) under drought stress (Bhardwaj and Yadav, 2012).

Ceyhan *et al.*, (2012) reported that drought stress showed increase in superoxide dismutase activity in chickpea genotype. Drought treatment increased superoxide dismutase activity in chickpea leaves and superoxide dismutase activity was higher in drought tolerant genotype of chickpea than drought susceptible genotype of chickpea (Patel and Hemantarajan, 2012).

Raheleh *et al.*, (2012) reported that water deficit increases the superoxide dismutase activity in chickpea cultivar. The superoxide dismutase activity was higher in drought tolerant chickpea cultivar (MCC 392 and MCC 877) than susceptible cultivar (MCC 68 and MCC 448).

Amongst the different generations, B2 generation recorded significantly higher total sugar content 2.95 mg g^{-1} FW, followed by the genotype P_2 (RSLG 2332)with 2.93 mg g^{-1} FW under moisture stress condition (Table 4). The percent increase in total sugar content in the leaves of B_2 generation and P_2 genotype over non stress condition was to the extent of 79.35 and 70.16 per cent, respectively.

Sugars are the main solutes that play a significant role in osmotic adjustment (Wang *et al.*, 1991). Sugar content is higher in young emerging leaves than in fully expanded leaves. Development of leaf water deficit in fully expanded sorghum leaves cause increased amounts of glucose, sucrose, and fructose but the relative contribution in osmoregulation was greater by glucose followed by sucrose, and fructose (Jones *et al.*, 1980).

Premchandra *et al.*, (1995) reported that sugars and potassium concentrations are the major solutes contributing to osmotic potential in sorghum. They observed increased sugar and potassium concentrations by 37.4 and 27 percent, respectively under water deficit condition in favour of decreasing osmotic potential. The genotypes RS 29 and M 35-1 also accumulated total sugars which also have higher grain yields than others (Pawar and Chetti, 1997). Deshmukh *et al.*, (2001) reported that as the water stress increased there was a proportionate decrease in total sugars.

Like other parameters e.g accumulations of proline, GB, SOD, total sugar and ascorbic acid act as compatible osmolyte during moisture stress. Yadav *et al.* (2005) had reported increase in soluble sugars under water stress condition in sorghum hybrid CSH 14 at vegetative, anthesis and grain filling stage. They have proposed the involvement of accumulation of soluble sugars in osmotic adjustment. Ibrahim and Aldesuquy (2003) reported marked increase in total soluble sugars in sorghum under water stress. Their work is very much supportive to the results obtained in the present investigation. Yadava *et al.* (1991) reported that in various genotypes of sorghum sugar contents were accumulated under drought condition at 50 per cent anthesis. This may be used for classifying the sorghum cultivars under study as drought susceptible or tolerant.

The mean ascorbic acid content in the leaves of P_2 (RSLG 2332) was lowest 6.36 mg g^{-1} FW under moisture stress condition (Table 4). Under non stress condition, the ascorbic acid accumulation was lowest in P_2 (7.10 mg g^{-1} FW) followed by F_2 (7.25 mg g^{-1} FW) and B2 generation (7.36 mg g^{-1} FW). Ascorbic acid is the most abundant, powerful and highly water soluble antioxidant which acts to prevent or minimize the damage caused by ROS in plant. It occur in all plant tissue, usually being higher in photosynthetic cell and meristem. Its concentration is reported to be highest in mature leaves with fully developed chloroplast and highest chlorophyll. It has been reported that ASH mostly remain available in reduced form in leaves and chloroplast mostly remain available in reduced form in leaves. It can provide protection to membranes by directly scavenging than O_{2-} and OH and to regenerate ?-tocopherol from tocopheroxyl radical. The maize had appreciably more amount of ascorbic acid in its leaves than wheat at moderate and severs stress level (Nayyar and Gupta, 2005). Patel *et al*., (2011) reported that the lower decrease in ascorbic acid content in response to drought in drought tolerant variety of chickpea (Tyson and ICC-4958) than drought susceptible variety of chickpea (JG 315 and DCP-4958).

Conclusions

In the present studies, the B_2 generation performed well under moisture stress condition by maintaining high relative leaf water content as well as drought related parameters like the osmolyte proline and antioxidative enzyme superoxide dismutase activity. While ascorbic acid content is reduced due to formation of ascorbate hence, these parameters could be considered as biochemical marker or indicators for screening or developing drought tolerant genotypes in *rabi* sorghum.

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J. Agric. Res. Technol., 42 (3) : 191-196 (2017)

Long-term Effect of Integrated Nutrient Management on Productivity and Soil fertility In Sorghum (*Sorghum bicolor* L.) - Wheat (*Triticum aestivum* L.) Cropping System

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Abstract

A long-term field experiment was conducted for 32 consecutive years on fixed site from 1984-85 to 2015-16 at MPKV, Rahuri, Maharashtra, India to assess the effect of integrated nutrient management on productivity and fertility status of soil in sorghum-wheat cropping system. The experiment comprised 12 treatments *viz*., levels of N, P and K fertilizer application as individual component and use of chemical fertilizers in conjunction with different organic sources to substitute 25 to 50% N through farm yard manure (FYM), wheat cut straw (WCS) and green manure (GM) in *kharif* sorghum followed by 50 to 100% recommended NPK fertilizer levels in wheat during *rabi* season. Continuous application of organic manure along with 50% dose of recommended NPK fertilizer was beneficial in enhancing crop productivity and soil fertility. The significantly highest grain (41.21 and 39.17 q ha^{-1}) and straw yields (77.88 and 50.57 q ha^{-1}) of sorghum wheat respectively, were obtained with the application of 50% recommended dose of NPK fertilizer + 50% N through FYM to *kharif* sorghum followed by 100% NPK fertilizer in wheat crop, respectively. System productivity in terms of sorghum grain equivalent yield (107.54 q ha^{-1}) and economic returns were also higher in this treatment. Application of 50% dose of recommended NPK fertilizer + 50%N through FYM in sorghum followed by 100% NPK in wheat increased OC (0.71%), available N (195 kg ha^{-1}), P (22 kg ha^{-1}), and K (669 kg ha^{-1}), decrease in soil pH (8.12) and EC (0.23 dSm^{-1}) and higher content of DTPA-extractable Fe, Mn, Zn, and Cu (8.96, 21.76, 0.94 and1.85 mg kg^{-1}), respectively at the end of 32 years. Similarly, microbial biomass in post harvest analysis revealed the increase in microbial activity at the end of 32 years.

Key words : Long-term integrated nutrient management, sorghum-wheat, productivity, soil properties, fertility status.

Soil-health degradation has emerged as a major factor responsible for the stagnation in agricultural production. The maintenance of good soil health needs balanced fertilization, which includes application of all the required plant nutrients in proper amount and form. Chemical fertilizers and organic manures alone cannot sustain the desired levels of crop production under continuous farming. Integrated nutrient management may be an option to restore the soil productivity. Arresting the decline of soil-organic carbon is the most potent weapon in fighting unabated soil degradation and sustenance of soil quality.

It is being increasingly realized that when crops are grown in system, the fertilizer requirements of the cropping system as a whole is important than that of the individual crop (Sharma and Singh, 2003). The integrated plant nutrient supply system, by which we can apply the nutrients in balanced form, is emerging as the most logical concept for managing and sustaining long term soil fertility and productivity. Prasad *et al.* (1995) reported that the integrated use of green manure (GM) and organic manure with chemical fertilizer resulted in a build-up of available nutrients in soil much more effectively than that of chemical fertilizer alone. Long-term experiments on different soil types have shown that incorporation of crop residues increased organic carbon, total N and available P and K contents in soil. Singh *et al.* (2006) observed an increase in Fe and Zn content in the treatments having integrated plant nutrient supply over control as well as sole chemical fertilizer application.

In view of the above the results of integrated nutrient management experiment, conducted for 32 years at Rahuri are discussed here to develop suitable integrated nutrient supply and management systems and to study the long-term effect of conjunctive use of fertilizers and organic manures on the productivity of cereal based crop sequences and on soil health.

Materials and method

The long-term field experiment on sorghum-wheat cropping system was conducted continuously on fixed site from 1984-85 to 2015-16 (32 years) under the network of All India Coordinated Research Project (AICRP) on Farming Systems at Rahuri. The soil of the experimental field has a clay loam texture (sand 22.3%, silt 26.4%, and clay 51.3%), with pH 8.15, organic carbon 0.64 g kg^{-1}, electrical conductivity 0.35 dS m^{-1}, bulk density 1.32 Mg m^{-3}, Infiltration rate 0.76 cm h^{-1} and CEC 10.7 cmol kg^{-1} of soil. The available N, P and K were 153, 14.2,705 kg ha^{-1}, respectively. The DTPA-extractable iron (Fe), manganese (Mn), zinc (Zn) and copper (Cu) were 12.95, 22.10, 0.87 and 3.27 ppm, respectively. Sorghum cultivar CSH-9 and wheat HD-2189 were grown in sequence during *kharif* and *rabi* season, respectively at the same site. The experiment consisted of twelve treatments, each replicated four times in randomized block design (RBD.The treatment details for *kharif* and *rabi* are given in Table1.

Dhaincha (*Sesbania aculeata*) was raised during late summer in separate field as green manuring crop and incorporated after 55 days growth period in respective treatment plots. Calculated amount of organics *viz*., well-

Table 1. Different treatment combinations in the long-term experiment

Treat-ments	***Kharif* sorghum**	***Rabi* wheat**
T_1	No fertilizer, no organic matter (control)	No fertilizer, no organic matter (control)
T_2	50% recommended NPK through fertilizers	50% recommended NPK through fertilizers
T_3	50 % recommended NPK through fertilizers	100% recommended NPK through fertilizers
T_4	75% recommended NPK through fertilizers	75 % recommended NPK through fertilizers
T_5	100% recommended NPK through fertilizers	100% recommended NPK through fertilizers
T_6	50% recommended NPK through fertilizers + 50% N through FYM	100% recommended NPK through fertilizers
T_7	75% recommended NPK through fertilizers + 25% N through FYM	75% recommended NPK through fertilizers
T_8	50% recommended NPK through fertilizers + 50% N through wheat straw	100% recommended NPK through fertilizers
T_9	75% recommended NPK through fertilizers + 25 % N through wheat straw	75% recommended NPK through fertilizers
T_{10}	50% recommended NPK through fertilizers + 50% N through GM	100% recommended NPK through fertilizers
T_{11}	75 % recommended NPK through fertilizers + 25 % N through GM	75% recommended NPK through fertilizers
T_{12}	Farmer's conventional practice	Farmer's conventional practice

FYM-Farm Yard Manure and GM- Green Manuring decomposed FYM and crop residue of wheat straw were uniformly spread and incorporated into the soil with the help of power tiller before sowing of sorghum in respective treatments. The N content (quantity applied) of FYM, WCS and GM used in the experiments over the years at 50% N were 0.50-0.62% (12.00 to 9.67 t ha^{-1}), 0.43 to 0.50% (13.95-12.00 t ha^{-1}) and 1.7-2.4% (3.52-2.5 t ha^{-1}) respectively. The recommended dose for sorghum and wheat was 120:60:40 kg N: P_2O_5:K_2O ha^{-1}.

After completion of crop cycles, soil samples were collected after harvest of wheat crop for analysis. Sorghum grain equivalent yield was calculated in terms sorghum using the following formula SEY = Yi x Pi/P (p) where SEY denotes sorghum equivalent yield; Yi = yield of wheat; Pi = price of wheat and P (p) = price of sorghum. The nutrient management treatments of the cropping systems were evaluated for superiority, based on sustainability yield index (SYI) as described by Singh *et al.*, (1990). The SYI = Y- sd/Ymax where SYI is sustainable yield index of the system (sorghum - wheat) was worked out Y is the mean sorghum equivalent yield of the treatments over the year, sd is the standard deviation and Ymax is the maximum sorghum equivalent yield obtained among all the 60 values in the experiment over every 5 years of cultivation.

Results and Discussion

Yield and system productivity : After 32 years data of grain and fodder/straw were presented in Table 2 and 3. Application of NPK, either through inorganic fertilizers or in combination with organic manures/crop residue/green manure, significantly increased the yields of sorghum, wheat and sorghum grain equivalent yield over control during all the years. Grain and fodder/straw yield of sorghum and wheat increased significantly with the increase in NPK levels from 50 to 100% (Table 2 and3). The maximum grain yield of sorghum (41.21 q ha^{-1}) and wheat (39.17 q ha^{-1}) and that of the system (107.54 q ha^{-1}) in terms of sorghum grain equivalent yield was recorded under T_6 (50% NPK through chemical fertilizer along with 50% N through FYM during *kharif* followed by 100% NPK during *rabi*). The sorghum grain equivalent yield that of the system in T6 was significantly superior to the rest of the treatments and at par with T_5. Substitution of 50% N through any of the organic sources, recorded significantly higher sorghum grain equivalent yield as compared to 25% N substitution rate. The integrated use of chemical fertilizers with organics *viz*., FYM, green manure and wheat cut straw (WCS) might have added huge quantity of organic matter in soil that resulted in higher grain yields. This could be ascribed to the contribution from annual use of organics that improved physico-chemical properties of soil and increased availability of plant nutrients (Chaudhary and Thakur 2007). Further the organic matter also supplies macro and micro nutrients and complexing agents that enrich the soil.

Sustainable yield index : The sustainable yield index (SYI) values were higher in T_6 treatments over the 32 years data. It was lowest (0.06) in control and the highest (0.76) with the integrated use of nutrients at 50% recommended NPK through fertilizers + 50% N through FYM to sorghum followed by 100% recommended NPK through fertilizers to wheat with the highest mean yield of sorghum(41.21 q ha^{-1}), wheat (39.17 q ha^{-1}) and system (107.54 q ha^{-1}).Based on 32 years analysis, INM systems with 50% recommended NPK through fertilizers + 50% N through FYM to sorghum followed by 100% recommended NPK through fertilizers to wheat found to be more stable. While in order of merit the INM treatment consisting 50% recommended NPK

Table 2. Long term effect of Integrated nutrient management on grain and fodder yield of sorghum

Treat-ment	Grain yield of sorghum (q ha^{-1})								Fodder yield of sorghum (q ha^{-1})							
	1984-85 to 88-89	1989-90 to 93-94	1994-95 to 98-99	1999-00 to 03-04	2004-05 to 08-09	2009-10 to 13-14	14-15 to 15-16	Mean	1984-85 to 88-89	1989-90 to 93-94	1994-95 to 98-99	1999-00 to 03-04	2004-05 to 08-09	2009-10 to 13-14	14-15 to 15-16	Mean
T_1	4.02	2.25	1.62	1.38	1.81	1.44	1.22	1.96	27.86	26.80	12.09	12.22	12.28	9.73	1.93	14.70
T_2	35.61	29.88	33.02	25.37	26.76	24.12	22.96	28.25	61.29	66.63	66.35	54.21	69.11	65.48	36.27	59.91
T_3	38.75	34.87	38.81	25.92	29.44	29.09	26.94	31.97	60.54	77.56	69.11	58.19	73.26	68.63	42.56	64.26
T_4	43.43	37.52	42.54	26.37	32.21	30.61	29.90	34.65	64.07	80.58	72.53	63.16	76.30	71.67	47.23	67.93
T_5	46.87	44.78	47.18	27.02	34.43	34.12	33.79	38.31	72.85	93.01	77.55	76.18	83.41	78.71	53.38	76.44
T_6	50.21	50.19	49.42	28.53	35.99	36.05	38.07	41.21	68.93	91.69	78.66	78.27	86.36	81.11	60.15	77.88
T_7	45.06	41.6	45.34	26.66	32.36	32.71	35.42	37.02	66.93	85.80	76.38	64.37	74.79	73.88	55.97	71.16
T_8	40.67	36.96	40.19	25.24	29.42	28.63	28.44	32.79	64.78	77.68	74.07	54.00	72.37	66.61	47.98	65.36
T_9	41.08	39.37	42.63	26.47	31.03	31.51	31.45	34.79	63.38	82.74	78.35	61.68	77.89	73.10	49.68	69.55
T_{10}	49.36	40.83	45.1	26.65	33.82	33.62	32.66	37.43	72.34	82.46	77.89	66.34	83.01	77.82	51.60	73.07
T_{11}	46.48	37.77	43.84	26.57	30.20	32.83	35.02	36.10	67.61	78.77	75.55	61.54	78.06	74.01	55.32	70.12
T_{12}	26.28	19.37	27.22	19.58	21.30	20.32	12.62	20.96	49.14	57.62	60.07	43.66	54.06	48.77	19.95	47.61
SE±	1.74	1.28	1.11	0.75	1.35	1.23	1.97	1.35	4.73	2.13	1.40	2.85	0.85	1.30	2.96	2.32
CD(0.05)	4.93	3.64	3.17	1.88	3.85	3.54	5.66	3.81	13.11	6.03	3.98	8.15	2.41	3.76	8.53	6.57

Table 3. Long term effect of Integrated nutrient management on grain and straw yield of wheat in sequence

Treat-ment	Grain yield of wheat (q ha^{-1})								Straw yield of wheat (q ha^{-1})							
	1984-85 to 88-89	1989-90 to 93-94	1994-95 to 98-99	1999-00 to 03-04	2004-05 to 08-09	2009-10 to 13-14	14-15 to 15-16	Mean	1984-85 to 88-89	1989-90 to 93-94	1994-95 to 98-99	1999-00 to 03-04	2004-05 to 08-09	2009-10 to 13-14	14-15 to 15-16	Mean
T_1	3.98	4.30	5.41	7.57	5.63	5.76	3.73	5.20	8.81	9.11	10.81	11.53	10.58	9.47	5.10	9.34
T_2	25.37	27.96	24.91	27.77	26.59	28.21	28.97	27.11	36.19	36.18	36.36	39.73	36.48	36.95	38.72	37.23
T_3	32.45	33.80	32.04	34.26	32.66	33.06	32.93	33.03	40.16	44.41	44.03	49.65	45.75	45.19	43.33	44.65
T_4	31.16	34.06	30.08	32.74	31.10	31.30	29.34	31.40	38.50	40.49	42.42	44.01	43.40	42.60	39.02	41.49
T_5	33.60	37.91	35.43	36.29	35.22	37.20	37.79	36.21	42.21	46.86	50.12	51.34	49.55	49.49	48.72	48.33
T_6	35.60	40.99	37.07	39.24	38.19	40.83	42.24	39.17	43.74	47.10	48.49	54.89	52.67	53.21	53.91	50.57
T_7	32.23	35.30	30.68	33.61	32.96	35.30	35.63	33.67	41.90	43.54	46.51	48.08	46.72	47.24	46.41	45.77
T_8	38.04	35.18	32.20	36.13	35.03	34.65	32.75	34.85	47.93	46.67	48.21	49.07	47.96	45.80	42.13	46.82
T_9	32.04	34.45	30.51	32.59	31.96	33.89	35.14	32.94	42.54	41.14	45.50	45.61	43.78	44.33	46.00	44.13
T_{10}	35.69	37.38	33.96	36.24	35.60	36.31	38.05	36.18	44.70	46.62	47.72	49.68	55.52	48.55	48.81	48.80
T_{11}	30.69	33.68	30.71	34.15	32.12	34.67	36.36	33.20	40.10	41.42	45.72	45.47	45.00	45.70	47.11	44.36
T_{12}	19.47	20.85	22.25	23.61	23.19	24.56	20.93	22.12	24.58	28.43	32.01	33.72	34.01	32.87	28.13	30.54
SE±	2.26	1.61	1.98	0.99	0.99	1.00	2.31	1.59	3.52	1.59	1.14	1.95	1.84	1.26	3.06	2.05
CD(0.05)	6.28	4.59	5.51	2.81	0.82	2.88	6.66	4.22	9.77	4.53	3.28	5.56	5.26	3.62	8.81	5.83

Table 4. Long term effect of Integrated nutrient management on sorghum grain equivalence yield (q ha^{-1}) and sustainable yield index

Treatment	Sorghum grain equivalent yield (q ha^{-1})								Sustainable yield index							
	84-85 to 88-89	89-90 to 93-94	94-95 to 98-99	99-00 to 03-04	04-05 to 08-09	09-10 to 13-14	14-15 to 15-16	Mean	84-85 to 88-89	89-90 to 93-94	94-95 to 98-99	99-00 to 03-04	04-05 to 08-09	09-10 to 13-14	14-15 to 15-16	Mean
T_1	10.83	10.28	11.93	10.10	14.24	10.28	6.56	10.60	0.05	0.07	0.04	0.06	0.09	0.05	0.03	0.06
T_2	79.88	72.23	80.51	68.41	81.77	68.09	66.51	73.91	0.57	0.52	0.40	0.45	0.58	0.45	0.60	0.51
T_3	95.08	88.88	97.36	81.50	93.54	80.67	75.68	87.53	0.70	0.63	0.53	0.52	0.66	0.54	0.70	0.61
T_4	100.01	89.17	97.28	79.32	91.83	79.30	73.78	87.24	0.74	0.63	0.51	0.49	0.64	0.53	0.78	0.62
T_5	106.12	101.46	113.70	91.45	103.80	92.27	88.58	99.63	0.81	0.73	0.56	0.55	0.71	0.61	0.87	0.69
T_6	114.74	109.62	117.97	98.79	113.28	99.64	98.72	107.54	0.84	0.79	0.60	0.63	0.78	0.67	0.99	0.76
T_7	102.29	93.55	101.12	84.00	97.23	87.97	87.62	93.40	0.76	0.68	0.55	0.50	0.67	0.58	0.92	0.67
T_8	108.34	91.49	98.51	80.00	98.73	82.56	78.20	91.12	0.78	0.66	0.50	0.50	0.68	0.54	0.74	0.63
T_9	97.49	90.16	97.97	79.37	95.38	84.50	81.67	89.51	0.74	0.63	0.49	0.47	0.66	0.55	0.81	0.62
T_{10}	112.61	97.86	106.34	89.30	103.73	90.26	88.28	98.34	0.85	0.70	0.55	0.56	0.72	0.60	0.84	0.69
T_{11}	101.84	88.65	100.03	84.62	96.85	87.13	86.79	92.27	0.76	0.63	0.51	0.52	0.67	0.58	0.90	0.65
T_{12}	61.13	51.97	69.65	58.27	67.83	58.49	44.26	58.80	0.46	0.34	0.35	0.41	0.46	0.37	0.28	0.38
SE±	2.74	4.48	2.68	3.50	5.86	2.39	4.41	3.72								
CD(0.05)	7.78	12.43	7.65	9.97	16.26	6.66	12.68	10.49								

Table 5. Long term effect of Integrated nutrient management on economics of sorghum-wheat sequence (Rs ha^{-1})

Treatment	Gross monetary returns (Rs. ha^{-1})								Net monetary returns (Rs. ha^{-1})							
	1984-85 to 88-89	1989-90 to 93-94	1994-95 to 98-99	1999-00 to 03-04	2004-05 to 08-09	2009-10 to 13-14	14-15 to 15-16	Mean	1984-85 to 88-89	1989-90 to 93-94	1994-95 to 98-99	1999-00 to 03-04	2004-05 to 08-09	2009-10 to 13-14	14-15 to 15-16	Mean
T_1	2799	2734	4529	5652	8347	10669	9461	6313	-2948	-3534	-2934	-12696	-15200	-22007	-36767	-13727
T_2	12264	18113	29387	36182	46305	71753	96466	44353	4914	8868	19507	13919	19803	33465	43577	20579
T_3	14452	21186	35631	42680	42829	84448	109811	50148	6996	11815	24429	18731	24849	41836	54366	26146
T_4	15410	21714	35439	41509	52035	83416	107211	50962	7775	12447	24051	17807	24057	40567	51808	25502
T_5	17094	24358	40869	47554	59035	96588	128631	59161	8334	14164	28495	22156	29579	49213	71030	31853
T_6	17611	26672	42492	51652	63998	104281	143364	64296	8029	15510	29280	25028	33293	54401	84175	35674
T_7	15842	22886	37742	43811	54934	91971	127319	56358	7339	12905	25518	18664	25597	46673	68751	29350
T_8	17272	22245	35933	41663	55585	86213	113592	53215	8527	12338	23008	15316	23877	40266	52814	25164
T_9	15882	22198	35824	41340	54014	88225	118545	53718	7528	12674	23759	16267	24171	43349	60558	26901
T_{10}	17681	23857	38674	46475	58728	94564	128325	58329	8530	13770	26254	20771	29201	47780	70708	31002
T_{11}	15764	21678	36355	44171	54782	91179	126059	55713	7477	12136	24591	19331	25999	46434	69440	29344
T_{12}	9538	13388	25569	28792	41522	60932	64091	34833	2096	4668	15681	7385	15029	25420	15389	12238

Table 6. Effect of different INM treatments on benefit : cost ratio (Rs ha^{-1})

Treat-ment	1984-85 to 88-89	1989-90 to 93-94	1994-95 to 98-99	1999-00 to 03-04	2004-05 to 08-09	2009-10 to 13-14	14-15 to 15-16	Mean
T_1	0.49	0.44	0.61	0.31	0.35	0.00	0.00	0.31
T_2	1.67	1.96	2.97	1.63	1.75	1.75	0.86	1.80
T_3	1.94	2.26	3.18	1.78	2.38	1.81	1.00	2.05
T_4	2.02	2.34	3.11	1.75	1.86	1.79	0.96	1.98
T_5	1.95	2.39	3.30	1.87	2.00	1.85	1.27	2.09
T_6	1.84	2.39	3.22	1.94	2.08	1.89	1.40	2.11
T_7	1.86	2.29	3.09	1.74	1.87	1.86	1.18	1.98
T_8	1.98	2.25	2.78	1.58	1.75	1.73	0.86	1.85
T_9	1.90	2.33	2.97	1.65	1.81	1.79	1.04	1.93
T_{10}	1.93	2.37	3.11	1.81	1.99	1.83	1.25	2.04
T_{11}	1.90	2.27	3.09	1.78	1.90	1.85	1.25	2.01
T_{12}	1.28	1.54	2.59	1.34	1.57	1.65	0.32	1.47

through fertilizers + 50% N through GM (T_{10}) exhibited second best index.

Economics : Economics of sorghum-wheat crop sequence under integrated nutrient supply system was computed on the prevailing market prices and are presented in Table 5 and 6. Highest gross monetary returns and net returns with B: C ratio were recorded in the treatment involving use of 50% RDF + 50% N through FYM to kharif sorghum and 100% RDF to wheat (T_6). Based on mean values of 32 years the highest gross monetary returns (Rs. 64296 ha^{-1}), net returns (Rs. 35674 ha^{-1}) were observed in this treatment. The higher benefit: cost ratio was obtained due to use of 50 per cent RDF + 50 per cent N through FYM to sorghum and 100 per cent RDF to wheat which was higher than rest of all the treatments studied, except in treatment involving 100 per cent RDF during both the seasons and there was marginal difference with each over 32 years of experimentation.

Conclusion : Based on 32 years of experimentations application of integrated nutrient management has positive effect and sustained the system productivity and economic returns in sorghum- wheat cropping sequence.

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J. Agric. Res. Technol., 42 (3) : 197-203 (2017)

Studies on Engineering Properties of Custard Apple (*Annona squamosa* L.)

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Abstract

The engineering properties of custard apple are necessary for design of pulp-flakes extractor machine, transport, process and storage equipments. The physical and physico-morphological characteristics of custard apple fruits (Cv. Balanagar) and physical properties of custard apple seeds were measured. The average length, breadth, thickness, size and sphericity of custard apple fruits were 84.00 mm, 74.25 mm, 65.15 mm, 74.04 mm and 0.88, respectively. The average peel, carpellary pulp, gritty pulp and seeds in fruit were 46.77, 35.36, 11.63 and 6.24 per cent, respectively. The average weight of fruit and seed was 238.68 and 0.300 g, respectively. The average length, breadth and thickness of custard apple seeds was found to be decreased from 13.68 to 6.09 mm, 13.03 to 5.60 mm, 12.97 to 5.48 mm at a moisture content of 15.40, 12.50 and 10.25 per cent (d.b.), respectively. The size and sphericity of custard apple seeds was decreased from 8.82 to 8.09 mm and 0.64 to 0.62, respectively with decrease in moisture content at three different levels from 15.40 to 10.25 per cent while, bulk density, true density and porosity of seeds was found to be increasing from 642.42 to 684.03 kg m^{-3}, 898.22 to 1002.73 kg m^{-3} and 28.46 to 31.74 per cent, respectively. The angle of repose of custard apple seeds was decreased from 29.47 to 25.84° with decrease in moisture content at three levels from 15.40 to 10.25 per cent. The measured value of bulk density and angle of repose of custard apple seed with flakes was 876.79 kg m^{-3} and 35.42°, respectively. The angle of repose value for custard apple pulp/flakes was 43.98°. The shearing force required for separating flakes from the seeds, pulp stickiness and viscosity of pulp was 1.84 N, 184.40 g and 50.9 cP, respectively.

Key words : Engineering properties, custard apple, moisture content.

Annona squamosa L. (Custard apple) is the most important and widely distributed among the annonaceous fruits. The custard apple is used as a dessert because of its delicious taste and nutritive values, which is widely grown across the world. It is generally classified as semi-wild fruit. It is hardy and thrives well under adverse climatic conditions. All annonaceae fruits are indigenous to tropical America. It is mostly cultivated in India, Australia, China, Israel, Cuba, Colombia, Pakistan, Philippeines. In India, it is the most commonly found in Andra Pradesh, Maharashtra, Tamil Nadu, Orissa, Assam, Uttar Pradesh, Bihar and Rajasthan. It is also widely distributed throughout tropics and subtropics in Maharashtra. The custard apple crop is grown on an area of 45,000 ha with the production of 2,31,550 MT (Shete *et al*., 2009).

Annona squamosa is a popular fruit of the tropical states of India, with a very sharp and short season, lasting for about 3-4 months a year. The custard apple fruits are available from August to December and the peak period during October and November. Though the fruit is known as minor, it is important from economical and nutritional point of view. The skin or covering of custard apple is thin but tough, which is usually yellow or brownish when ripe. Beneath the thin covering, a thick, cream-white layer of granular, flesh is present, which surrounds seeds. The flavour of the fruit is sweet and agreeable. Skin of fruits is high in

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phenols and causes rapid browning and strong off flavor during processing and storage.

A manual separation of pulp-flakes is very cumbersome, time consuming, unhygienic. It also leads to crushing of flakes to some extent. Further manual separation has constraints in separation of pulp-flakes on large scale. Very little work on mechanical extraction has been reported on the development of pulping machine with minimum damage to the flakes. Presently, a brush type pulping machine is being used for the operation but by this means the flakes are crushed to large extent. Thus, there is vital need to develop a machine to extract the pulp-flakes with minimum damage to flakes. Considering the facts of rapid increasing area under custard apple and its minimum shelf life, there is a need to develop suitable pulper and storage technology for custard apple. The present research work was carried out to measure the engineering properties for development of above said machines.

Materials and Methods

The custard apple fruits of Cv. Balanagar with uniform size were procured from research farm; Department of Horticulture, MPKV, Rahuri and engineering properties were measured using the facilities available with Department of Agricultural Process Engineering, Dr. A. S. College of Agricultural Engineering and Technology, Mahatma Phule Krishi Vidyapeeth, Rahuri.

Fruit properties : Randomly 50 fruits were selected for measuring the properties. The size of fruit was measured by using a vernier calliper having least count of 0.01. The physico-morphological properties of fruit were measured by separating the carpellary and gritty pulp separately (Kad *et al*., 2016).

Seed properties

Moisture content : The moisture content of the custard apple seeds was calculated by using air oven method. Three different moisture levels of 15.40 per cent (immediately after separation from the pulp-flakes), 12.50 per cent and 10.25 per cent were determined for studying the physical properties of seeds. The dry basis moisture content was considered for calculations.

$$M = \frac{W_1 - W_2}{W_2}$$

Where, M = Moisture content on dry basis, W_1 = Initial weight of seeds (g) and W_2 = Weight of seeds after drying (g)

Linear dimensions : The major, intermediate and minor axes were measured using a micrometer screw gauge having a least count of 0.001 of randomly selected hundred custard apple seeds.

Size and sphericity : The size and sphericity were calculated as follows with a reference of Mohsenin, 1986 and Chakravarty, 1995.

$$\text{Size} = (a \times b \times c)^{1/3}$$

$$\text{Sphericity} = \frac{(a \times b \times c)^{1/3}}{a}$$

Where, a, b and c are major, intermediate and minor axes of custard apple seed.

Bulk density : The bulk density was calculated by knowing the mass of seeds contained in a known volume on container (Mohensin, 1986).

$$\text{Bulk density (g/mL)} = \frac{\text{Mass of seeds (g)}}{\text{Volume of seeds (mL)}}$$

True density : It was determined by toluene liquid displacement method (Mohensin, 1986). Seed sample was submerged in toluene in a measuring cylinder having accuracy of 0.1 mL. The increase in the toluene volume due to sample was noted as true volume of the sample, which was then used to determine the true density of the sample. Average of five replications was considered as true density value of the sample.

$$\text{True density (g/mL)} = \frac{\text{Mass of seeds (g)}}{\text{Volume of tolune displaced by seeds (mL)}}$$

Porosity : The porosity of custard apple seeds at a moisture content of 15.40 % (d.b.) and 12.50 % (d.b.) was calculated by using the following formula.

$$\text{Porosity (\%)} = \frac{\text{True density} - \text{Bulk density}}{\text{True density}} \times 100$$

Angle of repose : The angle of repose was calculated by using following formula.

$$\theta = \tan^{-1} 2h/d$$

Where, θ - Angle of repose in degree, h - Height of cone, mm and d - Diameter of base of the cone, mm.

Force required to separate the seeds from flakes : It is the force required to produce a major break/rupture in a sample to separate the seeds from the flakes was measured with the help of texture analyzer.

Pulp stickiness : Stickiness/adhesiveness is the work/force necessary to overcome the attractive forces between the surface of the product and the surface of the probe with which the product comes in contact. It was commonly the textural property measured by texture analyzer and is product of hardness and cohesiveness (Peleg, 1996 and Breene, 2007).

Viscosity of pulp : The viscosity of custard apple pulp is a measure of its resistance to gradual deformation by shear stress or tensile stress. The viscosity of fresh custard apple pulp samples is measured with the help of Brookfield Viscometer DV-II+Pro. The spindle (probe) no. 64 was used for measurement of viscosity at 200 rpm with constant sample temperature of 23.4°C.

Results and Discussions

Physical properties of custard apple fruits : The average length, width and breadth of fruit were found to be 84.00, 74.25 and 65.15 mm, respectively. Average size and sphericity of the fruit was found to be 74.04 mm and 0.88, respectively. The results were in agreement with Dhumal (1994) and Beerh *et al*. (1983) for custard apple fruits.

Morphological properties of custard apple fruits : The average peel, carpellary pulp, gritty pulp and seeds were found to be 46.77, 35.36, 11.63 and 6.24%, respectively. The average weight of fruit and seed was 238.68 and 0.300 g, respectively. All these results were in agreement with Beerh *et al*. (1983), who studied the physico-morphological properties of 7 cultivars of custard apple fruits including Cv. Balanagar.

Linear dimensions : Linear dimensions of randomly selected 100 custard apple seeds were measured at three different moisture contents and seed size was calculated. The average respective length, breadth and thickness was found to be 13.68, 8.28 and 6.09 mm at a moisture content of 15.40 per cent (d.b.), 13.03, 7.71 and 5.60 mm at a moisture content of 12.50 percent (d.b.) and 12.97, 7.49 and 5.48 mm at a moisture content of 10.25 per cent (d.b.). The linear dimensions were found to be decreasing with decrease in moisture content.

Seed size : The seed size was also found to be decreasing from 8.828 to 8.091 mm with decreasing in moisture content at three levels from 15.40 to 10.25 per cent shown in Fig. 1

The results were in agreement with past study by Thakur and Singh (1967), which reported that the custard apple seeds were oblong in shape with an average length of 11.2 mm and a breadth of 6.8 mm. The results reporting the decrease in linear dimensions and seed size with decrease in moisture content were in agreement with Mishra and Kulkarni, (2009) for the physical properties of cumin seed as a function of moisture content.

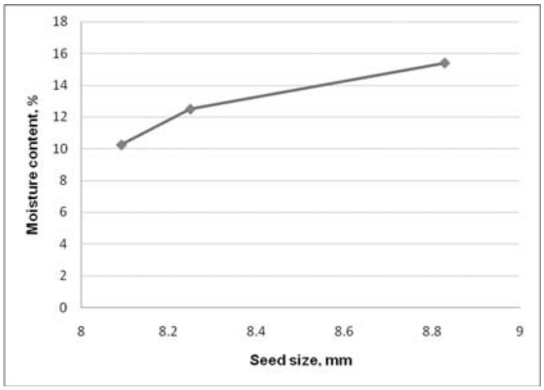

Fig. 1. Effect of moisture content on seed size of custard apple

Sphericity : The sphericity was found to be decreased from 0.648 to 0.625 with decrease in moisture content from 15.40 to 10.25 per cent (d.b.) (Fig. 2). Similar results of the effect of grain moisture on sphericity have been reported for barley grains (Mahmoud *et al.*, 2009). The results were also in agreement with effect of moisture content on physical properties of cumin seeds (Mishra and Kulkarni, 2009).

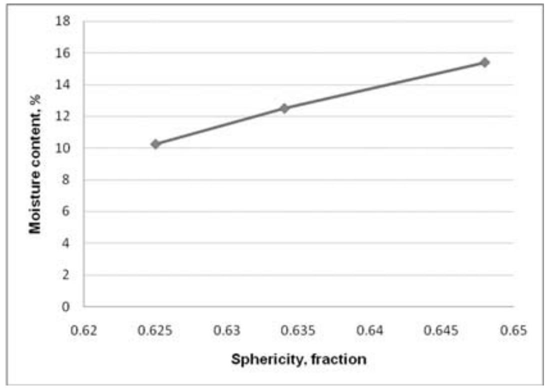

Fig. 2. Effect of moisture content on sphericity of custard apple seeds

Bulk density : The bulk density was found to increasing from 642.42 to 684.03 kg m^{-3} with decrease in moisture content of seeds from 15.40 to 10.25 per cent (Fig. 3). The increase in bulk density was due to reduction in seed volume after drying. The results were in agreement with Mahmoud *et al.*, (2009) who studied the physical properties of barley grains and with Ersef and Halil (2011) who studied the physical properties of white kidney beans at various moisture content. The average value of bulk density of custard apple seed with flakes was 876.79 kg m^{-3}.

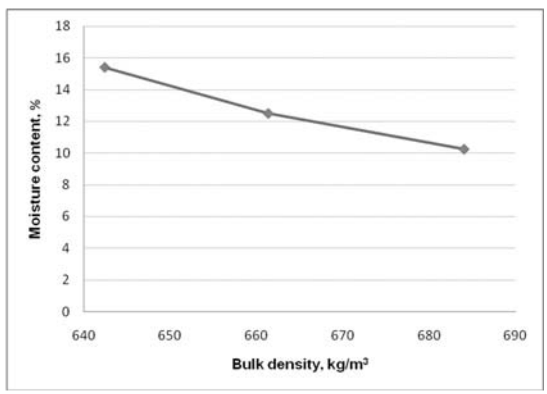

Fig. 3. Effect of moisture content on bulk density of custard apple seeds

True density : It was found that the true density increased with decreased in moisture content (Fig. 4). The measured values of true density were 898.22, 950.46 and 1002.73 kg m^{-3} at a moisture content of 15.40, 12.50 and 10.25 per cent, respectively.

There was increase in true density for custard apple seeds with decrease in moisture content might be due to the relatively lower true volume as compared to corresponding mass of the seed attributed due to loss of water. The results were in agreement with Mahmoud *et al*. (2009) for the physical properties of barley grains and with Ersef and Halil (2011) for the physical properties of white kidney beans.

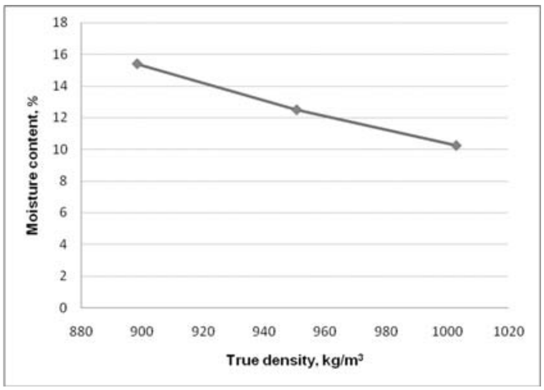

Fig. 4. Effect of moisture content on true density of custard apple seeds

Porosity : The porosity of custard apple seeds goes on increasing from 28.46 to 31.74 per cent with decrease in moisture content from 15.40 to 10.25 per cent (d.b.) (Fig. 5). This was due to increase in pore space with decrease in moisture content. The results showing increasing in porosity with the decrease in moisture content were in agreement with the earlier findings for barley grains (Mahmoud *et al*., 2009).

Angle of repose : A angle of repose decreased with the decrease in moisture content for custard apple seed (Fig. 6). The results indicated that the angle of repose value for custard apple seed was 29.47, 27.85 and

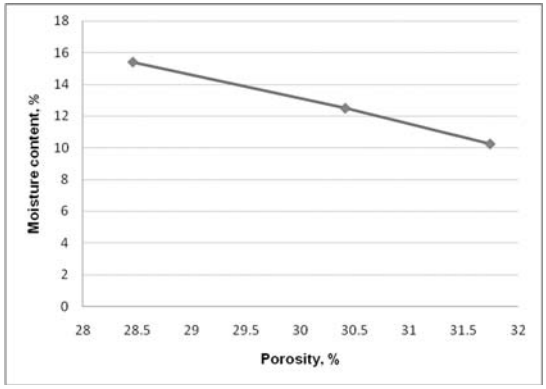

Fig. 5. Effect of moisture content on porosity of custard apple seeds

25.84° at moisture content (d.b.) of 15.40, 12.50 and 10.25 per cent, respectively. The similar results were reported by Mahmoud *et al*., (2009) for barley grains and Mishra and Kulkarni (2009) for cumin grains. The measured value of angle of repose of custard apple seed with flakes was 35.42° and custard apple pulp/flakes was 43.98°.

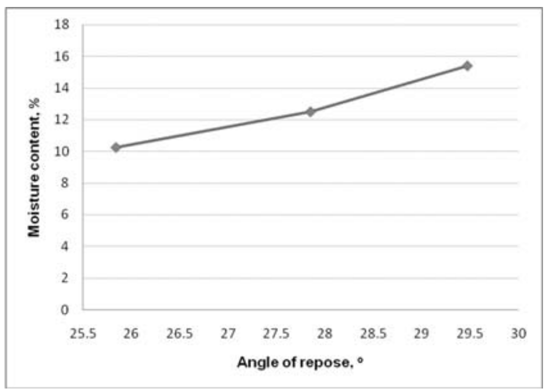

Fig. 6. Effect of moisture content on angle of repose of custard apple seeds

Shear force required to separate the seeds from flakes : The shearing force required for separating flakes from the seeds was determined through the experiment carried out on Brookfield Texture Analyzer (CT3). The maximum shear force required to separate

Table 1. Measurement of shear force required to separate the seeds from flakes

Replication	Shear force (N)
R1	2.25
R2	1.35
R3	1.65
R4	1.53
R5	2.53
R6	1.46
R7	2.16
R8	1.38
R9	2.26
R10	1.86
Average	1.84

Table 2. Measurement of textural properties of custard apple pulp

Replication	Hardness (g)	Cohesiveness	Stickiness (g)
R1	120	0.19	22.80
R2	285	0.20	57.00
R3	170	0.29	49.30
R4	565	0.39	220.35
R5	760	0.39	296.40
R6	665	0.31	206.15
R7	1470	0.23	338.10
R8	500	0.24	120.00
R9	735	0.09	66.15
R10	540	0.30	162.00
R11	340	0.61	207.40
R12	845	0.49	414.05
R13	225	0.26	58.50
R14	500	0.33	165.00
R15	1235	0.31	382.85
Average			184.40

seeds from flakes was 2.53 N (Table 1). The thickness of wire as determined by considering shearing force of single carpel and total number of carpel along the length of cylinder was 0.40 mm in diameter.

The similar results were reported by Soliva *et al*. (2002) for fresh cut pears and Kokini and Carrilo (1989) for tomato paste.

Pulp stickiness : The stickiness property is required for the adjustment of angle of casing and discharge of pulp - flakes outlet, so that pulp discharges smoothly and easily. The data on pulp stickiness of fifteen custard apple pulp samples was calculated and is as shown in Table 2. The minimum, maximum and average measured values of stickiness of custard apple pulp were 22.80 g, 414.05 g and 184.40 g, respectively.

The results are in agreement with the values reported by Sigita *et al*. (2013) for apple pulp, Ahmad *et al*. (2005) for fruit bar made from papaya and tomato.

Viscosity of pulp : The viscosity determined the flow characteristics of the pulp. The viscosity is required for determination of angle of outer casing and pulp-flakes outlet of the pulp-flakes extractor. The average values of viscosity and torque were 50.9 cP and 33.07 Nm, respectively.

The results are in agreement with the values reported by Sigita *et al*. (2013) for apple pulp and Shahnawaz and Shiekh (2011) for jamun fruit juice, squash and jam.

Conclusions

All the engineering properties of custard apple seed get affected with change in moisture content. An average length, width, breadth, weight of whole fruit and weight of seed were found to be 84.00 mm, 74.25 mm, 65.15 mm, 238.68 g and 0.300 g, respectively. The per cent peel, carpellary pulp, gritty pulp and seeds were recorded to be 46.77, 35.36, 11.63 and 6.24 per cent, respectively. The size and sphericity was decreased while bulk density, true density and porosity were increased with decrease in moisture content of the seed. The angle of repose was found to be decreased with decrease in moisture content. The maximum shear force required to separate seeds from flakes was 2.53 N. The minimum, maximum and average measured values of stickiness of custard apple pulp were 22.80 g, 414.05 g and 184.40 g, respectively. The measured values of viscosity and torque were 50.9 cP and 33.07 Nm, respectively.

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J. Agric. Res. Technol., 42 (3) : 204-209 (2017)

Studies on Preparation of Fig Jam Without Preservative

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Abstract

The present research was conducted to standardize the recipe for making of fig jam, to evaluate the quality of fig jam and to study the storage behavior of jam from fig at room temperature. The fruits were washed in clean water and then fig pulp was prepared with help of screw pulper. Twelve treatments with different level of sugars (700, 800, 900 and 1000 g) and pectin (2.0, 2.5 and 3.0 g) and constant level of fig pulp (1000 g), citric acid (4.75 g) were performed for studying the effect on fig jam during 30 days of storage. Add prescribed amount of sugar to the extracted pulp and mix well thoroughly. This mixture is boiled and stirred continuously. Add pectin and citric acid just before at the end point. Then check for the end point by using the refractometer having total soluble solids should not be less than 68.5°B. The prepared jam is filled in the 200 gauge polyethylene pouches. The jam filled pouches are sterilized by placing them in hot water for few minutes. Finally these pouches are stored in dry and cool place. The chemical composition of fig jam with different treatments revealed that there was increased in T.S.S., total sugars, reducing sugars and non-reducing sugars, while the ascorbic acid and titrable acidity was decreased during the storage of fig jam for a period of 30 days. The sensory evaluation of fig jam was also done for colour and appearance, taste, flavour and overall acceptability. There was decrease in score for colour and appearance, taste, flavour and overall acceptability during storage of 30 days. Among the different treatments, treatment with 1000 g fig pulp, 800 g sugar, 2.5 g pectin, 4.75 g citric acid was found to be best for preparation of fig jam in respect of chemical analysis and sensory evaluation.

Key words : Fig, jam, chemical properties, sensory evaluation.

Fig is one of the oldest cultivated fruits belongs to Moraceace family and botanically known as Ficus carcica L. It is native of Southern Arabia, namely Turkasthan (Condit, 1947) and cultivated chiefly in Mediterranean regions from Turkey to Spain and Portugal. It is also grown in some parts of U.S.A., Chile, Italy, Greece, Algeria, Morocco and Syria.

In India, fig is grown on small scale and fresh fig fruits are exported to some extent. The total area under fig cultivation in India is about 6000 hectares out of which 2000 hectares are in Maharashtra with the production of about 2705 metric tonnes. In India, its cultivation is mostly confined to western parts of Maharashtra, Uttar Pradesh (Lucknow & Saharanpur), Karnataka (Shrirangapatnam), Punjab, Andhra Pradesh (Anantpur), Tamilnadu (Coimbatore). In Maharashtra, it is cultivated on commercial scale in adjoining area of Pune and Aurangabad (Kad *et al*., 2011).

The fleshy fruit is consumed in processed form, the dried form being the most popular. It can also be canned or used for candy or jam making. From nutritional point of view, the fig is much valued and as it contains high sugar and low acid and it is rich in calories (269 kcal/100 g), calcium (higher than milk), iron and copper content (Mortenson and Bullard, 1968). Figs are good source of carbohydrates including fibre (Desai and Kotecha, 1995). Fresh fruits are valued for its laxative properties and used in

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treatment of skin infection to maintain acidal alkali balance of body by very effectively neutralizing excess acid. Steam distillate of fruit contains benzaldehyde, which has shown considerable antitumor activity. Both fresh and dry figs contain appreciable quantities of vitamin A and vitamin C, smaller quantities of vitamin B and vitamin D (Anonymous, 1984) with total mineral content of 2 to 4 times more other than fresh fruit. The fresh ripe fruits are highly perishable and difficult to transport and cannot be stored long even under refrigeration. Hence, it is necessary to process it for improving keeping quality. Fresh fruits can be held only for about a week at 0°C and 90 per cent relative humidity (Condit, 1947).

The present work will be carried out with following objectives for the standardization of fig jam and to study changes in chemical composition and sensory properties of fig jam.

Materials and Methods

Uniform size and healthy fruits of fig Cv. Poona were procured from All India Co-ordinated Research Project on Arid Zone Fruits (Fig and Custard Apple), Jadhavwadi, Tahasil-Purandhar, District- Pune and from the orchards of progressive farmers.

Materials : The materials used during preparation are fig pulp, sugar, citric acid and 200 gauge food grade polythene pouches. The instruments used for this purpose are screw type pulper machine, refractometer, electronic weighing balance and pouch sealing machine. The different types of chemicals and glassware's are also used for determination of different chemical parameters.

Methodology : The methodology followed during the preparation of the jam and conduction of chemical tests is as follows.

Experimental design : Based on the review of literature and preliminary trails, the experimental parameters were identified. The treatment details are presented in Table 1 and experimental flow chart for preparation of fig jam are given in Fig 1.

Fig Fruit	: Cv. Poona
Fig Pulp	: 1000 g
Sugar	: S1-700g, S2-800g, S3-900g, S4-1000g
Pectin	: P1-2g, P2- 2.5g, P3-3g
Citric acid	: 4.75g
Preservative	: Sodium benzoate -350ppm
Packaging material	: 200 gauge polyethylene pouches
Storage	: Room temperature - 32°C ± 4
Treatment combinations	: 1X4X3X1X1X1 = 12
Number of replications	: 3
Design	: Factorial Completely Randomized Design
Sample size	: 200 g per pack
Treatment combinations	: As below

Preparation of fig jam : The fruits were washed in clean water and then fig pulp was prepared with help of screw pulper. Add prescribed amount of sugar to the extracted pulp and mix well thoroughly. This mixture is boiled by using gas supply and it is stirred

Table 1. Treatment details

Treat-ments		Fig pulp (g)	Sugar (g)	Pectin (g)	Citric acid (g)
T_1	P1S1	1000	700	2.0	4.75
T_2	P1S2	1000	800	2.0	4.75
T_3	P1S3	1000	900	2.0	4.75
T_4	P1S4	1000	1000	2.0	4.75
T_5	P2S1	1000	700	2.5	4.75
T_6	P2S2	1000	800	2.5	4.75
T_7	P2S3	1000	900	2.5	4.75
T_8	P2S4	1000	1000	2.5	4.75
T_9	P3S1	1000	700	3.0	4.75
T_{10}	P3S2	1000	800	3.0	4.75
T_{11}	P3S3	1000	900	3.0	4.75
T_{12}	P3S4	1000	1000	3.0	4.75

continuously. Then check for the end point by using the refractometer having TSS should not be less than 68.5°B. Then the prepared jam is filled in the polythene pouches and they are sealed by using the sealing machine. The jam filled pouches are sterilized by placing them in hot water for few minutes. Finally these pouches are sent for storage purpose after sterilization.

Chemical analysis of fig jam : The jam prepared from various treatments were analyzed for chemical composition as per the procedures cited by Ranganna (1986) viz., TSS, acidity, reducing sugars, total sugars, non-reducing sugars, Vitamin 'C' (Ascorbic acid) by the standard procedures as described under. The observations were recorded initially, 15 days and 30 days after preparation of jam.

Fig
↓
Cleaning and washing
↓
Blanching (2 to 3 min for 80°C)
↓
Extraction of Fig pulp (Screw pulper)
↓
Addition of sugar
↓
Mixing
↓
Boiling
↓
Addition of citric acid and pectin
↓
Checking of end point
(TSS not less than 68.5 °B)
↓
Filling and sealing
↓
Sterilization
↓
Storage of Jam

Fig. 1. Experimental work plan for preparation of jam

Sensory evaluation of fig jam : The sensory evaluation was carried out by the procedure given by Amerine *et al.* (1965) on nine point hedonic scale. The sensory evaluation was performed by a panel of 10 judges of different age groups and food habits for colour and appearance, taste, flavour and overall acceptability of fig jam.

Statistical analysis : The data obtained for chemical composition and sensory analysis was analyzed for the statistical significance according to the procedure given by Panse and Sukhatme (1967).

Results and Discussions

Chemical composition of fresh Poona fig fruit : The data revealed that fresh Poona fig fruit had 77.00 per cent moisture content on wet basis, 18.34°B T.S.S, 0.25 per cent titrable acidity, 14.08 mg ascorbic acid, 14.28 per cent reducing sugars, 2.15 per cent non reducing sugars, 16.43 per cent total sugars . The results obtained in the present investigations are similar to earlier values recorded by Parmer and Kaushal (1982), Gawade and Waskar (2003) and Chaskar *et al.* (2009) for fresh fig fruits.

Total Soluble Solids (T.S.S.) : From the data (Table 2), it was observed that T.S.S. content increased during storage period, which might be due to reduction of moisture content, conversion of insoluble carbohydrates into soluble sugars and increase in total sugars content of pulp during storage. All the interactions significantly affect the TSS content of fig jam up to the storage period of 30 days. For interaction effect P3S4 (80°B) was significantly superior over the other treatments followed by P3S3 (79.780°B) and P3S2 (78.63°B). The results are in agreement with the research work carried out by Patil (1996) for mango jam, Sawant (2000) for jackfruit jam, Bhosale and Singh (2007) kokum jam blended with pineapple and Chaskar *et al*. (2009) for fig Jam.

Titrable acidity (%) : The result (Table 2) shows that there was decrease in acidity significantly during storage period of 30 days. The interaction effect of pectin and sugar levels on acidity was statistically significant over the advancement of storage period. For the interaction effect, P3S1 (0.81 per cent) was significantly superior over other treatments and followed by P1S4 (0.80 per cent). The acidity was decreased during storage as reported by Chaskar *et al*. (2009) for fig jam blended with pineapple, Patil (1996) for mango jam, Sawant (2000) for jackfruit jam and Bhosale and Singh (2007) kokum jam blended with pineapple.

Ascorbic acid (%) : The result (Table 2) showed that there was significant difference in ascorbic acid of fig jam with advancement of storage period. The decrease of ascorbic acid content of fig jam might be due to oxidation of ascorbic acid. The interaction of pectin and sugar levels was statistically significant over the advancement of 30 days of storage. For the interaction effect, P3S1 (9.86 mg 100^{-1} g) was significantly superior over other treatment and followed by P3S2 and P2S1 (9.80 mg 100^{-1} g) and lowest was in P1S3 (8.21 mg 100^{-1} g). The results obtained in present study are in conformity with the results observed by Chaskar *et al*. (2009) for fig jam blended with pineapple, Patil (1996) for mango jam, Sawant (2000) for jackfruit jam and Bhosale and Singh (2007) for kokum jam blended with pineapple.

Reducing sugars (%) : The observations regarding the changes in reducing sugars content of fig jam are presented in the Table 2. The data revealed that there was increase in reducing sugars content with advancement of storage period. During the advancement of storage period, the reducing sugars were increased which might be due to hydrolysis of non-reducing sugars to reducing sugars. All the interactions significantly affect the reducing sugars content of fig jam. The interaction P2S4 (42.80 per cent) was significantly superior over other treatments followed by P3S4 (42.40 per cent) and P3S1 (41.90 per cent). Similar results of increase in reducing sugars during storage have been reported by Chaskar *et al*. (2009) for fig jam and Bhosale and Singh (2007) for kokum jam blended with pineapple.

Non-reducing sugars (%) : The observations regarding the changes in non-reducings sugar content of fig jam are presented in the Table 2. There was a gradual increase in non-reducing sugar of fig jam as time progresses during storage which might be due to increase in reducing sugars. All the interactions significantly affect the non-reducing sugars content of fig jam over the period of 30 days of storage. The interaction P3S3 (31.50 per cent) was significantly superior over all other treatments followed by P3S1 (31.35 per cent), P2S4 (31.06 per cent), which was at par with each other and found lowest in P1S2 (29.45 per cent). Similar results of increase in non-reducing sugar during storage have been reported by Chaskar *et al*. (2009) for fig jam and Bhosale and Singh (2007) for kokum jam blended with pineapple.

Total sugars (%) : The data on changes in total sugars content of fig jam during storage is presented in Table 2. The result showed that there was significant effect on total sugars of fig jam during the storage in both pectin and sugar levels. There is significant effect in the total sugars content of fig jam for all the interactions. For interaction effect, P2S4 (73.86 per cent) was significantly superior over other treatments, which was followed by P3S1 (73.25 per cent). The total sugars content of fig jam during storage was increased as reported by Chasker *et al*. (2009) and Kad *et al*. (2011).

Overall acceptability : The data on changes in overall acceptability of fig jam influenced by different interactions of pectin and sugar levels with advancement of storage period is showed in Table 2. All treatments had statistically significant effect on overall acceptability. A gradual decrease in overall acceptability of fig jam was observed during the storage period of 30 days. In all interactions, the overall acceptability decreased with increase in storage period of 30 days. For interaction effect, P2S2 (8.43) was significantly best over all the interactions followed by P2S3 (8.31). The lowest score of overall acceptability was found in treatment P1S4 (7.32).

Bhosale and Singh (2007) evaluated the sensory properties of kokum jam blended with pineapple and reported gradual decrease in overall acceptability score from 7.46 to 6.91 during the 45 days of storage. Chaskar *et al*. (2009) studied the sensory properties of fig jam

Table 2. Effect of pectin and sugar levels on chemical and sensory parameters of fig jam

Para-meters	Storage period (days)	Treatment combinations													
		P1S1	P1S2	P1S3	P1S4	P2S1	P2S2	P2S3	P2S4	P3S1	P3S2	P3S3	P3S4	SE (m)±	CD at 5%
TSS (°B)															
	0	75.00	75.68	76.25	77.15	75.22	75.85	76.50	77.20	75.30	75.95	76.70	77.25	0.02	0.07
	15	75.75	76.30	77.00	77.76	76.20	76.50	77.00	77.80	77.75	77.56	79.21	78.98	0.02	0.07
	30	76.10	77.10	77.25	78.10	76.52	78.50	77.25	78.50	76.50	78.63	79.78	80.00	0.02	0.07
Titrable acidity (%)															
	0	0.87	0.85	0.84	0.83	0.88	0.87	0.85	0.84	0.88	0.85	0.84	0.85	0.02	0.07
	15	0.84	0.77	0.75	0.80	0.81	0.82	0.72	0.81	0.83	0.81	0.79	0.82	0.02	0.07
	30	0.76	0.63	0.70	0.80	0.76	0.73	0.69	0.77	0.81	0.78	0.75	0.78	0.02	0.07
Ascorbic acid (%)															
	0	9.08	8.86	8.42	8.40	9.96	9.85	8.70	9.50	10.05	9.95	9.80	9.65	0.02	0.07
	15	9.00	8.62	8.30	8.32	9.86	9.70	9.62	9.42	9.91	9.85	9.68	9.57	0.02	0.07
	30	8.80	8.56	8.21	8.25	9.80	9.62	9.53	9.30	9.86	9.80	9.62	9.48	0.02	0.07
Reducing sugars (%)															
	0	38.30	39.12	39.70	40.12	39.25	39.60	39.95	40.30	39.50	39.58	40.05	40.45	0.02	0.07
	15	39.50	40.15	40.65	40.96	39.98	40.40	41.25	41.60	40.58	40.75	41.30	41.62	0.02	0.07
	30	40.60	40.80	40.98	41.40	40.50	41.00	41.89	42.80	41.90	41.75	41.50	42.40	0.02	0.07
Non-reducing sugars (%)															
	0	30.20	29.76	29.28	29.03	29.37	29.32	29.14	28.96	29.35	29.20	29.20	28.97	0.02	0.07
	15	30.48	29.85	29.17	29.29	29.62	29.88	29.51	29.90	31.52	30.25	30.70	29.58	0.02	0.07
	30	30.50	29.45	29.72	29.80	29.65	29.90	30.11	31.06	31.35	29.75	31.50	29.80	0.02	0.07
Total sugars (%)															
	0	68.50	68.86	68.98	69.15	68.62	38.92	69.09	69.26	68.85	69.05	69.25	69.42	0.02	0.07
	15	69.98	70.00	69.82	70.25	69.60	70.28	70.76	71.50	72.10	71.00	72.00	71.20	0.02	0.07
	30	71.10	70.25	70.70	71.20	70.15	70.90	72.00	73.86	73.25	71.50	73.00	72.20	0.02	0.07
Overall acceptability (Sensory evaluation)															
	0	7.65	8.24	8.18	7.39	7.71	8.5	8.41	7.48	7.82	8.05	7.93	7.57	0.02	0.07
	15	7.62	8.15	8.06	7.36	7.68	8.47	8.36	7.44	7.76	7.98	7.89	7.55	0.02	0.07
	30	7.59	8.05	8	7.32	7.64	8.43	8.31	7.42	7.74	7.92	7.73	7.51	0.02	0.07

blended with pineapple and concluded that gradual decrease in overall acceptability score from 9.0 to 6.67 during 30 days of storage.

Conclusions

The chemical composition of fig jam with different treatments revealed that there was increased in T.S.S., total sugars, reducing sugars and non- reducing sugars. An ascorbic acid and titrable acidity were decreased during the storage of fig jam for a period of 30 days. The sensory evaluation of fig jam was also done for colour and appearance, taste, flavour and overall acceptability. A gradual decreased was observed in score for colour and appearance, taste, flavor and overall acceptability during storage of 30 days. Among the different treatments, treatment with 1000 g fig pulp, 800 g sugar, 2.5 g pectin, 4.75 g citric acid was found to be best for preparation of fig jam in respect of chemical analysis and sensory evaluation.

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J. Agric. Res. Technol., 42 (3) : 210-213 (2017)

Genetic Divergence Studies in Okra (*Abelmoschus esculentus* (L.) Moench.) under Marathwada Climatic Conditions

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Abstract

The present investigation was carried out to estimate the genetic divergence in okra and to identify divergent genotypes to use as donor parents in hybridization programmes under Marathwada climatic conditions (Av. temp -30.80C, RH - 85.33% and rainfall 45.88 mm during Kharif). Twenty genotypes (Pusa Sawani, Arka Anamika, Arka Abhay, IC-43743, IC-10533, IC-42490, IC-45804, PBNOK-1, IC-18960, IC-22237, Parbhani Kranti, IC-10265, EC-755647, EC-755648, PBNOK-2, PBNOK-3, PBNOK-4, PBNOK-5, PBNOK-6 and PBNOK-7) were sown in Randomized Block Design with two replications during *Kharif* 2016-2017 at Horticulture Research Scheme (Vegetable), VNMKV, Parbhani. It was observed that the clusters showing high genetic divergence could be effectively utilized in heterosis breeding programme. The D^2 analysis for eighteen characters partitioned the twenty genotypes into five clusters. The characters number of branches plant^{-1}, number of fruits plant^{-1}, total number of pickings, fruit weight, fruit length and fruit yield plant^{-1} contributed greatly towards diversity. The results revealed that the maximum genetic divergence was observed between cluster III and V followed by between clusters I and V. The maximum intra cluster distance (75.57) was observed in cluster II. On the basis of mean performance of the genotypes among traits IC-43743 from cluster III, the PBNOK-2 from cluster V and IC-22237 from cluster II were found to be the best in almost all the attributes i.e., growth, earliness, fruit traits, and yield. Hence, for exploitation of fruit quality genotypes IC-10533, PBNOK-2, PBNOK-5 and EC-755648 were found to be the best for qualitative characters and would be used as parental source in future breeding programmes under Marathwada climatic conditions.

Key words : Okra, genetic divergence, clusters and D^2 analysis.

Okra (*Abelmoschus esculentus* (L.) Moench) is one of the important members of Malvaceae family having higher chromosome number of 2n=130 and polyploidy in nature (Joshi *et al*., 1974). India is the largest okra growing country contributing about 72.9 per cent of the world okra production. In India, okra occupies an area of 5.0 million hectares with an annual production of 5.8 million tonnes accounting to an average productivity of 11.90 metric tonnes per hectare, contributing 3.9 percent of the total vegetable production. (Anon, 2015). Multivariate analysis is a potent tool in divulging the divergence among the genotypes based on multiple characters. Generalized distance estimated by D^2 statistic (Mahalanobis, 1936) has been generally used as an efficient tool in the quantitative estimation of genetic diversity for a rational choice of potential parent in a breeding programme. The estimate of direct selection parameters like coefficient of variation, heritability, genetic advance and genetic divergence are useful in formulating suitable selection strategy for higher yield in okra.

The genetic variability is the raw material of vegetable breeding industry on which selection acts to evolve superior genotypes. The wide genetic diversity that exists in the available genotypes provides ample scope for further improvement. Yield being a complex

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quantitative character, direct selection for yield may not result in successful improvement. Information on character association and direct and indirect effects of component traits on yield would greatly help in formulating the selection criteria and using them effectively in crop improvement programme. Therefore, it is necessary to partition the observed variability into heritable and non-heritable components by calculating genetic parameters such as genotypic and phenotypic coefficient of variation, heritability and genetic advance.

Material and methods

The present study was conducted at the Horticulture Research Scheme (Vegetable), VNMKV, Parbhani, Maharashtra, during 2016-17. The investigation material comprised of 20 genotypes of okra *viz*., Pusa Sawani, Arka Anamika, Arka Abhay, IC-43743, IC-10533, IC-42490, IC-45804, PBNOK-1, IC-18960, IC-22237, Parbhani Kranti, IC-10265, EC-755647, EC-755648, PBNOK-2, PBNOK-3, PBNOK-4, PBNOK-5, PBNOK-6 and PBNOK-7 which were collected from various sources in India. All the genotypes were grown in Randomized Block Design with two replications. Observations were recorded on five randomly selected parents per replication for each genotype. All the package of practices was followed for growing a successful crop by giving necessary fertilizer with a spacing of 60×45 cm. The mean values of all the traits were subjected to statiscal analysis. Multivariate analysis was done by utilizing Mahalanobis D2 statistics (Mahalanobis, 1936) and the genotypes were grouped into different clusters through Tocher's method given by Rao (1952).

Results and Discussion

The quantitative assessment of genetic divergence was made by adopting Mahalonobis D^2 statistic for yield and its contributing characters. The D^2 values between any two genotypes was calculated as the sum of squares of the differences between the mean values of all the eighteen characters and used for the final grouping of the genotypes. Procedure suggested by Tocher (Rao, 1952) has been used to group 20 genotypes into five clusters by treating the estimated D2 values as the square of the generalized distance. Based on D^2 values, the 20 genotypes were grouped into fifteen highly divergent clusters (Table1). Based on D2 values, the twenty genotypes were

Table 1. Cluster classification of twenty genotypes of okra

Cluster	No. of genotypes	Name of Genotype
I	10	IC-45804, PBNOK-6, IC-42490, IC-18960, Arka Anamika, PBNOK-1, PBNOK-3, PBNOK-5, IC-10533, IC-10265
II	6	Arka Abhay, Parbhani Kranthi, Pusa Sawani, PBNOK-4, IC-22237, EC-755647
III	1	IC-43743
IV	2	EC-755648, PBNOK-7
V	1	PBNOK-2

Table 2. Average intra (bold) and inter-cluster D^2 values for five clusters in twenty genotypes of okra

Clusters	I	II	III	IV	V
I	59.37	141.01	228.56	132.56	253.84
II		75.57	118.52	180.62	135.09
III			0.00	228.16	82.90
IV				67.52	281.31
V					0.00

Table 3. The nearest and farthest clusters from each cluster based on D^2 values in okra genotypes

Cluster No.	Nearest cluster with D^2 values	Farthest cluster with D^2 value
I	IV (132.56)	V (253.84)
II	I (141.01)	III (118.52)
III	II (118.52)	IV (180.62)
IV	V (82.90)	III (228.16)
V	III (82.90)	IV (281.31)

grouped into five highly divergent clusters showed in Table 4 and fig.4. Among V clusters, cluster I was the largest consisting of ten genotypes *viz*., IC-45804, PBNOK-6, IC-42490, IC-18960, Arka Anamika, PBNOK-1, PBNOK-3, PBNOK-5, IC-10533, IC-10265, while cluster II (Arka Abhay, Parbhani Kranthi, Pusa Sawani, PBNOK-4, IC-22237, EC-755647) consisted of six genotype and cluster III (IC-43743) consisted of one genotype. The cluster IV had two genotypes *viz*., EC-755648, PBNOK-7. Cluster V had one genotype viz., PBNOK-2.

Data presented in Table 2 indicated that the mean intra and inter cluster D^2 values among the five clusters. The intra cluster D^2 value ranged from 0.00 (cluster III and cluster V) to 75.57 (cluster II). The cluster II had the maximum D^2 value (75.57) followed by cluster IV (67.52), cluster I (59.37). The inter cluster D^2 values of the five clusters revealed that highest inter cluster generalized distance (281.31) was between cluster IV and cluster V, while the lowest (82.90) was between cluster III and cluster V.

The nearest and distant clusters from each of the cluster based on D^2 values are presented in Table 3. Cluster I was nearest to cluster IV (132.56) and distant from cluster V (253.84). Cluster II exhibited close proximity with cluster I (141.01) and maximum divergence with cluster III (118.52). Cluster III was nearest to cluster II (118.52), while it was farthest from cluster IV (180.62). Cluster IV was nearest to cluster I (132.56) and distant from cluster III (228.16). Cluster V exhibited intimate relation with cluster III (82.90) and wide diversity with cluster IV (281.31).

The cluster mean for the eighteen characters were studied in okra genotypes revealed considerable differences among all the clusters (Table 4). The highest plant height was recorded in cluster III (108.56 cm) and lowest in

Table 4. Mean values of clusters for eighteen characters in twenty okra genotypes of okra

Cluster	Plant height (cm)	No. of branches plant-1	Inter nodel length (cm)	Days to first flowering	Days to 50% flowering	Days to first harvest	Days to last harvest	Fruit length (cm)	Fruit girth (cm)	Fruit weight (g)	No. of fruits plant-1	No. of seeds fruit-1	Fruit yield plant-1 (g)	100 seed weight (g)	Total no. of picking	Crude fibre content (%)	Iodine content (mg 100-1 g)	Iron content (mg 100-1 g)
I	92.05	3.32	5.81	37.61	42.84	49.77	90.89	15.96	5.61	33.98	8.06	72.98	67.38	5.17	8.25	7.79	73.86	23.77
II	92.49	3.66	5.94	37.96	43.24	48.87	91.86	15.64	5.73	30.38	7.90	76.37	198.44	5.48	8.61	8.28	77.41	23.42
III	108.56	4.60	5.59	37.90	41.20	49.20	91.90	16.25	5.62	42.01	9.40	78.40	300.92	5.35	8.54	5.44	58.63	35.26
IV	103.60	3.90	6.21	47.55	55.45	60.40	103.03	16.60	5.80	21.96	8.73	81.50	79.65	5.13	7.35	10.40	75.84	28.87
V	73.97	3.10	5.40	35.35	40.30	44.70	92.70	14.29	6.28	30.63	10.10	79.50	294.37	5.45	9.60	12.20	69.09	28.43

Table 5. Per cent contribution of different characters towards diversity in okra genotypes

Characters	Times ranked 1st	Per cent contribution
Plant height	0	0.00 %
Number of branches	0	0.00 %
Inter nodal length	0	0.00 %
Days to first flowering	0	0.00 %
Days to 50 % flowering	0	0.00 %
Days to first harvest	0	0.00 %
Days to last harvest	0	0.00 %
Fruit length	0	0.00 %
Fruit girth	0	0.00 %
Fruit weight	0	0.00 %
Number of fruits plant^{-1}	0	0.00 %
Number of seeds fruit^{-1}	1	0.53 %
Fruit yield plant^{-1}	8	4.21 %
100 seed weight	1	0.53 %
Number of picking	0	0.00 %
Crude fiber content	6	3.16 %
Iodine content(mg 100^{-1} g)	116	61.05 %
Iron content (mg 100^{-1} g)	58	30.53 %

cluster V (73.97 cm). Maximum number of branches per plant was recorded in cluster III (4.60), whereas minimum was recorded in cluster V (3.10). The cluster VI had the maximum inter nodal length (6.21 cm), whereas cluster V had the minimum inter nodal length (5.40 cm). The cluster V had the early days to first flowering (35.35 day) and 50% flowering (40.30 day), whereas cluster IV had the late day to first flowering (47.55 day) and 50% flowering (55.45 day). The cluster V had the early harvest (44.70 day), whereas cluster IV had the late day to first harvest (60.40 day) and the cluster IV had the more days to last harvest (103.03 day), whereas cluster I had the less day to last harvest (90.89 day). The genotypes of cluster IV had maximum fruit length (16.60 cm), whereas genotypes of cluster V (14.29 cm) had minimum fruit length. Fruit girth had the maximum in cluster V (6.28 cm) and minimum in cluster I (5.61 cm). Fruit weight had the maximum in cluster III (42.01 g) and minimum in cluster IV (21.96 g). Number of fruits per plant was recorded maximum in cluster V (10.10) and minimum in cluster II (7.90), number of seeds per fruit was recorded maximum in cluster IV (81.50) and minimum in cluster I (72.98). 100 seed weight was recorded maximum in cluster II (5.48), while minimum in cluster IV (5.13), number of pickings was recorded maximum in cluster V (9.60), while minimum in cluster IV (7.35), Fruit yield per plant was highest in cluster III (300.92 g) and lowest in cluster I (67.38 g). Crude fiber content (%) was recorded highest in cluster IV (12.20%), while minimum in cluster III (5.44%), Iodine (mg 100^{-1} g) was highest in cluster II (77.41 mg) and lowest in cluster III (58.63 mg) and Iron was recorded maximum in cluster III (35.26%) and minimum in cluster II (23.42%).

The per cent contribution of each character towards divergence is presented in (Table 5). The data revealed that the maximum (61.05%) Iodine content contributed towards divergence followed by Iron content (30.53%), fruit yield per plant (4.21%), crude fiber content (3.16%), number of seeds fruit^{-1} (0.53%), 100 seed weight (0.53). The remaining characters *viz*., plant height, number of branches plant^{-1}, inter nodal length, days to first flowering, days to 50 per cent flowering, days to first harvest, days to last harvest, fruit length, fruit girth, fruit weight, number of fruits plant^{-1} and number of pickings did not contribute to the total divergence.

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J. Agric. Res. Technol., 42 (3) : 214-219 (2017)

Genetic Diversity in Tomato (*Solanum lycopersicon* (Mill. Wettsd.)) under Marathwada Climatic Conditions

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Abstract

The present investigation was carried out to estimate the genetic divergence in tomato and to identify divergent genotypes to use as donor parents in hybridization programmes under Marathwada climatic conditions. The climatic and weather conditions during crop growing period were average temp.-33.5-15.8°C, RH - 70.66-27.22% and rainfall 1.07 mm. Fourty one genotypes (Pusa Sadabahar, Pusa Sheetal, Pusa Rohini, Pusa-120, Pusa Ruby, Arka Meghali, Arka Alok, Arka Vikas, Arka Abha, Arka Saurabh, PKM-1, Dhanashree, Phule raja, Dantiwada local, PBNT-1, PBNT-2, PBNT-3, PBNT-4, PBNT-5, PBNT-6, PBNT-7, PBNT-8, PBNT-9, PBNT-10, PBNT-11, PBNT-12, PBNT-13, PBNT-14, PBNT-15, PBNT-16, PBNT-17, PBNT-18, PBNT-19, PBNT-20, PBNT-21, PBNT-22, PBNT-23, PBNT-24, PBNT-25, PBNT-26 and PBNT-27) were sown in Randomized Block Design with two replications during *Rabi* 2015-2016 at Horticulture Research Scheme (Vegetable), VNMKV, Parbhani. It was observed that the clusters showing high genetic divergence could be effectively utilized in heterosis breeding programme. The D^2 analysis for twenty two characters partitioned the fourty one genotypes into fifteen clusters. The characters *viz*., Ascorbic acid, acidity, non-reducing sugar, number of flower clusters per plant, TSS, tomato leaf curl virus and lycopene content contributed greatly towards diversity. The results revealed that the maximum genetic divergence was observed between clusters IX and XIV. The maximum intra cluster distance was shown by cluster VI. On the basis of the mean performance of the genotypes among traits, the promising lines for further crop improvement were identified in tomato *viz*., PBNT-5, PBNT-15, PBNT-27, Arka Meghali, Arka Alok, PBNT-25, PBNT-26, and PBNT-12 under Marathwada climatic conditions.

Key words : Genetic diversity, genotypes, tomato, D^2 analysis.

Tomato (*Solanum lycopersicum* L.) is a member of the family solanaceae and significant vegetable crop of special economic importance in the horticultural industry worldwide (He *et al*., 2003). It has a chromosome number of 2n=24 and native of Peru Ecuador region (Rick, 1969). It is the most important warm-season fruit vegetable grown throughout the world. Tomato is the most important vegetable crop next only to potato because of its wider adaptability, high yielding potential and multipurpose uses. In India, tomato occupies an area of 0.88 million hectares with a production of 18.73 million tonnes and productivity of 21.2 tonnes per hectare. In Maharashtra tomato is cultivated in an area of 0.05 million hectares with a production of 1.20 million tonnes (Anonymous, 2015).

Genetic diversity is an important factor for any heritable improvement. Knowledge of genetic diversity, its nature and degree is useful for selecting desirable genotypes from a germplasm for the successful breeding programme. The wide genetic diversity that exists in the available genotypes provides ample scope for further improvement. Yield being a complex quantitative character, direct selection for yield may not result in successful improvement. Information on character association and direct and indirect effects of

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component traits on yield would greatly help in formulating the selection criteria and using them effectively in crop improvement programme. Therefore, it is necessary to partition the observed variability into heritable and non-heritable components by calculating genetic parameters such as genotypic and phenotypic coefficient of variation, heritability and genetic advance.

Material and methods

The present study was conducted at the Horticulture Research Scheme (Vegetable), VNMKV, Parbhani, Maharashtra, during 2015-16. The investigation material comprised of 41 genotypes of tomato *viz*., Pusa Sadabahar, Pusa Sheetal , Pusa Rohini , Pusa-120, Pusa Ruby , Arka Meghali, Arka Alok, ArkaVikas, Arka Abha, Arka Saurabh, Dhanashree, Phule raja, Dantiwada local, PBNT-1, PBNT-2, PBNT-3, PBNT-4, PBNT-5, PBNT-6, PBNT-7,PBNT-8, PBNT-9,PBNT-10, PBNT-11, PBNT-12, PBNT-13, PBNT-14, PBNT-15, PBNT-16, PBNT-17, PBNT-18, PBNT-19, PBNT-20, PBNT-21, PBNT-22, PBNT-23, PBNT-24, PBNT-25, PBNT-26 and PBNT-27 were collected from various sources in India. All the genotypes were grown in Randomized Block Design with two replications. Observations were recorded on five randomly selected parents per replication for each genotype. All the package of practices were followed for growing a successful crop by giving necessary fertilizer with a spacing of 60 x 45 cm. The mean values of all the traits were subjected to statiscal analysis. Multivariate analysis was done by utilizing Mahalanobis D^2 statistics (Mahalanobis, 1936) and the genotypes were grouped into different clusters through Tocher's method given by Rao (1952).

Results and Discussion

The quantitative assessment of genetic divergence was made by adopting Mahalonobis D^2 statistic for yield and its contributing characters. The D^2 values between any two genotypes was calculated as the sum of squares of the differences between the mean values of all the twenty two characters and used for the final grouping of the genotypes. Procedure suggested by Tocher (Rao, 1952) has been used to group 41 genotypes into fifteen clusters by treating the estimated D^2 values as the square of the generalized distance. Based on D^2 values, the 41 genotypes were grouped into fifteen highly divergent clusters (Table1). Some of genotypes were so divergent in all the characters; hence each single genotype formed a separate cluster. Thus thirteen clusters viz., II, III, IV, V, VII, VIII, IX, X, XI, XII, XIII, XIV and XV were solitary with one genotype in each cluster. Cluster I was biggest with (22 genotypes) and cluster VI (6 genotypes).

Table 1. Cluster classification of 41 genotypes of tomato

Cluster	No. of genotypes	Genotypes
I	22	PBNT-7, PBNT-11, PBNT-18, PBNT-10,PBNT-8, PBNT-17, PBNT-16, PBNT-6, PBNT-13, PBNT-21, PBNT-9, PBNT-3, PBNT-20, PBNT-19,PBNT-23, , PBNT-24, Arka Vikas, Pusa Sheetal , PBNT-14, PBNT-26, PBNT-1,Dantiwada Local.
II	1	PBNT-25
III	1	PBNT-27
IV	1	PBNT-12
V	1	PBNT-15
VI	6	Dhanashree , Phule raja , Pusa Ruby, PKM-1, PBNT-2 , Arka Alok
VII	1	PBNT-22
VIII	1	PBNT-4
IX	1	Arka Abha
X	1	Pusa Rohini
XI	1	Arka Saurabh
XII	1	Arka Meghali
XIII	1	Pusa -120
XIV	1	PBNT-5
XV	1	Pusa Sadabahar

The cluster mean for the twenty two characters were studied in tomato genotypes revealed considerable differences among all the clusters (Table 2). The highest plant height was recorded in cluster XIV (90.95 cm) while lowest plant height was recorded in cluster XV (41.42 cm). The maximum number of primary branches was recorded in cluster XIV (11.90) whereas; minimum number of primary branches was recorded in cluster XI (3.40). The cluster XV was recorded minimum days to 50 per cent flowering (26.50 days) whereas, cluster X was observed maximum days to 50 per cent flowering (55.80 days). Whereas, in case of number of flowers cluster per plant, the maximum number of flowers cluster per plant was recorded in cluster XIV (34.40) while, minimum mean value was found in cluster XI (6.90). The maximum mean of days to first harvest was observed in cluster X (97.00) whereas, minimum days to first harvest were found in cluster XV (48.10). The maximum number of fruits per plant was recorded in cluster V (46.40) while minimum numbers of fruits per plant was found in cluster XI (18.20). The maximum fruit length was observed in genotypes of cluster XI (4.83 cm) followed by in cluster IV (4.58 cm), while, minimum fruit length was observed in the genotypes of cluster V (3.47 cm) followed by cluster IX (3.63 cm). The maximum diameter of fruit was observed in the genotypes of cluster XIV (4.21 cm) followed by cluster VII (4.11 cm) while, minimum diameter of fruit was recorded in the genotypes of cluster XV (2.76 cm) followed by cluster IX (2.82 cm). Maximum number of locules per fruit was recorded in cluster V (5.70) whereas minimum was recorded in cluster IX (2.30). The highest average fruit weight was recorded in cluster III (59.20 g) whereas, lowest average fruit weight was recorded in cluster XV (34.10 g). The highest ascorbic acid content was recorded in cluster XIV (26.65 mg/100g of fruit), while, lowest ascorbic acid content was recorded in cluster XII (18.29 mg/100g of fruit). The genotypes of cluster XII had maximum TSS value (5.57) whereas, minimum TSS was observed in genotypes of cluster VIII

Table 2. Mean values of clusters for twenty two characters in 41 tomato genotypes

Cluster	Plant height (cm)	No. of branches plant^{-1}	Days to 50% flowering	No. of flower clusters plant^{-1}	Days required for 1st harvest	No. of fruits plant^{-1}	Length of fruit (cm)	Diameter of fruit (cm)	No. of locules fruit^{-1}	Average fruit weight (g)	Ascorbic acid (mg 100^{-1}g)
I	63.97	6.21	43.09	13.75	74.40	25.95	3.85	3.73	4.09	45.83	20.76
II	77.81	9.90	45.20	28.70	80.90	36.60	3.96	3.62	4.30	50.3	24.60
III	81.76	10.60	41.10	32.30	79.00	35.70	4.34	4.02	4.90	59.2	25.16
IV	75.15	9.30	40.90	25.40	76.50	30.70	4.58	3.25	4.50	58.90	23.33
V	79.39	9.30	43.60	30.20	73.20	46.40	3.47	4.09	5.70	46.10	25.55
VI	66.73	6.60	40.43	19.22	75.72	28.18	4.70	4.02	4.20	49.10	26.34
VII	70.79	8.30	47.60	21.70	75.80	29.50	4.46	4.11	4.60	52.50	24.51
VIII	69.85	8.80	43.40	23.80	76.50	30.60	4.11	4.09	4.40	46.90	21.63
IX	58.36	4.20	40.50	8.00	77.10	18.50	3.63	2.82	2.30	45.80	20.53
X	61.77	5.00	55.80	14.40	97.00	26.70	4.34	4.02	3.10	49.70	20.87
XI	53.67	3.40	42.50	6.90	80.90	18.20	4.83	3.82	3.30	48.20	24.79
XII	76.59	9.80	45.20	23.60	80.50	38.50	4.34	3.70	4.00	51.90	18.29
XIII	67.58	5.70	40.30	10.80	73.20	21.50	4.26	3.02	3.50	37.80	22.57
XIV	90.95	11.90	46.00	34.40	72.20	43.00	4.03	4.21	5.10	56.70	26.65
XV	41.42	5.10	26.50	7.30	48.10	20.00	4.35	2.76	3.50	34.10	25.23

Table 2. Contd.

Cluster	T.S.S (%)	Acidity (%)	Reducing sugars (%)	Total sugars (%)	Lycopene (mg 100-1g)	Fruit yield $plant^{-1}$ (kg)	Fruit yield $plot^{-1}$ (kg)	Fruit yield ha^{-1} (qt.)	Fruit borer incidence (%)	Tomato leaf curl virus (%)
I	4.40	0.31	2.63	3.22	25.90	1.19	42.37	436.76	15.58	14.78
II	4.75	0.32	2.78	3.38	26.30	1.85	57.39	591.67	6.95	7.43
III	4.95	0.35	2.78	3.42	27.80	2.08	58.32	601.23	8.55	7.01
IV	5.07	0.34	2.66	3.18	26.60	1.80	55.71	574.29	12.73	11.95
V	4.99	0.32	2.51	3.01	26.50	2.10	60.09	619.44	9.72	6.95
VI	5.11	0.33	2.70	3.54	27.07	1.37	47.21	486.70	10.93	11.92
VII	5.02	0.53	2.94	3.44	26.50	1.56	56.03	577.60	9.80	9.25
VIII	4.11	0.43	2.58	3.11	27.95	1.41	50.52	520.74	11.15	2.78
IX	4.48	0.24	2.68	3.62	27.10	0.82	26.43	272.48	18.06	17.10
X	4.21	0.26	2.70	3.27	30.95	1.21	42.73	440.54	13.05	15.48
XI	4.26	0.30	2.92	3.93	25.40	0.88	23.51	242.38	10.93	22.23
XII	5.57	0.26	2.68	3.62	27.10	1.91	59.14	609.67	8.39	4.73
XIII	4.34	0.77	2.59	3.12	26.60	0.81	29.48	303.85	15.20	13.22
XIV	4.89	0.80	2.84	3.35	27.90	2.30	62.64	645.72	6.12	4.17
XV	4.16	0.27	2.56	3.15	27.54	0.65	22.89	235.99	9.52	18.06

Table 3. Average intra (bold) and inter-cluster D^2 values for fifteen clusters in 41 genotypes of tomato

Clusters	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV
I	13.89	18.56	21.18	20.43	19.72	21.91	22.45	18.27	17.83	18.09	20.99	19.27	25.59	34.61	28.47
II		0.00	7.81	8.83	11.13	20.01	12.45	12.59	27.39	21.24	28.25	15.45	22.54	21.98	31.60
III			0.00	9.21	9.62	18.16	13.93	14.72	29.57	25.79	28.86	18.90	23.64	20.55	31.02
IV				0.00	13.92	18.64	10.93	16.18	28.79	25.28	28.80	19.97	19.09	21.32	28.01
V					0.00	19.21	18.69	18.01	27.50	26.65	29.22	20.11	27.15	25.35	29.47
VI						15.00	21.49	23.21	24.11	28.22	20.97	24.86	24.63	31.50	22.96
VII							0.00	13.86	32.37	24.39	30.76	21.82	16.01	16.57	32.64
VIII								0.00	28.50	17.49	28.41	16.72	22.66	24.71	34.82
IX									0.00	23.35	14.38	25.16	30.75	44.40	25.99
X										0.00	24.20	20.24	29.13	37.38	37.74
XI											0.00	29.03	28.96	42.64	24.44
XII												0.00	30.32	32.53	37.38
XIII													0.00	22.97	29.30
XIV														0.00	42.29
XV															0.00

(4.11). The maximum titrable acidity content was recorded in cluster XIV (0.80%) while, minimum titrable acidity value was recorded in cluster IX (0.24%). The maximum reducing sugar value was recorded in genotypes of cluster VII (2.94) whereas; genotypes of the cluster V (2.51) had minimum reducing sugar. The maximum total sugars value (3.93) was recorded in genotypes of cluster XI , whereas, genotypes of the cluster V (3.01) had minimum total sugars. The highest Lycopene content was observed in cluster X (30.95 mg 100^{-1} g of fruit), whereas, lowest Lycopene content was observed in cluster XI (25.40 mg 100^{-1} g of fruit). The highest fruit yield per plant was recorded in cluster XIV (2.30 kg) while, lowest fruit yield per plant was recorded in cluster XV (0.65 kg). The highest fruit yield per plot was found in cluster XIV (62.60 kg) whereas, lowest fruit yield per plant was recorded in cluster XV (22.89 kg). The highest fruit yield per hectare was recorded in cluster XIV (645.72 qt) while, lowest fruit yield per hectare was recorded in cluster XV (235.99 qt). The minimum friut borer per cent infestation was observed in cluster XIV (6.12) while, maximum friut borer infestation was recorded in cluster IX (18.06%) . The minimum tomato leaf curl virus incidence was recorded in cluster VIII (2.78) whereas, maximum tomato leaf curl virus incidence was found in cluster XI (22.23%).

Data presented in Table 3 indicated that the mean intra and inter cluster D^2 values among the fifteen clusters. The intra cluster D^2 value was ranged from 0.00 (Cluster II, III, IV, V, VII, VIII, IX, X, XI, XII, XIII, XIV and XV) to 15.00 (Cluster VI). The cluster VI had the maximum D^2 value (15.00) followed by Cluster I (13.89). The inter cluster D^2 values of the fifteen clusters revealed that highest inter cluster generalized distance (44.40) was between cluster IX and cluster XIV, while the lowest (7.81) was between cluster II and cluster III.

The nearest and distant clusters from each of the cluster based on D^2 values were presented in (Table 4). Cluster I was nearest to cluster IX (17.83) and distant from cluster XIV (34.61). Cluster II exhibited close proximity with cluster III (7.81) and maximum divergence with cluster XV (31.60). Cluster III was nearest to cluster II (7.81), while it was farthest from cluster XV (31.02). Cluster IV showed close proximity with cluster II (8.83) and maximum divergence with cluster XI (28.80). Cluster V exhibited intimate relation with cluster III (9.62) and wide diversity with cluster XV (29.47). Nearest and farthest clusters for cluster VI, III (18.16) and XIV (31.50) clusters, respectively. Cluster VII was nearest to cluster IV (10.93) and distant from cluster XV (32.64). Cluster VIII exhibited close proximity with cluster II (12.59) and maximum divergence with cluster XV (34.82). Cluster IX was nearest to cluster XI (14.38), while it was farthest from cluster XIV (44.40). Cluster X showed close proximity with cluster VIII (17.49) and maximum divergence with cluster XV (37.74). Cluster XI exhibited intimate relation with cluster IX (14.38) and wide diversity with cluster XIV (42.64). Nearest and farthest clusters for cluster XII are II (15.45) and XV (37.38) clusters, respectively. Cluster XIII was nearest to cluster VII (16.01) and distant from cluster IX (30.75). Cluster XIV exhibited close proximity with cluster VII (16.57) and maximum divergence with cluster IX (44.40). Cluster XV was nearest to cluster VI

Table 4. The nearest and farthest clusters from each cluster based on D^2 values in tomato genotypes

Cluster No.	Nearest cluster with D^2 values	Farthest cluster with D^2 value
I	IX (17.83)	XIV (34.61)
II	III (7.81)	XV (31.60)
III	II (7.81)	XV (31.02)
IV	II (8.83)	XI (28.80)
V	III (9.62)	XV (29.47)
VI	III (18.16)	XIV (31.50)
VII	IV (10.93)	XV (32.64)
VIII	II (12.59)	XV (34.82)
IX	XI (14.38)	XIV (44.40)
X	VIII (17.49)	XV (37.74)
XI	IX (14.38)	XIV (42.64)
XII	II (15.45)	XV (37.38)
XIII	VII (16.01)	IX (30.75)
XIV	VII (16.57)	IX (44.40)
XV	VI (22.96)	XIV (42.29)

Table 5. Per cent contribution of different characters towards diversity in tomato

Characters	Times ranked 1st	% contri-bution
Plant height	0	0.00
Number of branches plant^{-1}	0	0.00
Days to 50% flowering	5	0.61
No. of flower clusters plant^{-1}	86	10.49
Days required for 1st harvest	6	0.73
Number of fruits plant^{-1}	0	0.00
Length of fruit	11	1.34
Diameter of fruit	13	1.59
Number of locules fruit^{-1}	8	0.98
Average fruit weight	0	0.00
Ascorbic acid	273	33.29
T.S.S	80	9.76
Acidity	173	21.10
Reducing sugars	2	0.24
Total sugars	0	0.00
Lycopene	25	3.05
Fruit yield plant^{-1}	0	0.00
Fruit Yield plot^{-1}	0	0.00
Fruit Yield hectare^{-1}	3	0.37
Fruit borer incidence	5	0.61
Tomato leaf curl virus	32	3.90

(22.96), while it was farthest from cluster XIV (42.29).

The per cent contribution of each character towards divergence is presented in (Table 5). Data presented in Table 5 showed that the maximum (33.29%) ascorbic acid content was contributed towards divergence followed by acidity (21.10%), number of flower clusters per plant (10.49%), TSS (9.76%), tomato leaf curl virus (3.90%), lycopene (3.05%), diameter of fruit (1.59%) , length of fruit (1.34%), number of locules per fruits (0.98%), days required for 1st harvest (0.73%), days to 50 per cent flowering (0.61%), fruit borer incidence (0.61%), fruit yield per hectare (0.37%), and reducing sugar (0.24%). The rest of the characters *viz.*, plant height, number of branches plant^{-1}, number of fruits plant^{-1}, average fruit weight, fruit yield plant^{-1}, fruit yield plot^{-1} and total sugar did not contribute to the total divergence.

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J. Agric. Res. Technol., 42 (3) : 220-223 (2017)

Response of Tomato to Polyethylene Mulch under Drip Fertigation

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Abstract

The field experiment was conducted to study the effect of polyethylene mulch on yield of tomato under drip irrigation during winter seasons of 2013-2014, 2014-2015, 2015-2016 at the field of the Department of Irrigation and Drainage Engineering, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, India. There were five treatments replicated four times *viz*., 40% evapotranspiration (ET) with polyethylene mulch (PM), 60% ET with polyethylene mulch, 80% ET with polyethylene mulch, 100% ET with polyethylene mulch and 100% ET without polyethylene mulch (control). Pooled analysis reveals that treatment T_3 (80% ET with PM) recorded significantly highest fruit yield of tomato and found to be superior over rest of the treatments, followed by treatments T_4 (100% ET with PM), T_2 (60% ET with PM) and T_1 (40% ET with PM). Treatment T_5 (100% ET without PM) recorded significantly lowest fruit yield. Gross return, net return and B:C ratio recorded under treatment T_3 (80% ET with PM) were found to be highest, followed by treatment T_4 (100% ET with PM).

Key words : polyethylene mulch, drip fertigation, evapotranspiration levels.

As water is becoming limiting resource, there is no scope to increase irrigation potential by using additional water. Hence, only way to increase food production is by increasing water use efficiency. For this purpose water saving and more yielding irrigation methods have to be used. Micro-irrigation systems satisfy this requirement.

Tomato is considered as one of the important commercial vegetable crop in India. India is the second largest producer of vegetable crops in the world. Tomato ranks third in priority after Potato and Onion in India, but ranks second after potato in the world. India ranks second in the area as well as in production of tomato.

Since last few decades, water use efficiency (WUE) level has been enhanced through breeding of high yielding cultivars and managing the soil resource in an effective way. In contrast, little progress has been made in keeping the yield at higher level even with the minimization of actual evapotranspiration (ETc). In irrigated ecosystem, amount of total irrigation determines the quantum of seasonal evapotranspiration. Besides, frequency of irrigation plays a crucial role on growth and yield of tomato. At this moment, demand for water in other sectors is increasing; as a result share of irrigation is continuously decreasing. Due to this, irrigation scientists are forced to develop water saving irrigation strategies. In case of deficit irrigation, there is a need to adopt appropriate technology to conserve the water in the soil profile and its best possible utilization for plant growth. This can be achieved by introducing advanced and sophisticated methods of irrrigation and improved water management practices.

Among the management practices for increasing water use efficiency one of them is

1. Professor, 2. Associate Professor, 3. & 4. Assistant Professor, 5. Associate Professor.

mulching. Mulching (organic and inorganic) is an appropriate approach to enhance efficiency level of irrigation besides improving crop yield. Any material spread on the surface of soil to protect it from rain drop, solar radiation or evaporation is called mulch. By creating a barrier between soil surface and adjacent atmosphere, mulching minimizes the evaporation loss from soil surface and thus utilizes the conserved water for higher transpiration and improves yield and WUE of tomato.

Mulching is a soil and water conserving practice, in which any suitable material is used to spread over the ground between rows of crops or around the tree trunks. This practice helps to retain soil moisture, prevents weed growth and enhances soil structure. There are various types of mulching such as polythene mulching, live vegetative barriers, straw mulching etc. Organic (plant materials) and synthetic mulches (plastic of different colors like white, black, red, green, and yellow and transparent) are widely used in vegetable production for their efficacy to conserve soil moisture by altering water distribution between soil evaporation and plant transpiration. Thus, the conserved water can be used more effectively by the crops towards transpiration. Conventionally, mulches increase the yield and water use efficiency (WUE) to a great extent by augmenting the water status in the root zone profile. Also mulch, plastic films have served many functions, such as weed prevention, moisture retention and to raise soil temperatures, all of which contribute to higher crop yield and quality.

The color of plastic mulch largely determines its energy-radiation behavior and its influence on the microclimate around the plant. Colour also affects the surface temperature of mulch and underlying soil temperature.

Considering above aspects to grow more crop per drop of water, a field experiment was carried out at the field of Department of Irrigation and drainage engineering, College of Agricultural Engineering and Technology, Dr. PDKV, Akola, Maharashtra, India.

Materials and Methods

The field experiment was conducted to study the effect of polyethylene mulch on yield of tomato under drip irrigation during winter seasons of 2013 - 2014, 2014 - 2015, 2015 - 2016. The treatment details and experimental details are given in Table 1 and 2 respectively.

Table 1. Details of treatments

Treat-ment	Specification
T_1	40% ET with Polyethylene mulch
T_2	60%ET with Polyethylene mulch
T_3	80% ET with Polyethylene mulch
T_4	100% ET with Polyethylene mulch
T_5	100% ET without Polyethylene mulch (control)

Table 2. Experimental details

Particulars	Specification
Crop	Tomato (Solanumlycopersicum)
Variety	Phule Raja
Seed rate	300 g ha^{-1}
Spacing	90 x 50 cm
Duration of the crop	180 days
Experimental design	Randomized Block Design
Irrigation system	Inline drip irrigation system
Number of treatments	Five
Number of replications	Four
Plot size	3.5 x 5.4 m
Number of plants/plot	42
Plastic mulch	Silver/black of 50 µm thickness
Recommended fertilizer dose (N:P:K)	300:150:150 kg ha^{-1}
Planting time	*Rabi* season

Results and Discussion

Common irrigation was provided to all plots before transplanting seedlings, to bring the soil to the field capacity. Then seedlings were transplanted. After transplanting, the irrigation was scheduled to alternate days for tomato crop. The water requirement of tomato crop was worked out on the basis of class 'A' open pan evaporation. The data on the daily pan evaporation was collected from Department of Agronomy, Agro meteorology Centre, Dr. PDKV, Akola during the period of investigation. The drip irrigation system was operated for the time required to supply the desired quantity of water depending up on the treatment. The duration of operation of drip system was worked out for different levels of irrigation, i.e. for different treatments (40% ET, 60% ET, 80% ET, 100% ET with polyethylene mulch, and 100% ET without polyethylene mulch).

Fruit yield and water applied : The pooled analysis of tomato fruit yield and water applied as influenced by different irrigation levels and polyethylene mulch is presented in Table 3.

It is seen from Table 3 that treatment T_3 (80% ET with PM) recorded significantly highest fruit yield of tomato and found to be superior over rest of the treatments, followed by treatments T_4 (100 % ET with PM), T_2 (60% ET with PM) and T_1 (40% ET with PM). Treatment T_5 (100% ET without PM) recorded significantly lowest fruit yield as compared to all other treatments. Fruit yield of tomato recorded in treatment T_2 (60% ET with PM) was found at per with treatment T_1 (40% ET with PM).

Pooled means of water applied with percent saving of water reveals that water saving was found to be highest (55.73 %) in treatment T_1 (40% ET with PM) followed by treatment T_2 (60% ET with PM) (37.14 %) and treatment T_3 (80% ET with PM) (18.73 %).

Cost economics : Total cost per hectare of drip irrigation with polyethylene mulch was determined from the fixed cost and operating cost. The cost economics is worked out and the results are presented in Table 4.

It is seen from Table 4 that gross return, net return and B:C ratio recorded under treatment

Table 3. Pooled analysis of fruit yield and water applied

Treatment	Fruit yield ($q\ ha^{-1}$)				Water applied (cm) (with percent saving of water)			
	2013-14	2014-15	2015-16	Pooled mean	2013-14	2014-15	2015-16	Pooled mean
T_1 (40% ET with PM)	253.04	108.67	180.83	180.85	13.37 (53.77)	13.21 (53.71)	10.71 (60.02)	12.43 (55.73)
T_2 (60%ET with PM)	261.24	117.36	189.16	189.25	18.55 (35.85)	18.33 (35.77)	16.07 (40.01)	17.65 (37.14)
T_3 (80% ET with PM)	355.82	186.48	263.66	268.65	23.73 (17.95)	23.30 (18.36)	21.43 (20.01)	22.82 (18.73)
T_4 (100% ET with PM)	277.78	152.00	215.00	214.93	28.92	28.54	26.79	28.08
T_5 (100% ET without PM)	210.58	64.41	145.67	140.22	28.92	28.54	26.79	28.08
F test	Sig	Sig.	Sig	SIG				
SE (m) ±	3.56	6.38	2.75	3.99				
CD at 5%	10.99	19.66	8.49	12.29				
CV (%)	10.5	10.14	2.76	6.95				

Table 4. Cost economics of the study

Treatment	Yield of tomato (q ha^{-1})	Gross return (Rs. ha^{-1})	Total cost (Rs. ha^{-1})	Net return (Rs. ha^{-1})	B:C ratio (3/4)
1	**2**	**3**	**4**	**5**	**6**
T_1	180.85	180850	105153	75697	1.72
T_2	189.25	189250	105195	84055	1.80
T_3	268.65	268650	105237	163413	2.55
T_4	214.93	214930	105278	109652	2.04
T_5	140.22	140220	91880	48340	1.53

Note: The market rate of tomato was Rs 1000/- per quinta

T_3 (80% ET with PM) were found to be highest, followed by treatment T_4 (100% ET with PM), T_2 (60% ET with PM) and T_1 (40% ET with PM). Treatment T_5 (100% ET without PM) recorded lowest gross return, net return and B:C ratio as compared to all other treatments.

It is concluded from results that drip irrigation at 80% ET with polyethylene mulch recorded significantly highest fruit yield of tomato with 18.73% saving of water, followed by drip irrigation at 100% ET with polyethylene mulch. Drip irrigation with scheduling at 100% ET without mulch recorded significantly lowest fruit yield of tomato. Drip irrigation at 80 % ET with polyethylene mulch recorded highest gross return (Rs. ha^{-1}), net return (Rs. ha^{-1}) and B:C ratio.

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J. Agric. Res. Technol., 42 (3) : 224-226 (2017)

"Phule PVC Bhat Lavani Choukat" A Low Cost Precision Tool in Paddy Transplanting in Western Ghat Zone

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Abstract

The cost and drudgery of a labour in paddy cultivation has a major input and its saving was quantitatively reduced in PVC Bhat lavani Choukat over the rope method is about to 33.33 % especially two male labours. There is less labour required in conventional method over PVC Choukat on contrary to loss of seed and fertilizers. Overall the PVC Bhat Lavani Choukat has improved the yield by 35.48% and 12.89% over conventional and rope method respectively due to higher productive tillers over other treatment. Due to application of this PVC Bhat Lavani Choukat for transplanting indicates projected saving for Maharashtra is likely to be labour saving of 51.29 crores and additional income of 322.6 crores from additional yield due to improved method of technology.

Key words : Paddy, Drudgery, Transplanting, Labour saving, PVC choukat.

Rice is the staple food of more than 50 percent population of the world. About 90 percent rice area exists in Asia (Das, 2012). The average rice yield in India is only 2.09 t ha^{-1}, as compared to 6.58 t ha^{-1} in Japan and world average of 3.91 t ha^{-1} (Dinesh and Shivay, 2007). In Maharashtra rice is grown over an area of 14.99 lakh hectares with an annual rice production of 32.37 lakh tones and average productivity of the state is 2.01 t ha-1 ranks 13th place in rice production in country. The gap can be shortened by only adopting modern rice production technology of four fold i.e "Charsutri Technology". This envisages the use of Urea-Dap briquette as slow releasing fertilizers for better fertilizer use efficiency (70 %) and increasing in yield (20%). The success of this technology is relies spaced transplanting at a spacing of 15 x 25 cm^2 with rope and marker guided tool. But during the peak period due to non availability of labours especially male labours makes the failure of the technology.

1. Chief Scientist, 2. Soil Physicist, 3. Jr. Agronomist and 4. Asstt. Research Engineer.

In paddy cultivation transplanting is very drudgerious operation in overall paddy cultivation processes and 22.3% of total time is spent in this operation (Gite,2012). From these about 50 percent would be women against 42% at present. In addition, the migration from rural to urban areas in Asia has decreased substantially the labour resource in agriculture. In addition to the adoption of high-yielding and early maturing rice varieties, the application of combinations of existing technologies would save time, land and water for intensification of rice production in the future.

Keeping this in view, the present experiment was conducted to compare economic cost and quantum of drudgery with conventional and improved method of paddy transplanting (Mondal and Basu, 2009)This research was aimed to know the cost cutting on labour and fertilizer without reduction in production potential by using low cost precision implement against the conventional and previous improved methods for their physiological fatigue, human drudgery and ergonomical evaluation of both the methods.

Objectives

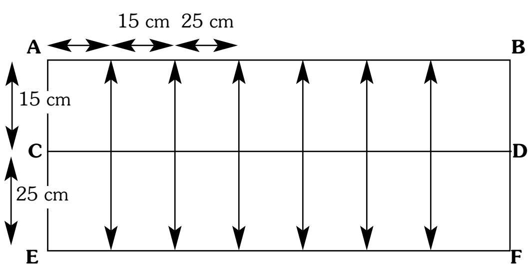
The experiment was planned with following objectives to develop manually operated paddy transplanting marker for maintaining proper plant geometry of paddy crop. Conduct the performance evaluation of the developed paddy transplanting marker in comparison with conventional method. Compare the yield and cost economics of paddy transplanting marker with conventional methods.

Methodology

A field experiment was conducted during Kharif 2014 at Zonal Agricultural Research Station, Western Ghat Zone, Igatpuri., Dist. Nasik (M.S.) in randomized block design with three treatments replicated on 30 farmers field. The low cost precision farming Phule PVC Bhat lavani Choukat (Paddy transplanting marker frame) was designed and developed technically for spaced transplanting. An on station and on farm ergonomic evaluation was conducted at 5 locations and 30 farmers field with

The design of the frame is as follows

Design of paddy transplanting marker



The treatments are comprised of 1.Conventional method of transplanting. 2. Rope and marker method and 3. Phule PVC Bhat lavani choukat were undertaken. The data on ergonomics study including, Body mass Index (BMI), Discomfort scale, Time of operation, Area covered with the implement were collected and all the relevant data were statistically analyzed.

Results and Discussion

The results of 12 Male and 18 female farmers were under study. The results revealed that The BMI was ranged from 17.33 to 28.88.The area covered in a stipulated period of 30 min time has ranged from 22 to 29 m2 area. Table no 1 shows that labour requirement were lowered down than rope method but higher than conventional with less reliance on male labours. The ergonomics study shows that the discomfort scale of this implement has ranged from 1 to 2 having no to low discomfort.

The table no.1 indicates that the plant population in the PVC Bhat lavani Choukat and rope method are remains the same but 32.5 % more seedlings with higher seed rate was recorded in conventional method. The 31.25 % and 38.88% more number of tillers were recorded in rope and PVC Choukat transplanting over conventional method. The direct effect of PVC Bhat lavani Choukat on reduction in seed rate and improvement in tillers over conventional method is statistically significant. Similar results were observed by Wang ZaiMan and *et al*. 2010.

The major aspect of labour saving was quantitatively reduced in PVC Bhat lavani Choukat over the rope method is 33.33 % especially two male labours. There is less labour required in conventional method over PVC Choukat on contrary to loss of seed and fertilizers.Overall the PVC Bhat Lavani Choukat has improved the yield by 35.48 % and 12.89% over conventional and rope method respectively due to higher productive tillers over other treatment.

Table 1. Comparitive labour required, labour saving, no. of plants m^{-2}, yield (q ha^{-1})

Particulars	**Labour required ha^{-1}**	**Labour saving ha^{-1}**	**No. of plants m^{-2}**	**No. of plants m^{-2}**	**Yield (q ha^{-1})**	**Per cent yiels increase**
Conventional Method (Farmers practice)	24	0 %	195	11	31	100% (base fig.)
Rope and Marker method	36	+9 (133.33%)	147	16	38	122.58%
Phule Bhat Lavani Choukat	27	100% (base fig.)	147	18	41	135.48%

Table 2. Projected cost saving in Maharshtra paddy growers

Particulars	**Labour required ha^{-1}**	**Labour cost saving**	**Additional yield (t)**
Conventional Method (Farmers practice)	24	–	–
Roap and Marker method	36	–	–
Phule Bhat Lavani Choukat	27	51.29/- Crores	129040/- 322.6 Crores additional returns (Avg rate :Rs. 2500/-per t)

As the table 2. indicates that the projected saving for Maharashtra is likely to be labour saving of 51.29 crores and additional income of 322.6 crores from additional yield due to improved method of technology. The cost of frame is Rs.275/- per unit.

Conclusions

This Choukat helps in application of resource conservation technology which conserve the seed rate, fertilizers and labours. This implement is advantageous to adopt the improved recommended charsutri technology (Four fold) of spaced planting and use of briquette. It is not only saving fertilizers than conventional method but saves the seed quantity. This implement can be used from single user to multi user easily. The choukat is light in weight and can be transported to any corner of the field easily. Very low in cost and can be made locally.

The Phule PVC Bhat Lavani choukat (Paddy transplanting marker) will be beneficial to small and marginal farmers for successful implementation of improved charsutri rice production technology with labour saving and increase in yield. The use of this frame will enable the in national goal of food security as well as pollution control and climate change effects.

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(Continued on inside back cover)

Edited and Published by Dr. S. D. Gorantiwar at College of Agriculture, Pune 411 005. Email : editorinchiefjart@gmail.com

Typeset Processed and Printed by : Flamingo Business System, 19, Laxminagar Comm. Complex-1, Pune-411 009. Tel. : 24214636

Date of Issue : December, 2017

Date of Publication : December 15, 2017