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A Critical Look into Curve Number Method for Direct Runoff Estimation

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Abstract

The curve number model is a lumped parameter, event based, conceptual model of hydrologic abstraction of storm rainfall. This method relies only on a single conceptual parameter called curve number (CN) or its transformation, maximum potential retention (S). The curve number for a given land use complex varies as a function of five major runoff producing characteristics. These are hydrological soil group, land use, conservation treatment, hydrologic surface conditions and antecedent moisture condition. Though the method is widely accepted there are certain limitations for the SCS-CN method. Some of them are (i) the effect of rainfall intensity on the curve number determination is not thought of explicitly; (ii) the amount of initial abstraction differs in different watersheds; (iii) decision about antecedent moisture condition has no logical assumptions. Due to availability of fast computing machines, distributed as well as continuous models have also been thought for long term hydrologic simulation, keeping the essence of CN model intact during last seven decades by different hydrologists throughout the world. In view of such capabilities, limitations, and potential of the SCS-CN model it was considered that the work of different hydrologists should be put together in this paper in five sections, *viz.*, Origin and development of CN method; Computation of curve number and effect of variability of curve number on runoff estimation; Effect of Rainfall Intensity on determination of Curve Number; Relation between initial abstraction and potential maximum retention, and antecedent moisture condition. The work from 1949 to 2016 is divided in different sections to bring out systematic development of the method.

Key words : SCS-CN model, initial abstraction, development of CN method, effect of rainfall intensity on CN, antecedent moisture condition.

The interaction of storm rainfall with land surface is very complex hydrological process and the hydrologists are always concerned with this process for storm runoff. In hydrologic literature, the term storm runoff is interchangeably used as direct runoff or surface runoff. As the name suggests, the surface runoff travels over the land surface and through channel network to watershed outlet. It is a surface phenomenon that varies from storm to storm and represents the overall hydrological response of land surface to given rainfall. The estimation of this runoff component, especially from ungauged watershed is one of the major

activities in applied hydrology. Similarly, it is one of the important steps in the prediction of peak flows by unit hydrograph method or similar techniques. Such estimations are always needed in the design of engineering structures, in the post event appraisal works, for evaluation of various land use practices and for assessment of environmental impact of developed watersheds.

Some of well known hydrological models such as Stanford watershed model or USDAHL-74 model require detailed hydrological studies as input. However, the prediction accuracy of these models is very low as compared to detailed inputs (Williams and La Seur, 1976). In developing countries like India,

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there are many ungauged watersheds where such detailed hydrological information is seldom available, perhaps the most popular technique for such situation is the SCS curve number method, pioneered and developed by Soil Conservation Service - now the Natural Resources Conservation Service (NRCS) of U. S. Department of Agriculture (USDA). The method is well documented in SCS, National Engineering Handbook, Section - 4 or NEH - 4 (SCS, 1985).

Curve number (CN) method is a simple, predictable and stable model for estimation of direct runoff depth from storm rainfall depth. The method requires less input details such as daily rainfall with minimum information on soil-vegetation which is readily available at any ungauged watershed sites. It is, therefore, one of the well established techniques in applied hydrology and has wide adoption in U.S. as well as in other countries.

However, as regards to model structure, the curve number technique is a lumped parameter, conceptual model of hydrologic abstraction of storm rainfall. It does not take into account the spatial and temporal variations of infiltration or other abstractive losses; rather it aggregates these losses into calculation of depth of total loss for a given rainstorm and drainage area. So it can also be referred to as an infiltration loss model, although it may also account for interception and surface storage loss through initial abstraction. This is one of the most significant advantage that the method relies only on a single conceptual parameter called maximum potential retention (S) or its corresponding transformation called as curve number (CN). However, the prediction accuracy of this method is strongly related to accurate selection of CN. It ultimately reflects the most professional judgement of the user. Hawkins (1975) as well as Bondelid *et al.* (1982) therefore emphasized the importance of

accurate selection of CN. The curve number for a given land use complex varies as a function of five major runoff producing characteristics. These are hydrological soil group, land use, conservation treatment, hydrologic surface conditions and antecedent moisture condition.

There are four hydrologic soil groups, *viz.* A, B, C and D with increasing runoff potential, respectively. Curve numbers are tabulated for 9 land uses. In case of cultivated land 3 conservation treatments are considered while in pasture land only one treatment is considered. Three hydrologic surface conditions are considered, *viz.* poor, fair, and good for deciding CN. Curve numbers describe average conditions that are useful for design purposes. Hence the CN are given for AMC II and need to be converted for AMC I or III as the case may be. The user should understand the assumption reflected in the initial abstraction term (I_a) and should ascertain that the assumption applies to the situation. I_a , which consists of interception, initial infiltration, surface depression storage, evapotranspiration and other factors, was generalized as $0.2S$ based on data from agricultural watersheds, S being the potential maximum retention after runoff begins *i.e.* the difference between precipitation and direct runoff depth. Runoff from snowmelt or rain on frozen ground cannot be estimated using these procedures as the SCS runoff procedures apply only to direct surface runoff.

The parameters such as initial abstraction, hydrologic surface conditions and antecedent moisture condition are directly or indirectly related to the predictive performance of CN model. These parameters are originally based on some empirical data mostly taken from mid-western U.S. and therefore, while adapting to other geographic locations or climatic situations, they always need modifications or validations.

This paper is divided into following five sections, viz., Origin and development of CN method; Computation of curve number and effect of variability of curve number on runoff estimation; Effect of Rainfall Intensity on determination of Curve Number; Relation between initial abstraction and potential maximum retention, and antecedent moisture condition.

Origin and development of CN method

The origin of curve number methodology can be traced back to thousands of infiltrometer tests carried out by SCS in the late 1930s and early 1940s. The intention was to develop basic data, to evaluate the effects of watershed treatment and soil conservation measures on rainfall-runoff process. A major catalyst for the development and implementation of runoff curve number methodology was the passing of watershed protection and flood prevention act of August, 1954 in U.S.

Mockus (1949) proposed that the estimates of surface runoff for ungauged watershed could be based on information on soil, land use, antecedent rainfall, storm duration and average annual temperature. He combined these factors into an empirical parameter "b" characterizing the relationship between rainfall depth (P) and runoff depth (Q) as,

$$Q = P (1 - 10^{-bP}) \quad (1)$$

Andrews (1954) developed a graphical procedure for estimating runoff from rainfall for several combinations of soil texture, type and amount of cover and conservation practices), using infiltrometer data from Texas, Oklahoma, Arkansas and Louisiana. The methodology developed was referred to as "Soil-cover complex".

Williams and LaSeur (1976) developed water yield model based on SCS curve number

method and Soil-moisture index accounting procedure. The intent of model development was to predict runoff from agricultural watershed with area up to 2590 sq. km. Prediction accuracy was found better as compared to original SCS curve number model. The model was also tested for simulating monthly and annual runoff yield on 47 watersheds in Texas. The required inputs for the model are estimates of CN for AMC-II, measured monthly runoff, daily rainfall and average monthly lake evaporation.

Gifford and Hawkins (1978) emphasized the need of understanding the hydrological impact of grazing intensity on range land condition, since the knowledge is important for water yield potential, recharge of surface moisture and ground water storage. The authors reviewed most of the infiltration studies carried out on range lands of Western U.S. and found that only a few studies provide reasonable estimates of final infiltration rate (fc) and available data were not sufficient to evaluate hydrological impact.

Smith and Eggert (1978) raised some objections in their discussion paper on "Infiltration formula based on SCS curve number method" by Aron *et al.* (1977) as (i) the hydrologic soil group classification is based on visual field estimate and does not constitute any valuable quantification of infiltration parameters, (ii) greater importance has been given on relationship between precipitation rate and infiltration rate incorporated in the proposed equation and (iii) the variation in the best fitted parameters 'fo' and 'Kf' is not sufficient to condemn Horton's infiltration equation.

Hawkins (1981) examined the rainfall-runoff traits under spatially variable loss rates and found that (a) apparent loss rate is non - negative function of rainfall intensity, (b)

interpretation of rainfall intensity and runoff rate relationship is possible in real terms, and (c) the apparent loss rate defines the mean areal loss rate only when maximum loss rate has been defined.

Boszany (1989) objected to introduction and application of arbitrary parameter, curve number, despite the basic formula itself is sufficient to obtain direct solution to the problem of runoff estimation; and the use of predetermined portion of storage index *S* for initial abstraction, neglecting its real magnitude which is strongly dependent on a number of changing watershed characteristics. To overcome these constraints, author proposed graphical solution based on original SCS concept. These graphs can be used without any prior assumptions and forms a generalized approach to modified SCS method.

Cundy and Hawkins (1989) developed a continuous distributed model of storage dominated watershed runoff. It is a combined form of earlier conceptual models, *viz.* Continuous distribution infiltration dependent model developed by Hawkins and Cundy (1987) and discrete distributed storage model developed by Boughton (1987). Additional element covered was the direct influence of antecedent moisture on the storage available and thus, its direct conservation of mass influence on runoff. An important feature of this model is to predict rainfall-runoff from ungauged basin. However, the input required are statistical characteristics of either steady state infiltration characteristics (rate limited) or the soil moisture holding capacity (depth form).

Tenreiro *et al.* (1989) proposed new method to determine monthly runoff in small watershed. They used SCS curve number method to monthly runoff instead of storm runoff with few necessary modifications.

Hawkins *et al.* (1995) studied some of

the South- Western desert watersheds for their rainfall-runoff response. The study revealed a variety of different runoff behaviour patterns. Inactive, complacent, standard, abrupt and violent were the most common runoff responses noted for their "linear" hydrograph behaviour. Prior rainfall was not found to be the major component of response factors but the storm rainfall patterns, depth and intensity were found to be the significant factors. Similarly, there was a broad drainage area effect observed on runoff depth but the local results were not considered for the region as a whole.

Chunale *et al.* (1999) narrated the perceived advantages of Curve Number method as simple, predictable and stable conceptual model, which relies on single conceptual parameter, curve number, and thus has wider acceptability throughout the world. The limitations of the method have been given as sensitivity of method to choice of curve number, no clear guidance about variation of antecedent moisture condition, the consideration of initial abstraction as fraction of potential maximum retention, which may not be the case for all geologic situations, and development of method based on regional data, which sometimes poses difficulty in adoption in other climatic areas. The method needs to be applied to smaller watersheds.

Mishra and Singh (1999) modified the popular form of the SCS-CN model and proposed its general form as below with value of 'a' to be equal to 0.5.

$$Q = \frac{(P - I_a)^2}{[S + a(P - I_a)]} \quad (2)$$

Satpute *et al.* (2002) studied the runoff curve numbers (CNs) for sorghum crop under (i) no conservation treatment (along slope cultivation), (ii) Contour sowing along *Leucaena*

keylines, and (iii) contour sowing along Vetiver keylines for AMC-I, II, and III. The CN were found to be 71, 83, 90, 67, 79, 85 and 62, 80, 86, respectively. Evaluation study of estimated CNs showed statistically non significant difference between the actual and estimated runoff.

Geetha et al. (2008) proposed a new lumped conceptual model based on the Soil Conservation Service Curve Number (SCS-CN) concept for long-term hydrologic simulation and it has been tested using the data of five catchments from different climatic and geographic settings of India. When compared with the Mishra *et al.* (2005b) model based on variable source area (VSA) concept, the proposed model performed better in all applications. Both the models exhibited a better match between the simulated and observed runoff in high runoff producing watersheds than did in low runoff producing watersheds. Using the results of the proposed model, dominant/dormant processes involved in watershed's runoff generating mechanism have also been identified. The presented model is found useful in the continuous simulation of rainfall-runoff process in watersheds.

Ajmal et al. (2016) derived a new model by ensembling original CN model and GR4J model, a French daily lumped four-parameter rainfall-runoff model, which is soil moisture accounting model (Perrin *et al.*, 2003), with pre-storm moisture content concept (Michel *et al.*, 2005). It exhibited better and consistent results than earlier three models; *viz.* CN model, Michel *et al.* (2005) model and Mishra *et al.* (2006) model; for 39 forest dominated small and large watersheds in South Korea.

Computation of curve number and effect of variability of curve number on runoff estimation

Hawkins (1975) assumed an input error of

10 per cent and found that runoff prediction is more sensitive to CN chosen for a considerable precipitation range up to 9 inches (228.6 mm). Therefore, he emphasized the importance of accurate curve number in estimation of storm runoff.

Hawkins (1978a) described that CN-AMC relationship is discrete, which implies that if there is a sudden shift in CN, there is a quantum jump possible in Q. Moreover, there is no background development or statement of assumptions available. Based on these difficulties, the author proposed a procedure of relating CN to site moisture and developed following expression:

$$CN_2 = \frac{1200}{(1200/CN_1) + [ET - (P - Q)]} \quad (3)$$

Where, CN_1 and CN_2 are the curve numbers at beginning and ending times of study interval, P is interim storm rainfall and $[ET - (P - Q)]$ is the interim change in site moisture due to evapotranspiration (ET) and drainage losses.

This method requires estimates of both evapotranspiration and drainage losses, which are not routinely available. But it may, with judgement, be used as an alternative to SCS handbook methods.

Hawkins (1978b) clarified some of the questionable features raised by Smith and Eggert (1978) on, "Infiltration formula based on SCS runoff curve number", by Aron *et al.* (1977) in his discussion on the paper. He suggested that the supportive literature on the reliability of SCS soil infiltration and curve number data should be cited for the physical linkage between soil groups and curve numbers.

Hjelmfelt (1979) adopted SCS curve number method to estimate time distribution of

infiltration during a storm. However, the application shows variation with other infiltration methods. But the infiltration formula developed under particular case of storm of constant rainfall intensity and zero continuous infiltration rate was found to be identical with Holton-Overton infiltration equation. This comparability helps to enhance the interpretation of infiltration estimates using CN method.

Hawkins (1979) re-examined the previously obtained relationship that a constant curve number is independent of storm size and found that it is not appropriate under all situations. He, therefore, analysed the observed rainfall runoff data from some instrumented Western forested watersheds and hypothesized some causes for observed variations in curve number. After testing the hypothesis, it was found that in some cases, runoff is simple fraction of storm rainfall, for which there may be a constant "impervious" runoff source area like channel interception, accompanied by infiltration rate relative to rainstorm intensity and a constant role of antecedent moisture.

Hawkins (1980) described the analogy between infiltration and curve number as both represent the index of hydrologic condition of land and allocates rainfall pattern into "losses" and rainfall "excesses". However, he has narrated some basic problems of relating infiltration with curve number as,

i) The infiltration is most appropriate on small areas whereas, CN is a lumped expression of net basin performance. ii) There are some dimensional variations in both the parameters. iii) There are several means to express infiltration rate but the basic or long term rate equivalent to saturated hydraulic conductivity is most commonly used.

Hence the author related the infiltration rate

with curve number in following ways:

$$\text{i. Analytically, } f = i (P/S + 0.8)^{-2} \quad (4)$$

$$\text{ii. Empirically, } f = 10^{b[(100 / CN) - 1]} \quad (5)$$

$$\text{iii. Algebraically, } \Phi/i = (P/S + 0.8)^{-1} \quad (6)$$

Where, f is infiltration rate, i is rainfall intensity, b is empirical constant, S is storage index and P is storm rainfall.

Hjelmfelt (1980) proposed a procedure of transferring the frequency distribution of rainfall to that of runoff to investigate the validity of SCS curve number technique. The study was carried out by using observed rainfall-runoff events of five different U.S. watersheds. The observed events were ordered by their magnitude and plotting positions were established on log-normal probability paper. By assuming rainfall to follow log-normal distribution, the fitted line was drawn using the method of moments. Frequency distribution of rainfall was then transformed to runoff distribution. Agreement was found quite well in humid watersheds whereas found poor in arid watersheds. It was due to the fact that the humid watershed retains a small fraction of rainfall during runoff whereas, arid watershed retains large amount of rainfall.

Ragan and Jackson (1980) developed an alternative approach of determining curve number by using Landsat data. It can cover large area and the data can be made available in a digital format on magnetic tapes. The land-cover categories can be developed through computer-aided analysis of Landsat data. CN can be efficiently defined for larger watershed or portions thereof.

Wood and Blackburn (1984) found that the hydrologic soil group classification suggested by SCS curve number method was inadequate for arid and semi-arid range land

situation as it gave incorrect estimation of infiltration as well as runoff when tested. Authors, therefore, suggested that new criteria should be introduced to modify the existing system of hydrologic soil group classification to determine the curve numbers properly.

Hawkins et al. (1985) developed following correlation between dry or wet potential retention (SI and SIII) and average potential retention (SII).

$$S_I = 2.281 S_{II} \quad (7)$$

$$(r^2 = 0.999 \text{ and } Se = 0.206)$$

$$S_{III} = 0.427 S_{II} \quad (8)$$

$$(r^2 = 0.994 \text{ and } Se = 0.088)$$

These relations are applicable in the range $55 < CN < 95$ which encompasses the most estimated or experienced CN. Based on these correlations, the expressions for QI and QIII were also developed. The authors suggested to use only large or very large event for which $P/S_{II} > 0.46$ or $Pr(Q/S_{II} > 0) > 0.90$ for determination of CN from observed rainfall runoff data. However, because of some consequent problems arising in the above censoring criteria, the authors further simplified it by suggesting a thumb rule ($Q/P > 0.12$) for quick check of data set and derived rainfall limits for different storm groups as given in Table 1.

Chong and Teng (1986) proposed another method of determination of CN via storage index S. They related S to the saturated infiltration rate K_s (m/s) and sorptivity S_o (m-s-1/2) as,

$$S = a_1 K_s^{a_2} S_o^{a_3} \quad (9)$$

Where, a_1 , a_2 and a_3 are empirical constants to be determined by regression analysis. The coefficient of determination was

found to be more than 0.76, whereas the constant a_1 was found to be ranging from 1.621 to 5.328, a_2 from 1.06 to 1.21 and a_3 from 0.529 to 0.713. The equation was found most promising for ungauged watersheds.

Hawkins (1993) described the technique of determining runoff curve number from observed rainfall-runoff events. The technique matches the rank ordered (i.e. sorted) rainfall and runoff which preserves the return period matching between storm rainfall and storm runoff. From the observed secondary relationship between CN and storm rainfall, three clear categories of response were found. They were complacent, standard and violent. The standard and violent cases define a constant CN with increasing rainfall; however the complacent case does not lead to a safe determination of curve number. It is indeterminate. Two measures of reliability or asymptotic attainment are offered.

Mane (1995) studied the rainfall and runoff from two adjacent watersheds in Agadgaon, Distt. Ahmednagar, Maharashtra State, India. A water harvesting structure was constructed in one watershed. He computed the values of CN using the rainfall-runoff data and also the land use, land cover, treatments data as required for published table values of CN. He found that the deviation in computed and table values of CN was more in case of watershed having water harvesting structure.

Mane and Patil (1996) verified the CN model for the watersheds in sub-humid and

Table 1. Derived rainfall limits for different storm groups

Relative storm size P/SII	Rainstorm group
0.0 to 0.085	Very small storm
0.085 to 0.20	Small storm
0.20 to 0.456	Medium storm
0.456 to 0.600	Large storm
More than 0.600	Very large storm

semi-arid regions of Maharashtra. They compared the computed values of CN from rainfall-runoff data pairs with the published table values of CN and found large deviation in both watersheds. So they suggested modifying CN method for the prevailing sites.

Ponce and Hawkins (1996) illustrated CN model as a lumped conceptual model of hydrologic abstraction of storm rainfall. They further elaborated the method sensitivity which is strongly dependent on the selection of value of CN. While describing the perceived limitations of the method, the authors suggested some possible refinements on variation of antecedent moisture condition with respect to spatial and scale effect as well as on revision of initial abstraction based on different geologic and climatic setting.

Simanton *et al.* (1996) considered runoff curve number as a measure of watershed's runoff response. Three different methods were used to determine curve numbers from 18 semi-arid watersheds in Southeast Arizona. Each of the methods produced similar results and supported the CN Vs. drainage area relationship. Authors expressed the relationship as linear regression model. Curve number was observed to decrease with increasing drainage area. This response might be a reflection of spatial variability in rainfall and infiltration losses in the coarse textured material of the channels associated with larger drainage basin.

Supe (1998) concluded that the handbook method of SCS Curve Number do not predict storm runoff for the small watershed in sub-humid region. It was further emphasized that the table values of CN need to be modified possibly by using rainfall intensity, rainfall duration and rainfall amount for estimation of storm runoff more accurately.

King *et al.* (1999) compared two methods of simulating excess rainfall on a large basin

with multiple rain gauges. The SCS daily curve number method (CN) was compared with the Green-Ampt Mein-Larson (GAML) method on the Goodwin Creek Watershed (GCW). GCW is 21.3 km² in area and has 32 rain gauges located within and surrounding the watershed. The model used was the Soil and Water Assessment Tool (SWAT). SWAT is a comprehensive watershed scale model developed to simulate management impacts on water, sediment and chemical yields for ungauged basins. SWAT was modified to accept breakpoint rainfall data and route stream flow on a sub-daily time-step. Eight years of measured climatic data were used in the study. Simulated and measured stream flows at the watershed outlet were evaluated. Results were not calibrated. Monthly model efficiencies were 0.84 for CN and 0.69 for GAML. The use of a sub-daily routing technique allowed for very good correlation between measured and simulated hydrographs. Results suggest that no significant advantage was gained by using breakpoint rainfall and sub-daily time-steps when simulating the large basin used in this study.

Silveira *et al.* (2000) discussed the applicability of the curve number procedure developed by the US Soil Conservation Service (SCS) to estimate direct runoff in basins characterized by small to gentle undulating slopes mainly covered with natural grasslands. Rainfall and runoff data measured in the Canada de Los Chanchos basin in Uruguay is used to fit the curve numbers and to analyse the antecedent soil moisture condition proposed by the SCS.

Mishra *et al.* (2004) used a large set of rainfall-runoff data from 234 small to large watersheds from USA, and evaluated the modified version of the Mishra and Singh (MS) model which is based on the Soil Conservation Service Curve Number (SCS-CN) methodology

and incorporates the antecedent moisture in direct surface runoff computations. They considered total six models for study named as model 1 to model 6 out of which model 1 and 4 were two parameter models and these parameters were CN and λ . Comparison with the existing SCS-CN method using the t-test and the ranking-based grading shows that the modified MS model performs far better than the existing SCS-CN model. The modified version (model 4) of the Mishra and Singh Model performs better than any other model formulations considered. According to the t-test, the existing version of the SCS-CN method (model 2) performs poorest of all the models. Among the models considered, model 6 can be recommended for real-world applications, for it has only one parameter CN, allows for direct incorporation of the antecedent moisture, and obviates sudden jumps in CN-variation with AMC.

Mishra *et al.* (2005a) opined that SCS-CN method estimates direct surface runoff from given amount of rainfall. The initial abstraction coefficient (λ), which largely depends on the climatic conditions, as taken as a constant value of 0.2 in the method and it is perhaps the most ambiguous parameter to be considered for modification. Though the Mishra and Singh (MS) model allows variation in λ and, in turn, initial abstraction I_a , it obviates its dependence on the antecedent moisture M . In fact, larger the antecedent moisture, lesser will be the initial abstraction, and vice versa. This study presents a modification to the initial abstraction (I_a)-potential maximum retention (S) relationship of the existing SCS-CN method and MS model for M . In an application to a large set of data from 84 small watersheds of U.S.A., the proposed modified model for varying λ is found to perform much better than the existing one and other considered variations. The proposed method advantageously obviates sudden jumps in the curve number with antecedent moisture

condition, an unreasonable and undesirable feature of the existing SCS-CN model. Finally a better one - parameter model is also suggested for field applications.

Huang *et al.* (2006) used soil moisture data and curve number method for estimating runoff in the Loess Plateau of China. The dataset consisted of 10 years of rainfall, runoff and soil moisture measurements from experimental plots cropped with millet, pasture and potatoes. Results indicate that the standard CN method underestimated runoff depths for 85 of the 98 observed plot-runoff events, with a model efficiency E of only 0.243. For our experimental conditions, the discrete and linear approaches improved runoff estimation, but still underestimated most runoff events, with E values of 0.428 and 0.445, respectively. Based on the measured CN values and soil moisture values in the top 15 cm of the soil, a non-linear equation was developed that predicted runoff better with an E value of 0.779. This modified CN equation was the most appropriate for runoff prediction in the study area, but may need adjustments for local conditions in the Loess Plateau of China.

Mishra *et al.* (2008) conducted study on a rain duration-dependent procedure based on the popular Soil Conservation Service Curve Number (SCS-CN) methodology for computation of direct runoff from long duration rains. Curve numbers are derived from long-term daily rainfall-runoff data, and antecedent moisture condition (AMC) related with antecedent duration. Analysis of data from five Indian (large, in terms of area) watersheds reveals the calculated curve numbers to decrease with the considered duration, showing the existence of a characteristic value of minimum CN or maximum initial abstraction to occur in a watershed for a pre-selected AMC. The testing of the proposed procedure on the separate (measured) rainfall-runoff event data

sets from the same watersheds suggests satisfactory workability of the method.

Elhakeem and Papanicolaou (2009) carried out study to identify the effects of the following variables on runoff CN: rainfall intensity, soil type, soil moisture condition, tillage practice, and residue cover. The study also re-evaluated the range of the existing CN values for the different hydrologic soil groups in Iowa, and revised the equations describing the CN method to consider variables such as residue cover and soil moisture in a more detailed manner than the existing USDA method. The range of the estimated CN values in summer agreed well (deviation less than 6%) with the reported CN values. However, the range of the estimated CN values in fall was generally less than the reported CN values (deviation of about 40%) due to the high residue levels found in the fields after harvest. The effects of tillage practice and crop type were insignificant compared to residue cover and soil moisture. The study has also shown that the initial abstraction I_a is not linearly proportional to the potential maximum retention S , which agrees with the available literature.

Banasik and Woodward (2010) used over sixty rainfall-runoff events, collected during 29 years (1980-2008) in a small ($A=23.4 \text{ km}^2$), lowland and agricultural watershed in the centre of Poland, to determine runoff Curve Number and to check change tendency. In 1990s the investigation was a part of Polish - US project (PLARS-195). The watershed is characterized by mean annual rainfall and runoff of 606 mm and 107 mm, respectively. The observed CN, ranging from 59.8 to 97.1, declines with increasing storm size, which could be classified as a standard response of watershed. Variability of CN during a year is also demonstrated. Analyses showed that empirical CN computed for events of precipitation larger than 20 mm is

very close to CN estimated on base of land use and soil types for the watershed.

El-Hames (2012) developed an empirical method that utilizes the SCS curve number and catchment characteristics to help in the prediction of peak discharge in unguaged arid and semi-arid region catchments. The morphological factors that were found to control peak discharge are catchment area and slope, and main channel length. The hydrological controls, however, are the effective rainfall that reflects the antecedent wetness condition of the catchment which was calculated from the determined catchment curve number (CN). The data incorporated in the developed method are easy to obtain from satellite images and by utilizing GIS techniques without the need for intensive field visits or relying on historical runoff records. The developed method has been calibrated and validated against 76 rainfall-runoff events from six different countries around the world and it has shown encouraging performance when compared with observed peak discharge data or the results from other models. The developed method performs very well with catchments larger than 45 km^2 with coefficient of correlation of 0.92. However, for catchments with areas less than 45 km^2 the obtained coefficient of correlation was 0.67. Also, the developed method performs very well with either event-based or return-period-based peak discharge prediction and it can be considered a good alternative to the rational method.

Nayak *et al.* (2012) investigated the Uri river watershed in Lower Narmada basin in Central India about the effects of land-use change on surface runoff. Satellite imageries pertaining to two different periods, i.e. year 2001 and 2007 have been interpreted in ILWIS GIS platform for preparation of land use/cover maps, analysis of their spatial distribution and changes between the two

periods. The weighted average Curve Numbers (CN) for both the year calculated on the basis of land use/cover type and hydrologic soil class in the catchment area. The direct surface runoff volume computed by the SCS Curve Number method have been compared with the observed runoff calculated from recorded hydrograph at G&D site for the selected rainfall events. It was shown from the results that the agricultural area have been increased drastically and forest area has reduced considerably resulting in 20-40 % increased surface runoff volume in recent years (i.e. 2007) in comparison to those in 2001 for the similar rainfall events.

Tandon and Nimbalkar (2014) developed a relationship between direct runoff and the mean areal rainfall and validated it using statistical model. They used five methods of rainfall runoff relationship for the Morbe dam catchment watershed apart from which suggested using curve number method or Inglis method by changing factor used. The rainfall and runoff data ranging from year 1958 to 2011 had been utilized for detail analysis. This study investigated the response of stream flow to rainfall on gauged, small watersheds of the Morbe dam watershed project using methods to estimate runoff. Even calibrated curve numbers contain large uncertainties, thus requiring statistical proof that estimated runoff adequately agrees with observations. Estimation of the runoff is required in order to determine and forecast its effects.

Nambi et al. (2015) attempted to investigate the influence of the Curve Number (CN) and Initial abstraction coefficient (λ) on runoff estimation using SCS-CN method. The study area is an ungauged watershed delineated from IWRIS (C18PAL37) which falls within the Chittoor district. A study period of 14 years was considered in the investigation. The duration was classified into two models, i.e. Water-Year (WY) models and Rainfall-Event (RE) models.

Each model was further classified into three models based on the CN values considered. Model-1, Model-2 and Models-3 for Pre monsoon, Post monsoon and Pre monsoon-Post monsoon CN values respectively. The CN values were developed by using LANDSAT imageries for the month of March and October during the years 2000 and 2010. With each model the initial abstraction values varied from 0 to 0.3 at 0.1 raise. The runoff was estimated for recorded daily rainfall depths using the standard SCS CN equation. The resulted depths of runoff were checked for accuracy using R^2 -test.

Kowalik and Walega (2015) investigates a possibility of using asymptotic functions to determine the value of curve number (CN) parameter as a function of rainfall in small agricultural watersheds. It also compares the actually calculated CN with its values provided in the Soil Conservation Service (SCS) National Engineering Handbook Section 4: Hydrology (NEH-4) and Technical Release 20 (TR-20). The analysis showed that empirical CN in the National Engineering Handbook tables differed from the actually observed values. Calculations revealed a strong correlation between the observed CN and precipitation (P). In three of the analyzed watersheds, a typical pattern of the observed CN stabilization during abundant precipitation was perceived. It was found that Model 2, based on a kinetics equation, most effectively described the P-CN relationship. In most cases, the observed CN in the investigated watersheds was similar to the empirical CN, corresponding to average moisture conditions set out by NEH-4. Model 2 also provided the greatest stability of CN at 90% sampled event rainfall.

Sundara Kumar et al. (2016) used IRS-P4-LISS IV data to develop land use/land cover pattern for 1252.99 sq.km Sarada River basin in Vishakhapatnam district of Andhra Pradesh,

India. They adopted MNRCS-CN method to estimate runoff. The estimated runoff using MNRCS-CN model when compared with that of actual runoff the coefficient of determination R^2 value was found to be more than 0.72 for the selected basin.

Effect of rainfall intensity on determination of Curve Number

Hawkins (1978c) proposed a procedure to introduce the effect of rainfall intensity and its duration to SCS curve number method. Using rainfall partitioning approach or constant loss rate (ϕ index) and fixed distribution of rainfall intensity, he developed following functional expression for specific intensity duration distribution.

$$i(t) = 1.5 P/\tau [5/a+(t/\tau) - 1] \quad (10)$$

It gives the rainfall intensity $I(t)$ at time (t) for a storm (P) of duration (T) . The deviation from this distribution was referred to as "CN distribution". However, the author suggested using this concept only for small homogeneous watershed with all available data on rainfall intensity, duration and ϕ index.

Bangal *et al.* (2000) tried to develop multiple linear regressions for different intensity groups between calculated curve number and table curve number, rainfall intensity, rainfall amount and rainfall duration using rainfall runoff data of 86 events during 1990-1996 at ZARS, Shenda Park, Kolhapur. They estimated the direct runoff using the corrected CN and developed a linear equation between Q observed (Q_o) and Q estimated (Q_e) as $Q_o = a + bQ_e$. The coefficients a and b as well as the difference of mean observed and mean estimated direct runoff were tested by student 't' test. The statistical test revealed that mean direct runoff is estimated correctly by the modification suggested.

Chavan and Pawar (2000) studied the Maheshgad watershed located at Central Campus, MPKV, Rahuri for inclusion of rainfall intensity in CN Model. The storm rainfall-runoff data for eight subwatersheds were analysed to compute maximum potential retention (S) and CNs. These computed values of CN were correlated with table values of CN, precipitation amount, average intensity of storm and duration of storm. The computed values of CN deviate from table values of CN. Thus, there is scope of inclusion of rainfall intensity in the correction of curve number from table values. The result showed that the multiple linear regression between CN_c and CN_t , precipitation, average intensity and duration of rainfall was highly significant when tried irrespective of intensity classes.

Carlesso *et al.* (2011) used a portable rainfall simulator to study the effect of different soils classes at different rainfall intensities (30, 60 and 120 mm h⁻¹) on the runoff in Southern Brazil. The runoff measured was compared to Smith's modified and Curve Number (USDA-SCS) models. The cumulative runoff losses were 67, 45 and 27 per cent of the total rainfall, for a Rhodic Paleudalf, Typic Quartzipsamment and Rhodic Hapludox, respectively. An inverse relationship was observed between initial runoff and the runoff rate, independently of the soil surface and rainfall conditions. Increasing rainfall intensity decreased the time to runoff and increased runoff rate. The Smith's modified model presented a better estimate for both higher and lower rainfall intensities (120 and 30 mm h⁻¹). The SCS Curve Number model overestimated the cumulative runoff by about 34%. This large overestimate was probably due to non consideration of the soil tillage system used in the field by farmers, particularly for irrigated conditions. The SCS Curve Number model

overestimated the cumulative runoff and its use needs adjustments particularly for no-tillage management system.

Nawale *et al.* (2015) concluded that corrected curve number can be determined using table value of curve number, rainfall, average intensity of rainfall and duration of rainfall by using multiple linear regression based on their study for Solapur Station of Maharashtra.

Relation between initial abstraction and potential maximum retention

Aron *et al.* (1977) suggested to use $I_a = 0.1S$ or even lower value instead of $0.2S$ as it seems to work well for large storms but usually underestimates the runoff from small and medium storms. They developed infiltration formula based on SCS curve number model. The intent was to have an improvement over the Horton's (1940) infiltration equation.

Cazier and Hawkins (1984) analysed a sample of 109 watersheds scattered throughout the U.S. for goodness of fit to the CN-rainfall-runoff equation (with and without the constraint of $I_a = 0.2S$), and to the linear equation, $Q = a + bP$. The linear equation fit best 85 per cent of the time. They found that the best fit for CN equation was not $I_a = 0.2S$ but $0.0S$ in most cases. There was little apparent regional clustering of equation preference. It was therefore suggested to categories the rainfall-runoff relationship. Hawkins (1984) compared 110 cases of handbook predicted and hydrologically derived CNs from different land use systems. The study showed that the agricultural watersheds led to most accurate prediction whereas, the CNs predicted from forested watersheds were almost entirely unrelated to observed reality. In general, there was poor matching between predicted and observed CNs. Author called it as most error prone prediction possibly resulted due to

incorrect estimation or poor input data or incorrect analysis or basic error inherent in the methodology. He therefore, suggested that the CN estimation should be more precise and consistent with the input soil and vegetation data.

Shrivastava and Bhatiya (1992) tested the SCS curve number model for Indore region, wherein the maximum potential retention S was determined from observed soil moisture and evapotranspiration data. The observed and predicted daily runoff values using this approach were found to be in good agreement.

Dawkhar and Shinde (1995) tested the applicability of CN method for estimation of weekly runoff in small agricultural watershed of 9.02 ha and concluded that the CN method can be used to predict weekly runoff from small watershed with certain modifications. They suggested that the level of I_a should be considered as $0.1S$ instead of $0.2S$ for the watershed under study.

Chunale (1997) prepared only three groups of rainstorms for convenience, using the approach suggested by Hawkins *et al.* (1985) for sub-humid zone of Maharashtra as shown in Table 2. Based on the studies it was concluded that the CN model cannot be used as it is for the Shenda Park watershed in sub-humid region of Maharashtra. The model needs to be modified for the choice of hydrologic condition and level of initial abstraction.

Chunale *et al.* (2001a) tested the validity of SCS curve number technique for sub humid region of Maharashtra and found that SCS-CN

Table 2. Rainfall limits for modified storm groups

Rainstorm groups	Rainfall limits, mm
Small	Up to 30.0 mm
Medium	30.0 to 60.0 mm
Large	More than 60.0 mm

model when tested with $I_a = 0.2S$, for Shenda Park watershed has shown invalid estimation, underestimation or overestimation for most of the storm groups (Chunale, 1997). This necessitated the need to alter I_a levels for different storm size. Four different levels of I_a along with $I_a = 0.2S$ were tried these were 0.0, 0.1S, 0.3S, 0.4S. For this study 88 rainstorm events during 1990-96 were selected. The statistical evaluation showed that the curve number model estimates the runoff from small and medium storms of AMC I better when I_a is 0.0. The runoff from large storms of AMC I and small and medium storms of AMC II can be estimated correctly with I_a equal to 0.1S. I_a value needs to be increased to 0.3S for large storms of AMC III. For large storms of AMC III, the I_a value needs to be increased to 0.4S and the hydrologic condition needs to be considered good. The results clearly indicate that while using curve number model for estimating runoff from the storms flat rate of $I_a = 0.2S$ does not apply to all conditions (Chunale *et al.*, 2001b).

Woodward *et al.* (2003) assumed the Initial Abstraction ratio (I_a/S , or λ) in the Curve Number (CN) method in its original development to have a value of 0.20. Using event rainfall-runoff data from several hundred plots this assumption is investigated, and determined values by two different methods. Results indicate a value of about 0.05 gives a better fit to the data and would be more appropriate for use in runoff calculations. The effects of this change are shown in terms of calculated runoff depth and hydrograph peaks, CN definition, and in soil moisture accounting. The effect of using $\lambda = 0.05$ in place of the customary 0.20 is felt mainly in calculations that involve either lower rainfall depths or lower CNs.

Xiao *et al.* (2011) studied the applicability of the SCS-CN model to a small watershed,

Liudaogou, on the plateau. The most appropriate initial abstraction ratio (I_a/S) value in the model was quantified by the inverse method. The results showed that the standard SCS-CN model was applicable to the estimation of runoff in the Liudaogou watershed and the model performance was acceptable according to the values of relative error and Nash-Sutcliffe efficiency. The most appropriate I_a/S value for the watershed was 0.22 because with this modified I_a/S value, the model performance was slightly improved. The model performance was not sensitive to the modification of the I_a/S value when one heavy rainfall event (50.1 mm) was not considered, which implied that the model, using a standard I_a/S value, can be recommended for the Liudaogou watershed because single rainfall events exceeding 50 mm seldom occurred in that region. The runoff amount predicted for the Liudaogou watershed by the SCS-CN model, using the modified I_a/S value, increased gradually with increasing rainfall when rainfall values were lower than 50 mm. Whereas, the predicted amount increased rapidly when the rainfall exceeded 50 mm. These findings may be helpful in solving the problem of serious soil and water loss on the Loess Plateau of China.

Antecedent Moisture Condition

Chiang (1975) developed an equation for flood volume estimation from small humid watershed by using Numbers of Wetness Curve (NWC) instead of CN. He showed that S values for each soil-cover complex under AMC I and III are too limiting and therefore recommended to use SCS curve number approach via. NWC. The antecedent soil moisture, initial base flow and five day antecedent maximum daily temperature were found to be the best predictor of optimal NWC.

Gray *et al.* (1982) studied the antecedent moisture condition probabilities for the use of SCS curve number method and Illinois Urban

Drainage Area Simulator (ILLUDAS). They used linear regression of average annual rainfall from stations in Indiana, Kentucky and Tennessee and proposed the equation for predicting the probability of antecedent moisture conditions in various class interval. However, the authors took the exceptions to the conclusion that these equations should be used with caution to provide estimates of upper and lower boundaries in more arid areas.

Hjelmfelt *et al.* (1982) found that the AMC I represents 90 per cent, AMC II as 50 per cent and AMC III as 10 per cent cumulative probabilities of exceedence of runoff depth for a given rainfall. In other words, AMC II represents the central tendency, whereas AMC I and AMC III accounts for dispersion in the data. In this role, site moisture per cent acts as a surrogate for all other sources of variability, beyond that which could be attributed to soil, land use / treatment and surface conditions.

Cronshey (1983) reviewed the papers on, "Antecedent moisture condition probabilities", by Gray *et al.* (1982) and gave some comments

- i) It is not necessary to determine antecedent moisture condition for most of applications of SCS curve number method. Average condition CN (AMC II) should be used in most instances
- ii) Antecedent precipitation is not used in development of CN. It is important only when specific event is to be analysed
- iii) Any variation in watershed or event condition is expressed by range of CN from AMC I to AMC III. Variation is not due to the antecedent precipitation.

Hope (1984) studied the R-index method for calculating stream flow volumes. He used four procedures for representing catchment antecedent moisture condition in the model. The effects on model calibration of two events of extreme magnitude were dealt. He observed that R-index was suitable for stream flow estimation in semi-arid catchment. He further

found that the parameter values for model differed markedly to those in humid and sub-humid catchment and the effect of antecedent moisture conditions on streamflow volumes in those catchments was generally not important, particularly for large events.

Haan and Schulze (1987) proposed a method based on derived distribution for estimating the magnitude of a return flow volume and for placing the confidence interval on that estimate for the given return period rainfall. Authors illustrated this proposed methodology by using SCS curve number technique which gave 80 per cent confidence limit on runoff estimation equation for AMC I and AMC III CNs.

Stone (1993) tested SCS curve number method along with several modifications for small agricultural watershed. Best predictions for runoff volume were obtained when all events were considered under AMC III and initial abstraction was treated as nil. However, these considerations were found to lead over predictions of peak rates of flow. Yoo *et al.* (1993) studied the conventional (CvT) and conservation (CsT) tillage systems of cotton for six years on a 3.8 ha watershed to determine their effect on SCS curve numbers. The study was conducted in limestone valley region of Northern Alabama. The tillage included three years of conventional (CvT), followed three years of conservation tillage (CsT). The results showed that the curve numbers (CN II) calculated by log-normal methods were 83 and 88 for CvT and CsT respectively. These were slightly higher than those (82 and 86) calculated from observed rainfall-runoff data. But the two methods agreed that the CN II of CsT was higher than that of CvT.

Geetha *et al.* (2007) made an attempt to modify the existing SCS-CN model in two ways by varying the CN using antecedent moisture

condition (designated as Model I), and by using antecedent moisture amount (designated as Model II). The daily moisture storage is updated based on varying the curve number and other hydrologic abstractions. These two models are constructed to compute stream flow components: Direct surface runoff, base flow and hydrological abstractions. These methodologies were successfully applied to daily data of catchments of Cauvery, Narmada, Ganga and Ulhas Rivers, lying in different climatic regions of India and the results were analyzed. It is found that the proposed models reasonably simulate the catchment response and these SCS-CN-based models are applicable to complex natured watersheds.

Conclusions

The Soil Conservation Service Curve Number model can be said as lumped parameter, conceptual, event based model. Cundy and Hawkins tried to develop continuous, distributed parameter model for runoff estimation in 1989. A new lumped conceptual model for long term hydrologic simulation was proposed in 2007 by Geetha and others. Efforts to obtain simple rainfall-runoff model for watersheds are underway since 1949. Due to availability of fast computing machines, distributed as well as continuous models have also been thought, keeping the essence of CN model intact during last seven decades.

The efforts for computation of curve number using rainfall runoff data pairs as well as assessing the effect of variability of selected curve number on the estimation of runoff are underway since last four decades. The scientists have emphasized the need for correct selection of curve number, especially Hawkins, Hjelmfelt. Originally the effect of rainfall intensity on the curve number determination was not thought of explicitly. But Hawkins suggested the

procedure to introduce the effect of rainfall intensity to SCS curve number method in 1978. Since then some scientists tried to include rainfall intensity, explicitly in determination of curve number for estimation of runoff. The initial abstraction ratio (?) suggests the relationship between initial abstraction (I_a) and maximum potential retention (S). This relationship is of prime importance as initial abstraction amount decide the amount of rainfall required to initiate the direct runoff from the watershed. Many scientists have suggested different values of ? ranging from 0 to 0.4 in different parts of world. The variability of curve number largely depends on the antecedent moisture condition. The SCS have suggested different limits of cumulative rainfall on previous 5 days under two situations to demarcate dry condition (AMC I), Average condition (AMC II) and wet condition (AMC III). However, there seems no logic behind consideration of previous 5 day cumulative rainfall or amount of rainfall to decide AMC I, AMC II or AMC III. The consideration of soil moisture for varying the curve number based on moisture condition of watershed was tried by Geetha and others in 2007, which seems to be logical.

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Effect of Graded Levels of Fertilizer on Herbage Yield of Coriander (*Coriandrum sativum* L.) var. Konkan Kasturi

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Abstract

A field experiment was conducted to study the effect of graded levels of nitrogen (N) and constant phosphorus (P) and potash (K) on growth and herbage yield of coriander var. Konkan Kasturi under Konkan agroclimatic conditions at the Vegetable Improvement Scheme, Central Experiment Station, Wakawali, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Dist. Ratnagiri (M.S.) during the Rabi season 2014-15. The experiment consisted of five treatment combinations viz. T₁ (40:30:30 NPK kg ha⁻¹), T₂ (60:30:30 NPK kg ha⁻¹), T₃ (80:30:30 NPK kg ha⁻¹), T₄ (100:30:30 NPK kg ha⁻¹) and T₅ (120:30:30 NPK kg ha⁻¹). The experiment was laid out in randomized block design with four replications. The results revealed significant differences in growth and seed yield parameters among the treatments. Application of 120:30:30 NPK kg ha⁻¹ recorded the maximum values for all parameters. However a dose of 100:30:30 NPK kg ha⁻¹ was found economical.

Key words : Coriander, nitrogen, phosphorus, potassium, herbage yield.

Coriander (*Coriandrum sativum* L.) belongs to the family Apiaceae is one of the oldest spices used by mankind since as early as 5000 BC. It is native to Mediterranean region. Coriander is known as low volume but high value crop of arid and semi-arid regions. The coriander plant gives two primary products i.e. fresh green herb and the spice and are used for flavoring purposes. The herb is used for culinary purposes as flavouring agent in Asia, Middle East, Central and South America (Ramadan *et al.*, 2002).

Though it is a popular crop of North India, it is also cultivated in Konkan region of Maharashtra especially during rabi season as the climatic conditions prevailing during rabi season are quite suitable for cultivation of coriander. Thus, it fits well in rice based cropping system. Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth Dapoli has released

a variety 'Konkan Kasturi' during 2013. Due to short duration and early crop as herbage yield, it is gaining popularity among the farmers under Konkan agro-climatic conditions. However, the information available on coriander nutrition management is limited; therefore the present investigation was carried out to study the effect of fertilizers on growth and herbage yield of coriander (*Coriandrum sativum* L.) var. Konkan Kasturi.

Materials and Methods

The field experiment was conducted at Vegetable Improvement Scheme, Central Experiment Station, Wakawali, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli (M.S.) during the rabi 2014-15. The experiment was laid out in randomized block design with five fertilizer treatment combinations viz., T₁ (40:30:30 NPK kg ha⁻¹), T₂ (60:30:30 NPK kg ha⁻¹), T₃ (80:30:30 NPK kg ha⁻¹), T₄ (100:30:30 NPK kg ha⁻¹) and T₅ (120:30:30 NPK kg ha⁻¹) and replicated

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four times. Seeds of the Coriander var. Konkan Kasturi were sown with line spacing 0.45 m apart. The other cultural operations and plant protection measures were followed to maintain the better plant health. Observations were recorded on plant height, number of leaves, number of branches, shelf life, edible portion recovery, fresh and dry weight plant⁻¹, leaf yield plant⁻¹ and hectare⁻¹. Data obtained was statistically analyzed as per the methods prescribed by Panse and Sukhatme (1995).

Results and Discussion

Growth parameters : Data presented in Table.1 revealed that all the growth parameters were significantly differed with grade levels of nitrogen. The highest plant height was recorded in T₅ with the values 8.18 cm, 20.15 cm and 40.53 cm at 15, 30 DAS and at harvest respectively and it was followed by T₄ with the values 8.08, 20.01 and 40.43 cm and the shortest plants were found in T₁ with the values 7.01, 17.28 and 33.73 cm at 15, 30 DAS and at harvest respectively. The plant height increased linearly in proportion with increase in dose of N, Oliveira *et al.* (2003). Significant variation due to increased levels of nitrogen in plant height was also reported by

Moosavi *et al.* (2013), Patel *et al.* (2013) and Moniruzzaman *et al.* (2014) in coriander.

Similarly, the highest number of leaves was recorded in T₅ with the values 9.05, 18.74 and 53.84 followed by T₄ with the values 8.93, 18.69 and 53.65 and minimum number of leaves were found in T₁ with the values 6.83, 12.61 and 35.50 at 15, 30 DAS and at harvest respectively (Table 1). The above results are in conformity with Moniruzzaman *et al.* (2014) in the coriander.

The highest number of branches were recorded in T₅ with the values 2.93 and 6.63 at 30 DAS and at harvest respectively and was followed by T₄ with the values 2.85 and 6.60. Lowest number of branches were found in T₁ with the values 2.28 and 5.13 at 30 DAS and at harvest respectively. There was no branching at 15 DAS in all the treatments under study (Table 1). The variation in above character affected by fertilizer doses was also recorded by Patel *et al.* (2013) in coriander.

The increase in growth parameters like plant height, number of leaves and number of branches from T₁ to T₄ was obviously due to the availability of more nutrients which might

Table 1. Effect of graded fertilizer doses on vegetative growth parameters and shelf Life of coriander var. Konkan Kasturi under Konkan agro climatic conditions

Treatments	Plant height (cm)			No. of leaves			No. of branches			Shelf life (days)
	At 15 DAS	At 30 DAS	At harvest	At 15 DAS	At 30 DAS	At harvest	At 15 DAS	At 30 DAS	At harvest	
T ₁	7.01	17.28	33.73	6.83	12.61	35.50	-	2.28	5.13	3.90
T ₂	7.03	18.03	36.30	7.50	14.41	41.58	-	2.68	5.80	3.87
T ₃	7.55	19.10	38.25	8.18	15.55	45.98	-	2.76	6.35	3.83
T ₄	8.08	20.01	40.43	8.93	18.69	53.65	-	2.85	6.60	3.80
T ₅	8.18	20.15	40.53	9.05	18.74	53.84	-	2.93	6.63	3.78
Range	7.01-8.18	17.28-20.15	33.73-40.53	6.83-9.05	12.61-18.74	35.50-53.84	-	2.28-2.93	5.13-6.63	3.90-3.78
Mean	7.57	18.91	37.85	8.10	16.0	46.11	-	2.70	6.10	3.83
S.E. (m) ±	0.11	0.32	0.58	0.22	0.14	1.37	-	0.08	0.22	0.04
C.D. at 5%	0.33	0.99	1.78	0.68	0.44	4.21	-	0.23	0.68	0.12

had affected positively in increasing the height, number of leaves and number of branches. The further increase in fertilizer dose in T₄ and T₅ had not contributed significantly in increasing the plant height, number of leaves and number of branches. It was might be due to the fact that height, number of leaves and number of branches recorded at T₄ was towards the maximum potential height, number of leaves and number of branches of the variety.

However shelf life was significantly increased with decrease in fertilizers levels. It was in the range of 3.78 to 3.90 days. Significantly the highest shelf life was obtained in the treatment T₁ and was significantly superior over all the treatments.

Yield parameters : Data presented in Table. 2 revealed that all the yield parameters were varied significantly with increase in fertilizer levels. The recovery of edible portion in response to all treatments under study was varied significantly and values were increased with increased dose of nitrogen, more number of leaves and branches. Thus, the recovery of edible portion was maximum in T₅ (120:30:30 kg NPK ha⁻¹) which was at par with T₄ (100:30:30 kg NPK ha⁻¹) with recovery of 79.75 per cent and 79.73 per cent respectively.

Significantly the highest value with respect to fresh weight plant⁻¹ was observed in T₅ i.e. 9.94 g and was at par with T₄ i.e. 9.93 g weight. The treatment T₁ recorded minimum value of 7.16 g weight per plant. It was might be due to more number of leaves and branches due to increased dose of nitrogen. Similarly the highest dry weight per plant (5.01 g) was in T₅ followed by T₄ with 4.98 g weight. T₁ had minimum value with 3.80 g weight per plant. Findings in relation to fresh and dry weight per plant affected by fertilizes were also observed by Rana *et al.* (2012) in black cumin.

The fresh weight as well as dry weight of the plant depends upon the biomass produced by respective plant, which in turn depend upon the various growth parameters like plant height, number of leaves, number of branches etc. The magnitude of these various growth parameters was higher in T₅ and T₄ which might have ultimately contributed in more fresh and dry weight plant⁻¹.

The critical perusal of data revealed that the highest herbage yield per plot was recorded in T₅ with 4.77 kg plot⁻¹ and T₄ with 4.76 kg plot⁻¹. The lowest yield was noticed in T₁ with 4.12 kg yield plot⁻¹. Similarly, the highest herbage yield ha⁻¹ was recorded in T₅ (117.87 q ha⁻¹) which was at par with T₄ (117.63 q

Table 2. Effect of graded fertilizer doses on yield parameters coriander var. Konkan Kasturi under Konkan agro climatic conditions

Treatments	Recovery of edible portion (%)	Fresh wight (g plant ⁻¹)	Dry weight (g plant ⁻¹)	Leaf yield (kg plot ⁻¹)	Leaf yield (q ha ⁻¹)
T ₁	72.50	7.16	3.80	4.12	101.74
T ₂	74.50	8.59	4.31	4.25	104.98
T ₃	76.75	9.26	4.64	4.51	111.35
T ₄	79.73	9.93	4.98	4.76	117.63
T ₅	79.75	9.94	5.01	4.77	117.87
Range	72.50-79.75	7.16-9.94	3.80-5.01	4.12-4.77	101.74-117.87
Mean	76.65	8.97	4.55	4.48	110.71
S.E. (m) ±	0.33	0.08	0.06	0.01	0.16
C.D. at 5%	1.01	0.25	0.17	0.02	0.49

ha⁻¹), the lowest yield was observed in T₁ having 101.74 q yield ha⁻¹. The above results are in conformity with Oliveira *et al.* (2003), Moniruzzaman *et al.* (2014) in coriander.

Coriander is a leafy vegetable and yield of commercial part is directly depend upon the biomass produced by respective plant which in turn depend upon the various growth parameters like plant height, number of leaves, number of branches etc. the magnitude of these various growth parameters was higher in T₄ and T₅ which might have ultimately contributed in maximum leaf yield..

Conclusion

From the present findings, it could be concluded that increased levels of nitrogen significantly affected the herbage yield. The high herbage yield (117.87 q ha⁻¹) was recorded in T₅ (120:30:30) which was closely followed by T₄ (100:30:30) with herbage yield of 117.63 q ha⁻¹. Hence, for getting more herbage yield of coriander var. Konkan Kasturi a fertilizer dose of 100:30:30 kg NPK hectare⁻¹ should be given under Konkan agroclimatic condition.

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Seed yield of Coriander (*Coriandrum sativum* L.) var. Konkani Kasturi as Affected by Graded Levels of Nitrogen

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Abstract

A field experiment was conducted to study the effect of nitrogen (N), phosphorus (P) and potash (K) on growth and seed yield of coriander var. Konkani Kasturi under Konkani agroclimatic conditions at the Vegetable Improvement Scheme, Central Experiment Station, Wakawali, Dr. Balasaheb Sawant Konkani Krishi Vidyapeeth, Dapoli, Dist. Ratnagiri (M.S.) during the Rabi season 2014-15. The experiment consisted of five treatment combinations viz., T₁ (40:30:30 NPK kg ha⁻¹), T₂ (60:30:30 NPK kg ha⁻¹), T₃ (80:40:40 NPK kg ha⁻¹), T₄ (100:50:50 NPK kg ha⁻¹) and T₅ (120:60:60 NPK kg ha⁻¹). The experiment was laid out in randomized block design with four replications. The results revealed significant differences in growth and seed yield parameters among the treatments. Application of 120:60:60 NPK kg ha⁻¹ recorded the maximum values for all parameters. However a dose of 80:40:40 NPK kg ha⁻¹ was found economical.

Key words : Coriander, nitrogen, phosphorus, potassium, seed yield.

In India cuisine Coriander (*Coriandrum sativum* L.) is generally called as "Dhania". It is also known as Cilantro and Chinese parsley. Cilantro is the Spanish word for coriander deriving from *coriandrum*. Coriander is an annual herb from family Apiaceae mainly cultivated for its tender green leaves as well as seeds. Coriander is native to Mediterranean region. It is probably one of the first spice used by mankind and known to mankind since as early as 5000 BC, Nese and Bunyamin, (2005). The fruits are an important ingredient of curry powder (Ramadan *et al.*, 2002). These are used as a pickling spice, in seasonings and sausages and also in pastries, buns, cakes, and other confectionary. The dry fruits are known as coriander seeds. Coriander is known as low volume but high value crop of arid and semi-arid regions.

Dr. Balasaheb Sawant Konkani Krishi Vidyapeeth Dapoli has released a variety

'Konkani Kasturi' during the year 2013. This variety is quite suitable for commercial cultivation for leafy purpose under Konkani agro-climatic conditions. The response of farmers for cultivation of this variety is increasing but the availability of seed is major bottleneck in increasing the area under this crop in Konkani agro-climatic conditions. Seed production of coriander can also be profitable venture for the farmers of Konkani region. However, nutrition management for seed yield of coriander under Konkani conditions has not been standardized. Therefore, keeping in view, the importance of this crop, an experiment was conducted to study the effect of fertilizers on growth and seed yield of coriander (*Coriandrum sativum* L.) var. Konkani Kasturi.

Materials and Methods

The field experiment was conducted at Vegetable Improvement Scheme, Central Experiment Station, Wakawali, Dr. Balasaheb Sawant Konkani Krishi Vidyapeeth, Dapoli (M.S.) during the rabi 2014-15. The

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experiment consisted of five treatment combinations *viz.*, T₁ (40:30:30 NPK kg ha⁻¹), T₂ (60:30:30 NPK kg ha⁻¹), T₃ (80:40:40 NPK kg ha⁻¹), T₄ (100:50:50 NPK kg ha⁻¹) and T₅ (120:60:60 NPK kg ha⁻¹). The experiment was laid out in randomized block design with four replications. Coriander var. Konkan Kasturi were sown with line spacing 0.45 m apart. The other cultural operations and plant protection measures were applied as per package of practices. Observations were recorded on plant height, number of leaves, number of branches, days to initiation of flowering, days to flowering, days to completion of 50% flowering, days to completion of flowering, flowering span, days to harvest, 1000 fresh and dry seed weight, number of seeds umbellet⁻¹, number of seeds umbel⁻¹, number of umbels plant⁻¹, number of umbellets umbel⁻¹, number of umbels plant⁻¹, number of seed plant⁻¹, seed yield plot⁻¹ and seed yield hectare⁻¹. Data obtained was statistically analyzed as per the method prescribed by Panse and Sukhatme (1995) to draw valid conclusion.

Results and Discussion

Growth parameters : Data presented in Table 1 revealed that plant height, number of

leaves and number of branches increased linearly with increasing levels of N, P and K. The application of fertilizer levels exerted significant influence on growth parameters.

The maximum plant height was recorded in T₅ with the values 8.63 cm, 23.19 cm, 55.95 cm and 72.31 cm at 15, 30, 45 DAS and at harvest, respectively. It was followed by T₄ with the values 8.61 cm, 23.04 cm, 55.49 cm and 71.38 cm and T₃ with the values 7.88, 22.95, 54.51 and 70.75 cm. Minimum plant height was recorded in T₁ with the values 7.27 cm, 19.36 cm, 45.50 cm and 57.03 cm at 15, 30, 45 DAS and at harvest respectively (Table 1). The significant effect of different fertilizer doses on plant height was also reported by Khalid (2012), Godara *et al.* (2014), Yousuf *et al.* (2014) in coriander.

Further, significantly highest number of leaves was recorded in T₅ with the values 9.47, 23.81, 55.84 and 49.35 at 15, 30, 45 DAS and at harvest, respectively. It was followed by T₄ with the values 9.39, 23.60, 55.65 and 48.63 and T₃ with the values 9.26, 23.47, 54.29 and 48.43. Significantly the lowest number of leaves was found in T₁ with the values 7.34, 15.88, 42.04 and 36.95 at 15,

Table 1. Effect of fertilizer doses on growth parameters of coriander var. Konkan Kasturi at various growth stages under Konkan agro climatic conditions

Treatments	Plant height (cm)				No. of leaves				No. of branches			
	At 15 DAS	At 30 DAS	At 45 DAS	At harvest	At 15 DAS	At 30 DAS	At 45 DAS	At harvest	At 15 DAS	At 30 DAS	At 45 DAS	At harvest
T ₁	7.27	19.36	45.50	57.03	7.34	15.88	42.04	36.95	-	2.28	5.13	5.45
T ₂	7.77	20.32	46.09	58.53	8.16	17.94	43.86	40.36	-	2.68	5.80	5.92
T ₃	7.88	22.95	54.51	70.75	9.26	23.47	54.29	48.43	-	3.40	7.24	7.76
T ₄	8.61	23.04	55.49	71.38	9.39	23.60	55.65	48.63	-	3.58	7.37	7.79
T ₅	8.63	23.19	55.95	72.31	9.47	23.81	55.84	49.35	-	3.64	7.43	7.80
Range	7.27-8.63	19.36-23.19	45.50-55.95	57.03-72.31	7.34-9.47	15.88-23.81	42.04-55.84	36.95-49.35	-	2.28-3.64	5.13-7.43	5.45-7.80
Mean	8.03	21.77	51.51	66.0	8.72	20.94	50.34	44.74	-	3.11	6.59	6.94
S.E. (m) ±	0.10	0.42	0.40	0.44	0.17	0.25	1.32	0.91	-	0.12	0.23	0.17
C.D. at 5%	0.32	1.29	1.22	1.35	0.53	0.76	4.07	2.80	-	0.37	0.72	0.51

30, 45 DAS and at harvest respectively (Table 1). Khalid (2012) reported positive effects of increased N and P doses and Moniruzzaman *et al.* (2014) reported significant variation due to increased N levels in coriander.

The appearance of branches was not observed at 15 DAS in all the treatments under study. However at 30, 45 DAS and at harvest, significantly the highest number of branches was recorded in T₅ with the values 3.64, 7.43 and 7.80 and it was followed by T₄ with the values 3.58, 7.37 and 7.79 and T₃ with the values 3.40, 7.24 and 7.76. Significantly the lowest number of branches was observed in T₁ with the values 2.28, 5.13 and 5.45 at 30, 45 DAS and at harvest respectively (Table 1). The variation in this character due to increased levels of fertilizer doses was also recorded by Khalid (2012), Patel *et al.* (2013), Godara *et al.* (2014), Yousuf *et al.* (2014) in coriander.

The increase in fertilizer dose in T₃, T₄ and T₅ had not contributed significantly in increasing the plant height, number of leaves and number of branches, which might be due to the fact that height, number of leaves and number of branches recorded at T₃ was

maximum potential height, number of leaves and number of branches of the variety Konkan Kasturi of coriander.

Days required for flowering increased with increased in fertilizer doses. It might be due to the fact that availability of more nutrients resulted in more vigorous vegetative growth which resulted in more days required to reproductive growth i.e. flowering. The data presented in Table 2 indicated that each NPK increment significantly delayed flowering in coriander. The maximum days were required in T₅ whereas minimum days in T₁ with respect to initiation of flowering, days to flowering, days to completion of 50 per cent flowering, days to completion of flowering and flowering span. The results of the present investigations are in close agreement with the findings of Hans and Thakral (2008) in fennel. Also Ali *et al.* (2007), in onion seed production, reported delayed blooming due to increased nitrogen doses.

More nutrients delayed flowering, which resulted in delayed maturity and ultimately required the maximum days for harvesting. The maximum days required to harvest were in T₅ (90.00 days), whereas minimum in T₁ (88.04

Table 2. Effect of fertilizer doses on flowering behavior, days to harvest and 1000 seed weight of coriander var. Konkan Kasturi under Konkan agroclimatic conditions

Treatments	Flowering					Days to harvest	1000 seed weight	
	Bud initiation (days)	Days to flowering	50% flowering (days)	Completion of flowering (days)	Flowering span (days)		Fresh weight (g)	Dry weight (g)
T ₁	31.90	38.90	51.20	55.16	23.26	88.04	57.36	19.17
T ₂	31.95	38.95	51.45	55.33	23.38	89.41	59.00	19.68
T ₃	32.43	39.78	52.45	56.23	23.80	89.70	63.39	21.26
T ₄	32.60	40.10	52.48	56.86	24.26	90.18	63.41	21.27
T ₅	32.68	40.18	52.61	57.08	24.40	90.99	63.45	21.29
Range	31.90-32.68	38.90-40.18	51.20-52.61	55.16-57.08	23.26-24.40	88.04-90.99	57.36-63.45	19.17-21.29
Mean	32.31	39.58	52.04	56.13	23.82	89.66	61.32	20.53
S.E. (m) ±	0.14	0.21	0.14	0.17	0.16	0.15	0.65	0.21
C.D. at 5%	0.44	0.65	0.44	0.52	0.49	0.48	2.01	0.64

days). The results are in conformity with Yousuf *et al.* (2014) in coriander.

Physical parameters : Significantly the highest value for fresh 1000 seed weight was recorded in T₅ (63.45 g) followed by T₄ (63.41 g) and T₃ (63.39 g), whereas the lowest was in T₁ (57.36 g). Similarly, dry 1000 seed weight also varied significantly. The highest value for dry 1000 seed weight (21.29 g) was recorded in T₅ followed by T₄ (21.27 g) and T₃ (21.26 g). The lowest was in T₁ (19.17 g). The variation in 1000 seed weight due to graded fertilizer doses was also recorded by Bhat and Sulikeri (1992), Yousuf *et al.* (2014) in coriander.

Yield parameters : Significantly the highest number of seeds umbellet⁻¹ was recorded in T₅ (8.06) followed by T₄ (8.05) and T₃ (8.03) whereas the lowest was in T₁ (6.67). The significant variation in number of seeds per umbellet was recorded by Patel *et al.* (2013) with increased levels of nitrogenous fertilizers and Godara *et al.* (2014) with inorganic fertilizers in coriander.

The highest number of seeds per umbel was recorded in T₅ (26.69) followed by T₄ (26.56) and T₃ (26.50) whereas the lowest was in T₁

(20.23). The number of seeds per umbel was increased due to fertilizer application, Carrubba and Ascolillo (2005), Datta *et al.* (2008) in coriander.

The highest number of umbellets per umbel was recorded in T₅ (8.94) followed by T₄ (8.93) and T₃ (8.91) whereas the lowest was in T₁ (6.75). The positive effects of fertilizers on number umbellets per umbel were also recorded by Datta *et al.* (2008), Tripathi *et al.* (2009) and Godara *et al.* (2014) in coriander.

The highest number of umbels plant⁻¹ was recorded in T₅ (33.38) followed by T₄ (33.35) and T₃ (33.33) whereas the lowest was in T₁ (21.76). Number of umbels plant⁻¹ was affected by different levels of fertilizer doses and was also reported by Khalid (2012), Patel *et al.* (2013), Godara *et al.* (2014), Yousuf *et al.* (2014) in coriander.

Significantly the highest number of seeds plant⁻¹ was recorded in T₅ (350.08) followed by T₄ (350.07) and T₃ (350.05) whereas the lowest was in T₁ (237.90). The significant variation in number of seeds plant⁻¹ as affected by different fertilizer doses was also recorded by Yousuf *et al.* (2014) in coriander.

Table 3. Effect of different fertilizer doses on yield parameters of coriander var. Konkan Kasturi under Konkan agroclimatic conditions

Treatments	Seeds umbellet ⁻¹ (n)	Seeds umbel ⁻¹ (n)	Umbe- lletes umbel ⁻¹ (n)	Umbels plant ⁻¹ (n)	Seeds plant ⁻¹ (n)	Seed yield (g plot ⁻¹)	Seed yield (q ha ⁻¹)
T1	6.67	20.23	6.75	21.76	237.90	373.75	9.24
T2	7.10	22.15	7.15	22.33	242.35	411.25	10.16
T3	8.03	26.50	8.91	33.33	350.05	565.00	13.95
T4	8.05	26.56	8.93	33.35	350.07	565.50	13.97
T5	8.06	26.69	8.94	33.38	350.08	566.25	13.98
Range	6.67-8.06	20.23-26.69	6.75-8.94	21.76-33.38	237.90-350.08	373.75-566.25	9.24-13.98
Mean	7.58	24.42	8.13	28.83	306.09	496.35	12.26
SE	0.12	0.19	0.17	0.28	2.17	8.02	0.20
CD @ 5 %	0.37	0.59	0.51	0.87	6.70	24.70	0.61

Significantly the highest seed yield plot⁻¹ was recorded in T₅ (566.25 g plot⁻¹) followed by T₄ (565.50 g plot⁻¹) and T₃ (565.00 g plot⁻¹) whereas the lowest was in T₁ (373.75 g plot⁻¹). Similarly, in case of seed yield hectare⁻¹ the highest seed yield was recorded in T₅ (13.98 q ha⁻¹) followed by T₄ (13.97 q ha⁻¹) and T₃ (13.95 q ha⁻¹) whereas the lowest was in T₁ (9.24 q ha⁻¹). The positive effects of increased levels of fertilizer doses are also recorded by Bhat and Sulikeri (1992), Khalid (2012), Godara *et al.* (2014), Yousuf *et al.* (2014) in coriander.

Conclusion

From the present findings, it could be concluded that increased levels of nitrogen, phosphorus and potassium significantly affected the seed yield. Significantly the highest seed yield with 13.98 q ha⁻¹ was recorded in T₅ (120:60:60) which was at par with T₄ (100:50:50) with 13.97 q ha⁻¹ and with T₃ (80:40:40) seed yield of 13.95 q ha⁻¹. Hence, a fertilizer dose of 80:40:40 NPK kg hectare⁻¹ is optimum for maximization of seed yield of coriander var. Konkan Kasturi under Konkan agroclimatic condition.

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Evaluation of Chilli Genotypes for Yield and Yield Attributing Traits Under Coastal Climatic Condition of Konkan Region

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Abstract

The experiment was conducted at the Vegetable Improvement Scheme, Central Experimental Station, Wakawali, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, during the Rabi season of 2013-14. Among nineteen genotypes evaluated significantly superior plant height was observed in LCA-334 (70.20 cm), maximum branches plant⁻¹ in Konkan Kirti (9.55), maximum plant spread in 'Pachora Local-1 (53.85 cm), minimum days to initiation for flowering and fruit set (41.50, 48.50) in Karvir Local while minimum disease incidence in Pant-C3 (5.3%). Regarding yield attributes Pant-C-3 exhibited significantly superior performance with production of highest green fruit yield plant⁻¹ (555.63g), green fruit yield hectare⁻¹ (19.72t) and maximum pickings (4.95) over rest of genotypes. As regards to others yield components genotypes Pashighat-7 took minimum days to 1st harvest and recorded maximum days to last harvesting while genotype Karver Local recorded maximum green fruit weight (6.05g), minimum days to first fruit harvest (74.50) and longest chilli fruit (12.40cm) on the basis on mean performance for fruit length, these genotypes were genotypes were classified as short (Pashighat-7, Pashighat-1, DPL-C-4, DPL-C-1), Long (Pashighat-5, DPL-C-5, DPL-C-2, Phule Sai, Pant-C-3, Arka supriya, LCA-334, Pachora Local-1) and very long (Karver Local, Pusa Jwala, ACSS-9818, Jayanti, LCA-206). Overall performance revealed that the genotype, Pant-C-3 exhibited as superior genotype for most of the traits studied and hence could be selected as suitable genotypes for cultivation under coastal climatic condition of Konkan region.

Key words : Chilli, Konkan region, vegetative growth parameters, yield components.

Chilli (*Capsicum annum* L.) is one of the most important commercial crops of India. This cultivated species has its unique place in the diet as a vegetable cum spice crop. India has large diversity of chilli with different quality factors shape, size, yield, quality and other traits. Resistant to biotic and abiotic stress, identification of a genotype better suited for a particular region and its improvement is of immediate task to exploit its potential. But no such record is available about the performance of the different genotypes of chilli, particularly in the western parts of the Maharashtra. In Konkan region diverse types of chilli genotypes are found with varying characters. However, no systematic research work in respect of selection

of suitable type undertaken so far. Hence, there is need to evaluate chilli genotypes under Konkan condition for excellent quality, yield & growth performance, and resistant to biotic and abiotic stress. In view of this, present investigation was undertaken in chilli to gather information on vegetative growth performance as well as yield contributing characters suitable for Konkan agro climatic conditions.

Materials and Methods

The experiment was conducted at the Vegetable Improvement scheme, Central Experimental Station, Wakawali during the Rabi season of 2013-14. The experiment was laid out in a randomized block design with nineteen treatments and two replications. Gross plot size 3.6 x 2.4 m and net plot was

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2.4 x 1.8 m. 51 days old seedlings of each genotype were transplanted in the experimental field with 65 x 45 cm spacing. Soil was acidic in reaction having pH 6.4. Various chilli genotypes were evaluated for vegetative growth performance and yield attributing characters. The recorded data was statistically analyzed by ANOVA method given by Panse and Sukhatme (1995).

Results and Discussion

Vegetative growth and flowering performance : The vegetative growth and flowering performance of various chilli genotypes is presented in the Table1. Among the genotypes verified highest plant height was recorded in 'LCA-334' (70.20 cm) while lowest

height 'Konkan Kirti' (48.90 cm), these results agree with Smitha and Basavaraja (2006), Tembhrne *et al.*, (2008). Konkan kirti' showed maximum Number of branches per plant (9.55) while minimum showed by 'Phule Sai' (3.25). These results were also reported by Ukkud, *et al.* (2007), Amit *et al.* (2014). These may be due to difference in the genotypes genetic make-up, environment and soil factors. Maximum plant spread was observed in the genotype Pachora Local' (53.85 cm) while minimum plant spread was observed in the genotype 'Phule Sai' (41.55 cm) these result also noticed by Nehru *et al.* (2003), may be due to direct effect of soil and agro-climatic condition of the Konkan region and indirect effect of number of branches plant⁻¹.

Table 1. Vegetative growth, flowering behaviour parameters and incidence of leaf curl (%) of various chilli genotypes

Genotypes	Plant height (cm)	No. of branches plant ⁻¹	Plant spread (cm)	Days to initiation of flowering	Days to 50% of flowering	Days to initiation of fruit set	Incidence of leaf curl (%)
Konkan Kirti	48.90	9.55	46.50	49.50	54.50	58.50	9.70
LCA-206	66.90	7.80	49.05	47.50	53.50	56.50	9.61
LCA-334	70.20	8.40	50.10	41.50	46.50	49.50	6.11
Arka Supriya	63.50	7.30	51.65	47.50	51.50	54.50	11.37
Jayanti	53.00	7.70	46.75	42.50	46.50	50.50	8.49
Pant-C3	64.70	8.50	51.05	55.50	60.50	63.50	5.39
ACSS-9818	62.00	8.10	47.02	51.50	54.50	57.50	8.37
Phule Sai	54.20	3.25	41.55	53.50	57.50	61.50	12.65
Pusa Jwala	60.85	8.59	51.60	53.50	58.50	63.50	7.04
DPL-C1	58.70	6.50	47.00	45.50	50.50	53.50	8.42
DPL-C2	59.00	7.90	42.95	45.50	51.50	53.50	9.32
DPL-C4	54.20	8.45	52.10	45.50	50.50	54.00	12.33
DPL-C5	55.80	7.55	47.80	47.50	51.50	54.50	13.43
Pashighat-1	58.15	7.35	42.80	47.50	51.50	55.50	14.67
Pashighat-2	63.50	6.90	47.75	46.50	50.50	54.50	11.87
Pashighat-5	53.60	6.10	42.40	42.50	47.00	50.00	15.96
Pashighat-7	57.80	8.25	40.50	80.50	84.50	88.54	18.90
Karvir Local	69.50	7.10	50.60	41.50	45.50	48.50	8.62
Pachora Local-1	55.20	6.95	53.85	74.50	78.50	82.50	14.72
Range	48.90-70.28	9.55-3.25	53.85-40.50	41.50-80.50	45.5-84.50	48.50-88.54	15.96-5.39
Mean	59.55	6.4	47.17	50.50	55.00	61.94	10.67
S.E ±	1.235	0.403	0.457	0.500	0.542	0.608	
CD at (5%)	3.669	1.198	1.340	1.486	1.610	1.806	

The flowering behaviour performance of various chilli genotypes was presented in the Table 1. Minimum days to initiation flowering were observed in the genotypes 'LCA-206' and 'Karvir Local' genotypes of chilli (41.50) while maximum days in the genotype 'Pashighat-7' (80.50). The present results are in agreement with findings of Amit *et al.* (2014). 'Karvir Local' recorded minimum days to 50% flowering (45.50) and maximum days in the genotype 'Pashighat-7' (84.50). Karvir Local was also found to be having minimum days to initiation fruit set (48.50) while 'Pashighat-7' recorded maximum days (88.54). Similar findings were reported by Shiva *et al.* (2013) and Vijaya *et al.* (2014). These results may be due to highly genetic make up of genotypes, effect of environment and vigor growth of crop.

From the Table 1, minimum leaf curl incidence was found in 'Pant-C3' (5.3%) while maximum incidence was observed in 'Pashighat-7' (18.90%). Parallel results are in conformity with Sreelatha Kumary and Rajamony (2004) and Datta and Chakraborty (2013).

Regarding fruiting behavior (Table 2), the genotypes having similar character of fruiting behavior 'Solitary'. These result due to highly effect of genetic behavior of genotypes, less influence weather condition of Konkan region. These results are associated with Mahmood *et al.*, (2002). All genotypes showed 'Pendent' fruit position habit except in the 'genotypes DPL-C4' and 'Pashighat-1' that showed 'Erect' position. Variation of the fruit position in different genotypes could be genotypic character. These due to maximum possibility of genetic make-up and less effect of environmental factors. Dhamayanthi and Reddy (2003) also associated results on chilli genotypes.

Yield attributing characters : Mean

performance of various chilli genotypes for different yield components (Table 3) revealed that, the genotype Karvir Local recorded minimum days to first harvest (74.50) and maximum (116.00) by Pashighat-7 and hence Karvir Local exhibited as early genotype over rest of the genotypes which is one of the most desirable trait for further improvement through hybridization or selection. This variation might be due to genetic make of particular genotype and influence of environmental factors. These finding are in accordance with the earlier finding of Amit *et al.* (2014).

The fruit length is also important yield component which ranged from 4.36 to 12.40 cm. Significantly superior fruit length was observed in the genotype Karvir Local (12.40 cm) followed by LCA-206 (10.38 cm), Jayanti (9.88 cm) and ACSS-9818 (9.55 cm) where as least fruit length was noticed in Pashighat-7 (4.36 cm) (Table 3).

Table 2. Fruit behaviour and fruit position of different chilli genotypes

Genotypes	Fruiting behavior	Fruit position
Konkan Kirti	Solitary	Pendent
LCA-206	Solitary	Pendent
LCA-334	Solitary	Pendent
Arka Supriya	Solitary	Pendent
Jayanti	Solitary	Pendent
Pant-C3	Solitary	Pendent
ACSS-9818	Solitary	Pendent
Phule Sai	Solitary	Pendent
Pusa Jwala	Solitary	Pendent
DPL-C1	Solitary	Pendent
DPL-C2	Solitary	Pendent
DPL-C4	Solitary	Erect
DPL-C5	Solitary	Pendent
Pashighat-1	Solitary	Erect
Pashighat-2	Solitary	Pendent
Pashighat-5	Solitary	Pendent
Pashighat-7	Solitary	Pendent
Karvir Local	Solitary	Pendent
Pachora Local-1	Solitary	Pendent

Fruit yield is also dependent on mean fruit weight. Increase in mean fruit weight ultimately resulted in increase in yield. The mean fruit weight varied from 1.65 to 6.05 g. Significant superior fruit weight exhibited in the genotype Karvir Local (6.05 g) followed by Arka Supriya (4.56 g), Phule Sai (4.19 g) and Pachora Local-1 (4.10 g), while the lowest fruit weight was observed in Pashighat-7 (1.65 g). (Table 3). Similar finding for variation in fruit weight was also reported by Amit *et al.* (2014) in chilli.

Table 3 also depicts a wide variation for number of fruits per plant which ranged from 32.30 to 173.00. The highest number of green fruits plant⁻¹ were recorded by Konkan Kirti (173.00) followed by LCA-334 (156.70), Jayanti (155.50), Pant-C-3 (151.40), LCA-206 (141.00) and ACSS-9818 (133.30) while least number of green fruit plant⁻¹ was noticed in Phule Sai (32.30). Vijaya *et al.* (2014) reported similar results. A wide variation was observed for green fruit yield plant⁻¹. It varied from 118.00 to 555.63 g plant⁻¹. The highest green fruit yield plant⁻¹ was noticed in Pant-C-3 (555.63 g) followed by LCA-334 (531.43 g), Jayanti (517.81 g), DPL-C-1 (515.15g), Pusa Jwala (492.76 g), and Karvir Local (462.77 g), whereas lowest green fruit yield plant⁻¹ was recorded by Pashighat-2 (118.30 g). These findings were supported by Nakansah *et al.* (2011) and Amit *et al.* (2014).

The yield is a complex trait and resultant of performance of many other yield attributing traits. Much variation was also exhibited for the green fruit yield per hectare. It ranged from 2.72 to 19.72 t ha⁻¹. The highest green fruit yield per ha was recorded in Pant -C-3 (19.72 t ha⁻¹) followed by LCA-334 (19.61 t ha⁻¹) and Pusa Jwala (18.24 t ha⁻¹) while very poor yield was observed in Pashighat-7 (2.72 t ha⁻¹) (Table 3). A wide variation in yield might be due to variation in fruit length, fruit weight and number of green fruits plant⁻¹. These results

were in accordance with the earlier results reported by Ukkund *et al.* (2007).

Days to last harvest varied from 115.90 to 166.00 days. Maximum days to last harvest was observed in Pashighat-7 (166 days) followed by Pachora Local-1, and Konkan Kirti (146.00) whereas least days to last harvest were observed in the Pashighat-2 (115.90 days). Least variation was exhibited for harvesting span which varied from 31.00 to 57.50 days. The highest span of harvesting was noticed in Konkan Kirti (57.50 days) followed by Pant-C-3 (55.00 days). Table 3 also revealed comparatively low variation for number of pickings which ranged from 3.00 to 4.95. The maximum number of pickings were observed in Pant-C-3 (4.95) followed by ACSS-9818 (4.85), Jayanti (4.85) Konkan Kirti (4.75) while minimum number of pickings was recorded in Pachora Local-1 (3.00). Similar results have been reported by Tembhurne *et al.* (2008) and Sharma *et al.* (2010) in chilli.

On the basis of mean performance for fruit shape and colour, genotypes were classified and presented in Table 4. Chilli genotypes were grouped into three classes *viz.* short, long and very long. Long fruits are always desirable as it also contributed towards total yield and maximum recovery of chilli powder. In the present investigation, genotypes *Viz* Karvir Local, LCA-206, Jayanti and ACSS-9818 exhibited as very long genotypes as they recorded maximum fruit length. The other genotypes *viz.* Pusa Jwala, Pashighat-2, Pant-C-3, Phule Sai, Pachora Local-1, Konkan Kirti, Arka supriya, DPL-C-2, LCA-334, DPL-C-5 and Pashighat-5 observed as long genotype and rest of the genotypes grouped into short (Table 4). Colour of the chilli fruits is directly correlated with its pungency. Dark green colour fruits were highly pungent than light green and green coloured fruits.

From Table 3 it was also observed that minimum incidence of fruit fly was recorded by Pant C3 (0.35) while maximum was observed in Pashighat-5 (1.30). These results are in conformity with Datta and Chakraborty (2013).

Thus, while evaluating the nineteen genotypes of chilli, it can be concluded that on the basis of growth observations, flowering behavior and incidence of pest and disease, the genotypes LCA-334, Konkan kirti, Karvir Local and Pant-C3 while chilli genotypes viz., Pant-C-3, LCA-334, Jayanti and Karvir Local could be selected as early and high yield potential genotypes suitable for Konkan region.

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Effect of Varieties and Nutrient Management Practices on Growth, Yield and Nutrient Uptake of Soybean

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Abstract

A field experiment was conducted during *kharif* season of 2015 on silty clay loam soil at MPKV, Rahuri (MS). The results showed that, the variety KDS-344 recorded significantly the highest grain and stover yield of soybean. It also recorded highest economic indices like gross, net monetary returns and B:C ratio than variety KS-103 and JS-9305. The grain yield of soybean was significantly higher by application of fertilizer dose of 125% GRDF + 0.5% Grade IInd foliar spray at 30 and 45 DAS than other treatments, however, it was found at par with 75% GRDF + 0.5 Grade IInd foliar spray at 30 and 45 DAS and 100% GRDF + 0.5% Grade IInd foliar spray at 30 and 45 DAS. Similarly, growth and yield attributes *viz.*, plant height (cm), number of branches, number root of nodules, number of pod plant⁻¹ and weight of seeds plant⁻¹ (g) were recorded maximum under 125% GRDF + 0.5 Grade IInd foliar spray at 30 and 45 DAS. Application of fertilizer dose to soybean 75% GRDF + 0.5% Grade IInd foliar spray at 30 and 45 DAS The total uptake of N, P and K in soybean was recorded significantly the higher by variety KDS-344. The total uptake of nitrogen and phosphorus were recorded significantly higher with application of 125% GRDF (62.5:93.75:00 N:P₂O₅:K₂O kg ha⁻¹ + 6.25 tons FYM ha⁻¹) + 0.5% Grade IInd foliar spray at 30 and 45 DAS (kg ha⁻¹) than the rest of the treatments, however it was found at par with treatment of 75% GRDF + 0.5 Grade IInd foliar spray at 30 and 45 DAS and 100% GRDF + 0.5% Grade IInd foliar spray at 30 and 45 DAS. On the basis of experiment. It could be concluded that, the optimum yield, nutrient uptake and higher economic returns of soybean can be achieved by sowing variety KDS-344 fertilized with 75% GRDF (37.5:56.25:00 N, P₂O₅, K₂O kg ha⁻¹ + 3.75 tons FYM ha⁻¹) + 0.5% Grade IInd foliar spray of micronutrient at 30 and 45 DAS.

Key words : Varieties, nutrient management, grain yield and economics.

Soybean is the premier oilseed crop of India, occupies an area of 116.85 lakh ha and contributes 84.42 lakh tonnes towards oilseed production with 772 kg ha⁻¹ productivity. Maharashtra occupies 35.85 lakh ha area under soybean and contributes 27.83 lakh tons oilseed production with 776 kg ha⁻¹ productivity (Anonymous, 2015). Selection of suitable genotype plays a vital role in crop production, particularly in new areas of introduction. The choice of suitable genotype of soybean helps to augment crop productivity by 20-25 per cent. Balanced and timely

nutrient management practices applied for soybean contributes to sustainable growth of yield and quality of produce. It also influences plant health and reduces environmental risks. Nutrient management practices involves the use of appropriate combination of organic (FYM) and Inorganic (chemical) fertilizers and foliar spray of IInd grade micronutrient at 30 and 45 days after sowing to achieve sustained crop production and for maintaining better soil health. This is best approach for better utilization of resources and to produce crops with less expenditure in soybean (Shinde *et al.*, 2015). It is important to identify the appropriate cultivar and combination of organic, inorganic and foliar spray of

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micronutrients which increases yield, improve quality produce and nutrient uptake of soybean.

In the present study, an attempt was made to assess the performance of different promising newly released soybean varieties and different nutrient management practices to increase yield potential of *kharif* soybean, for this purpose experiment was conducted on "Performance of varieties and different nutrient management practices on growth, yield and nutrient uptake of soybean".

Materials and Methods

A field experiment was conducted at Instructional Farm of Post Graduate Institute, MPKV, Rahuri, (19° 48' N latitude and 74° 32' E longitude and 495 meter above mean sea level), in factorial randomized block design with three replications during *kharif* season of 2015. The soil was silty clay loam, having pH 7.72, medium in organic C (0.47%), low in available N (144.57 kg ha⁻¹) and medium in available P (17.24 kg ha⁻¹) and available K (388.20 kg ha⁻¹) and Moderate in organic carbon, pH and EC were 0.47 %, 7.72 and 0.25 dS m⁻¹ of soil, respectively. Climatologically, this area falls in the semi-arid

tract with an annual rainfall varying from 307 to 619 mm. The average annual rainfall at Rahuri is 520 mm. The experiment consists of three varieties *viz.*, V₁: KDS-344, V₂: JS-9305 and V₃: KS-103 and five nutrient management practices *viz.*, N₁: GRDF (50:75:00 N, P₂O₅, K₂O kg ha⁻¹ + 5 tons FYM ha⁻¹), N₂ : 75% GRDF (37.5:56.25:00 N, P₂O₅, K₂O kg ha⁻¹ + 3.75 tons FYM ha⁻¹) + 0.5% foliar spray of grade IInd at 30 and 45 DAS, N₃: 100% GRDF (50:75:00 N, P₂O₅, K₂O kg ha⁻¹+ 5 tons FYM ha⁻¹) + 0.5% foliar spray of grade IInd at 30 and 45 DAS, N₄: 125% GRDF (62.5:93.75:00 N, P₂O₅, K₂O kg ha⁻¹+ 6.25 tons FYM ha⁻¹) + 0.5% foliar spray of grade IInd at 30 and 45 DAS and N₅: 50:75:30 N, P₂O₅, K₂O kg ha⁻¹ + 5tons FYM ha⁻¹ with 15 treatment combinations. The crop soybean was sown by dibbled at 30 cm x 10 cm in Ist week of July and harvested at Ist to IIIrd week of october. The whole dose of fertilizer (N, P₂O₅ and K₂O kg ha⁻¹) were applied at the time of sowing through urea, single super phosphate and muriate of potash. Common treatments of Rhizobium and PSB were given at the time of sowing and 0.5% foliar spray of grade IInd micronutrient (Fe-2.5%, Zn-3.0%, Mn-1.0%, Cu-1.0%, Mo-0.1% and Bo-0.5%) was done at

Table 1. Interaction effect between grain yield of soybean by different treatments

Treatment	Grain yield (q ha ⁻¹)		
	V ₁ : KDS-344	V ₂ : JS-9305	V ₃ : KS-103
Varieties/Nutrient managment			
N ₁ : GRDF (50:75:00 N, P ₂ O ₅ , K ₂ O kg ha ⁻¹ + 5tons FYM ha ⁻¹)	36.75	31.35	32.45
N ₂ : 75% GRDF (37.5:56.25:00 N, P ₂ O ₅ , K ₂ O kg ha ⁻¹ + 3.75 tons FYM ha ⁻¹) + 0.5% foliar spray of grade II nd at 30 and 45 DAS	38.51	33.09	32.99
N ₃ : 100% GRDF (50:75:00 N, P ₂ O ₅ , K ₂ O kg ha ⁻¹ + 5tons FYM ha ⁻¹) + 0.5% foliar spray of grade II nd at 30 and 45 DAS	37.29	31.55	35.70
N ₄ : 125% GRDF (62.5:93.75:00 N, P ₂ O ₅ , K ₂ O kg ha ⁻¹ + 6.25 tons FYM ha ⁻¹) + 0.5% foliar spray of grade II nd at 30 and 45 DAS	39.97	31.91	35.28
N ₅ : 50:75:30 N, P ₂ O ₅ , K ₂ O kg ha ⁻¹ + 5tons FYM ha ⁻¹	30.36	31.97	35.22
Source (A x B)	SEm±	C.D. at 5%	
	1.10	3.18	

30 DAS and 45 DAS of soybean. The intercultural operations, protective irrigation as per critical growth stages and plant protection measures were carried out as per the recommendations of respective crops. The plant stand and crop conditions were good during the experimental period.

Results and Discussion

Growth and yield : The growth and yield parameters of different varieties and nutrient management practices of soybean were influenced significantly at harvest in Table1.

Effect of varieties : The growth and yield parameters *viz.*, plant height (75.10 cm), number of branches (4.46), number of nodules plant⁻¹ (23.11), number of pod plant⁻¹ (58.88), weight of seeds plant⁻¹ (11.92) and 100 seed weight (12.39 g) were recorded significantly higher by soybean variety KDS-344 than variety KS-103 and JS-9305. The

variety KDS-344 exhibited superior for grain and stover yield. The higher growth and yield attributes were responsible for achieving higher grain yield (36.61 q ha⁻¹) and stover yield (46.41 q ha⁻¹) of soybean variety KDS-344 and it was 14.29 and 7.45 per cent higher than JS-9305 and KS-103. It also recorded highest economic indices like gross (Rs.127978), net monetary returns (87355) and B:C ratio (3.17) than variety KS-103 and JS-9305. Similarly, the variety KDS-344 has ability to produce higher photosynthates and dry matter partitioning between roots and shoots. The rate of growth and duration are interrelated into yield, total biomass accumulation and economic returns of crop. These results are in conformity with those reported by Andrade *et al.* (2005), Kathmale *et al.* (2013) and Lomte *et al.* (2006)

Effect of nutrient management practices : The application of fertilizer dose of

Table 2. Growth and yield of soybean as influenced by different treatments

Treatment	Plant height (cm)	No. of branches plant ⁻¹	No. of modules at 50% flowering	No. of pods plant ⁻¹	Weight of seeds plant ⁻¹ (g)	100 seed weight (g)	Grain yield (q ha ⁻¹)	Stover yield (q ha ⁻¹)
A. Varieties								
V ₁	75.10	4.46	23.11	58.88	11.92	12.74	36.61	46.41
V ₂	63.35	4.16	21.06	46.49	10.23	11.35	32.03	38.22
V ₃	73.94	4.12	22.39	52.85	10.98	12.39	34.07	40.73
SEm ±	0.54	0.07	0.45	0.55	0.12	0.10	0.47	0.55
CD at 5%	1.56	0.20	1.29	1.59	0.35	0.29	1.38	1.59
B. Nutrient management								
N ₁	70.34	4.3	21.88	53.02	10.86	12.22	33.51	41.43
N ₂	71.11	4.08	21.63	51.17	10.85	11.87	34.53	42.10
N ₃	70.99	4.15	22.59	53.26	11.12	12.02	34.84	41.92
N ₄	72.46	4.74	23.62	54.30	11.31	12.35	35.79	43.42
N ₅	69.24	3.94	21.20	51.96	11.06	12.34	32.51	40.07
SEm ±	0.65	0.09	0.58	0.71	0.04	0.13	0.61	0.71
CD at 5%	1.89	0.26	1.67	2.05	0.15	0.37	1.78	2.06
C. Interaction (A x B)								
SEm ±	3.28	0.15	2.89	1.23	0.27	0.36	1.07	2.56
CD at 5%	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	3.09	N.S.

varieties showed significant effect on the oil and protein yield of soybean in Table 2.

Effect of varieties : The soybean variety KDS-344 was also recorded maximum oil and protein content and significantly higher oil yield (7.04 q ha⁻¹) as well as protein yield (13.48 q ha⁻¹) than rest of varieties KS-103 and JS-9305.

Effect of nutrient management practices : Different nutrient management treatments did not showed any significant differences in oil and protein content as well as oil yield in soybean. While protein yield was significantly affected due to different nutrient management treatments. Application of fertilizer dose @ 125% GRDF (62.5:93.75:00 N:P₂O₅:K₂O kg ha⁻¹ + 6.25 tons FYM ha⁻¹) + 0.5% Grade IInd foliar spray at 30 and 45 DAS recorded significantly maximum protein yield (13.40 q ha⁻¹). This might due to soybean grains were accumulated higher concentration of nitrogen which increase the protein and oil synthesis (Table 2). Similar results were also recorded by Ashraf *et al.*, (2013) and Eman Abdel *et al.*, (2014).

Nutrient uptake

Effect of Varieties : In varietal studies, among the varieties the variety KDS-344 recorded significantly the maximum uptake of N (205.53 kg ha⁻¹), P (35.33 kg ha⁻¹) and K (79.39 kg ha⁻¹) in soybean.

Effect of nutrient management practices : Studies on chemical analysis indicated that the total uptake of nitrogen, phosphorus and potassium were found to be significant due to different nutrient management treatments. The total uptake of nitrogen (199.01 kg ha⁻¹) and phosphorus (34.64 kg ha⁻¹) were recorded significantly higher with application @ 125% GRDF (62.5:93.75:00 N:P₂O₅:K₂O kg ha⁻¹ + 6.25

tons FYM ha⁻¹) + 0.5% Grade IInd foliar spray at 30 and 45 DAS than the rest of the treatments but it was at par with treatments of N₃ (195.17 kg ha⁻¹) in case of N uptake and in case of P uptake it remains at par with N₂ (34.11 kg ha⁻¹) and N₃ (33.63 kg ha⁻¹). While potassium uptake was significantly maximum under treatment of N₅ (83.26 kg ha⁻¹). This might be because of balanced application of nutrition with foliar spray in soybean crop, which produces more growth, yield and nutrient uptake. The findings corroborated the results of Morshed *et al.* (2008), Rana and Badliyal (2014) and Sale and Nazirkar (2013).

Interaction Effects : Interaction effect between varieties and different nutrient management practices were significant in respect of grain yield of soybean. The data are presented in Table1a. The interaction effects between variety KDS-344 with application of 125% GRDF+ 0.5% IInd Grade foliar spray at 30 and 45 DAS recorded significantly highest grain yield (39.97 q ha⁻¹) than rest of treatments but however it was at par with variety KDS-344 with application of 75% GRDF+ 0.5% IInd Grade foliar spray at 30 and 45 DAS (38.51 q ha⁻¹) and KDS-344 with application of 100% GRDF+ 0.5% IInd Grade foliar spray at 30 and 45 DAS recorded significantly highest grain yield (37.29 q ha⁻¹).

The results showed that, the variety KDS-344 with application @ 125% GRDF (62.5:93.75:00 N:P₂O₅: K₂O kg ha⁻¹ + 6.25 tons FYM ha⁻¹) + 0.5% Grade IInd foliar spray at 30 and 45 DAS recorded significantly maximum yield of soybean but at par with 75% GRDF (37.5:56.25:00 N, P₂O₅, K₂O kg ha⁻¹ + 3.75 tons FYM ha⁻¹) + 0.5 Grade IInd foliar spray of micronutrient at 30 and 45 DAS.

On the basis of the results of experiment, It could be concluded that, the optimum yield, nutrient uptake and higher economic returns of

soybean can be achieved by sowing of variety KDS-344 fertilized with 75% GRDF (37.5:56.25:00 N, P₂O₅, K₂O kg ha⁻¹ + 3.75 tons FYM ha⁻¹) + 0.5 % Grade IInd foliar spray of micronutrient at 30 and 45 DAS.

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Effect of Sowing Dates, Spacings and Topping Practices on Growth, Seed Yield and Economics of Jute (*Corchorus olitorius* L.)

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Abstract

A field experiment was conducted during *kharif* season of 2013 to 2015 on medium black soil at Jute AINP Project, MPKV, Rahuri (MS). The results showed that, sowing date of 24th MW recorded significantly higher plant height, number of branches, basal diameter, number of pods plant⁻¹ and seed yield of jute as compared to 26th MW and 28th MW during three years and pooled mean, respectively. Similarly, it also recorded maximum gross, net returns and B:C ratio. Spacing of 60 x 15 cm² recorded significantly higher seed yield, net returns and B:C ratio than other spacing of 45 x 15 cm², 45 x 30 cm², 60 x 30 cm². Topping at 45 DAS recorded significantly higher seed yield, net returns and B:C ratio than no topping and topping at 30 DAS during period of experimentation. Thus, results revealed that sowing of jute (*C. olitorius*) during 24th MW (11-17th June), spacing of 60 x 15 cm² and topping at 45 DAS were the beneficial for higher growth, seed yield and maximum economic returns of jute in irrigated conditions.

Key words : Date of sowing, spacing, topping, seed yield and economics.

Jute, one of the most important commercial crops of eastern Indian states of West Bengal, Assam, Bihar, Orissa and eastern Uttar Pradesh is an important foreign exchange earner and is supporting nearly 7 million small and marginal families, industrial employees and trade (Kumar *et al.*, 2010).

Seed is the critical input in any agricultural system for high yield. Quality of seed can be obtained only with improved agro-techniques. Abundant research has been done aiming at standardization of different factors for seed production in many crops but most of the agronomic practices have still not been standardized for seed crop of Jute. At present jute seed crop particularly *C. olitorius* varieties were grown mainly in Andhra Pradesh, Maharashtra and Gujarat. Non-availability of quality jute seed to the farmers at a lower price and proper time is the major constraints faced

by jute farmers. To minimize the hindrances towards getting higher jute fibre production with uniform productivity across the growing zones, these issues of those are to be readily addressed for standardization of quality jute seed production technology. Date of sowing is one of the major factor affecting seed yield of different crops. Spacing influences growth rate and crop yield as a result of inter-plant competition for different inputs needed for growth and development (Tripathi *et al.*, 2013). Thus, investigation on spacing arrangements becomes mandatory for understanding the mechanism of yield enhancement. Apical topping breaks the apical dominance and induces development of lateral branches thereby increasing the site for pod and capsule development. The practice of topping has proved to be effective in increasing the yield levels of different crops (Sajjan *et al.*, 2002; Singh *et al.*, 2011). Very meager information is available on interactive effect of different sowing dates, spacings along with

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topping management practices on seed production of jute and allied fibre crops. Keeping these in view, the present investigation was carried out to study the effect of sowing dates, spacings and topping management practices on growth, seed yield and economics of jute (*Corchorus olitorius* L).

Materials and Methods

The experimental site was located in the farm of Jute AINP Project, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra (situated at lies between 19° 48' N and 19° 57' N latitude and 74° 32' E and 74° 19' E longitude. The altitude varies from 495 to 569 m above mean sea level). The soil is medium black, having pH 8.3, medium in organic C (0.54%), low in available N (172.03 kg ha⁻¹) and medium in available P (17.60 kg ha⁻¹) and available K (421.50 kg ha⁻¹). Climatologically, this area falls in the semi-arid tract with an annual rainfall varying from 307 to 619 mm. The average annual rainfall at Rahuri is 520 mm. The maximum rainfall is received from south-west monsoon during the rainy months of June to September. The mean annual maximum and minimum temperature ranges from 33° to 43°C and 6° to 18°C, respectively. The relative humidity during morning and evening hours are 59 and 35 per cent, respectively. The field experiment was conducted during June to November 2013 to 2015. The three dates of sowing i.e. D₁- 24th MW (11-17th June), D₂- 26th MW (25th - 01st July) and D₃- 28th MW (8-15th July), three spacing (S₁-45 x 15 cm², S₂-45 x 30 cm², S₃- 60 x 15 cm² and S₄- 60 x 30 cm²) and three topping management practices (T₁-No Topping, T₂- 30 DAS and T₃- 45 DAS) were laid out in split-split plot design and replicated thrice with jute variety of "JRO-524" was tested in study. Date of sowing was assigned to the main plots, spacing to the sub-plots and topping to the sub-sub-plots having total 36

combinations. The gross and net plot sizes were 4.50 x 3.60 m² and 3.60 x 2.70 m², 3.60 x 2.40 m². Fertilizer doses of 60, 30 and 30 kg ha⁻¹ N, P₂O₅ and K₂O were applied, respectively. N was applied in two equal split doses one as basal dose and another top dressed at 30 DAS, when hand weeding was done.

As regards, for data collection on growth and other yield attributing characters five plants were selected randomly from each plot. The

Table 1. Pooled mean of effect of sowing dates, spacings and topping management practices on growth and yield attributes of jute

Treatments	Plant height (cm)	No. of branches plant ⁻¹	Basal diameter (cm)	No. of pods plant ⁻¹
A) Sowing date				
24 th MW	247.91	26.60	2.28	118.76
26 th MW	213.87	20.29	1.86	107.31
28 th MW	187.55	17.46	1.62	96.88
SEm ±	2.33	0.56	0.02	2.66
CD at 5 %	7.17	1.72	0.07	8.19
B) Spacing				
45 x 15 cm ²	228.14	19.28	1.88	86.33
45 x 30 cm ²	232.23	24.23	2.06	116.10
60 x 15 cm ²	232.56	24.58	2.14	117.94
60 x 30 cm ²	230.64	26.69	2.28	141.77
SEm ±	1.89	0.44	0.03	2.06
CD at 5 %	N.S.	1.24	0.08	5.84
C) Topping				
1. No topping	242.89	21.21	1.98	100.66
2. 30 DAS	217.67	24.25	2.15	117.91
3. 45 DAS	232.12	24.87	2.07	120.53
SEm ±	2.67	0.27	0.01	2.34
CD at 5 %	7.59	0.78	0.03	6.66
D) Interaction				
D x S	NS	NS	NS	*
D x T	NS	NS	NS	NS
S x T	NS	NS	NS	NS
D x S x T	NS	NS	NS	NS

* Significance at 5% level of probability

crop was harvested and threshed as per sowing dates treatment wise and seed yield obtained from net plot was converted into q ha⁻¹. In case of economic analysis, prevalent market price for sale of jute seed was considered (Rs 60.00 kg⁻¹). Net return was calculated by deducting cost of cultivation from gross income and benefit/cost ratio was calculated by dividing cost of cultivation (Rs.) to gross return (Rs. ha⁻¹).

Results and Discussion

Effect of date of sowing : The pooled mean revealed that sowing dates influenced different growth parameters significantly (Table 1). The crop sown in 24th MW recorded significantly higher plant height (247.91 cm) as well as number of branches (26.60) plant⁻¹ than other sowing dates. Similarly, basal diameter of plant⁻¹ (2.28 cm) and number of pods plant⁻¹ (118.76) were significantly more in 24th MW sown crop during pooled mean of three years. These results are in line with the findings of Guha and Das (1997). The sowing date of 28th MW recorded significantly the lowest values of all the growth and yield attributes reflected in pooled mean of three years. This sowing date of 24th MW recorded significantly higher jute seed yield (25.80, 26.56, 17.94 and 23.43 q ha⁻¹) as compared to 26th MW (23.06, 19.61, 15.02 and 19.23 q ha⁻¹) and 28th MW (17.61, 17.12, 13.08 and 15.94 q ha⁻¹) as shown by the data of three years and pooled mean, respectively. It recorded 46.98 and 21.48 per cent higher seed yield than the sowing date of 28th MW and 26th MW respectively on pooled mean of three years (Table 2). The sowing date of 24th MW received maximum photoperiod and rainfall during the entire vegetative growth period and it helped to develop reproductive parts (pods) as compared to 26th MW and 28th MW. This was also reported by Guha and Das (1997) and Mishra and Nayak (1997). Therefore, the sowing date of Jute in 24th MW

resulted in significantly higher gross returns (Rs. 141171 ha⁻¹), net returns (Rs.102986 ha⁻¹) and B:C ratio (3.69) in Table 3. Similarly, Das et al., (2014) and Roy and Mazumdar (1995) also reported.

Effect of spacing : Spacing influenced significantly at all growth parameters except plant height (Table 1). The sowing of jute with spacing of 60 x 30 cm² significantly increased the growth and yield attributes viz., number of branches plant⁻¹ (26.69), basal diameter (2.28 cm) and number of pods plant⁻¹ (141.77) than spacing of 45 x 15 cm², 45 x 30 cm² and 60

Table 2. Effect of sowing date, spacing and topping management practices on jute seed yield (q ha⁻¹)

Treatments	2013	2014	2015	Pooled
A) Sowing date				
24 th MW	25.80	26.56	17.94	23.43
26 th MW	23.06	19.61	15.02	19.23
28 th MW	17.61	17.12	13.08	15.94
SEm ±	0.33	0.49	0.38	0.41
CD at 5 %	1.30	1.92	1.49	1.25
B) Spacing				
45 x 15 cm ²	24.64	22.24	15.86	20.91
45 x 30 cm ²	24.86	22.40	15.78	21.01
60 x 15 cm ²	25.90	24.90	17.00	22.60
60 x 30 cm ²	22.32	22.78	17.29	20.80
SEm ±	0.34	0.44	0.30	0.37
CD at 5 %	1.01	1.31	0.90	1.10
C) Topping				
No topping	23.29	21.44	15.18	19.97
30 DAS	24.58	23.25	16.38	21.84
45 DAS	25.41	24.56	17.88	22.18
SEm ±	0.32	0.34	0.34	0.09
CD at 5 %	0.92	0.95	0.97	0.26
D) Interaction				
D x S	*	NS	NS	NS
D x T	NS	NS	NS	NS
S x T	NS	NS	NS	NS
D x S x T	NS	NS	NS	NS

* Significance at 5% level of probability

x 15 cm² (Table 1). Wider spacing available more space and nutrients to this crop and harvested more solar energy which is beneficial for production higher growth and yield attributes per unit area. Similar observations were recorded by Madakadze *et al.*, (2007). Spacing of 60 x 15 cm² recorded significantly higher seed yield (25.90, 24.90 and 22.60 q ha⁻¹) than spacing of 45 x 15 cm², 45 x 30 cm² and 60 x 30 cm² during 2013, 2014 and pooled mean of three years, but the same treatment was at par with spacing of 60 x 30 cm² (17.29 q ha⁻¹) in 2015 (Table 2). Similarly highest seed yield is converted into highest gross returns (Rs.136723 ha⁻¹) and net returns (Rs. 98475 ha⁻¹) were manifested by 60 x 15 cm² and it was achieved higher B:C ratio (3.57) than rest of all treatments in pooled mean of three years (Table 3). It is clearly stated by Das *et al.* (2014) and Mishra and Naik (1997).

Effect of topping management : It was observed that different topping management practices had significant effects on the growth and yield parameters (Table 1). Earlier topping i.e. topping at 30 DAS had harmful effect on plant height but rendered beneficial effect in terms of other growth parameters like basal diameter plant⁻¹. This could be because of topping at 30 DAS was beneficial due to early removal of apical portion of the plant which checked the vertical growth from early growing stage. Topping at 45 DAS exhibited superior performance with regard to all the growth and yield parameters *viz.*, number of branches plant⁻¹ (24.87), number of pods plant⁻¹ (120.53). This might be due to topping at 30 DAS promoting maximum vegetative growth but better reproductive growth was obtained with topping at 45 DAS. Topping at 45 DAS registered significantly higher seed yield (25.41, 24.56, 17.88 and 22.18 q ha⁻¹) than over no topping and topping at 30 DAS. It also recorded 11.07 and 9.36 per cent higher seed yield of jute over no topping and topping at 30

DAS. This line of research work was done by Mishra and Naik 1997, Sajjan *et al.*, (2002) and Singh *et al.*, (2011). Similarly, it was also noted that significantly higher gross return (Rs.133094 ha⁻¹), net return (Rs.93986 ha⁻¹) and B:C ratio (3.41) were achieved by topping at 45 DAS (Table 3). Similar results were reported by Das *et al.*, (2014) and Tripathi *et al.*, (2013).

Interaction effects : The interaction effect between sowing dates and spacing were

Table 3. Pooled mean of effect of sowing dates, spacing and topping management practices on economics for jute seed production

Treatment	Gross returns (Rs. ha ⁻¹)	Cost of cultivation (Rs. ha ⁻¹)	Net returns (Rs. ha ⁻¹)	B:C ratio
A) Sowing date				
24th MW	141171	38185	102986	3.69
26th MW	115380	38185	77195	3.02
28th MW	95619	38185	57435	2.50
SEm ±	2390	-	2390	0.06
CD at 5 %	7365	-	7365	0.19
B) Spacing				
45 cm x 15 cm	125496	38143	87353	3.29
45 cm x 30 cm	126095	38188	87907	3.30
60 cm x 15 cm	136723	38248	98475	3.57
60 cm x 30 cm	124787	38158	86629	3.27
SEm ±	2175	-	2175	0.05
CD at 5 %	6166	-	6166	NS
C) Topping				
No topping	119830	36336	83494	3.29
30 DAS	129235	39109	90126	3.30
45 DAS	133094	39108	93986	3.41
SEm ±	893	-	891	0.04
CD at 5 %	2536	-	2536	NS
C) Interaction				
D x S	NS	NS	NS	NS
D x T	NS	NS	NS	NS
S x T	NS	NS	NS	NS
D x S x T	NS	NS	NS	NS

significant in pooled mean of pod yield plant⁻¹ and seed yield of jute during 2013.

Thus, the present investigation revealed that sowing of jute (*C. olitorius*) during 11-17th June, spacing at 60 x 15 cm² and topping at 45 DAS were beneficial for higher growth, seed yield and economic returns of jute under protective irrigation condition.

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Effect of Different Sowing Dates on Growth and Yield of Wheat (*Triticum aestivum*) Cultivars under Sub-Montane Zone of Maharashtra

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Abstract

A field experiment was conducted during the *rabi* season of 2010-11 to 2012-13 at Agriculture Research Station, Karad to study the effect of different sowing dates and genotypes on growth and yield of wheat (*Triticum aestivum* L). The experiment was conducted in split plot design with three replications and treatment comprising of six date of sowing, viz., November 1, November 15, December 1, December 15, January 1 and January 15 in main plot and three genotypes of wheat viz., NIAW-34, LOK-1 and HD-2189 in subplots. Sowing on November 15 significantly influenced most yield attributes and yield and which was at par with November 1 and December sowings, but significantly superior over later sowings. The highest grain yield was obtained with November 15 sowing (72.02, 68.31 and 58.43 q ha⁻¹), respectively during three experimental years, which was at par with November 1 and December 1 sowings and was significantly superior over extreme late sown condition on January 1 and January 15 sowings. Amongst the cultivars, Lok-1 was found best and gave the significantly more grain yield (61.87, 63.83 and 52.45 q ha⁻¹) in respective three years than NIAW-34 and HD-2189 during first year and at par with NIAW-34 during second and third year under study. In biomass production non-significant variation was recorded among the different sowing time and cultivars during all three years except third year in case of sowing time, higher biomass production was recorded with November 15 sowing.

Key words : Growth, Yield attributes, Yield, Sowing time, Wheat Genotypes

Wheat is cultivated under diverse agro-climatic conditions during *rabi* season in tropical, sub-tropical and temperate region. Yield potential of wheat being exploited due to many factors, among which use of proper sowing dates and varieties are the most important ones. Cooler season and long crop condition duration are the most congenial condition to achieve fairly good yield of wheat. Date of sowing plays an important role in productivity of wheat. Drastic reduction in yield of wheat has been recorded with the delay of sowing beyond optimum time. It has been estimated that delay in sowing of wheat beyond December 15, resulted in yield reduction of 50 kg grain day⁻¹ ha⁻¹ (Singh *et al.*, 2001). Late sown wheat is exposed to both the extreme of temperature i.e. low temperature during early

growth period, which restrict the vegetative phase and high temperature during post anthesis period, which reduces the duration of grain development and consequently the grain yield. Therefore, an experiment was planned to find out optimum date of sowing for different varieties of wheat for the conditions prevailing in sub- mountain zone of Maharashtra.

Materials and Methods

The experiment was conducted during the *rabi* season of 2010-11 to 2012-13 at Agricultural Research Station, Karad Dist. Satara, Maharashtra. The soil was medium deep black with organic carbon (0.62), available N (232 kg ha⁻¹), Available P (25.2 kg ha⁻¹) and available K (363 kg ha⁻¹) and had pH 7.8. The total rainfall received during crop growth period was 44.0, 00.0 and 49.0 mm, respectively in

1. Assistant Professor.

three years of experimentation. The minimum temperature ranged from 5.6 to 16.1, 7.2 to 16.3 and 10.6 to 16.3 °C and maximum temperature 27.9 to 31.4, 24.5 to 30.2 and 28.5 to 34.8 °C during the experimental growing season, respectively. The experiment was laid out in split plot design with three replications with treatments, comprising of six sowing dates *viz.* November 1, November 15, December 1, December 15, January 1 and January 15 in main plots and three cultivars *viz.* NIAW-34, LOK-1 and HD-2189 in sub plots. Wheat varieties were sown at 22.5 cm apart as per treatment scheduled. The crop was fertilized with recommended dose of fertilizer *i.e.* 120:60:40 kg NPK ha⁻¹. The half dose of N and full dose of P and K was given at the time of sowing as a basal dose and remaining nitrogen was applied in two splits. The sources of nutrients were Urea, Single Super Phosphate and Muriate of Potash for NPK, respectively. The management practices were

adopted as per recommendations of wheat crop under irrigated condition. The growth and yield observations were recorded as per normal procedure. The crop was harvested as per sowing dates and maturity of crop.

Results and Discussion

Growth characters : Significant differences were exhibited with date of sowing and cultivars on growth character (Table 1). Date of sowing significantly influenced the growth character *i.e.* plant height. The mean plant height was more with November 15 sowing and was followed by November 1 and December sowing dates. Decrease in plant height in late sowings was due to shorter growing period, these results are in line with those reported by Mukherjee, (2012).

Wheat cultivars showed significant difference in mean plant height. Taller plants was recorded with HD-2189 genotype and was

Table 1. Effect of different sowing dates and genotypes on growth and yield of wheat (2010-11 to 2012-13)

Treatments	Mean plant height (cm)	Mean no. of grains panicle ⁻¹	Mean effective tillers m ⁻² (No)	Grain yield (q ha ⁻¹)			Straw yield (q ha ⁻¹)				
				2010	2011	2012	Mean	2010	2011	2012	Mean
Sowing dates											
S ₁ - 1 st Nov.	84.22	38.67	121.11	68.23	66.67	54.73	63.21	72.70	68.59	52.67	64.65
S ₂ - 15 th Nov.	85.11	39.67	122.78	72.02	68.31	58.43	66.25	74.07	72.70	58.98	68.58
S ₃ - 1 st Dec.	83.67	38.89	116.67	65.76	64.00	52.87	60.87	69.96	71.32	53.77	65.02
S ₄ - 15 th Dec.	84.44	38.44	108.33	62.27	63.65	48.14	58.02	71.33	69.96	49.93	63.74
S ₅ - 1 st Jan.	80.00	33.56	100.78	52.81	55.41	44.00	50.74	64.47	64.47	44.17	57.70
S ₆ - 15 th Jan.	71.44	28.56	100.67	37.04	46.09	42.94	42.02	53.50	49.38	42.25	48.37
SE ±	2.77	2.13	4.03	4.13	3.12	2.51	-	4.42	4.74	3.16	-
CD at 5%	6.91	6.30	12.48	13.01	9.84	7.20	-	NS	NS	9.95	-
Genotypes											
V ₁ - NIAW-34	77.89	35.67	111.06	58.86	58.61	50.17	55.88	66.53	63.09	50.62	60.08
V ₂ - LOK-1	85.33	38.89	117.17	61.87	63.83	52.45	59.38	65.84	65.84	50.48	60.72
V ₃ - HD- 2189	88.22	33.83	106.94	58.34	59.63	47.94	55.30	69.27	69.27	49.79	62.77
SE ±	1.10	1.12	1.45	0.86	1.81	1.13	-	2.30	2.30	2.26	-
CD at 5%	3.30	3.49	4.80	2.50	5.63	3.39	-	NS	NS	NS	-
Interactions											
CD at 5%	NS	NS	NS	NS	NS	NS	-	NS	NS	NS	-

at par with LOK-1 genotype. The differences in plant height among varieties might be attributed to their genetic diversity. These results are similar to those of Mishra, (2006).

Yield attributes and yield : All the yield attributes were significantly affected by the date of sowing. Delayed sowing decreased grain ear⁻¹ and effective tiller per m². Effective tillers considered as the most important yield determinant varied significantly under different date of sowing. Sowing on November 15, significantly influenced the yield attributing characters and at par with November 1 and December 1 sowing and significantly superior to other dates of sowing. Mean pooled grain and straw yields were higher with November 15 sowing. Late sowing of wheat produced the poor yield attributes this might be due to decrease in temperature in late sown condition which reduces cell division and cell expansion. Reduced cell expansion also carries a primary effect on meristematic development of yield

component such as inflorescences or tiller initials in the wheat leading to potentially small reproductive organs and reduced yield (Akhthar *et al.* 2002). Further, data revealed that number of grains ear⁻¹ was maximum with November 15 sowing and at par with November 1 and December sowings. Less number of grains per panicle in late sowing was due to less production of photosynthates due to shorter growing period. These results are in line with those reported by Shahzad *et al.*, (2002).

Various cultivars showed significant variation for yield attributing characters. The mean effective tillers per m² and mean grain number per panicle were highest with LOK-1 and was at par with NIAW-34 and significantly higher to HD-2189. Differences in number of effective tillers per m² among the varieties might be attributed to their genetic diversity (Akhthar *et al.* 2002).

The significant differences in grain as well as

Table 1. Contd.

Treatments	Biological yield (q ha ⁻¹)				Harvest index (%)			
	2010	2011	2012	Mean	2010	2011	2012	Mean
Sowing dates								
S ₁ - 1 st Nov.	140.9	135.3	107.4	127.9	48.41	49.29	50.95	49.55
S ₂ - 15 th Nov.	146.1	141.0	117.4	134.8	49.29	48.44	49.76	49.16
S ₃ - 1 st Dec.	123.3	135.3	106.6	131.3	53.34	47.29	49.57	50.06
S ₄ - 15 th Dec.	117.0	133.6	98.07	116.3	53.19	47.63	49.08	49.96
S ₅ - 1 st Jan.	117.3	119.8	88.17	108.4	45.02	46.22	49.90	47.04
S ₆ - 15 th Jan.	90.54	95.47	85.19	90.4	40.91	48.27	50.40	46.53
SE ±	6.10	4.70	3.70	-	3.80	0.40	0.30	-
CD at 5%	18.20	14.10	11.25	-	11.40	NS	NS	-
Genotypes								
V ₁ - NIAW-34	125.4	121.7	100.8	115.9	46.94	48.15	49.77	48.28
V ₂ - LOK-1	127.7	129.7	102.9	120.1	48.44	49.22	50.95	49.54
V ₃ - HD- 2189	128.9	128.9	97.73	118.5	45.23	46.26	49.05	46.84
SE ±	0.98	1.15	1.20	-	0.80	0.60	0.38	-
CD at 5%	3.10	3.40	3.60	-	2.40	NS	NS	-
Interactions								
CD at 5%	NS	NS	NS	-	NS	NS	NS	-

biological yield was recorded with the different dates of sowing and varieties (Table1). Grain yield is a function of various yield attributing characters and maximum grain yield was obtained with November 15 sowing (72.02, 68.31 and 58.43 q ha⁻¹), respectively which was at par with November 1 and December sowing in all three years. This was statistically similar with each other mainly because of yield attributing characters. This corroborates with the findings of Akhthar *et al.* (2002). Cultivar performance in wheat varies with time of sowing. Among the cultivars LOK-1 was recorded the highest grain yield (61.87, 63.83 and 52.45 q ha⁻¹), respectively. It may be because of higher values of yield attributing characters and which are at par with NIAW-34 in second year and third year of experiment.

In biomass production showed non-significant variation in different dates of sowing and cultivars except the third year in case of date of sowing. Higher biological yield was obtained with November 15 sowing (146.9, 141.0 and 117.4 q ha⁻¹), respectively and which are at par with November 1 and December 1 sowing. Mean pooled biological yield was also higher with 15 November sowing. Harvest index was significant only in the first year of experiment. Maximum harvest index was recorded with December 1 sowing

and at par with November 1, November 15 and December 1 sowing, and significantly superior to other date of sowing. Among the cultivars, maximum harvest index was recorded with LOK-1 and at par with NIAW-34 during first year of experiment. However, during further years no significant difference was found. Deswal *et al.*, (1996). Also reported the similar genotypic variation in yield and harvest index.

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Effect of zinc and boron application on growth and yield of kharif groundnut (*Arachis hypogaea* L.) grown in lateritic soils of Konkan in Maharashtra

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Abstract

Micronutrient assessment work was carried out on lateritic soils of konkan at Agricultural Research Station, Shirgaon, Tal. Dist. Ratnagiri (Maharashtra) during three consecutive years of *kharif* 2009-2011 to elicit groundnut cultivar TKG Bold response to zinc and boron application. The experiment was laid out in Randomized Block Design (RBD) replicated three times which comprised of eleven treatments. Treatment containing soil application of ZnSO₄ @ 20 kg ha⁻¹ was recorded significantly higher pod yield (2881 kg ha⁻¹) over seed dressing treatments of 5 kg and 10 kg ha⁻¹ ZnSO₄; 3 kg and 6 kg ha⁻¹ boric acid and control, but at par with rest of all levels of zinc and boron application through soil. The increment in pod yield due to soil applied 20 kg ha⁻¹ ZnSO₄ over control was recorded to the magnitude of 15.87 per cent. However, similar kind of results were noticed for kernel and haulm yield of groundnut. Soil application of 20 kg ha⁻¹ ZnSO₄ registered higher net returns of Rs. 10,481/- with higher benefit to cost ratio of 1.14:1 which was followed by soil application of 6 kg ha⁻¹ boric acid with net returns of Rs. 7,393/- and 1.11:1 benefit to cost ratio. Hence, soil application of 20 kg ZnSO₄ ha⁻¹ along with recommended dose of fertilizer (25 kg N + 50 kg P₂O₅) obtained maximum yield with higher net monetary returns of Kharif groundnut under South Konkan conditions.

Key words: Boron, zinc, groundnut, nutrient content, pod yield.

Groundnut (*Arachis hypogaea* L.) is a major oilseed crop in India and its seed contain high quality of 50 per cent edible oil, 25-30 per cent digestible protein, 20 per cent carbohydrates and 5% fiber and ash which make a sustainable contribution to human nutrition (Fageria *et al.* 1997). Groundnut is considered as poor man's almond. It is cultivated on 7.50 mha area with the production of 6.96 mt and average productivity of 1.31 t ha⁻¹ (Madhusudhana, 2013). The area under groundnut crop in konkan was more than 10,000 ha with 1550 kg ha⁻¹ productivity during *kharif* 2013-14 (Anonymous, 2013).

Zn and B are recognized as key micronutrients in promoting growth, yield and quality of groundnut. Organic matter helps in

increasing adsorptive power of soil for cations, anions and micronutrients. These adsorbed ions are released slowly in soil solution for absorption by root of crop during entire growth period. Organic manures improve the organic carbon status, available primary and secondary nutrients and supply sufficient quantity of micronutrients in available forms (Badanur *et al.* 1990 and Khar, 1993).

Zinc is an essential micronutrient and plays a key role as a structural constituent or regulatory cofactor of a wide range of different enzymes and proteins in many important biochemical pathways like carbohydrate metabolism, photosynthesis, conversion of sugars to starch, protein metabolism, auxin (growth regulator) metabolism, pollen formation, integrity of biological membranes and resistance to infection by certain pathogens

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(Alloway, 2008). Boric acid (H_3BO_3) is the main constituents of soluble Boron in soil, and this acid does not dissociate under most prevailing soil pH conditions and thus, in contrast to all other essential plant nutrients, boron is mainly present in a non ionized form in soil solution.

The deficiency of Zn and B is common in lateritic soils. In spite of recommended application of fertilizer (NPK i.e. nitrogen, phosphorus, potassium) the productivity is much below the national productivity as the soils are low nutrient status with mineral deficiencies and unreliable weather conditions. Moreover, foliar application is done at later growth stages when the crops are established. The seed treatment is a better option from an economical perspective as less micronutrient is needed, it is easy to apply and seedling growth is improved (Singh *et al.* 2003). Intensive cropping leads to deficiency of secondary and micronutrients, which is the main constraint for low yield of groundnut. The poor retention and leaching of nutrients also necessitates for the increased rate of nutrients application in red

and lateritic soils. Realising the key role played, by Zn and B in various growth promoting and enzyme activities of crop, the present study was undertaken to study the effect of these micronutrient application on groundnut yield.

Materials and Methods

The field investigation was conducted at Agricultural Research Station, Dr. B.S. Konkan Krishi Vidyapeeth, Shirgaon, Dist. Ratnagiri (MS) during the *kharif* seasons 2009-2011. The soil of experimental site was high in organic carbon (1.49%), moderately acidic in reaction (pH of 6.60) with electrical conductivity of 0.050 dS m^{-1} and low in available nitrogen (278 kg ha^{-1}), medium in available phosphorus (13.0 kg ha^{-1}) and high in available potassium ($376.30 \text{ kg ha}^{-1}$). The DTPA extractable Zn was 0.334 mg kg^{-1} and hot water soluble B 0.33 mg kg^{-1} . The experiment comprised of 11 treatments *viz.*, soil application of 10 kg, 20 kg and 30 kg $ZnSO_4 \text{ ha}^{-1}$, seed dressing of 5 kg and 10 kg ha^{-1} of $ZnSO_4$, soil application of 6 kg, 9 kg and 15 kg ha^{-1} of boric acid, seed dressing of 3 kg and 6 kg ha^{-1} boric acid and control.

Table 1. Growth and yield attributes of groundnut as influenced by different treatments (Pooled data of 3 years)

Treatments	Plant height (cm)	No. of branches plant ⁻¹	Total no. of pods plant ⁻¹	Dry pod weight (g plant ⁻¹)	Shelling (%)	Mature kernels (%)	100 kernel weight (g)
T ₁ - 10 kg $ZnSO_4 \text{ ha}^{-1}$ soil application	55.8	6.0	23.7	28.9	77.0	81.9	55.6
T ₂ - 20 kg $ZnSO_4 \text{ ha}^{-1}$ soil application	53.4	6.0	25.9	31.9	70.9	82.9	55.5
T ₃ - 30 kg $ZnSO_4 \text{ ha}^{-1}$ soil application	54.6	5.6	23.6	29.3	73.7	81.4	55.2
T ₄ - 05 kg $ZnSO_4 \text{ ha}^{-1}$ seed dressing	55.3	6.2	21.4	25.2	74.6	81.3	52.0
T ₅ - 10 kg $ZnSO_4 \text{ ha}^{-1}$ seed dressing	53.0	6.2	22.0	26.1	76.6	80.0	53.4
T ₆ - 06 kg Boric acid ha^{-1} soil application	53.9	5.8	25.1	30.0	66.7	82.6	53.4
T ₇ - 09 kg Boric acid ha^{-1} soil application	59.4	6.2	24.1	28.8	67.5	82.3	54.1
T ₈ - 15 kg Boric acid ha^{-1} soil application	54.7	5.5	23.4	28.1	71.7	80.1	52.0
T ₉ - 03 kg Boric acid ha^{-1} seed dressing	56.1	6.8	21.0	24.1	64.4	79.5	52.9
T ₁₀ - 06 kg Boric acid ha^{-1} seed dressing	52.0	6.4	18.2	20.7	65.0	81.0	52.2
T ₁₁ - Control	56.6	6.1	23.0	28.4	74.9	82.8	53.1
S.E(m) ±	3.15	0.59	1.61	2.19	1.93	1.26	1.45
CD (p=0.05)	NS	NS	4.55	6.19	5.46	3.55	4.1

Experiment was laid out in randomized block design and replicated thrice. Groundnut variety 'Trombay Konkan Groundnut-Bold' (TG 19A) was sown at 30 x 15 cm spacing with seed rate of 125 kg ha⁻¹. The experiment was conducted at same site with same randomization for three years with application of recommended fertilizer dose i.e. 25:50:00 NPK kg ha⁻¹ was applied to all treatments. The recommended packages of practices were carried out as per need. The monetary returns were calculated based on prevailing market prices of inputs.

Results and Discussion

Growth and yield attributes : The yield attributing characters viz., total number of pods plant⁻¹, dry pod weight of groundnut, shelling

per cent, mature kernels and 100 kernel weight of groundnut were significantly influenced by application of zinc and boron through soil as well as seed dressing (Table 1). The pooled data revealed that, soil application of ZnSO₄ @ 20 kg ha⁻¹ recorded significantly higher number of pods plant⁻¹ (25.9), dry pod weight plant⁻¹ (31.9 g) and mature kernels (82.9 %) over rest of the treatments, but at par within each other. Application of ZnSO₄ and boric acid through seed dressing recorded the lower growth and yield attributes of groundnut as compared to soil application. Moreover, lower dose of soil applied ZnSO₄ i.e. @ 10 kg ha⁻¹ noticed higher shelling per cent (77%) and 100 kernel weight (55.6 g) over rest of other treatments. This might be due to improvement in the nodulation

Table 2. Yield and economics of groundnut as influenced by different treatments (Pooled data of 3 years)

Treatments	Yield (kg ha ⁻¹)				Economics		
	Dry pod	Kernel	Haulm	Gross returns (Rs. ha ⁻¹)	Cost of cultivation (Rs. ha ⁻¹)	Net returns (Rs. ha ⁻¹)	B:C ratio
T ₁ - 10 kg ZnSO ₄ ha ⁻¹ soil application	2.52	1.93	2.69	74124	67155	6969	1.10
T ₂ - 20 kg ZnSO ₄ ha ⁻¹ soil application	2.88	2.05	2.98	84267	73786	10481	1.14
T ₃ - 30 kg ZnSO ₄ ha ⁻¹ soil application	2.56	1.89	2.59	74344	67578	6766	1.10
T ₄ - 05 kg ZnSO ₄ ha ⁻¹ seed dressing	2.35	1.75	2.43	68264	63243	5021	1.08
T ₅ - 10 kg ZnSO ₄ ha ⁻¹ seed dressing	2.28	1.74	2.42	66213	62010	4203	1.07
T ₆ - 06 kg Boric acid ha ⁻¹ soil application	2.58	1.73	2.71	75494	68101	7393	1.11
T ₇ - 09 kg Boric acid ha ⁻¹ soil application	2.61	1.76	2.78	75323	68139	7184	1.11
T ₈ - 15 kg Boric acid ha ⁻¹ soil application	2.62	1.87	2.67	74325	67645	6680	1.10
T ₉ - 03 kg Boric acid ha ⁻¹ seed dressing	1.59	1.00	1.95	47344	49857	-2513	0.95
T ₁₀ - 06 kg Boric acid ha ⁻¹ seed dressing	1.46	0.92	1.68	44179	48035	-3856	0.92
T ₁₁ - Control	2.42	1.81	2.80	71105	64983	6122	1.09
S.E(m) ±	0.14	0.09	0.19	-	-	-	-
CD (p=0.05)	0.39	0.22	0.54	-	-	-	-

Produce and input rates:

Kharif season	Pod yield (Rs. kg ⁻¹)	Haulm (Rs. kg ⁻¹)	N (Rs. kg ⁻¹)	P ₂ O ₅ (Rs. kg ⁻¹)	FYM (Rs. tonne ⁻¹)	Labour charges (Rs. day ⁻¹)	Seed rate (Rs. kg ⁻¹)
2009	25	0.50	12.04	20.63	1000	80	46.6
2010	30	1.0	12.04	20.63	1000	120	46.6
2011	30	1.0	12.04	20.63	1000	120	50.0

and N fixation by enhanced root growth and by activation of several enzyme systems and auxins due to zinc whereas boron influenced the nitrogen and carbohydrate metabolism of plants which might have contributed for the better plant growth (Malewar *et al.* 1982). The seed dressing of both ZnSO₄ and boric acid was recorded reduction in all growth and yield attributing characters which ultimately reflected in low yield.

Yield : The dry pod, kernel and haulm yield of groundnut were significantly influenced due to ZnSO₄ and boric acid application through soil as well as seed dressing (Table 2). Soil application of ZnSO₄ @ 20 kg ha⁻¹ was noticed significantly highest dry pod, kernel and haulm yield (2881, 2046 and 2981 kg ha⁻¹, respectively) over 3 kg and 6 kg ha⁻¹ boric acid application through seed dressing and control. But was at par with rest of soil applied ZnSO₄ and boric acid treatments, and seed dressing with ZnSO₄ @ 5 and 10 kg ha⁻¹. Seed dressing with zinc recorded higher pod and kernel yield compared to boric acid seed treatment. Similar

trend was recorded for kernel and haulm yield.

There was very meagre difference between levels of dry pod yield as influenced by soil application of ZnSO₄ and boric acid. However, this difference is aggravated in seed dressing application of boric acid, ZnSO₄ and control. In case of soil applied ZnSO₄, initial increment from 10 kg ha⁻¹ to 20 kg ha⁻¹ was effective for pod yield whereas, it was decreased onwards to 30 kg ha⁻¹. The increase in pod yield due to soil applied ZnSO₄ @ 20 kg ha⁻¹ over soil application of boric acid 6 kg and 3 kg ha⁻¹ through seed dressing was to the tune of 49.18 and 44.91 per cent, respectively. Seed dressing to either zinc or boron recorded the lees yield compared to soil applied treatments. This might be due to adverse effect of micronutrient application through seed dressing on seed germination and growth of crop. These findings are in harmony with those reported by Singh *et al.* 2007 who revealed that, seed dressing with boric acid caused damaged to seed initially, as a result reduction in field germination and this could not cope up with

Table 3. Soil properties and nutrient status at harvest as influenced by different treatments

Treatment	Soil properties			Nutrient status in soil				
	pH	Org. C (%)	EC (dS m ⁻¹)	Available N (kg ha ⁻¹)	Available P (kg ha ⁻¹)	Available K (kg ha ⁻¹)	Zn (mg kg ⁻¹)	B (mg kg ⁻¹)
T ₁ - 10 kg ZnSO ₄ ha ⁻¹ soil application	6.3	1.59	0.050	294.3	19.0	406.6	0.840	0.331
T ₂ - 20 kg ZnSO ₄ ha ⁻¹ soil application	6.6	1.59	0.048	287.0	19.9	422.3	0.906	0.334
T ₃ - 30 kg ZnSO ₄ ha ⁻¹ soil application	5.8	1.62	0.045	297.0	18.1	381.4	0.941	0.341
T ₄ - 05 kg ZnSO ₄ ha ⁻¹ seed dressing	6.0	1.62	0.052	309.0	21.1	395.1	0.704	0.332
T ₅ - 10 kg ZnSO ₄ ha ⁻¹ seed dressing	6.5	1.66	0.041	296.7	17.7	414.6	0.755	0.333
T ₆ - 06 kg Boric acid ha ⁻¹ soil application	6.5	1.66	0.036	293.9	15.3	342.3	0.625	0.331
T ₇ - 09 kg Boric acid ha ⁻¹ soil application	6.4	1.57	0.050	292.4	17.3	396.3	0.528	0.336
T ₈ - 15 kg Boric acid ha ⁻¹ soil application	6.3	1.74	0.051	299.5	20.8	403.8	0.637	0.332
T ₉ - 03 kg Boric acid ha ⁻¹ seed dressing	6.4	1.60	0.049	291.0	18.3	345.4	0.539	0.322
T ₁₀ - 06 kg Boric acid ha ⁻¹ seed dressing	6.0	1.56	0.047	296.7	18.3	333.6	0.544	0.332
T ₁₁ - Control	6.1	1.20	0.043	308.0	19.0	349.2	0.396	0.336
S.E(m) ±	0.098	0.028	0.002	4.19	1.60	11.04	0.012	0.003
CD (p=0.05)	0.288	0.085	0.006	12.36	NS	32.56	0.036	NS
Initial nutrient status	6.60	1.49	0.050	278	13.0	376.3	0.334	0.330

growth and field cover to produce significant increase in yield and other parameters. Hence, instead of seed dressing soil application of either boric acid or borax were excellent. Similarly, Singh *et al.* 2009 reported that seed dressing with boron was highly detrimental to peanut as it decreased germination and caused reduction in yield attributes and yield of crop.

Nutrient status : Zinc sulphate and boric acid applied through soil as well as seed dressing (Table 3) had significant effect on properties of soil *viz.*, soil pH, organic carbon, EC and available nitrogen, potash and DTPA extractable zinc after harvest of groundnut. However, available phosphorus and hot water soluble boron content of soil did not influenced significance. Soil pH was not much influenced and maintained around o its initial value (pH 6.60) through application of 20 kg ha⁻¹ ZnSO₄. However, the highest build up of organic carbon was observed by soil applied boric acid @ 6 g ha⁻¹. There was very meagre change in electrical conductivity, which ranged between 0.036- 0.052 dS m⁻¹. The successive increment in soil applied zinc tends to increase in concentration of available N (297.0 kg ha⁻¹) and DTPA extractable Zn (0.941 mg kg⁻¹). However, available nitrogen content was significantly higher in ZnSO₄ application of through seed dressing @5 kg ha⁻¹ (309.0 kg ha⁻¹) over rest of treatments. The ZnSO₄ and boric acid application through seed dressing resulted highly low available nutrients of potassium and zinc. Moreover, the build up in potassium was found significantly higher due to soil applied ZnSO₄ @ 20 kg ha⁻¹ over control and all seed dressing treatments.

Monetary returns : Soil application of 20 kg ha⁻¹ ZnSO₄ recorded higher net monetary returns of Rs. 10,481 ha⁻¹ with benefit to cost ratio of 1.14:1 which was followed by soil applied boric acid @ 6 kg ha⁻¹ (Rs. 7,393 ha⁻¹

and 1.11:1 benefit to cost ratio, respectively). The lowest net monetary returns of Rs. -8,999 ha⁻¹ with benefit to cost ratio of 0.92:1 was observed with seed dressing of boric acid 6 kg ha⁻¹.

The soil application of 20 kg ZnSO₄ ha⁻¹ along with recommended dose of fertilizer (25 kg N + 50 kg P₂O₅ ha⁻¹) were found to be efficient for obtaining maximum pod yield with higher net monetary returns from groundnut in lateritic soils of South Konkan Maharashtra during *Kharif* season.

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Studies on Growth and Yield of Post Kharif Maize as Influenced by Irrigation and Fertigation Management

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Abstract

An experiment was laid out in split plot design with three replications. Each replication consist of 12 treatment combinations with three irrigation levels *viz.*, I₁: 1.0 PE through drip, I₂: 0.8 PE through drip and I₃ : 0.6 PE through drip as main plot and four fertigation levels *viz.*, F₁ : 100% RDF through drip, F₂ : 75% RDF through drip. F₃ : 50% RDF through drip, F₄ : 100% RDF through soil in sub plot. The growth attributes *viz.*, plant height, leaf area and dry matter plant⁻¹, yield attributes *viz.*, number of cobs plant⁻¹, average weight of cob, number of grain cob⁻¹ and number of grain rows cob⁻¹, weight of grains plant⁻¹, grain yield, fodder yield and biological yield and net monetary returns recorded significantly higher values in the irrigation level at 1.0 PE (I₁) than irrigation at 0.6 PE (I₃) and were comparable with irrigation at 0.8 PE (I₂). However, irrigation at 0.6 PE recorded higher water use efficiency than higher levels of irrigation *viz.*, 0.8 and 1.0 PE, respectively. Similarly, Fertigation with 100% of recommended dose of fertilizer *i.e.* 150:75:75:10 NPKZn ha⁻¹ recorded significantly higher values of above mentioned growth and yield attributes as well as seed, fodder and biological yield than 50 per cent RDF through fertigation and 100 per cent RDF through soil, respectively and was at par with 75 per cent RDF through fertigation. However, though 100 per cent RDF through fertigation recorded maximum net monetary returns it was at par with 75 per cent RDF through fertigation as well as 100 per cent RDF through soil application, respectively and significantly more than 50 per cent RDF through fertigation.

Key words : Maize, fertigation, drip irrigation, PE.

Maize (*Zea mays* L.) also called corn, is one of the most crucial and strategic crop in the world. Its origin is in Mexico (Central America) and it is also called as queen of cereals due to its great importance in human and animal diet with high yield potential. It is ranked third after wheat and rice in area and production in the world, but in productivity, it surpasses all cereals. In India, area and production of maize is about 9.43 million hectares and 24.35 million tones, respectively, having average productivity of about 2337 kg ha⁻¹ (Anonymus, 2014). Under Marathwada condition, low temperature and lack of irrigation facilities during the post-rainy and rabi season are the major constraint for growth and development of rabi maize. When crop is

grown at low temperature, there is delayed germination and poor plant stand. However, to exploit the production of post kharif maize, there is urgent need of proper cultivation technology.

In regards to Marathwada region with only 12.17 per cent of irrigated area, it is necessary to bring more land under irrigation. This can be achieved by adoption of advanced irrigation system particularly drip irrigation system which gives greater water use efficiency (WUE).

Generally, irrigation frequency and water application methods play an important role to achieve the full yield potential of food, fiber and vegetable crop. Hence, it become essential to give more concern over scheduling of irrigation, which will help to achieve the higher

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productivity, optimum use of water with better irrigation efficiency particularly for crop like maize.

Fertigation refers to the combined application of water and soluble fertilizer through an irrigation system. Normally many soils in India are with low organic matter content and are inherently low in fertility. Such soils often require replenishment of nutrient deficiency by application of manures and fertilizers to increase crop yield. Now a day's micro irrigation technique such as the drip and micro sprinkler irrigation systems are gaining momentum and popularity amongst the farmers. Conventional method of applying fertilizers by broadcasting uniformly on the surface or by drilling a continuous band of fertilizers alongside the row crop are not compatible with drip irrigation system, because in drip irrigation system water is applied only to a fraction of soil volume (near the root zone). In this wetted zone only, we have to apply fertilizers with nutrients, which are essential for plant growth. Surface application of dry fertilizers may not ensure optimum placement, moreover, requires lot of man power and time consuming compared to fertigation through drip system. Drip irrigation is more desirable than any other irrigation methods for several reasons. Two major advantages are (1) water conservation (drip requires about half as much water over the growing season as surface irrigation) and (2) the potential for significantly improving fertilizer management. Reddy and Reddy (2016) reported that drip irrigation can save water up to 40-70 per cent as well as increasing the crop production to the extent of 20-100 per cent. Fertigation is timely application of small amount of fertilizer through drip tubes directly to the root zone. Compared to conventional soil application, fertigation improves fertilizer use efficiency. Subsequently, comparable or better yields and quality can be

produced with 20-50 per cent less fertilizers.

Material and Methods

The field experiment was conducted during 2015-16 post kharif on the experimental farm of Water Management Centre, Vasanttrao Naik Marathwada Krishi Vidyapeeth, Parbhani. The soil in the experimental plot was medium deep black and well drained. The topography of the land was fairly leveled. During the crop growth period minimum temperature ranged between 14°C to 20°C and maximum temperature ranged between 30 to 35°C, whereas, minimum evaporation ranged between 2.6 to 2.8 mm and maximum evaporation ranged between 8.6 to 8.8 mm.

The experiment was laid out in split plot design with three replications. Each replication consist of 12 treatment combinations with three irrigation levels *viz.*, I₁ : 1.0 PE through drip, I₂ : 0.8 PE through drip and I₃ : 0.6 PE through drip were taken in main plot and four fertigation levels *viz.*, F₁ : 100% RDF through drip, F₂ : 75% RDF through drip, F₃ : 50% RDF through drip, F₄ : 100% RDF through soil in sub plot. The gross plot size was 6m x 5m and net plot size 3.6 x 4.4 m.

Irrigations were applied as per treatments. The pan evaporation was measured daily from the U.S.W.B. class 'A' open pan evaporimeter installed at the Central Meteorological Observatory, Department of Meteorology, VNMKV, Parbhani during the experimental period. The volume of water to be applied was calculated as per the treatment of irrigation level.

The recommended dose of maize 150:75:75:10 kg NPKZn per hectare was applied. For F₁, F₂ and F₃ treatments NPKZn dose was applied through water soluble fertilizers namely Urea, 0:52:34, 0:0:50 and zinc sulphate. Fertigation was given through the

venture of 0.75 inches. Up to 80 days 4 split doses of nitrogen were given at 20 days interval and P, K and Zn in 2 splits at the time of sowing and 30 days after sowing each of 50 per cent. For the treatment 100 percent RDF through soil (F₄) 50 percent dose of N, P, K and Zn was applied as a basal dose and remaining percent applied 30 days after sowing through urea, 10:26:26 and zinc sulfate, respectively.

Result and Discussion

Effect of irrigation levels:

Growth attributes : Irrigation scheduled at 1.0 PE recorded significantly maximum plant height, leaf area plant⁻¹ and dry matter plant⁻¹ at harvest. This was followed by irrigation levels at 0.8 PE and 0.6 PE, for all growth attributes at harvest. This trend in growth attributes showed corresponding improvement with increased irrigation levels from 0.6 PE to 1.0 PE. Better growth attributes with increased irrigation levels also reported by Bharathi *et al.* (1997), Abdullah *et al.* (2001), Bharti *et al.* (2007), Patil *et al.* (2012) and Basva sharana. (2012).

Better growth of maize under drip might be attributed to better moisture availability, soil aeration and also crop did not experience stress during the crop growth period at 1.0 PE irrigation schedule. This ultimately reflected better physiological activity in plant and there by increased plant height, mean number of functional leaves, leaf area per plant and dry matter production plant⁻¹. Similar findings were reported by Leta Tulu (1998).

Yield attributes : Irrigation levels at 1.0 PE (I₁) recorded significantly higher values of yield attributing characters *viz.*, number of cobs plant⁻¹, average weight of cob, number of grain cob⁻¹ and number of grain row cob⁻¹, weight of grain plant⁻¹ over 0.6 PE (I₃) irrigation level and were comparable with 0.8 PE (I₂). This might

be due to the water stress under low PE which resulted in poor plant growth due to reduced nutrient translocation, photosynthesis and metabolic activities of plant system. All these above referred yield attributes were decreased with subsequent decrease in the level of irrigation. These findings are in close conformity with those of Bharti *et al.* (2007).

Grain yield and fodder yield :

Significantly higher grain yield, fodder yield and biological yield was observed with irrigation at 1.0 PE (I₁) than irrigation at 0.6 PE (I₃), however, it was found comparable with 0.8 PE (I₂). This might be attributed due to better growth and yield attributes under 1.0 PE (I₁) compared to irrigation at lower PE values. These findings are in conformity with the findings of Gautam *et al.* (2000), Tariq *et al.* (2003) and Ponnuswamy and Santhi (2008).

Under moisture stress condition all the growth factors were affected adversely to a greater extent. This was evident from the significantly reduced plant height, number of functional leaves plant⁻¹ and dry matter production plant⁻¹ with irrigation at 0.6 PE (I₃) compared to significantly higher plant height, number of leaves plant⁻¹ and dry matter production plant⁻¹ due to irrigation at 1.0 PE. This resulted in the reduction in dry fodder yield due to low moisture availability and was also shown by Classen and Show (1970). Thus, revealing the significance of growth parameters in enhancing the fodder yield. These results are in line with those of reported by Thorat and Ramteke (1988) and Vijayalakshmi *et al.* (1994).

Harvest index showed little variation among irrigation levels, 1.0 PE (I₁) was numerically higher than rest of treatments followed by 0.8 PE (I₂) and 0.6 PE (I₃), respectively. This indicated little effect on sink-source relation due to fertigation levels.

Water use efficiency : Irrigation water supplied for maize crop during entire crop growth period was 570, 467 and 360 kg ha⁻¹ mm during the period of investigation for 1.0 PE through drip (I₁), 0.8 PE through drip (I₂) and irrigation at 0.6 PE through drip (I₃), respectively (Table 2).

The highest water use efficiency (WUE) of 17.81 kg ha⁻¹-mm was observed with irrigation at 0.6 PE (I₃) and was gradually decreased with increased irrigation levels i.e. 0.8 PE (15.19 kg ha⁻¹-mm) and 1.0 PE (13.69 kg ha⁻¹-mm) although yield levels were high for high

irrigation level. Water use efficiency showed reverse trend this might be due to comparable performance of maize under lower irrigation levels compared to yield obtained under 1.0 PE (I₁). This indicated that for obtaining more maize grain yield per unit of water, 0.6 PE (I₃) irrigation can be used under limited water resource for obtaining certain amount of yield for maize crop. Similar result was reported by Jana and Puste (1985).

Net monetary returns : Net monetary returns were significantly influenced due to different level of irrigation. Application of

Table 1. Effect of irrigation and fertigation levels on growth, yield attributes and yield of Maize in post *kharif*

Treatment	Plant height (cm)	Leaf area (dm ²)	Dry matter production	No. of cob plant ⁻¹	No. of grain cob ⁻¹	No. of grain row cob ⁻¹	Grain weight plant ⁻¹ (g)	Grain yield (kg ha ⁻¹)	Fodder yield (kg ha ⁻¹)	Bio-logical yield (kg ha ⁻¹)	Har-vest index	NMR (Rs.)
Irrigation levels												
I ₁ - Irrigation at 1.0 PE	205.2	83.6	259.8	1.30	483.7	14.06	186.77	8845	12511	23199	38.1	122298
I ₂ - Irrigation at 0.8 PE	191.0	79.0	242.2	1.22	451.6	13.13	174.39	8259	11815	21795	37.9	115493
I ₃ - Irrigation at 0.6 PE	178.8	75.0	227.0	1.15	425.2	12.36	164.19	7775	11213	20609	37.7	109607
S.E ±	4.18	1.65	5.14	0.03	9.31	0.27	3.59	170	245	451	-	7864
C.D at 5%	16.40	6.46	20.19	0.10	36.54	1.06	14.11	668	965	1772	-	9435
Fertigation levels												
F ₁ - 100% RDF through drip	207.5	84.6	262.7	1.32	488.1	14.19	188.47	8926	12653	23436	38.1	123688
F ₂ - 75% RDF through drip	199.3	81.9	252.8	1.27	471.3	13.70	182.00	8619	12251	22624	38.1	119759
F ₃ - 50% RDF through drip	174.3	73.1	221.4	1.12	415.1	12.06	160.28	7590	10928	20145	37.1	103273
F ₄ - 100% RDF through soil	185.3	77.2	235.1	1.18	439.5	12.77	169.72	8037	11552	21265	37.8	116477
S.E ±	5.95	2.29	7.40	0.04	13.09	0.38	5.05	239	341	627	-	4540
C.D at 5%	17.68	6.79	21.99	0.11	38.89	1.13	15.02	711	1016	1863	-	13491
Interaction effects												
S.E ±	10.30	3.96	12.82	0.06	22.67	0.66	8.75	414	592	1086	-	7864
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	NS
Grand mean	191.7	79.2	243.0	1.22	453.52	13.18	175.12	8293	11846	21867	37.90	115799

irrigation at 1.0 PE (I_1) recorded significantly maximum net monetary returns (Rs.122298) over irrigation at 0.6 PE (Rs. 109607) and found comparable with irrigation at 0.8 PE (I_2). The lowest NMR was obtained with irrigation at 0.6 PE (Rs. 109607) which was comparable with 0.8 PE (Rs. 115493).

Effect of fertigation levels :

Growth attributes : The 100 per cent RDF through drip showed significantly maximum plant height, leaf area plant⁻¹ and dry matter plant⁻¹ than rest of the fertigation levels at harvest. However, it was at par with 75 per cent RDF through drip (F_2). The 50 per cent RDF through drip (F_3) recorded lowest value of all growth attributes.

Better growth attributes under 100 per cent RDF through drip as compared to lower dose of fertilizer through soil application indicated that maize crop showed better response to increased fertilization of NPK and Zinc and also better performance of water soluble fertilizers over application of fertilizers through soil. This might be attributed to better availability of nutrients under application of water soluble fertilizer which resulted in better or on par growth attributes with low fertigation levels i.e. 50 per cent RDF and 75 per cent RDF through

drip over 100 per cent RDF through soil. Similar results were reported by Sampatkumar and Pandian (2010) and Muthurakrishnan and Anitta Fanish (2011).

Yield attributes : Yield attributing characters of maize *viz.*, number of cobs plant⁻¹, average weight of cob, number of grain cob⁻¹ and number of grain row cob⁻¹, weight of grain plant⁻¹ were differed statistically due to various fertigation levels. 100 per cent RDF through drip recorded significantly higher values of all above referred yield attributes over 100 per cent RDF through soil application and 50 per cent RDF through fertigation, respectively. However, the treatment of 100 per cent RDF through fertigation was at par with 75 per cent RDF through fertigation for all yield attributes. The lowest values of yield attributes were observed with 50 per cent RDF through drip and were at par with 100 per cent RDF through soil application. This effect was obviously due to high efficiency and easy availability of plant nutrients through the water soluble fertilizers. As availability of source in respect of maize increased with the increase in level of fertigation, the production in sink in the crop also followed same trend. These results are in conformity with those obtained by Gholap (1999) and Iqbal *et al.*(2003)

Table 2. Water use efficiency as influenced by different treatment

Irrigation level	Water applied (mm)	Effective rainfall (mm)	Total water use (mm)	Water use efficiency (kg ha-mm)
Irrigation levels				
Irrigation at 1.0 PE	570.20	76.00	646.20	13.69
Irrigation at 0.8 PE	467.81	76.00	543.81	15.19
Irrigation at 0.6 PE	360.55	76.00	436.55	17.81
Fertigation levels				
100% RDF through fertigation	466.18	76.00	542.18	16.46
75% RDF through fertigation	466.18	76.00	542.18	15.90
50% RDF through fertigation	466.18	76.00	542.18	14.00
100% RDF through soil	466.18	76.00	542.18	14.83

Significantly higher grain yield, fodder yield and biological yield was observed with 100 per cent RDF through drip than 100 per cent RDF through soil and 50 per cent RDF through drip, however, it was found comparable with 75 per cent RDF through drip. Moreover, 75 per cent RDF with fertigation was on par with 100 per cent RDF through soil and their by saving 25 per cent NPK and Zn. Application of water soluble fertilizer with drip also proved useful for saving of labour. Ponnuswamy and Santhi (2008) also reported higher yield under water soluble fertilizer with drip. Similar trend was also observed for fodder yield.

Harvest index showed little variation among fertigation levels, 75 per cent RDF through drip was numerically higher than rest of treatments followed by 100 per cent RDF through drip, 100 per cent RDF through soil and 50 per cent RDF through drip, respectively. This indicated little effect on sink-source relation due to fertigation levels.

Water use efficiency : Water use efficiency for various fertigation levels showed little variation as compared with effect of irrigation levels (Table 2). Though, highest water use efficiency was noted with 100 per cent RDF through drip followed by 75 per cent RDF through drip, 100 per cent RDF through soil and 50 per cent RDF through drip, respectively. As water applied for each fertigation level was same, the variation in water use efficiency was due to variation in grain yield under fertigation levels. This also indicated better performance of 100 per cent RDF through drip over the rest of the fertigation levels when 466 mm of water applied.

Net monetary returns : The application of fertilizer at 100 per cent RDF through drip showed significantly higher net monetary returns (Rs. 123688) over application of at 50

per cent RDF through drip (Rs 103273), however, it was on par with 75 per cent RDF through drip (Rs. 119759) and 100 per cent RDF through soil application (Rs. 116477). 50 per cent RDF through drip gave significantly lower NMR than rest of the treatments except 100 per cent RDF through soil.

Interaction effect : Interaction effect due to different irrigation and fertigation levels were non significant for all growth attributes, yield attributes, grain yield, fodder yield and biological yield.

Conclusion

It can be concluded from the results that in Marathwada region during post kharif season maize crop under drip should be irrigated at 1.0 PE and fertigated with 75 per cent RDF through drip (WSF) for obtaining higher grain and fodder yield, net returns. However, due to higher cost of water soluble fertilizers (4 times more than straight fertilizers), it is advisable that maize should be grown under drip irrigation with 1.0 PE and fertilized with 100 per cent RDF through soil application for getting maximum B:C ratio.

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Evaluation of Molecular Markers for Pod Shattering in Soybean [*Glycine max* (L.) Merrill]

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Abstract

Fifty Indian soybean genotypes were screened using 26 SSR primers known to amplify markers specific for different pod shattering loci. Out of these, seven markers were found to be informative and showed association with pod shattering trait. The finding of this study indicated that SSR Satt621_{280bp}, Sat_350_{250bp/270bp}, Satt215_{170bp/150bp}, Satt350_{300bp}, Satt296 (4 alleles), Satt355_{250bp} and Satt409_{260bp/170bp} markers are associated with pod shattering in selected genotypes. These results suggest that pod shattering tolerant cultivars harbour pod shattering resistance alleles at QTL regardless of their origin and these molecular markers near to *qPDH1*, *qPDH1-7*, *qPDH3-4*, *qPDH3-3*, *qPDH3-6*, *qPDH1-1* and *qPDH4-1* loci. Thus these markers could be used for marker assisted selection for pod shattering tolerance in soybean.

Key words : Pod shattering, soybean, SSR markers, qPDH.

"Wonder crop" soybean is cheapest and easiest source of best quality protein and fats and having many uses as food and industrial products. The pod in a legume is derived from an ovary and its morphological and anatomical structure is well conserved in legume plants (Esau, 1997; Kang *et al.*, 2009). The extent of yield loss due to pod shattering in soybean [*Glycine max* (L.) Merrill] ranges from 34 to 99 per cent depending upon delayed harvesting after maturity, environmental conditions during harvesting as well as genotype (Tiwari and Bhatnagar, 1961; Bhor *et al.*, 2014). The mechanisms involved in pod shattering and resistance to the same have been reported (Mitsuda and Ohme-Takagi, 2008; Zhong *et al.*, 2010; Dong, 2014; Funatsuki *et al.*, 2014 and Dong and Wang, 2015).

Methods for evaluating pod shattering have been established (Tukamuhabwa *et al.*, 2002) and have proven usable in breeding programs

(Tsuchiya, 1986); however, more efficient methods, such as marker-assisted selection (MAS), are desirable since conventional methods involve heat treatment of pods which is not a very convenient (Shoemaker and Specht, 1995). SSR markers have been used for studying fine mapping of pod shattering resistance genes (Bailey *et al.* 1997; Funatsuki *et al.* 2005; 2006; Yamada *et al.* 2009; Kang *et al.*, 2009). Pod dehiscence has been reported to be controlled by a single QTL *qPDH1* with major effect along with many QTLs with minor effect (Kang *et al.*, 2009).

In India high levels of shattering resistance have become necessary both in moderately humid and dry areas, due to increasing trend of mechanical harvesting. For this there is need to screen the Indian varieties for presence of *pdh1*; a major QTL conditioning the pod dehiscence in soybean was identified on Chromosome no. 16 LG J in soybean varieties (Bailey *et al.*, 1997; Suzuki *et al.*, 2009; Yamada *et al.*, 2009; Funatsuki *et al.*, 2006;

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2012) and minor QTLs on LG D1b, E and L have been reported (Bailey *et al.*, 1997; Kang *et al.*, 2009).

Materials and methods

Plant materials : The experimental material consisted of 50 soybean genotypes collected from the Soybean Breeder, Agricultural Research Station, Kasbe Digraj, District Sangli (Table 1). Field experiment was conducted using 50 genotypes of soybean originated from different places of India (Table 1). The experiment was laid in randomized block design with two replications at the PGI farm, Botany, MPKV, Rahuri, during *kharif* season of 2015. In each replication the genotypes were grown in 3 m long rows with spacing of 45 x 10 cm for row to row and plant to plant, respectively. Within a row, seeds were hand dibbled 10 cm apart. Fertilizer dose of 50 kg N and 75 kg P₂O₅ ha⁻¹ for irrigated situation was applied at the time of sowing. Standard package of practices was followed to raise the good crop.

Assessment of pod shattering in soybean : At physiological maturity pod shattering was scored as per oven dry method (Tiwari and Bhatnagar 1997). The properly harvested 50 pods of selected plants of each variety were kept in brown paper bags at room temperature for 15 days to equalize the moisture content of all pods. Then the bags were subjected to oven drying at 40°C (6 hrs in a day and ambient temperature at night) for 7 days. After every 7 days the number of shattered pods were counted and expressed in percentage. When pods were shattered, percentage of shattering was recorded by using following formula

$$\text{Pod shattering percentage (\%)} = \frac{\text{No. of pds shattered}}{\text{Total no. of pods}} \times 100$$

Percentage of pod shattering induced was recorded and determined according to 1-5 scale used by Asian Vegetable Research Development Centre (AVRDC) (Anonymous, 1979). The scoring was done as per in 1 to 5 scale 1=0%, 2=1-10%, 3=11-25%, 4=26-50% and 5=>50% where, very resistant, resistant, moderately resistant/tolerant, moderately susceptible and very susceptible, respectively.

Molecular characterization : DNA was extracted from young leaves sampled of 50 genotypes using CTAB method described by Doyle and Doyle (1990) and amplified using 24 different SSR primers. The polymerase chain reaction (PCR) mixture contained 30 ng of total

Table 1. Soybean genotypes used for analysis

Genotype	Pod shattering	Genotype	Pod shattering
KDS 726	Intermediate	RKS 18	Intermediate
KDS 738	Intermediate	MAUS 71	Intermediate
KDS 753	Intermediate	Bragg	Resistant
KDS 775	Resistant	MACS 1442	Intermediate
KDS 904	Resistant	MACS 1416	Intermediate
KDS 920	Intermediate	RVS 2008-4	Intermediate
KDS 975	Intermediate	RVS 2007-6	Intermediate
KDS 976	Intermediate	Birsa soya	Resistant
KDS 978	Intermediate	AMS 1002	Intermediate
KDS 979	Intermediate	NRC 99	Intermediate
KDS 980	Intermediate	DS 9712	Resistant
KDS 999	Intermediate	Kalitur	Intermediate
KDS 1045	Intermediate	MAUS 706	Intermediate
KDS 1046	Intermediate	PS1556	Intermediate
KDS 730	Intermediate	NRC 93	Resistant
KDS 743	Intermediate	DS3101	Resistant
KDS 780	Intermediate	RSC 1046	Intermediate
KDS 921	Intermediate	DSb 21	Resistant
KDS 1043	Intermediate	MACS 450	Resistant
KDS 1044	Intermediate	EC 241780	Intermediate
KDS 1047	Intermediate	KDS 344	Intermediate
KDS 1048	Intermediate	DS 228	Intermediate
KDS 869	Intermediate	JS 93 05	Intermediate
KDS 754 W	Intermediate	JS 335	Intermediate
AMS MB 5-18	Intermediate	JS 95 60	Intermediate

Table 2. Status of SSR alleles in resistant and susceptible soybean genotypes

Primer	Allele (bp)	No. of genotype		Total alleles	Efficiency of Allel (%)	
		Resistant genotype (total 9)	Intermediate genotype (total 41)		Resistant genotype	Intermediate genotype
Satt621	280	3	0	3	33.3	0
	230	7	41	48	77.8	100
SRM0	240	0	1	1	0	2.4
	220	9	40	49	100	97.6
SRM1	230	9	41	50	100	100
SRM2	190	9	40	49	100	97.6
	180	0	1	1	0	2.4
Satt166	450	1	4	5	11.1	9.8
	340	1	4	5	11.1	9.8
	270	2	14	16	22.2	34.1
	220	8	30	38	88.9	73.2
Sat_366	220	0	2	2	0	4.9
	200	9	39	48	100	95.1
Sat-350	1500	8	41	49	88.9	100
	1200	8	41	49	88.9	100
	1000	8	41	49	88.9	100
	270	6	38	44	66.7	92.7
	250	2	3	5	22.2	7.3
Satt350	190	8	41	49	88.9	100
	300	0	7	7	0	17.1
Satt215	260	9	38	47	100	92.7
	170	1	30	31	11.1	73.2
Satt244	150	6	6	12	66.7	14.6
	140	2	5	7	22.2	12.2
	220	3	8	11	33.3	19.5
Satt431	190	9	40	49	100	97.6
	170	9	40	49	100	97.6
Satt238	200	9	39	48	100	95.1
Satt243	175	9	41	50	100	100
Satt183	220	0	2	2	0	4.9
	200	9	39	48	100	95.1
Satt185	270	1	5	6	11.1	12.2
	250	8	36	44	88.9	87.8
Satt062	240	9	41	50	100	100
Sat_407	220	9	40	49	100	97.6
	200	9	40	49	100	97.6
	180	9	40	49	100	97.6
Satt674	220	5	32	37	55.6	78.0
	200	5	8	13	55.6	19.5
	140	4	33	37	44.4	80.5
Satt296	240	0	1	1	0	2.4
	220	9	40	49	100	97.6
Satt296	200	2	23	25	22.2	56.1
	180	0	3	3	0	7.3
	160	4	10	14	44.4	24.4
	130	2	12	14	22.2	29.3

Table 2. Contd.

Primer	Allele (bp)	No. of genotype		Total alleles	Efficiency of Allel (%)	
		Resistant genotype (total 9)	Intermediate genotype (total 41)		Resistant genotype	Intermediate genotype
Satt355	300	0	6	6	0	14.6
	275	2	17	19	22.2	41.5
	250	7	18	25	77.8	43.9
Sat_339	190	9	41	50	100	100
Satt409	340	0	1	1	0	2.4
	290	2	8	10	22.2	19.5
	260	1	16	17	11.1	39
	220	0	2	2	0	4.9
Sat_342	170	6	14	20	66.7	34.1
	280	4	20	24	44.4	48.8
	200	5	23	28	55.6	56.1
Sat_093	120	4	20	24	44.4	48.8
	220	8	40	48	88.9	97.6
	175	1	0	1	11.1	0
	150	8	40	48	88.9	97.6

genomic DNA, 0.25 mM primers, 1 mM of each dNTP, 2.1 mM MgCl₂, 0.045 U of Taq polymerase and 1x PCR buffer (100 mM Tris-HCl, pH 8.3; 500 mM KCl and 0.1% gelatin) for a total volume of 20 mL. The PCRs were performed with a GeneAmp PCR System (Corbett Palm Cyclyer) using the following program: 35 cycles at 94 °C for 30 s, 55 °C for 30 s and 72 °C for 30 s.

The amplified products were separated on 2.5 per cent high resolution metaphor agarose gel. In the eletrophoresis with ethidium bromide staining, the PCR products were mixed with 3µL of 6x gel loading dye (25% glycerol, 50 mM Tris, 5 mM EDTA, 0.2 per cent bromophenol blue) and then were loaded on the gel containing ethidium bromide (10 mg ml⁻¹). Electrophoresis was performed at a constant voltage of 80 V for 2 h. After electrophoresis, the DNA fragments were visualized under UV light and photographed using gel documentation system (Gel logic 1500 imaging system, using KODAK Molecular Imaging Software). Polymorphic

information content (PIC) values were calculated for each SSR marker as described by Powell *et al.* (1996) with the following formula:

$$PIC_i = 1 - \sum_{j=1}^n P_{ij}^2$$

Where P_{ij} is the frequency of the jth allele for the ith marker.

Results and discussion

It was observed that total of 61 alleles were amplified by these 24 primers. Out of which 47 loci were polymorphic and 14 loci were monomorphic. Unique alleles were observed in Primer SRM0, SRM2, Satt674, Satt409 and Sat_093. Thus 77.05 per cent polymorphism was observed. Each primer produced on an average 2.61 polymorphic bands. The polymorphism information content (PIC) values of primers ranged from 0.04 for SSR primers SRM0, SRM2 and Satt674 to 0.89 for SSR primer Satt215.

Allelic efficiency of each primer in resistant and tolerant genotypes is calculated (Table 2). Hosamani *et al.*, (2013) used allelic efficiency to identify markers with limited discrimination ability to distinguish polygenic trait like seed longevity. Seven primers were found informative and were shortlisted as they yielded profile polymorphic between genotypes differing for pod shattering trait *viz.*, Satt621, Sat_350, Satt350, Satt215, Satt296, Satt355, and Sat_409 though none of these showed clear difference between resistant or intermediate genotypes (Table 2). The SSR markers Satt621280bp and Sat_350_{250bp} linked to *qPDH1* and *qPDH1-7* on linkage group J showed allelic efficiencies of 33.3 and 22.2 per cent respectively, in resistant genotypes. The SSR primer Satt215 amplified Satt215_{170p} and Satt215_{150bp} markers linked to *qPDH3-4* that exhibited contrasting allelic efficiency in genotypes differing for pod shattering. This in agreement with Kang *et al.* (2009) who reported the single major QTL Satt215 positioned on LG J conditioning PD.

The Satt350_{300bp} marker linked to *qPDH3-3* on linkage group D1b showed allelic efficiency of 17.1 per cent in intermediate genotypes. The allele Satt409260bp was present in one resistant genotype and 16 intermediate genotypes with allelic efficiency of 39 per cent in intermediate genotypes. The Satt355_{300bp} linked to *qPDH1-1* showed efficiency of 14.6 per cent in intermediate genotypes. The Satt296_{200bp} linked to *qPDH3-6* exhibited allelic efficiency of 56.1 per cent in intermediate genotypes. Another allele Satt296180bp was present in 3 intermediate genotypes *viz.*, KDS 743, KDS 1043 and KDS 754-W thus the allelic efficiency was 7.3 per cent in intermediate genotypes. Bailey *et al.* (1997) found QTLs on LGs D1b, E, L and N in a cross between Young and PI416937.

In divergence studies, 2 major and 2 minor groups were formed among fifty soybean genotypes studied (Figure 1). Major group I, with 27 genotypes formed 2 Sub-groups *viz* Ia and Ib. The Sub-group Ia again divided into two sub sub-groups *i.e.* Iai (3 genotypes) and Iaii (15 genotypes). The Ib Sub-group has 9 intermediate genotypes, 8 of which shared common parents JS 9305 x AMS 1. Group II with 21 genotypes formed 4 Sub-groups *viz.*, IIa, IIb, IIc, and IId. Sub-group IIa comprised of intermediate landrace Kalitur, IIb comprised two shattering resistant genotypes (Bragg and NRC 93); Sub-group IIc comprises 17 genotypes of which two (DS 9712, and DS 3101) were shattering resistant and Sub-group IId comprises of a single genotype (shattering resistant MACS 450). Group III (shattering resistant Birsa soya) and Group IV (KDS 921) were the most distinct genotypes (Figure 1).

The genotypes clustering observed in dendrogram is reflected in their 2 D scatter plot replacement (Figure 2). Almost all the genotypes placed in two major groups, *i.e.* Group I (except AMS 1002) and Group II where distinguished from each other by the first component (x-axis) being placed on its opposite

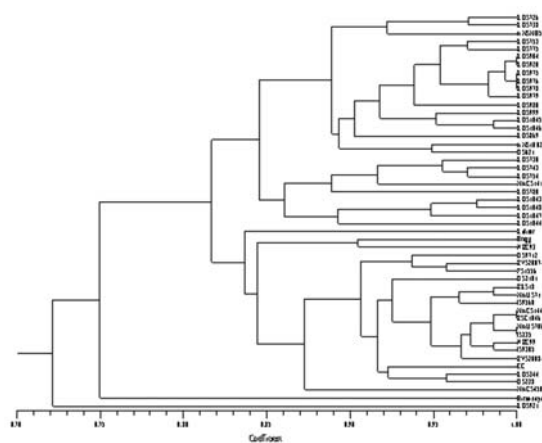


Fig. 1. Consensus tree showing clustering of fifty soybean genotypes using SSR analysis

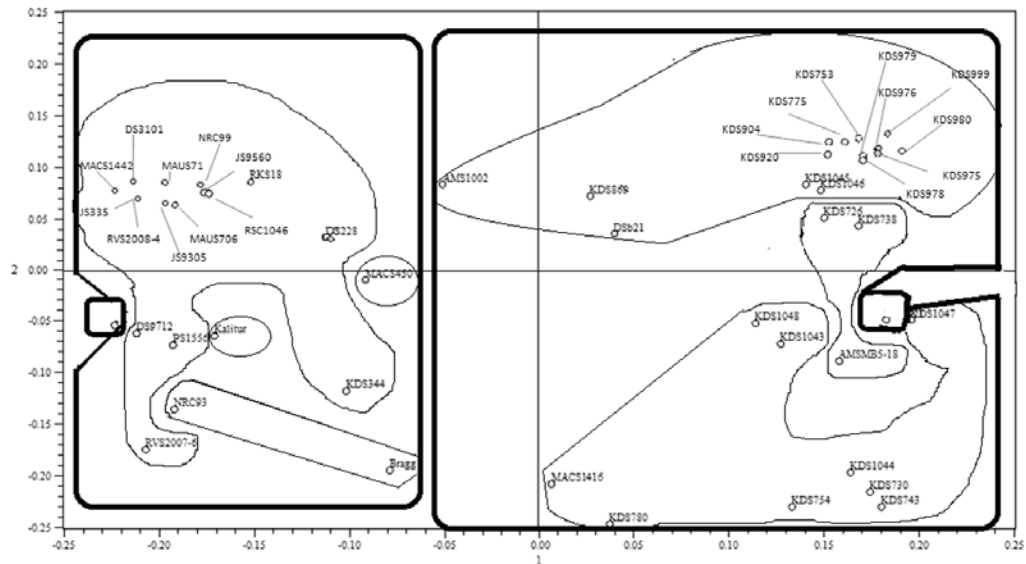


Fig. 2. SSR data analysis derived 2D Scatter Plot

half). However other two mono genotype Group III (Birsasoya) and Group IV (KDS 921) which appeared distinct from rest of genotypes in dendrogram were placed along with Group II and Group I respectively (Figure 2). However, this suggested that their actual positions was not reflected in a 2-D scatter plot and to reveal the actual position study of third component axis i.e. 3D scatter plot may required.

Better resolution of SSR alleles in our studies showed that various SSR primers are powerful tools in diversity analysis as they are highly polymorphic. The identification of the minor genes, the development and screening of DNA markers associated with PD and identification of shattering resistant genotypes by using such molecular markers will further accelerate the various local genotypes using different breeding strategies.

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Gene Action in the Inheritance of Yield and its Components in Three Crosses of Soybean

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Abstract

Field experiments were conducted to study the gene action involved in the inheritance of yield and its components in six generations (P_1 , P_2 , B_1 , B_2 , F_1 and F_2) of three crosses of soybean [*Glycine max* (L.) Merrill] viz., DS-228 x Type-49, KDS-705 x JS-335 and KDS-708 x JS-335 in Randomized block design with three replications. The studies on gene action revealed the preponderance of dominance gene action for all the characters in all the crosses except number of branches plant⁻¹ in KDS-705 x JS-335 and KDS-708 x JS-335 and number of seeds pod⁻¹ in DS-228 x Type-49 and KDS-705 x JS-335. All types of gene effects (d, h, i, j and l) were significant in all the crosses for most of the characters except for the characters, number of branches plant⁻¹ in the crosses KDS-705 x JS-335 and KDS-708 x JS-335 and number of seeds pod⁻¹ in all crosses. Duplicate type of epistasis was observed for characters viz., days to maturity, plant height, number of branches plant⁻¹, 100 seed weight and seed yield plant⁻¹ in all crosses. Complementary epistasis was observed for days to 50 per cent flowering, number of pods plant⁻¹, protein content and oil content in the cross DS-228 x Type-49.

Key words : Gene action, six generations, soybean.

Gene action refers to the behavior or mode of expression of genes in a genetic population. Knowledge of gene action helps in the selection of parents for use in the hybridization programs and also in the choice of appropriate breeding procedure for the genetic improvement of various quantitative characters. Hence, insight into the nature of gene action involved in the expression of various quantitative characters is essential to a plant breeder for starting a judicious breeding program. Gene action and gene effects have been extensively studied in many crop species. Gene action is important in determining cultivar type (hybrid, pure line, synthetic, etc.), breeding methodology used to develop cultivars, and in the interpretation of quantitative genetic experiments. The present study included analysis of gene action involved in the inheritance of yield and its components by six parameter model (Hayman, 1958).

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Material and method

The experimental material consists of six generations (P_1 , P_2 , F_1 , F_2 , B_1 and B_2) each from the given three crosses of soybean. The seed material was obtained from the Soybean Breeder, Agriculture Research Station (ARS), Kasbe Digraj, Sangli. The seed material for the present experiment was derived by making crosses between the selected parents Ds-228, Type-49, KDS-705, JS-335 and KDS-708 and F_1 , F_2 , B_1 and B_2 generations were raised in two seasons.

The seed material for the experiment was sown in *kharif*, 2015. The experiment was laid out in a Randomized Block Design (RBD) with three replications. The entries were sown in rows of 2 m length each with a spacing of 45 cm between the rows and 10 cm between the plants.

Result and discussion

Adequacy of additive dominance model was tested by simple scaling tests as well as joint scaling tests (Table 1). Presence of digenic epistatic interactions (non-allelic interactions) was detected in cross *viz.*, DS-228 x Type-49 for all the characters as shown by one, two, three or all scaling tests except seeds pod⁻¹. These results were further confirmed by joint scaling test.

Digenic epistatic interactions were also detected in the cross KDS-705 x JS-335 for all the characters except seeds pod⁻¹. In the cross KDS-708 x JS-335, digenic interactions were observed for all the characters under study. These results were further confirmed by joint scaling test.

In the cross DS-228 x Type-49, additive gene effects were present for the characters days to 50 per cent flowering, number of pods plant⁻¹, 100-seed weight and seed yield plant⁻¹. Similar results for the presence of additive gene action were reported by Croissant and Torrie (1970), Srinives and Sutakom (1985), Sharma *et al* (1993), Sood *et al.* (1996), Rahangdale and Raut (2002), Singh *et al* (2009) and Bhor *et al.* (2014). Dominance effects were present for the characters days to maturity, plant height, number of branches plant⁻¹, pods plant⁻¹, 100-seed weight and seed yield plant⁻¹ (Table 2). Maloo and Nair (2005), Maloo and Sharma (2007) and Singh *et al.* (2009) reported similar findings.

All the digenic epistatic interactions were significant for days to maturity, plant height, number of branches plant⁻¹, 100-seed weight and protein content. Complementary type of epistasis was present for days to 50 per cent flowering, number of pods plant⁻¹ and protein content (Bhor *et al.*, 2014). Duplicate type of epistasis was observed for days to maturity, plant height, number of branches plant⁻¹, 100-

seed weight, oil content and seed yield plant⁻¹ (Table 2). Similar findings were also reported by Maloo and Nair (2005) and Singh *et al.* (2009).

In the cross KDS-705 x JS-335, additive gene effects were present for days to 50 per cent flowering, plant height, 100-seed weight and seed yield per plant. Dominance effects were present for days to maturity, plant height, number of branches plant⁻¹, 100-seed weight, protein content, oil content and seed yield plant⁻¹. Duplicate type of gene interaction was prevalent for all the characters studied (Table 2). Similar results were observed by Raut *et al.* (2000), Rahangdale and Raut (2002), Singh *et al.* (2009), and Maloo and Nair (2005).

In the cross KDS-708 x JS-335, additive gene effects were significant for the characters plant height, number of pods plant⁻¹, 100-seed weight and seed yield plant⁻¹. Dominance gene effects were present for 50 per cent flowering, plant height, number of branches plant⁻¹, number of seeds pod⁻¹, protein content, oil content and seed yield plant⁻¹. Similar results were observed by Croissant and Torrie (1971), Srinives and Sutakom (1985), Sood *et al.* (1996) and Cho and Scott (2000).

Complementary type of gene action was observed for days to 50 per cent flowering and oil content. Duplicate type of gene action was seen for days to maturity, plant height, number of branches plant⁻¹, pods plant⁻¹, seeds pod⁻¹, 100-seed weight, protein content and seed yield plant⁻¹. Srinives and Sutakom (1985), Maloo and Nair (2005) and Singh *et al.* (2009) also reported similar results.

In all the three crosses, for most of the characters except number of branches plant⁻¹ (KDS-705 x JS-335 and KDS-708 x JS-335) and number of seeds pod⁻¹ (DS-228 x Type-49 and KDS-705 x JS-335), dominance gene action was predominant with duplicate and

Table 1. Estimates of scaling test for three crosses in soybean

Crosses	A	B	C	D	χ^2
Days to 50 per cent flowering					
DS-228 x Type-49	-7.033 ± 0.76**	-3.7 ± 0.837**	-10.17 ± 1.76**	0.28 ± 0.97	116.55**
KDS-705 x JS-335	5.33 ± 0.72**	-0.07 ± 0.63	4.427 ± 1.40**	-0.420 ± 0.71	58.06**
KDS-708 x JS-335	-0.833 ± 0.93	-6.333 ± 0.67**	-7.780 ± 1.58**	-0.307 ± 0.86	98.14**
Days to maturity					
DS-228 x Type-49	-5.20 ± 0.75**	-7.06 ± 0.896**	0.573 ± 1.565	6.420 ± 0.819**	109.76**
KDS-705 x JS-335	0.833 ± 0.75	5.967 ± 0.69**	-3.520 ± 1.74**	-5.160 ± 0.93**	87.39**
KDS-708 x JS-335	-13.93 ± 0.67**	-11.70 ± 0.64**	1.66 ± 1.49	13.64 ± 0.76**	726.87**
Plant height (cm)					
DS-228 x Type-49	30.44 ± 2.55**	-5.63 ± 2.78**	-19.66 ± 8.48**	-22.23 ± 4.27**	181.29**
KDS-705 x JS-335	16.80 ± 2.01**	9.17 ± 2.07**	5.15 ± 4.37	-10.41 ± 2.32**	83.24**
KDS-708 x JS-335	-8.377 ± 1.96**	-1.163 ± 2.65	-21.10 ± 3.69**	-5.77 ± 2.16**	43.98**
Number of branches plant⁻¹					
DS-228 x Type-49	-0.3 ± 0.37	-0.66 ± 0.38	2.31 ± 0.74**	1.64 ± 0.36**	20.70**
KDS-705 x JS-335	0.233 ± 0.42	1.133 ± 0.45**	0.073 ± 0.77	-0.647 ± 0.38	6.818**
KDS-708 x JS-335	2.50 ± 0.43**	-0.667 ± 0.40	1.047 ± 0.77	-0.393 ± 0.42	40.63**
Number of pods plant⁻¹					
DS-228 x Type-49	-26.60 ± 2.03**	-27.83 ± 2.05**	-33.26 ± 4.56**	10.58 ± 2.49**	331.39**
KDS-705 x JS-335	19.87 ± 1.68**	45.20 ± 1.53**	-45.82 ± 2.58**	-55.44 ± 1.48**	1694.66**
KDS-708 x JS-335	0.30 ± 2.26	29.23 ± 1.73**	-73.63 ± 3.57**	-51.58 ± 1.91**	1005.17**
100 seed weight (g)					
DS-228 x Type-49	1.54 ± 0.06**	2.81 ± 0.08**	-5.48 ± 0.33**	-4.91 ± 0.17**	2115.26**
KDS-705 x JS-335	1.957 ± 0.07**	-1.914 ± 0.06**	-2.561 ± 0.52**	-1.302 ± 0.26**	2663.88**
KDS-708 x JS-335	1.537 ± 0.10**	-0.845 ± 0.09**	55.739 ± 62.62	27.52 ± 31.31	666.19**
Number of seeds pod⁻¹					
DS-228 x Type-49	0.13 ± 0.23	-0.07 ± 0.23	-0.35 ± 0.36	-0.21 ± 0.19	2.58**
KDS-705 x JS-335	0.100 ± 0.22	0.000 ± 0.22	-0.287 ± 0.32	-0.193 ± 0.17	3.222**
KDS-708 x JS-335	0.067 ± 0.26	-0.033 ± 0.24	-0.927 ± 0.41**	-0.480 ± 0.20**	7.09**
Protein content (%)					
DS-228 x Type-49	0.34 ± 0.25	-2.33 ± 0.24**	-0.85 ± 0.47	0.57 ± 0.25**	101.71**
KDS-705 x JS-335	-0.945 ± 0.21**	-3.062 ± 0.21**	-8.327 ± 0.34**	-2.160 ± 0.18**	646.16**
KDS-708 x JS-335	1.945 ± 0.23**	-1.225 ± 0.29**	-10.99 ± 0.36**	-5.85 ± 0.21**	1238.15**
Oil content (%)					
DS-228 x Type-49	-1.76 ± 0.21**	-4.44 ± 0.22**	-5.26 ± 0.28**	0.47 ± 0.18**	609.02**
KDS-705 x JS-335	-0.714 ± 0.09**	-3.600 ± 0.11**	-8.478 ± 0.26**	-2.082 ± 0.12**	1718.69**
KDS-708 x JS-335	-0.429 ± 0.16**	-0.734 ± 0.08**	-2.927 ± 0.26**	-0.882 ± 0.15**	186.75**
Seed yield plant⁻¹ (g)					
DS-228 x Type-49	6.45 ± 0.40**	13.82 ± 0.63**	38.20 ± 1.48**	8.96 ± 0.81**	1296.52**
KDS-705 x JS-335	16.83 ± 0.43**	13.03 ± 0.47**	19.62 ± 1.40**	-5.12 ± 0.73**	2118.43**
KDS-708 x JS-335	16.68 ± 0.29**	9.479 ± 0.30**	23.26 ± 1.44**	-1.45 ± 0.72**	3454.53**

Table 2. Estimates of components of generation mean in three crosses of soybean

Cross	m	d	H	i	j	l	Type of epistasis
Days to 50 per cent flowering							
DS-228 × Type-49	40.64 ± 0.46**	-6.40 ± 0.50**	0.94 ± 1.97	-0.56 ± 1.94	-1.67 ± 0.54**	11.29 ± 2.68**	Complementary
KDS-705 × JS-335	36.67 ± 0.30**	4.97 ± 0.37**	1.57 ± 1.46	0.84 ± 1.42	2.70 ± 1.44**	-6.107 ± 2.05**	Duplicate
KDS-708 × JS-335	37.41 ± 0.35**	5.53 ± 0.49**	5.96 ± 1.75**	0.61 ± 1.71	2.75 ± 0.54**	6.55 ± 2.51**	Complementary
Days to maturity							
DS-228 × Type-49	100.69 ± 0.33**	2.5 ± 0.48**	-15.34 ± 1.69**	-12.84 ± 1.64**	0.93 ± 0.53	25.10 ± 2.47**	Duplicate
KDS-705 × JS-335	101.92 ± 0.41**	1.66 ± 0.44**	13.32 ± 1.88**	10.32 ± 1.85**	-2.57 ± 0.48**	-17.12 ± 2.47**	Duplicate
KDS-708 × JS-335	103.44 ± 0.33*	2.50 ± 0.38**	-29.67 ± 1.56**	-27.29 ± 1.5**	-1.11 ± 0.42**	52.93 ± 2.11**	Duplicate
Plant height (cm)							
DS-228 × Type-49	62.15 ± 2.04**	-1.28 ± 1.42	34.73 ± 8.64**	44.47 ± 8.54**	18.04 ± 1.83**	-69.28 ± 10.20**	Duplicate
KDS-705 × JS-335	60.91 ± 0.99**	9.297 ± 1.20**	29.62 ± 4.72**	20.82 ± 4.63**	3.82 ± 1.36**	-46.80 ± 6.5**	Duplicate
KDS-708 × JS-335	60.62 ± 0.80**	3.190 ± 1.45**	15.86 ± 4.42**	11.56 ± 4.32**	-3.607 ± 1.58**	-2.016 ± 6.86	Duplicate
Number of branches plant-1							
DS-228 × Type-49	5.78 ± 0.15**	0.333 ± 0.20	-2.297 ± 0.76**	-3.280 ± 0.73**	0.183 ± 0.22	4.247 ± 1.10**	Duplicate
KDS-705 × JS-335	5.89 ± 0.15**	-0.100 ± 0.25	2.610 ± 0.81**	1.293 ± 0.77	-0.45 ± 0.26	-2.66 ± 1.25	Duplicate
KDS-708 × JS-335	5.52 ± 0.17**	1.633 ± 0.25**	3.070 ± 0.86**	0.79 ± 0.84	1.58 ± 0.27	-2.62 ± 1.26	Duplicate
Number of pods pod-1							
DS-228 × Type-49	57.43 ± 1.06**	-4.53 ± 1.29**	29.28 ± 5.04**	-21.17 ± 4.97**	0.62 ± 1.35	75.60 ± 6.88**	Complementary
KDS-705 × JS-335	56.49 ± 0.55**	-9.37 ± 0.98**	143.53 ± 3.04**	110.89 ± 2.97**	-12.67 ± 1.09**	-175.96 ± 4.70**	Duplicate
KDS-708 × JS-335	57.63 ± 0.74**	-11.63 ± 1.20**	146.02 ± 3.94**	103.16 ± 3.81**	-14.46 ± 1.27**	-132.69 ± 5.97**	Duplicate
100 seed weight (g)							
DS-228 × Type-49	12.43 ± 0.08**	0.71 ± 0.04**	11.80 ± 0.34**	9.82 ± 0.34**	-0.63 ± 0.05**	-14.18 ± 0.37*	Duplicate
KDS-705 × JS-335	12.38 ± 0.13**	0.99 ± 0.03**	1.59 ± 0.52**	2.61 ± 0.52**	1.94 ± 0.04**	-2.65 ± 0.54**	Duplicate
KDS-708 × JS-335	27.61 ± 15.65	-0.58 ± 0.04**	-55.12 ± 62.62	-55.04 ± 0.04	1.19 ± 62.61**	54.36 ± 62.62	Duplicate
Number of seeds pod-1							
DS-228 × Type-49	2.48 ± 0.06**	0.03 ± 0.13	0.48 ± 0.39	-	-	-	-
KDS-705 × JS-335	2.52 ± 0.05**	-0.03 ± 0.13	0.43 ± 0.36	-	-	-	-
KDS-708 × JS-335	2.36 ± 0.07**	-0.13 ± 0.16	1.04 ± 0.44**	0.96 ± 0.42	0.05 ± 0.17**	-0.993 ± 0.73	Duplicate

Table 2. Contd.

Cross	m	d	H	i	j	l	Type of epistasis
Protein content (%)							
DS-228 × Type-49	38.28 ± 0.10**	2.09 ± 0.15**	0.33 ± 0.52	-1.14 ± 0.51**	1.33 ± 0.17**	3.13 ± 0.75**	Complementary
KDS-705 × JS-335	36.96 ± 0.07**	2.09 ± 0.12**	6.19 ± 0.38**	4.32 ± 0.37**	1.05 ± 0.14**	-0.31 ± 0.60	Duplicate
KDS-708 × JS-335	37.06 ± 0.07*	2.36 ± 0.16**	14.14 ± 0.44**	11.71 ± 0.42**	1.58 ± 0.17**	-12.43 ± 0.73**	Duplicate
Oil content (%)							
DS-228 × Type-49	17.97 ± 0.06**	0.82 ± 0.14*	0.32 ± 0.36	0.93 ± 0.35**	1.33 ± 0.14**	7.12 ± 0.61**	Complementary
KDS-705 × JS-335	17.93 ± 0.06**	1.05 ± 0.05**	4.84 ± 0.25**	4.16 ± 0.24**	1.44 ± 0.06**	0.15 ± 0.31	Complementary
KDS-708 × JS-335	18.02 ± 0.06**	-0.42 ± 0.08**	1.27 ± 0.30**	1.76 ± 0.29**	0.15 ± 0.08	-0.60 ± 0.41	Duplicate
Seed yield plant-1 (g)							
DS-228 × Type-49	36.79 ± 0.36**	-5.15 ± 0.36**	9.561 ± 1.63**	-17.93 ± 1.63**	-3.68 ± 0.36**	-2.34 ± 2.07	Duplicate
KDS-705 × JS-335	31.48 ± 0.34**	4.11 ± 0.28**	28.43 ± 1.48**	10.24 ± 1.46**	1.89 ± 0.30**	-40.10 ± 1.80**	Duplicate
KDS-708 × JS-335	34.45 ± 0.35**	5.70 ± 0.17**	25.14 ± 1.44**	2.90 ± 1.43**	3.60 ± 0.17**	-29.07 ± 1.58**	Duplicate

complementary epistasis, indicating that selection will not be effective as digenic epistatic interactions were detected.

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Effect of Methods of Tillage, Land Configurations and Sources of Nutrients on the Growth, Yield, Quality and Economics of Direct Seeded Rice (*Oryza sativa* L.)

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Abstract

From the two years research experiment conducted on "Effect of methods of tillage, land configurations and sources of nutrients on the performance of direct seeded rice (*Oryza sativa* L.)" was laid out in split-split plot design comprising 30 treatment combinations replicated thrice. The treatment flatbed (L₁) gave significantly the higher net monetary returns over rest of raised bed treatment. The yield contributing characters were observed to be significantly more and significantly more number of unfilled grain per panicle in treatment KAB with applying micronutrients (N₃) recorded higher values followed by treatment of Modified KAB in combination with micronutrients (N₄) which was at par with each other but significantly superior over rest of the treatments. Significantly the higher grain yield was found in treatment of KAB+ soil application of micronutrients (N₃) followed by treatment of application of modified KAB in combination with micronutrients (N₄) which were at par with each other but was observed to be significantly superior than the treatment of recommended dose of fertilizer (N₁) and recommended dose of fertilizer + soil application of micronutrients (N₂). Higher gross monetary returns were obtained by the treatment of N₃ followed by the treatment N₄ which were at par with each other but significantly superior over rest of the treatments. In the year 2014 treatment N₄ was followed by treatment N₂, N₁ and N₀ in descending order of significance while in the year 2015 treatments N₂ and N₁ were found to be at par with each other but significantly superior over treatment N₀. Net monetary returns of rice were significantly affected due to different sources of nutrient during both the years of study. The treatment N₃ gave significantly the highest net monetary returns but treatment N₃ was at par with treatment N₄ in the year 2015. The highest B: C ratio of 1.52 and 1.56 were recorded by the treatment combination T₁L₁N₃ i.e. conservation tillage with flat bed and application of KAB + along with soil application of Zinc sulphate 25 kg ha⁻¹ and Copper sulphate 5 kg ha⁻¹ over rest of treatment combinations.

Key words : Tillage, land configuration, nutrients, quality and economics.

Rice (*Oryza sativa* L.) is life for most of the people living in Asia. India is the world's second largest rice producer and consumer next to China. Total area under rice in India is 45.05 million hectares with annual production of 103.27 million tonnes, Though production is large, the per hectare yield is very poor i.e. 2.29 t ha⁻¹ as compared to other rice growing countries like Egypt (6.45 t ha⁻¹), USA (5.63 t ha⁻¹), Japan (4.73 t ha⁻¹) and China (4.74 t ha⁻¹). In Maharashtra, rice is cultivated over an area of 15.16 lakh hectares and an annual

production of about 28.78 lakh tonnes with a productivity of 1902 kg ha⁻¹. In Konkan, rice is cultivated over an area of 4.20 lakh hectares with an annual production of about 10.07 lakh tones with average productivity of 2.40 tones ha⁻¹ (Anonymous, 2013a). Dry direct seeded rice differs from transplanted rice in terms of crop establishment as well as subsequent crop management practices. Direct seeding offers certain advantages i.e., saves labour, faster and easier planting helps in timely sowing, less drudgery, early crop maturity by 7-10 days, less water requirements, high tolerance water deficit often higher yield, low production cost and less methane emission. Nambiar and Abrol, 1989

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reported that the puddling practices involve excessive tillage which, results not only in high energy consumption, but also deterioration in rice transplanting puddling decreases the soil aggregates and pore size, thereby restricting germination and rooting of the succeeding crop (Anonymous, 2013).

Direct sowing in the form of drilling is a quicker, easier, less soil movement and economical method which needs specific seed rate for optimum plant population taking into consideration local agro-ecological conditions. Paddy cultivation causes methane emission due to presence of biomass and water at the base of the crop. Direct seeding significantly reduces methane emission and offers an opportunity for farmers to earn from Carbon Credits. In recent years, conventional rice production technologies have been leading to deterioration of soil health and declining farm profitability due to high inputs of water and labor. Conservation agriculture (CA) based resource-conserving technologies i.e. zero-tillage (ZT), raised-bed planting and direct-seeded rice (DSR) has shown promise as alternatives to conventional production technologies to overcome these problems. Use of correct tillage methods may contribute to higher profits, crop yields, soil improvement and protection, weed control and optimum use of water resources since tillage has a direct impact on soil and water quality. Crop residues of previous crops if left on soil surface as mulch can suppress weeds in DSR through multiple mechanisms, including, creating a physical hindrance to emerging weeds or by releasing allelochemicals in the soil.

Zero tillage or reduce tillage establishment has therefore growing significance due to receding water table rising costs of labour for transplantation of paddy and adverse effects of puddling on the soil health. Conservation tillage is a set of practice that leaves crop residues on

the surface which increases water infiltration and reduces erosion. It is a practice used in conventional agriculture to reduce the effects of tillage on soil erosion. Surface mulch helps reduce water losses from the soil by evaporation and also helps moderate soil temperature. A cover crop or previous crop residue help reduce weed infestation through competition and not allowing weed seeds the light often needed for its germination. Mulch also helps with recycling of nutrients, especially when legume cover crops are used, through the association with below-ground biological agents and by providing food for microbial populations. Bed planting refers to a cropping system where the crop is grown on beds and the irrigation water is applied in furrows between the beds. This is common practice for row crops, but not for small grain crops such as wheat and rice. The conventional flat system of planting in rice with flood irrigation is a common practice in the Indo Gangetic Plains.

Therefore, it would be better if all the three major plant nutrients are used in the briquette form through the deep placement of briquettes containing N, P and K i.e. Urea-DAP, Urea-Godavari (14:35:14) and SSP-Suphala (15:15:15) briquettes in rice plants to use efficiently the applied nutrients by controlling their rate and duration of bioavailability and reducing their losses and nutrient use efficiency and uptake is increased. Accordingly, Konkan Annapurna Briquettes (KAB) developed by Dr. B.S.K.K.V., Dapoli by using Urea Godavari (14:35:14) in 1.5:1 ratio (1.5 Urea + 1 kg of 14:35:14 Godavari fertilizer) of 33.2:14:5.6 % NPK i.e. 56.14 N: 23.8 P: 9.52 K Kg ha⁻¹ used for rice crop. Copper (Cu) is involved in carbon assimilation and nitrogen metabolism having important function in plant metabolism as well as in utilization of ammoniac nitrogen by plants and regulates respiration in plants. Cu is involved in lignin biosynthesis which not only provides strength to cell walls but also prevents

wilting, leaf chlorosis, stunted growth and stem and twig dieback are common deficiency symptoms of Cu.

Materials and Methods

Two years research experiment was conducted during *Kharif* season of 2014 and 2015 to investigate the, "Effect of methods of tillage, land configurations and sources of nutrients on the performance of direct seeded rice (*Oryza sativa* L.)" at Agronomy Farm, College of Agriculture, Dapoli, Dist. Ratnagiri (M.S.). The soil of the experimental plot was clay loam in texture, moderately acidic in reaction, high in organic carbon content. In respect of micronutrients the soil was deficient in available zinc and copper content during the experimentation. The field experiment was laid out in split-split plot design comprising 30 treatment combinations replicated thrice. Main plot treatment consisted of three tillage methods i.e. Zero tillage (crop harvest at ground level) (T_0), Conservation tillage (stubble mulch) (T_1) and Conventional tillage (T_2). The sub plot treatment consisted of Land configuration i.e. flatbed (L_1) and raised bed (L_2) while, sub-sub plot treatment comprised of five sources of nutrients, Absolute control (no fertilizers) (N_0), recommended dose of fertilizer (100:50:50 NPK kg ha⁻¹) (N_1), Konkana Annapoorna Briquettes (56:24:10 NPK kg ha⁻¹) (N_2), Konkana Annapoorna Briquettes (56:24:10 NPK Kg ha⁻¹) with soil application of Zinc sulphate @ 25 kg ha⁻¹ and Copper sulphate @ 5 kg ha⁻¹ (N_3) and Modified Konkana Annapoorna Briquettes (46:20:8:8:1.5 N:P:K:Zn:Cu Kg ha⁻¹) (N_4).

The gross and net plot size of each treatment was 3.60 x 5.70 m and 3.15 x 5.40 m, respectively. Rice crop was directly sown at 22.5 cm spacing. While, flat bed consists of 16 Lines and raised bed consists of 12 lines, which was directly sown by drilling with the help of

drum seeder. The crop was fertilized with 100 kg N, 50 kg P₂O₅ and 50 kg K₂O ha⁻¹ in (N_1) RDF treatment. At the time of sowing of rice seed, 40 kg N dose and full dose of P₂O₅ and K₂O was applied as basal dose. Top dressing of 40 kg N dose was applied at 30 days after sowing and 20 kg at 50 days after sowing (at panicle initiation). In N_2 treatment Konkana Annapoorna Briquettes @ 175.00 kg ha⁻¹ was applied. In N_3 treatment Konkana Annapoorna Briquettes @ 175.00 kg ha⁻¹ in combination of Zinc sulphate @ 25 kg and 5 kg Copper sulphate ha⁻¹ was applied 14 days after direct seeding of rice seed with manual labour. Breeder seeds of rice variety Ratnagiri-1 (R-1) were obtained from Department of Agronomy. It is semi dwarf (100-105 cm), with dark green foliage and good tillering ability and moderately resistant to blast and neck blast. These seeds were treated with fungicide Thirum @ 3 g kg⁻¹ seeds.

Results and Discussion

Effect of methods of tillage : From the data presented in Table 1 it was observed that, height of the plant increased with the advancement in age of crop and numerically maximum height was observed in conventional tillage with flat bed at initial 20 DAS during both the years of investigation. Treatment conventional tillage (T_2) recorded higher plant height of rice crop followed by conservation tillage (T_1) which was at par with each other but recorded significantly superior over treatment zero tillage (T_0) at all the stages of growth except 20 DAS which might be due to more loose soil which might have facilitated more access to nutrients by roots which helped in establishing plant well, provided good conditions for germination and initial crop growth. These results are in agreement with those of Gangwar *et al.* (2008), Sahrawat *et al.* (2010).

From the data presented in Table 1 it was observed that, however, treatment conventional tillage (T_2) recorded higher number of tillers per 0.5 m length followed by treatment conservation tillage (T_1) which were at par with each other but significantly superior over treatment zero tillage (T_0) during both the years at 40, 60, 80 DAS and at harvest. It might be due to efficient utilization of nutrients at active tillering stage and availability of sufficient amount of light, water etc. in a comparatively larger net area for offshoot production. These results are in agreement with those of Choudhary and Singh 2007 and Awan *et al.* 2007.

Yield is a function of growth and yield attributes. From the data presented in Table 1 it was observed that, high production of total dry matter was first prerequisite for high yield. It is observed that the different tillage methods exhibit significant effect at all crop growth stages except at 20 DAS. The dry matter accumulation per 0.25 m length was highest in treatment conventional tillage (T_2), followed by treatment conservation tillage (T_1) which was at par with each other but found significantly superior over zero tillage (T_0) at all the growth stages except at 20 DAS of rice crop during both years of study.

Table 1. Effect of tillage methods, land configurations and sources of nutrient on growth and yield attributing characters of rice at harvest as influenced by different treatments during *Kharif* 2014 and 2015 (Pooled mean)

Treatment	Plant height (cm) at harvest	No. of tillers per 0.5 (m) length at harvest	Mean dry matter accumulation (g) at harvest	No. of panicles at harvest	Panicle length at harvest	Wt. of filled grains panicle ⁻¹	1000 grain wt. (g)
A. Tillage methods (T) :							
T_0 : Zero tillage	63.74	31.65	53.48	27.09	20.04	9.87	27.76
T_1 : Conservation tillage	70.34	34.84	58.64	29.59	21.68	10.99	29.34
T_2 : Conventional tillage	73.72	37.78	60.37	31.17	22.58	11.57	29.99
S.Em. \pm	1.10	0.79	1.15	0.46	0.34	0.23	0.22
C.D. at 5 %	4.30	3.09	4.53	1.78	1.32	0.88	0.85
B. Land Configurations (L) :							
L_1 : Flat Bed	71.17	35.96	58.59	29.92	21.90	11.21	29.61
L_2 : Raised Bed	67.36	33.56	56.41	28.70	20.97	10.42	28.45
S.Em. \pm	0.91	0.65	0.36	0.35	0.23	0.23	0.08
C.D. at 5%	3.13	2.23	1.24	1.20	0.77	0.81	0.26
C. Sources of Nutrients (N) :							
N_0 : Absolute control	62.80	30.89	51.16	26.22	18.33	9.57	27.27
N_1 : RDF	67.50	33.15	55.05	28.22	21.15	10.44	28.78
N_2 : RDF with soil application of micro.	68.57	34.48	57.45	29.14	21.71	10.73	29.01
N_3 : KAB with application of micro.	74.67	38.32	62.99	32.58	23.25	11.85	30.20
N_4 : Modified KAB in combination with micronutrients	72.79	36.96	60.82	31.79	22.73	11.46	29.90
S.Em. \pm	1.22	0.61	1.13	0.62	0.26	0.28	0.13
C.D. at 5%	3.46	1.73	3.22	1.78	0.73	0.79	0.37
D. Interaction effect :							
T x L	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
T x N	N.S.	N.S.	N.S.	N.S.	Sig.	N.S.	Sig.
L x N	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	Sig.
T x L x N	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
General mean	69.26	33.00	57.50	32.28	21.43	10.81	29.03

From the data presented in Table 1 it was observed that, Conventional tillage (T_2) recorded higher values of length of panicle, number of filled grains per panicle, weight of filled grains panicle⁻¹, 1000 grain weight (g) followed by treatment conservation tillage (T_1) which was observed to be at par with each other but recorded significantly superior over treatment zero tillage (T_0). However, significantly higher number of unfilled grains per panicle of rice was observed in treatment of zero tillage (T_0) followed by conservation tillage (T_1) and conventional tillage (T_2) in the year 2014 and 2015 (Table 1 and 2) during both the years of experimentation.

From the data presented in Table 2 it was observed that, significantly the highest grain yield of 44.41, 41.78 and 43.09 q ha⁻¹ during the years 2014, 2015 and in pooled analysis respectively, was recorded by treatment conventional tillage (T_2) followed by treatment conservation tillage (T_1) which was at par with each other but found significantly superior over treatment zero tillage (T_0). Increase in grain yield under conventional tillage was to the tune of 6.11, 0.24 and 3.18 per cent over conservation tillage and 22.51, 25.05 and 23.72 per cent over zero tillage during the years 2014, 2015 and in pooled data, respectively. Similar trend was also observed in straw yield during both the years of

Table 2. Mean grain, straw yield as influenced by different treatments of rice during the year 2014 and 2015 and in pooled data

Treatment	Grain yield (q ha ⁻¹)			Straw yield (q ha ⁻¹)		
	2014	2015	Pooled mean	2014	2015	Pooled mean
A. Tillage methods (T) :						
T_0 : Zero tillage	36.25	33.41	34.83	43.30	37.03	40.17
T_1 : Conservation tillage	41.85	41.68	41.77	49.35	45.15	47.25
T_2 : Conventional tillage	44.41	41.78	43.10	52.07	45.88	48.98
S.Em. \pm	1.13	1.11	1.12	1.44	1.56	1.50
C.D. at 5%	4.44	4.35	4.40	5.66	6.12	5.89
B. Land Configurations (L) :						
	D.					
L_1 : Flat Bed	43.6	41.74	42.67	51.51	45.88	48.70
L_2 : Raised Bed	38.08	36.16	37.12	44.97	39.5	42.24
S.Em. \pm	0.76	0.77	0.77	1.1	1.16	1.13
C.D. at 5%	2.63	2.65	2.64	4.12	4.03	4.08
C. Sources of Nutrient (N) :						
N_0 : Absolute control	28.34	28.1	28.22	33.86	30.61	32.24
N_1 : RDF	39.2	37.44	38.32	45.7	40.85	43.28
N_2 : RDF with soil application of micronutrients	41.6	39.65	40.63	48.71	43.33	46.02
N_3 : KAB with application of micronutrients	48.48	45.85	47.17	57.47	50.21	53.84
N_4 : Modified KAB in combination with micron	46.57	43.73	45.15	55.44	48.44	51.94
S.Em. \pm	0.95	0.93	0.94	1.12	1.06	1.09
C.D. at 5%	2.69	2.65	2.67	3.19	3.00	3.10
D. Interaction effect						
T x L	N.S.	N.S.	Sig.	N.S.	N.S.	Sig.
T x N	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
L x N	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
T x L x N	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
General mean	40.84	38.95	39.90	48.24	42.69	45.46

experimentation and in pooled analysis. It may be due to more availability of nutrients and soil moisture for the longer period reduces percolation losses of irrigation water in rice production. The increased yield attributes might be due to increased growth and development parameters which ultimately resulted in increased grain.

From the data presented in Table 3 it was observed that In respect of quality parameters, protein content of grain and straw the treatment conventional tillage (T₂) recorded higher protein content which was followed by treatment conservation tillage (T₁) which were at par with each other but found significantly superior over treatment zero tillage (T₀) during

both the years. These results are in close confirmation with the results reported by Kumar *et al.* (2005).

In case of economics, it was observed that treatment conventional tillage (T₂) recorded higher gross monetary returns and total cost of cultivation which were at par with conservation tillage (T₁) but recorded significantly superior over treatment zero tillage (T₀). Significantly the maximum net return and benefit cost ratio was recorded by conservation tillage followed by conventional tillage. The increase in net returns and benefit cost ratio under conservation tillage method were mainly due to lower cost of cultivation in direct seeded rice.

Table 3. Effect of methods of tillage, land configurations and sources of nutrient on the quality of grain & straw as influenced by different treatments of rice during the year 2014 and 2015 and in pooled data

Treatment	Protein content grain (%)			Protein content straw (%)		
	2014	2015	Pooled mean	2014	2015	Pooled mean
A. Tillage methods (T) :						
T ₀ : Zero tillage	5.89	5.91	5.90	2.28	2.19	2.24
T ₁ : Conservation tillage	6.67	6.58	6.63	2.38	2.37	2.38
T ₂ : Conventional tillage	7.17	7.07	7.12	2.52	2.46	2.49
S.Em. ±	0.15	0.14	0.15	0.03	0.03	0.03
C.D. at 5%	0.57	0.55	0.56	0.11	0.10	0.11
B. Land Configurations (L) :						
	D.					
L ₁ : Flat Bed	6.69	6.61	6.65	2.41	2.35	2.38
L ₂ : Raised Bed	6.47	6.42	6.45	2.34	2.31	2.33
S.Em. ±	0.09	0.09	0.09	0.013	0.016	0.015
C.D. at 5%	NS	NS	N.S.	NS	NS	N.S.
C. Sources of Nutrient (N) :						
	F.					
N ₀ : Absolute control	5.41	5.34	5.38	1.88	1.85	1.87
N ₁ : RDF	6.23	6.16	6.20	2.19	2.20	2.20
N ₂ : RDF with soil application of micronutrients	6.41	6.46	6.44	2.31	2.27	2.29
N ₃ : KAB with application of micronutrients	7.52	7.40	7.46	2.94	2.73	2.84
N ₄ : Modified KAB in combination with micron	7.32	7.23	7.28	2.65	2.66	2.66
S.Em. ±	0.17	0.13	0.15	0.027	0.040	0.03
C.D. at 5%	0.36	0.36	0.36	0.08	0.11	0.10
D. Interaction effect						
T x L	NS	NS	NS	NS	NS	NS
T x N	NS	NS	NS	NS	NS	NS
L x N	NS	NS	NS	NS	NS	NS
T x L X N	NS	NS	NS	NS	NS	NS
General mean	6.58	6.52	6.55	2.39	2.34	2.37

Effect of land configuration : Plant population per 0.5 m length at 20 DAS and at harvest in all the treatments did not differ significantly due to land configuration treatments under study. But when this plant count was converted on ha basis significantly less plant population in case of raised beds was observed. This was happened due to opening of 30 cm wide furrow between adjacent beds which caused 25 per cent reduction in plant population as compared to flat beds.

From the data presented in Table 1 it was observed that, it is seen from the data that though a remarkable influence of land configuration on the growth characters of rice crop was not observed during earlier growth period, a marked effect was observed during later growth period which coincided with grand growth stage. During this stage, growth and development parameters of rice *viz.*, plant height, number of tillers per 0.5 m length and dry matter accumulation (g) per 0.25 m length showed significant differences due to land configuration in direct seeded rice during both years of experimentation. The treatment flatbed recorded significantly more plant height, number of tillers per 0.5 m length and dry matter accumulation per 0.25 m length of rice over raised bed at all crop growth stages except at initial 20 DAS during both the years. The higher tiller production is due to better inducement of root growth for anchorage. It leads to better nutrient and water uptake and ultimately leads to higher number of tillers.

From the data presented in Table 1 it was observed that, in flat bed plant population of rice seedlings is more so dry matter accumulation is also higher as compared with raised bed, it might be due to better absorption of nutrients as a result of more foraging roots which ultimately led to higher dry matter accumulation also there is less weed competition for flat beds under high rainfall

condition which increased photosynthetic capacity of plant there by increasing the biological yield in terms of dry matter production. Similar findings were reported by Shelar (2014).

From the data presented in Table 1 it was observed that, the treatment flatbed recorded significantly the more number of panicle per 0.5 m length, highest length of panicle (g), highest number of filled grains per panicle, least number of unfilled grains per panicle, higher weight of filled grain per panicle and the higher 1000 grain weight than the raised bed treatment at all the growth stages of crop growth during the both year of investigation. These results are in agreement with the results reported by Singh and Kumar (2011) and Shelar (2014).

From the data presented in Table 1 it was observed that the grain yield of rice is a function of yield attributes of an individual plant *viz.*, number of panicles, length of panicle, number of filled grains per panicle, and test weight and ultimately the grain yield obtained from the plant. The increased yield attributes might be due to increased growth and development parameters which ultimately resulted in increased grain yield. Among land configurations, flat bed sowing produced more number of panicles than raised bed sowing. It might be due to the reason that each individual tiller enjoyed uniform supply of nutrients due to ample availability of space, light and aeration, The present results are in consonance with those of Kumar *et al.* (2005).

From the data presented in Table 2 it was observed that, it is revealed from the data that the flat bed treatment recorded significantly more grain yield of 43.60, 41.74 and 42.67 q ha⁻¹ during both the years and at par in pooled analysis respectively. Increased in grain yield due to treatment flatbed was to the tune of 4.85

Table 4. Effect of methods of tillage, land configuration and sources of nutrient on economics as influenced by different treatments of rice during the years 2014 and 2015 and in pooled data

Treatment	Gross monetary returns (Rs. ha ⁻¹)		Pooled mean		Cost of cultivation (Rs. ha ⁻¹)		Pooled mean		Net monetary returns (Rs. ha ⁻¹)		Pooled mean		B:C Ratio	
	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
A. Tillage methods (T) :														
T ₀ : Zero tillage	62535.83	57516.17	60026.00	58567.07	56656.63	57611.85	5427.71	4470.43	4949.07	1.06	1.04	1.05	1.04	1.05
T ₁ : Conservation tillage	71801.37	71535.80	71668.59	59272.63	57520.30	58396.47	14247.10	13368.92	13808.01	1.20	1.20	1.20	1.20	1.20
T ₂ : Conventional tillage	75744.80	71813.37	73779.09	71583.97	69117.83	70350.90	6314.49	5441.93	5878.21	1.05	1.06	1.06	1.06	1.06
S.Em. ±	2288.83	1937.75	2113.29	396.17	397.14	396.66	1622.43	1619.01	1620.72	0.03	0.03	0.03	0.03	0.03
C.D. at 5%	8987.05	7608.54	8297.80	1555.55	1559.38	1557.47	6370.44	6357.01	6363.73	0.12	0.10	0.11	0.10	0.11
B. Land Configuration (L) :														
L ₁ : Flat Bed	75054.73	71789.62	73422.18	62733.93	60741.11	61737.52	14587.84	12960.27	13774.06	1.18	1.16	1.17	1.16	1.17
L ₂ : Raised Bed	64999.93	62120.60	63560.27	63548.51	61455.40	62501.96	2738.36	2560.59	2649.48	1.04	1.02	1.03	1.02	1.03
S.Em. ±	1415.88	1355.45	1385.665	284.13	283.74	283.935	822.78	1195.44	1009.110	0.02	0.02	0.020	0.02	0.020
C.D. at 5%	4899.59	4690.46	4795.03	NS	NS	N.S.	2847.20	4136.77	3491.99	0.07	0.06	0.07	0.06	0.07
C. Sources of Nutrients (N) :														
N ₀ : Absolute control	48747.50	48255.89	48501.70	56102.61	54349.83	55226.22	-6050.37	-6826.48	-6438.43	0.88	0.87	0.88	0.87	0.88
N ₁ : RDF	66941.94	64331.17	65636.56	63758.72	61647.56	62703.14	4931.42	4173.23	4552.33	1.05	1.04	1.05	1.04	1.05
N ₂ : RDF with soil application of micro.	72166.28	67911.28	70038.78	62175.22	60270.94	61223.08	11392.01	9961.41	10676.71	1.16	1.14	1.15	1.14	1.15
N ₃ : KAB with application of micronutrients	82757.33	78832.72	80795.03	66721.61	64481.22	65601.42	19132.47	17497.02	18314.75	1.24	1.24	1.24	1.24	1.24
N ₄ : Modified KAB in combination with micronutrients	79523.61	75444.50	77484.06	66947.94	64741.72	65844.83	13909.96	13996.95	13953.46	1.18	1.19	1.19	1.18	1.19
S.Em. ±	1780.95	1577.95	1679.45	368.80	340.61	354.71	1153.00	1384.29	1268.65	0.02	0.02	0.02	0.02	0.02
C.D. at 5%	5064.09	4486.84	4775.47	1048.67	968.50	1008.59	3278.52	3936.17	3607.35	0.07	0.06	0.07	0.06	0.07
D. Interaction effect														
T x L	NS	NS	NS	Sig.	NS	NS	Sig.	NS	NS	NS	NS	NS	NS	NS
T x N	NS	Sig.	Sig.	NS	Sig.	Sig.	Sig.	Sig.	Sig.	NS	NS	Sig.	NS	Sig.
L x N	NS	NS	NS	Sig.	NS	NS	Sig.	NS	NS	NS	NS	NS	NS	NS
T x L x N	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
General mean	70027.33	66955.11	68491.22	63141.22	61098.26	62119.74	8663.10	7760.43	8211.77	1.10	1.08	1.09	1.08	1.09

per cent over raised bed (L_2). Similar trend was also observed with straw yield during both the years of experimentation and in pooled analysis.

From the data presented in Table 4 it was observed that, from economic analysis, significantly maximum gross monetary returns were obtained under flatbed (L_1) than the treatment of raised bed (L_2) during both years of study. While, in respect to cost of cultivation of rice were found to be non-significant during both the years of investigation. The treatment raised bed (L_2) recorded the higher cost of cultivation and net monetary returns during both years of investigation. The treatment flatbed (L_1) gave the highest benefit cost ratio which was followed by treatment of raised bed (L_2) during both years of study. These results are in agreement with those of Singh *et al.*, (2005).

Effect of sources of nutrient : Nutrients play very vital role in physiology of crop and essential for the transformation of carbohydrates and regulate consumption of sugars and play important role in enzyme activation. Therefore it is well emphasized that application of macronutrients along with micronutrients in recommended dose of application rates, significantly improved overall growth of the crop in terms of dry matter production per plant by virtue of its impact on morphological and photosynthetic components along with accumulation of nutrients.

From the data presented in Table 1 it was observed that, among various sources of nutrient treatment KAB with applying micronutrients (N_3) recorded higher plant height followed by treatment of Modified KAB (N_4) which was found to be at par with each other but significantly superior over rest of the treatments. Similarly treatment recommended dose of fertilizers along with micronutrients (N_3)

recorded higher plant height followed by treatment RDF (N_1) which was found to be at par with each other but significantly superior over treatment absolute control (N_0) at all the stages of crop growth except 20 DAS during both the years.

The enhancement in growth parameters could be due to the better and proper nourishment of the crop when fertilized through the briquettes. In case of application of Urea-DAP briquettes, it was placed deeply (5-6 cm) in reduced zone of soil layer so that it slowly get released essential plant nutrient into soil, mostly under puddled condition under rice crop. So, the maximum height under KAB briquettes was recorded due to maximum amount of nitrogen availability as compare to other treatments. Similar results were also obtained by Bulbule *et al.* (2005).

Significantly more number of tillers per 0.5 m length were recorded in treatment KAB with applying micronutrients (N_3) were significantly influenced at 40, 60, 80 DAS and at harvest but was observed to be non significant from 20 DAS. Treatment KAB with applying micronutrients (N_3) recorded higher plant height followed by treatment Modified KAB (N_4) which were at par with each other but significantly superior over rest of the treatments. However, treatment N_0 recorded significantly the lowest number of tillers per 0.5 m length at all the growth stages except 20 DAS in both the years of experimentation. Absorption of more nutrients in the treatment KAB briquettes resulted into vigorous growth through more number of leaves at all growth stages of crop. The highest number of tillers due to application KAB briquettes ultimately resulted into higher photosynthetic activity, the synthesis of higher amount of photosynthate by rice at all the crop growth stages. These results are in conformity with Virendra Kumar and Ladha (2011).

The dry matter accumulation (g) per 0.25 m length was significantly influenced by the various treatments. High production of total dry matter is the first prerequisite for high yield. Treatment KAB with soil application of micronutrients (N₃) recorded higher mean dry matter accumulation per 0.25 m length and significantly superior over N₀ and N₁ was at par with treatment application of modified KAB in combination with micronutrients (N₄) and N₂. Similar trend was found in pooled result. Whereas, significantly the highest number of panicle per 0.5 m length, length of panicle, number of filled grains per panicle, weight of filled grain per panicle, number of unfilled grains per panicle and 1000 grain weight was recorded in treatment N₃ and significantly superior over N₀ and N₁ and at par with treatment at N₄. Higher dry matter might be ultimately resulted into more transformations in the sink resulting into significantly higher yield attributes during both the years of experiment. These results are in the line with those reported by Mohanty (2004).

From the data presented in Table 2 it was observed that, significantly the highest grain yield was found in treatment of KAB + soil application of micronutrients (N₃) was significantly superior over all treatments except treatment application of modified KAB in combination with micronutrients (N₄). Treatment N₃ and N₄ was found to be at par with each other which were at par with each other, The increase in grain yield of rice may be accounted for significant improvement in yield attributes which finally converted into grain yield. Similar results were reported by Brar and Bullar (2013) and Bulbule *et al.* (2008).

From the data presented in Table 3 it was observed that, similar trend was recorded for protein content in both years and pooled analysis. This increase in protein content could

be attributed to increased concentration of nitrogen in grain and straw of rice under these fertilizer sources which augmented the synthesis of proteins and their content in grain and straw of rice. Similar results were also recorded by Singh and Namdeo (2004).

From the data presented in Table 4 it was observed that, the economics of different sources of nutrient showed that, higher gross monetary returns and cost of cultivation were obtained by the treatment of N₃ followed by the treatment N₄ which were at par with each other but significantly superior over rest of the treatments. These increased economic parameters were due to significant improvement in grain and straw yield of rice. Similar results were also reported by Bulbule *et al.* (2006). In case of benefit cost ratio treatment significantly maximum benefit: cost ratio were obtained by the treatment KAB + soil application of micronutrients (N₃) followed by application of modified KAB in combination with micronutrients (N₄), recommended dose of fertilizers along with micronutrients (N₂) and RDF (N₁) and significantly lowest benefit cost ratio in direct seeded rice was recorded in treatment absolute control (N₀) during both the years of experimentation.

For obtaining higher growth parameter and yield, maximum net monetary returns and benefit cost ratio from direct seeded rice it is be grown by conventional tillage method on flat bed system with use of KAB @175 kg ha⁻¹ in combination with soil application of zinc sulphate 25 kg ha⁻¹ and copper sulphate @ 5 kg ha⁻¹. Therefore, it can be concluded that direct seeded rice should be grown by adopting conservation tillage method on flat bed system along with the use of Konkan Annapurna Briquettes @ 175 kg ha⁻¹ in combination with soil application of zinc sulphate @ 25 kg ha⁻¹ and copper sulphate @ 5 kg ha⁻¹.

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Effect of Land Configurations, Establishment Techniques and Sources of Nutrients on Yield of *Suru* Sugarcane

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Abstract

Sugarcane is the second most important industrial crop of India with highest production of sugar after Brazil. India has to gear up to the new challenges of higher cane and sugar production to meet the future requirement. The field experiment was laid out in strip-split plot design comprising of 36 treatment combinations replicated thrice. Horizontal strips consisted of three land configurations. The vertical strips consisted of four establishment techniques with three sources of nutrients. The gross and net plot size of each treatment was 6.60 x 5.40 m and 6.00 x 3.60 m, respectively. Horizontal strips consist of land configurations viz., ridges and furrow (C₁), broad bed furrow (C₂) and flat bed (C₃). Vertical strips consist of establishment techniques viz., Planting two bud setts in field (M₁), planting single bud settlings raised in soil + FYM in 1:1 proportion (M₂), planting single bud settlings raised in soil + cocopeat in 1:1 proportion (M₃) and planting single bud settlings raised in soil + vermicompost in 1:1 proportion (M₄) and three sources of nutrients i.e application of 100% RDF through straight fertilizers (F₁), application of 75% RDF through Modified Konkan Annapurna briquettes 2:1:1 (F₂) and application of 50% RDF through modified Konkan Annapurna briquettes 2:1:1 (F₃). Numerically higher millable cane yield was recorded higher values of yield of sugarcane. Application of 100% RDF through straight fertilizers recorded significantly more millable cane yield over 50% RDF through modified Konkan Annapurna briquettes higher plant height, leaf area and dry matter accumulation followed by treatment of application of 75% RDF through Modified Konkan Annapurna briquettes but it was at par with application of 75% RDF through Modified Konkan Annapurna briquettes during both the years and in pooled data. Further, application of 50% RDF through modified Konkan Annapurna briquettes recorded significantly the lowest millable cane yield than other nutrient sources both the years and in pooled analysis. Thus for obtaining higher yield from sugarcane variety Co. 92005, it should be grown by paired row planting on ridges and furrows with drip irrigation by using single bud setting raised in soil+ FYM in 1:1 proportion and should be fertilized with recommended dose of fertilizers (250:125:125 NPK Kg ha⁻¹) through straight fertilizers.

Key words : Land configuration, establishment techniques, sources of nutrients, sugarcane.

Sugarcane, (*Saccharum officinarum* L.) is an old energy source for human beings and more recently, a partial replacement source as an alternative for fossil fuels and highly management responsive crop. It has been grown in South East Asia and Western India since 327 B.C. and has been an important crop in the Indian sub-continent since then. Sugarcane is the second most important industrial crop of India with highest production of sugar after Brazil. India has to gear up to the

new challenges of higher cane and sugar production to meet the future requirement. With the present trend of sugarcane and sugar production, India will hardly be able to meet 75 per cent of the projected requirement. Therefore, a sustained effort is needed to increase the present trend of cane production to such a level that India becomes a sugarcane surplus country. Determination of precise planting technique (land configuration) to improve uniformity in plant population and crop productivity in sugarcane is an important issue. Among different planting methods ridges

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and furrows planting method is much prevalent in Maharashtra. Paired row planting method (60:120 cm spacing) gave significantly higher cane yield than conventional (75 cm row spacing) planting. Furrow planting saves irrigation water and reduces crop lodging due to easiness in inter-culture and earthing-up operations. Sugarcane, being a high water demanding crop, receives great setback due to unpredictable behaviour of monsoon in sub tropical India. *Konkan* region is bestowed with assured rainfall with annual average of 3500 mm. In spite of such huge rainfall, the region faces scarcity of water after monsoon season. Thus, efficient use of water plays an important role for agricultural production in this region. Region has gained momentum in agro-tourism during last decade. Experimentation for several seasons had led to recommend *suru* plantation of sugarcane in *Konkan* during December to January. Large scale agro based Rasvanti business is flourishing in *Konkan* for about 200 days in a year. In this region large number of sugarcane crushers needs considerable quantity of sugarcane for extracting juice. Sugarcane is vegetative propagated through stem cuttings and stalk population is one of the most important components governing the cane yield which can be increased by adjusting the plant density. Both excess as well as deficit soil moisture conditions are harmful for crop growth. Therefore, proper monitoring and scheduling of irrigation are essential for achieving higher cane productivity. Scheduling of irrigation may vary with planting techniques. Thus it was imperative to find efficient use of water through irrigation scheduling in combination with planting methods.

Sugarcane being a non-conventional crop for farmers in *Konkan*, most of them go for a popular method of planting three budded setts conventionally. The recent studies at national

level have brought out the fact that the conventional method of planting three budded setts is costlier besides wastage of valuable seed material, poor germination as compared to recently evolved technique of (SSI) Sustainable Sugarcane Initiative. Use of single bud sugarcane setts as a planting material significantly improved the germination in nursery and tillering under field conditions as compared to two budded setts. Therefore, for avoiding wastage of seed material, to enhance germination, survival and tillering behavior single bud settlings should be prepared by using different germinating media.

The sugarcane is long duration and high yielding crop, gives response to fertilizer application. The high cost of manuring and fertilization is a basic problem in sugarcane cultivation. These difficulties need to be tackled through minimizing the present recommended dose of NPK fertilizer by increasing fertilizer use efficiency without sacrificing the cane yield. In view of this, to study the different land configurations with suitable establishment techniques and to increase the fertilizer use efficiency and assess the possibility of saving of fertilizers through briquette in sugarcane, the present investigation was conducted during *suru* seasons of 2014-2015 and 2015-2016.

Materials and Methods

The field experiment was conducted during the year 2014-15 and 2015-16 on *suru* sugarcane at the Agronomy Farm, College of Agriculture, Dapoli. The site was selected on the basis of suitability of soil for growing sugarcane. The plot used for experiment was uniform in topography with availability of drip irrigation facility. The field experiment was laid out in strip-split plot design comprising of 36 treatment combinations replicated thrice. Horizontal strips consisted of three land configurations *viz.*, Ridges and furrow (C₁),

Broad bed furrow (C_2), Flat bed (C_3). The Vertical strips consisted of four establishment techniques *viz.*, Planting two bud setts in field (*in situ*) (M_1), Planting single bud settlings raised in soil+ FYM in 1:1 proportion (M_2), Planting single bud settlings raised in soil + cocopeat in 1:1 proportion (M_3), Planting single bud settlings raised in soil + vermicompost in 1:1 proportion (M_4) and three sources of nutrients i.e. Application of 100% RDF through straight fertilizers (F_1), Application of 75% RDF through Modified Konkan Annapurna briquettes (2:1:1) (F_2), Application of 50% RDF through modified Konkan Annapurna briquettes (2:1:1) (F_3). The gross and net plot size of each treatment was 6.60 x 5.40 m and 6.00 x 3.60 m, respectively. The crop was fertilized with 250 kg N, 125 kg P_2O_5 and 125 kg K_2O hectare⁻¹ in (F_1) RDF treatment. At the time of planting 10 per cent dose of Nitrogen and entire dose of P_2O_5 and K_2O were applied by placement method just before planting of sugarcane crop. Remaining N were applied in three split doses @ 40, 10 and 40 per cent at an interval of six weeks from each preceding dose. Fertilizers were given in the form of straight fertilizers i.e. urea, single super phosphate and muriate of potash respectively. In case of treatment F_2 and F_3 , i.e. 75% and 50% RDF through Modified Konkan Annapurna Briquettes, briquettes were applied by deep placement method. Modified Konkan Annapurna Briquettes were applied @ 685 kg ha⁻¹ in treatment F_2 and 457 kg ha⁻¹ in treatment F_3 . Briquettes were prepared in 2:1:1 ratio (N:P:K) with help of briquette machine. 50% briquettes were applied at time of *in situ* planting and remaining 50% at 135 days after *in situ* planting with the help of crow bar at about 7 to 10 cm depth in soil. The holes were covered with soil. Single bud setts were prepared with the help of "Khilare sugarcane cutter" by cutting seed canes 2.5 cm above the bud and 5-6 cm below the bud. These single bud setts were sown in plastic portrays of 56 cm x 36 cm size having 42

rectangular cups with 70 mm length, 50 mm width and 75 mm depth. Single bud settlings were raised in soil along with different media *viz.*, F.Y.M, cocopeat and vermicompost as per treatments in 1:1 proportion by weight. The crop response to the different treatments under the present investigation was evaluated on the basis of growth, yield, quality and nutrient content and uptake of nutrient status of the soil after harvest of the crop.

Results and Discussion

Data regarding the millable cane yield (t ha⁻¹), green top weight, trash yield and biological yield (t ha⁻¹) as influenced by the different treatments, during the years 2014-15, 2015-16 and in pooled analysis are presented in Table 1.

Effect of land configurations : The millable cane yield, green top weight, trash yield and biological yield (t ha⁻¹) of sugarcane was not significantly influenced with different land configurations during both the years and in pooled analysis. Numerically higher millable cane yield was recorded by treatment ridges and furrows during both the years and in pooled analysis. Ridges and furrows method recorded higher values of yield of sugarcane. This might be due to proper utilization of rain water by the crop which improved overall growth and yield attributing characters and finally the yield. The evaluation carried out indicated that due to ridges and furrow planting, germination of eye buds as well as growth was not adversely affected by heavy and continuous rain as well as stagnant water. The furrow between two ridges also act as drainage channel through which excess water drains out from the field while at the end monsoon, these furrows support to conserve moisture. These findings are corroborated with the findings of Kumar *et al.* (2014) and Patil *et al.* (2010).

Effect of establishment techniques :

The various establishment techniques significantly influenced the millable cane yield, green top weight, trash yield and biological yield (t ha⁻¹) of sugarcane during the years 2014-15, 2015-16 and in pooled analysis. The planting of single bud settlings raised in soil + FYM recorded higher millable cane yield over rest of the establishment techniques followed by planting of two bud setts in field and planting of single bud settlings raised in soil +

vermicompost which were at par with each other but found significantly superior over planting of single bud settlings raised in soil + cocopeat during both the year and in pooled data. Significantly the highest millable cane yield, green top weight, trash yield and biological yield (t ha⁻¹) was recorded by treatment planting of two bud setts in field and planting of single bud settlings raised in soil + vermicompost in :1 proportion. This would be due to the fact that rooted settlings with rooting

Table 1. Effect of land configurations, establishment techniques and sources of nutrients on millable cane yield, green top weight, trash yield and biological yield of sugarcane at harvest

Treatments	Millable cane yield (t ha ⁻¹)			Green top weight (t ha ⁻¹)			Trash yield (t ha ⁻¹)			Biological yield (t ha ⁻¹)		
	2014	2015	Pooled	2014	2015	Pooled	2014	2015	Pooled	2014	2015	Pooled
Land configurations												
C ₁	116.77	118.11	117.44	14.71	15.08	14.89	8.46	9.47	9.96	139.94	142.66	141.30
C ₂	112.57	113.87	113.22	14.04	14.12	14.08	8.09	9.16	8.63	134.97	137.15	136.06
C ₃	110.36	112.13	111.25	13.68	14.27	13.97	8.09	9.09	8.59	132.13	135.49	133.81
S.E.±	3.794	4.567	2.68	0.502	0.511	0.35	0.263	0.287	0.19	4.283	5.944	2.88
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Establishment techniques												
M ₁	117.26	119.18	118.22	14.45	15.09	14.77	8.53	9.54	9.03	140.25	143.80	142.03
M ₂	122.15	123.09	122.62	15.37	15.62	15.50	8.88	9.97	9.43	146.78	148.69	147.73
M ₃	98.71	100.25	99.48	12.59	12.84	12.71	7.04	8.05	7.55	118.34	121.13	119.74
M ₄	114.81	116.31	115.56	14.15	14.40	14.28	8.39	9.40	8.89	137.35	140.11	138.73
S.E.±	4.601	4.152	2.72	0.372	0.522	0.32	0.354	0.362	0.25	5.343	5.478	3.10
C.D. at 5%	15.922	14.367	8.39	1.288	1.807	0.98	1.227	1.253	0.78	18.49	18.96	9.57
Sources of nutrient												
F ₁	119.37	121.15	120.26	15.65	15.90	15.77	8.55	9.61	9.08	143.57	146.67	145.12
F ₂	114.00	115.14	114.57	14.46	15.00	14.73	8.42	9.43	8.93	137.16	139.57	138.37
F ₃	106.32	107.82	107.07	12.31	12.56	12.44	7.67	8.68	8.17	126.30	129.06	127.68
S.E.±	2.027	2.181	1.33	0.411	0.363	0.52	0.165	0.189	0.11	2.297	2.535	1.47
C.D. at 5%	5.765	6.203	3.74	1.27	1.03	0.70	0.47	0.54	0.31	6.53	7.21	4.14
Interaction effect												
C x M	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C x F	SIG	SIG	SIG	NS	NS	NS	NS	NS	NS	NS	NS	NS
M x F	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C x M x F	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
General mean	112.94	114.52	113.73	14.14	14.49	14.31	8.21	9.24	8.72	135.29	138.25	136.77

C₁ : Ridges and furrows, C₂ : Broad bed furrow, C₃ : Flat bed, M₁ : *In situ*, M₂ : Soil + FYM, M₃ : Soil + cocopeat, M₄ : Soil + vermicompost, F₁ : 100% RDF, F₂ : 75% Konkan annapoorna briquettes, F₃ : 50% Konkan annapoorna briquettes

media were transferred to the field due to which related micro-organisms might have worked for favourable effects on crop by their activities in rhizosphere as plant growth promoting rhizomicrobes, which besides fixation of nutrients like N, mineralize native soil nutrients to available form and resist bacterial and fungal pathogens in respect of their pathogenic activities to the crop. The increased yield attributes might be due to increased growth and development parameters which ultimately resulted in increased yield. These results corroborated the findings of Jain *et al.* (2010) and Bhoopathi *et al.* (2000).

Effect of sources of nutrients : The sources of nutrients significantly influenced the millable cane yield, green top weight, trash yield and biological yield ($t\ ha^{-1}$) of sugarcane during both the years and in the pooled analysis. Application of 100% RDF through straight fertilizers recorded significantly more millable cane yield over 50% RDF through modified Konkan Annapurna briquettes but was at par with application of 75% RDF through modified Konkan Annapurna briquettes during both the years and in pooled data. Further, application of 50% RDF through modified Konkan Annapurna briquettes recorded significantly the lowest millable cane yield than other nutrient sources during both the years and in pooled analysis. Significantly the highest yield was found in application of 100% RDF through straight fertilizers and application of 75% RDF through Modified Konkan Annapurna briquettes which were at par with each other but was observed significantly superior over application of 50% RDF through modified Konkan Annapurna briquettes. The

increase in cane yield of sugarcane may be accounted for significant improvement in yield attributes which finally converted into yield. Similar results were reported by More *et al.* (2012) and Kumar *et al.* (2013).

For obtaining higher yield and profit from sugarcane variety Co. 92005, it should be grown by paired row planting on ridges and furrows with drip irrigation by using single bud settling raised in soil + FYM in 1:1 proportion should be fertilized with recommended dose of fertilizers (250:125:125 NPK $kg\ ha^{-1}$) through straight fertilizers.

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Identification of Molecular Markers Associated with Fertility Restoration in Cotton (*G. hirsutum* L.)

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Abstract

In various self-pollinating crop species, cytoplasmic male sterility (CMS) systems represent a valuable tool for the production of hybrid seeds. Use of a technique to rapidly distinguish between the sterile and fertile plants and confirmation of genetic purity of hybrids can save lot of time compared to the conventional field based evaluation. The objective of this research was to characterize the sterile, maintainer, restorer lines and hybrids of cotton using different molecular markers and to find the possibility of any of these markers being associated with fertility restoration in the newly developed cotton hybrids of the university. Different numbers of RAPD, ISSR and SSR markers were used for this purpose. Some of these SSR and all RAPD markers were earlier reported to be linked with the fertility restorer genes in different genetic background of cotton. Among these, one RAPD primer UBC607 and one SSR primer CIR222 showed presence of unique alleles in restorer line and hybrids, which were absent in CMS and maintainer lines of cotton used in this study confirming their association with fertility restoration. These markers can be used for characterization as well as a possible substitute for expensive grow out test for genetic purity of cotton hybrids used in this study.

Key words : Cotton; hybrids; molecular markers; fertility restoration; genetic purity.

Cotton belongs to the genus *Gossypium* of the Malvaceae family and consists of several species, majority of which are diploid ($2n=26$), while five are allotetraploid ($2n=52$). The commonly used cytoplasmic male sterility (CMS) in hybrid production is a maternally inherited trait in higher plants and is associated with the unique arrangements of mitochondrial DNA and unusual open reading frames in numerous species (Schnable and Wise 1998). Due to abnormal microsporogenesis or gametogenesis, CMS leads to sterile pollen or no pollen production. In order to produce commercial quantities of hybrid seeds without the need of hand emasculation this unique feature of CMS system has been used in many field crops including cotton (Kaul 1988; McVetty 1997).

Production of commercial F_1 cotton hybrids using CMS requires three breeding lines the A- B- and R- lines. The A- line is a male sterile line as it has a CMS cytoplasm and does not contain fertility restoring alleles. The B- line is a maintainer line as it is used as the pollen donor to increase seed of the A- line and has normal cytoplasm and no restorer alleles. The R- line is a restorer line and is genetically distinct from A- and B- lines as it is male fertile and homozygous for all necessary restorer alleles. In the field, F_1 hybrids are produced by planting alternating strips of A- and R- line plants and encouraging cross pollination, often by mechanical pollination or with the help of bees. Confirmation of hybridity of the newly developed F_1 s using conventional grow out test (GOT) is time consuming and the differences between true hybrids and off types for genetic purity analysis are not always apparent and cannot be recognised easily (Selvakumar *et al.* 2010). Moreover, conducting GOT is expensive

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and the hybrid seed cannot be made available in the market immediately which ultimately leads to the loss of seed viability (Ali *et al.* 2008).

Identification of molecular markers which are linked to the nuclear fertility restoration (*Rf*) genes could help breeders to efficiently distinguish male-sterile and fertile plants prior to flowering. These markers which are associated with genes are mainly useful in easy identification of desirable characters through marker assisted selection programmes. Molecular markers allow breeders to dissect complex traits without measuring the phenotypic characters every time, thereby reducing the burden of extensive field testing over time and space (Babu *et al.* 1996). There are two independent restorer genes in cotton, *Rf1* and *Rf2*. The literature search shows that several markers have been identified to be either linked with or in close vicinity of the fertility restorer genes in cotton. For instance, Guo *et al.* (1998) identified a random amplified polymorphic DNA (RAPD) marker, OPV 15-300 linked to *Rf1* while Lan *et al.* (1999) reported another RAPD marker UBC6592 linked to this gene and converted it into a restriction fragment length polymorphism marker. Liu *et al.* (2003) identified two RAPD and three simple sequence repeat (SSR) markers; whereas Zhang and Stewart (2004) reported another RAPD marker linked to this gene and converted it into a sequence tagged site (STS) marker. Similarly, Feng *et al.* (2005) developed four RAPD markers and converted them into STS markers with specific primer pairs. Yin *et al.* (2005) also reported five new SSR markers and two new STS markers and fine mapped the *Rf1* locus within a genetic distance of 0.9 cM using these markers. Use of these already known markers linked with the fertility restorer gene will not only save time, but also validates the suitability of these markers in the other genetic background.

Earlier RAPD markers have been used for the identification of genetic purity of the hybrids in cotton (Mehetre *et al.* 2004; Dongre and Parkhi 2005), sorghum (Akhare *et al.* 2008) and many other crops. Besides this, RAPD markers also proved to be an efficient technique for genetic fingerprinting of the cotton cultivars in the past (Multani and Lyon 1995), although in recent years, these markers are not preferred owing to the limitations associated with them. However, these markers can be converted to user friendly STS markers for their application in breeding programmes. On the other hand, inter simple sequence repeat (ISSR) is the reproducible marker system and has 92-95 % efficiency (Reddy *et al.* 2002) and have been used in genetic diversity and other studies in many crops including cotton. However, in self-pollinated crops with little intraspecific polymorphism SSRs are now considered as the marker of choice (Roder *et al.* 1998). The small repetitive DNA sequences in this marker system provide the basis for a PCR-based, multi-allelic, co-dominant genetic marker system. They have the ability to reveal high allelic diversity which is useful for distinguishing between closely related genotypes. Since CMS lines may play important role in cotton breeding, it is necessary to characterize these lines using molecular markers. Earlier, SSR markers have been successfully used for genetic purity testing of hybrids in many crops including cotton (Dongre *et al.* 2011) and soybean (Zang *et al.* 2014). The present study was aimed at molecular characterization of different sterile, maintainer, restorer lines and hybrids of cotton and to find the suitability of these known markers in identifying the fertility restorer gene in these cotton genotypes.

Material and Methods

The plant material used for the present investigation comprised of two *Gossypium hirsutum* L. hybrids MSRHH-0815 and

MSRHH-0823 along with their corresponding CMS lines (CMS 17A and CMS 19A), restorer line (AKH-2R) and two maintainer lines (17B and 19B). All these genotypes were procured from the Senior Cotton Breeder, All India Coordinated Cotton Improvement Project (AICCIP), Mahatma Phule Agricultural University, Rahuri, Maharashtra, India. The DNA was extracted from these cotton genotypes by following modified CTAB method (Saghai-Maroo *et al.* 1984) with required modifications.

In the present investigation, a total of 13 RAPD and 23 SSR markers earlier reported in literature in the studies involving cotton were used. All the RAPD and six of the 23 SSR markers were earlier reported to be linked to fertility restorer genes in different genetic background of cotton. In addition to this, 11 ISSR markers were also tried to find their suitability in distinguishing sterile and restorer lines. Amplification reaction mixtures for RAPD, ISSR and SSR primers were prepared separately in 0.2 ml thin walled flat capped PCR tubes. The total volume of each reaction mixture was 20 μ l. The PCR reactions were performed using a 20 μ l reaction mixture containing 10 x Taq DNA polymerase buffer A with MgCl₂, 25 mM MgCl₂, 10 mM dNTPs, 10 M Primer (RAPD/ISSR), while 10 M forward primer and 10 M reverse primer (SSR), 3 U Taq DNA polymerase, 40 ng template DNA and sterile distilled water. For DNA amplification using RAPD and ISSR primers, the thermal cycler (Eppendorf, Master cycler

gradient, Germany) was programmed as follows: initial denaturation at 95°C for 5 minutes; 40 cycles at 94°C for 1 minute (denaturation), temperature depending upon T_m of primer used for 1 minute (annealing) and 72°C for 1 minute (elongation), followed by one final extension cycle of 10 minutes at 72°C. For DNA amplification using SSR primers, the thermal cycler was programmed as follows: initial denaturation at 94°C for 5 minutes; 40 cycles at 94°C for 30 seconds (denaturation), temperature depending upon T_m of primer used for 30 seconds (annealing) and 72°C for 30 seconds (elongation), followed by one final extension cycle of 10 minutes at 72°C. After completion of the cycles the samples were kept at 4°C till electrophoresis. The PCR products of RAPD and ISSR primers were separated by electrophoresis on 1.2% (w/v) agarose gels while PCR products of SSR primers were separated on 2.5 % (w/v) agarose gels with 1 X TBE buffer containing ethidium bromide (1 mg 10⁻¹ ml). These PCR products were observed under UV transilluminator in gel documentation system and images were documented (M/s FluorChem™ Alpha Innotech, USA). The polymorphic markers were repeated for their reproducibility.

Results and Discussion

The clearly resolved PCR amplified products in cotton hybrids, their parents and maintainer lines with different markers were scored manually for their presence and absence. Only three RAPD primers were found polymorphic

Table 1. Details of polymorphic RAPD primers identified in the present study

RAPD primers	No. of alleles amplified	Polymorphic alleles	Monomorphic alleles	Polymorphic alleles (%)	Fragment size (bp)
UBC352	3	1	2	33.3	513 to 926
UBC607	4	1	3	25.0	500 to 1276
UBC722	5	1	4	20.0	521 to 2907

between different cotton lines. Details of these are given in Table 1. Out of 13 RAPD primers used, one primer UBC607 which was earlier reported to be linked with *Rf* gene amplified one unique allele in the restorer line (Table 1). In case of ISSR primers, one primer did not amplify, while the remaining ten primers were monomorphic suggesting that the ISSR primers used in the present study were not suitable for characterization of the cotton hybrids as well as their parental lines used in the present study. As ISSR primers were monomorphic, details of them are not given. In case of SSR analysis, out of total of twenty-three primer pairs used, four primers (BNL3090, JESPR230, BNL3580 and BNL1059) did not amplify. Remaining nineteen primers amplified, of which only eight showed polymorphism (Table 2). Less numbers of primers were found to be polymorphic, both in case of RAPD and SSR markers. This is expected as only A, B and R lines were used in the present study and most of the markers used were those which have been earlier reported to be either linked or mapped in the close vicinity of the *Rf* genes.

Identification of RAPD marker associated with fertility restoration : One RAPD marker, UBC607 amplified an allele of 500 bp in restorer line (AKH-2R) and hybrids (MSRHH-0815 and MSRHH-0823) (Fig. 1). This allele was absent in CMS lines (CMS 17A

and 19A) and corresponding maintainer lines (CMS 17B and 19B). Feng *et al.* (2005) previously identified four RAPD primers that co-segregated/ mapped in close vicinity with the fertility restorer gene *Rf1* in cotton. Of these four markers identified by them, UBC607 was the one which also amplified a polymorphic allele of 500 bp in their study. Thus the present investigation confirms association of UBC607 to restorer gene in restorer line AKH-2R and hybrids MSRHH-0815 and MSRHH-0823 of cotton used in this study. However, the other three RAPD markers reported to be co-segregating/in the close vicinity of the *Rf1* gene reported by Feng *et al.* (2005) and also used in the present study did not amplify any unique alleles. Moreover, the other two polymorphic RAPD markers (UBC352 and UBC722) could not clearly distinguish sterile and the restorer lines of cotton.

Identification of SSR marker associated with fertility restoration : The SSR marker CIR222 amplified unique alleles in the restorer line AKH-2R and the two hybrids MSRHH-0815 and MSRHH-0823. These two alleles were of 153 bp and 413 bp in size (Fig. 2). These alleles were absent in the two CMS lines and corresponding maintainer lines. Li *et al.* (2007) earlier identified five SSR markers

Table 2. Details of polymorphic SSR primers identified in the present study

SSR primers	No. of alleles amplified	Polymorphic alleles	Monomorphic alleles	Polymorphic alleles (%)	Fragment size (bp)
BNL1672	4	1	3	25.0	109 to 408
CIR354	6	1	5	16.6	125 to 729
BNL3435	6	4	2	66.6	130 to 1083
JESPR134	6	4	2	66.6	128 to 1071
BNL3867	3	2	1	66.6	127 to 377
CIR222	9	2	7	22.2	153 to 1038
NAU2135	9	1	8	11.1	203 to 1251
NAU1170	4	1	3	25.0	214 to 994

that were closely linked to Rf gene in Chinese-Jin A cotton. One of these markers was CIR222 which was also used in the present investigation and amplified two polymorphic alleles of 153 bp and 413 bp in restorer line AKH-2R and hybrids MSRHH-0815 and MSRHH-0823. Therefore, the present investigation confirms/validates association of SSR marker CIR222 with the restorer gene in restorer line and hybrids of cotton used in this study. Earlier, Nguyen *et al.* (2004) has mapped this SSR marker CIR222 onto linkage group D08. Although, eight SSR markers showed polymorphism in the different cotton genotypes, but only one primer (CIR222) could clearly distinguish sterile and fertile lines clearly.

The unique amplicons generated by RAPD primer UBC607 and SSR primer CIR222 in the restorer line and hybrids of cotton can be useful to identify plants with Rf gene at an early stage of plant development in these cotton hybrids. Similarly, these low cost markers can also be used as a possible substitute for the expensive and time consuming grow out test for genetic purity as well as confirmation of hybridity in the cotton hybrids used in the present study. Moreover, these markers can also be used for similar purposes where the restorer line AKH-2R is used as the male parent in the hybrid development programs. Further, these markers can also be useful to define the location of the restorer genes using these and other markers on the chromosome. Although, RAPD markers are not a preferred choice now a day, conversion of these markers in the form of user friendly STS can be very useful. The present study also highlights the importance of using already known markers linked with various genes for their use in the breeding programs, although all of them may not work in other genetic background.

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Economic Analysis of Cashewnut Plantation under EGS Linked Horticultural Development Programme in Konkan Region

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Abstract

The present study is based on primary data collected from 100 Cashew growers from Ratnagiri district of konkan region. The per hectare capital investment for establishing cashew orchard was Rs. 64,573.64. At an overall level, annual cost of maintenance of cashew orchard without and with subsidy was Rs. 36,683.6 and Rs. 33,517, respectively. At overall level, net returns from cashew orchard were Rs. 27,597.02. The analysis of financial feasibility of investment in cashew orchards showed that, the investment made without subsidy and with subsidy is financially viable with benefit cost ratio (BCR) greater than unity 1.38 and 1.63, respectively. Net present value (NPV) was positive (Rs. 30,237.75 and Rs. 93,040.56) in cashew. The internal rate of return (IRR) was higher (14.11% and 20.95%) than prevailing rate of interest. The payback period was 11 years and 8 years in both without and with subsidy respectively. The per hectare additional employment generated upto 15th year was 52.89 man days. The per hectare additional income generated through cashew was Rs. 38,065.10.

Key words : Maintenance cost, benefit cost ratio, net present value, and Internal rate of return.

The Government of Maharashtra realized the importance of fruit crops in employment generation and upliftment of poor marginal farmers and launched an ambitious Employment Guarantee Scheme linked Horticultural Development Programme in 1990-91. Fruit crops like mango, cashew, coconut, her, guava, orange, sweet lime and tamarind etc. are covered under the said programme. The main objectives of the programme are to generate sustainable employment on the farm itself, increase the production of high value crops, to increase the income and standard of living of farmers, to control soil erosion, to maintain ecological balance and to bring waste land under cultivation. From 1990-91, Government of Maharashtra has made huge investment on horticulture development in the state in general and Konkan region in particular. However, so

far no efforts have been made to evaluate the financial feasibility of investment and impact of this programme in Konkan region in particular. In view of this, attempt was made in the present study to assess the financial feasibility of investment in cashew plantation and to examine socio-economic impact of Horticultural Development Programme.

Materials and Method

Ratnagiri district from Konkan region is known for cultivation of cashew. The area under cashew in Ratnagiri district is 24308 hectare. In view of this Ratnagiri district was selected purposively for the present study. Considering the time limit and availability of secondary data, Dapoli tehsil from Ratnagiri district was selected purposively. On the basis of number of beneficiaries fifteen villages having maximum number of beneficiaries were selected purposively. From each village five beneficiaries were selected randomly. In

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addition the data on input utilization during establishment of cashew orchard i.e. up to five years were collected from 25 farmer who have old cashew orchards of various age groups were selected to collect data on maintenance of cashew orchard.

Estimation of investment on cashew orchard : Input wise cost of establishment was estimated for the first five years by integrating the expenditure over age of crop from planting to fifth year. The annual amortization cost was computed from the investment made on cashew orchard from the preparation of land for plantation to the first five years. Annual amortization cost was worked out by using the compounding cost formula and added it into respective cost for estimating the annual cost of maintenance of orchard.

$$a = \frac{p \times i(1 + i)^n}{(1 + i)^n - 1}$$

Where, a = amortization cost, p = establishment cost, i = interest rate, and n = time period.

Estimation of annual cost of maintenance : The growers have to incur expenditure for the maintenance of cashew orchard every year. The maintenance cost of the cashew was estimated by following standard cost concepts. Annual cost of cultivation comprises amortization and maintenance costs.

Financial evaluation of investment on cashew orchard : The financial evaluation of investment on cashew orchard was judged with following discounted measures.

i) Pay Back Period (PBP)

$$P = I / E$$

Where, P = Payback period of cashewnut in years, I = Investment on cashewnut in Rs. and

E = Annual net cash revenue in Rs.

ii) Net Present Value (NPV)

$$NPV = P_1 / (1+i)^{t1} + P_2 / (1+i)^{t2} + P_3 / (1+i)^{t3} + \dots + P_n / (1+i)^{tn} - C$$

Where, P_n = Net cash flow in nth year, i = discount rate, t = Life period and C - Initial cost of the investment.

i) Benefit Cost Ratio (BCR)

$$\sum_{t=0}^n B_t (1+r)^{-1} / \sum_{t=0}^n C_t (1+r)^{-1}$$

Where, B_t = Returns in period t, C_t = Cost in period t, r = discount rate and t = time period

ii) Internal Rate of Return (IRR)

Where,

$$IRR = \sum_{t=1}^n \frac{B_t - C_t}{(1+r)^t} = 0$$

Where, B_t = Benefit in year 'n', C_t = Cost in year 'n', r = discounting rate and t = time period

Estimation of income and employment generation : In Konkan region, varkas land is generally utilized for cultivation of crops like *nagli*, mango and cashew. Income from production of cashew was estimated. Similarly, income from varkas land utilized for *nagli* was estimated. The additional income from cashew plantation was estimated by deducting the income of *nagli* from income of cashew. Labour required for raising *nagli* was subtracted from the requirement of labour for cashew cultivation to ascertain additional employment generated due to cashew plantation.

Results and Discussion

Investment in cashew orchard : The horticultural crops requires certain gestation

period till they start yielding fruits. During gestation period farmers have to incur considerable expenditure for establishment of orchard. Similarly, farmers do not realize any returns from the orchards. Therefore, the cost of establishment of orchard can be regarded as capital cost. In the first five years of cashew, farmer has to incur the expenses on preparation of land, purchase of grafts and planting, watering, fencing, manures chemical fertilizers, etc. In view of this, an attempt has been made to assess the establishment cost of cashew orchard.

Establishment cost : Item wise per hectare establishment cost of cashew orchard is presented in Table 1. The per hectare cost incurred for establishing cashew orchard was Rs. 64,573.64. Out of this, labour cost accounted for 56.06 per cent. The expenses incurred on fencing, manures and chemical fertilizers, grafts, and plant protection were 23.47, 8.25, 5.88 and 3.67 per cent, respectively. The other inputs included cost on account of shade and support to plants which turned out to be 2.67 per cent of total cost of establishment of cashew orchard.

Further it is evident from Table 1 that, out of total cost of establishment of cashew orchard, 47.13 per cent cost was incurred in the first

year, 14.60 per cent in the second year, 12.88 per cent in the third year, and 25.39 per cent in fourth year. This indicated that the expenditure was maximum in the first year and it was found to be declining in subsequent years. Expenditure in the first year was more on labour, fencing, manures, fertilizers and grafts.

Annual cost of maintenance of cashew orchards : Once the gestation period is over, farmer has to incur expenditure on maintenance of orchard. In order to assess the impact of subsidy, the maintenance cost was estimated with and without subsidy. This will aid in assessing the impact of subsidy on financial feasibility of investment of cashew orchards.

Annual cost of cultivation of perennial horticulture crops comprises annual amortization and maintenance costs. The annual amortization cost was computed from the cost of establishment of cashew orchards, under the assumption that the rate of interest is 10 per cent and expected productive life of cashew orchards is 50 years. Average per hectare cost of maintenance of cashew with and without subsidy is presented in Table 2. The annual amortization cost per hectare was worked out to Rs. 6,457.46. The overall level, annual cost of maintenance of cashew orchard without and with subsidy was Rs. 36,683.60

Table 1. Itemwise per hectare establishment cost of cashew orchard (Figures in Rs.)

Particulars	1 st year	2 nd year	3 rd year	4 th year	Total
Human labour					
a) Family labour	1472.5 (4.84)	1419.6 (15.05)	1250 (15.03)	2708.6 (16.52)	6849.7 (10.61)
b) Hired labour	10541 (34.64)	5001.6 (53.04)	4817.9 (57.93)	8986 (54.81)	29346.5 (45.45)
Grafts	3400 (11.17)	250 (2.65)	150 (1.80)	-	3800 (5.88)
Manures and chemical fertilizers	2254.3 (7.41)	899.34 (9.54)	975 (11.72)	1200 (7.32)	5328.64 (8.25)
Plant protection	540 (1.77)	450 (4.77)	380 (4.57)	1000 (6.10)	2370 (3.67)
Fencing	12000 (39.43)	1290 (13.68)	563.8 (6.78)	1300 (7.93)	15153.8 (23.47)
Other	225 (0.74)	120 (1.27)	180 (2.16)	1200 (7.32)	1725 (2.67)
Total cost	30432.8 (100.00)	9430.54 (100.00)	8316.7 (100.00)	16394.6 (100.00)	64573.64 (100.00)

Figures in parentheses are percentages to total

and Rs. 33,517, respectively. The share of cost A and cost B in total cost of maintenance without subsidy was to the tune of 31.19 and 78.62 per cent, respectively. Whereas, the share of cost A and cost B in maintenance cost

with subsidy was 34.97 and 76.60 per cent, respectively. The foregoing analysis implied that there was reduction in the maintenance cost by about six per cent as a result of subsidy which is direct benefit to the cashew grower.

Table 2. Average per hectare cost of maintenance of cashew orchard without and with subsidy

Particulars	Overall					
	Without subsidy			With subsidy		
	Qty.	Rate (Rs.)	Amount (Rs.)	Qty.	Rate (Rs.)	Amount (Rs.)
Hired labour						
a) Male	21.03	150	3154.13 (8.60)	21.03	150	3154.13 (9.41)
b) Female	12.77	70	893.73 (2.43)	12.77	70	893.73 (2.67)
Human labour	33.80		4047.85 (11.03)	33.80		4047.85 (12.07)
Manures (tonnes)	5.99		3935.71 (10.73)	5.99		3935.71 (11.74)
Fertilizers (kg)	187.83		1851.90 (5.05)	187.83		1851.90 (5.52)
Plant Protection Chemicals (kg)			905.87 (2.47)			905.87 (2.70)
Land revenue		50	50.00(0.14)	50		500(0.15)
Depreciation			342.65 (0.93)			342.65(1.02)
Interest on working capital @6%			588.52(1.60)			588.52(1.75)
Cost A			11722.50 (31.19)			11722.50 (34.97)
Interest on fixed capital @10%			931.67(2.53)			931.67
Rental value of land (1/6th of the Gross Returns Minus Land Revenue)			9729.85 (26.52)			9729.85 (29.03)
Amortization cost			6457.46 (17.60)			3291.06 (9.82)
Cost B			28841.47 (78.62)			25675.07 (76.60)
Family labour						
Male	35.73	150	5359.50 (14.61)	35.73	150	5359.50 (15.99)
Female	18.72	70	1310.40 (3.57)	18.72	70	1310.40 (3.90)
Total	54.45		6669.90 (18.18)	54.45		6669.90 (19.90)
Supervision charges @ 10% of cost A			1172.25 (3.19)			1172.25 (3.50)
Cost C			36683.62 (100)			33517.22 (100)

Figures in parentheses are percentages to total

Table 3. Per hectare cost and returns from cashew orchard

Orchards	Age group	Yield (q ha ⁻¹)	Cost of cultivation (Rs. ha ⁻¹)	Gross returns (Rs. ha ⁻¹)	Net income (Rs. ha ⁻¹)
Cashew	5 to 10	18.023	35904.88	55838.35	19933.47
	11 to 20	25.45	39739.88	79531.25	39791.37
	21 to 40	22.58	34921.6	64488.48	29566.88
	Above 40	19.76	36168.11	57264.48	21096.37
	Overall	20.45	36683.62	64280.64	27597.02

Per hectare cost and returns from cashew orchard : In order to assess the financial feasibility of investment in horticultural crops, costs and returns over the life period of the crop are necessary. In view of this, an attempt was made to estimate costs and returns for different age groups of cashew orchard and same is presented in Table 3.

It could be seen from Table 3 that at an overall level, per hectare yield of cashew was estimated at 20.45q. Among the age groups of cashew, the per hectare yield was the highest (25.45 q) for 11-20 years age group and the lowest (19.76 q) for above 40 years age group. In the case of cashew yield per hectare increased upto 40 years and thereafter it started declining. At an overall level per hectare cost of cultivation of cashew orchards was Rs. 36,683.62 with net returns to the time of 27,597.02.

Financial feasibility of investment in cashew orchards : Unlike annual crops, investment on orchards demands vast resources and the flow of income are spread over a number of years. Also, once investment is made and resources committed no retrieval is possible. Therefore, to test the worthwhileness of the project cost and returns from the investment need to be analysed with a great deal of caution.

Taking into account the variation in cost of establishment and cost of maintenance the time series of cash out-flow (costs) and cash inflow (returns) were prepared for cashew crop. The cash flow statement was generated for cashew orchard by considering the economic life of 50 years and same was used for assessing financial feasibility. The financial feasibility parameters are presented in Table 4. The benefit cost ratio at 12 per cent discount rate was 1.38 without subsidy and 1.63 with subsidy, for cashew orchards. The net present value at 12 per cent

discount rate was Rs. 30237.75 and Rs.93040.56 without subsidy and with subsidy, respectively. The pay-back period was 11 years without subsidy and 8 years with subsidy. Internal rate of return was 14.11 per cent without subsidy and 20.95 per cent with subsidy.

The foregoing analysis revealed that the benefit cost ratios were more than unity at 12 per cent discount rate presumed. The net present value was positive and the internal rate of return was higher than the prevailing rate of interest. The pay back-periods were comparatively shorter. On the basis these financial feasibility parameters, it can be concluded that investment in cashew plantation is financially feasible.

Table 4. Financial feasibility of cashew without and with subsidy

Parameters	Without subsidy	With subsidy
Benefit cost ratio	1.38	1.63
Net present value (Rs.)	30,237.75	93,040.56
Internal rate of return (Per cent)	14.11	20.95
Pay-back period (Year)	11	8

Table 5. Per hectare employment and income generation (Figures in man days)

Year	Field crops (Nagli)	Cashew	Additional employment
A) Labour requirement			
1 to 4 year	340	328.69	-11.31
5 to 10 year	510	492.3	-17.7
11 to 15 year	425	506.9	81.9
Total	1275	1327.89	52.89
B) Income generation (Figures in Rs.)			
1 to 4	64000	-	-64000
5 to 10	96000	335030.1	239030.1
11 to 15	80000	285625	205625
Total	240000	620655.1	380655.1

Further it can be concluded that there was a positive impact of subsidy on financial feasibility parameters. The values of BCR, NPV and internal rate of return were greater than that of values without subsidy. The payback period with subsidy was less than pay back periods without subsidy. On the basis of these parameters it may be inferred that the impact of subsidy on these parameters is positive and cashew plantation is financially viable venture.

Impact of cashew plantation on employment generation : The state government has been implementing the programme to promote horticulture in the state through EGS linked horticultural development programme since 1990-91. One of the objectives of the said programme is to generate additional employment for the rural youths. In view of this, an attempt was made in the present study to evaluate this objective by estimating employment generation through horticultural plantation.

Information on employment generation in field crop and cashew is shown in Table 5. In order to assess the impact on employment generation, the employment would have been generated through field crop is compared with the employment generated through cashew. In general, the field crops like *nagli* and millets are grown on varkas land, which is also used for cashew cultivation.

Per hectare employment generation through cashew plantation : In is seen from Table 5 that, during the establishment period per hectare total employment generated through cashew plantation was 329 man days. Whereas, 340 man days employment would have been generated by growing field crops on the same piece of land. The per hectare total employment generated upto 15 year was 1327.89 man days which would have resulted in generation of additional employment to the tune 53 man days.

The foregoing analysis of employment generation revealed that there was positive impact of programme on employment generation in rural area.

Impact of programme on income generation : The attempt has been made in the present investigation to assess the impact of development programme on income generation. The information in this respect is shown in Table 5. In order to assess the impact of this programme on income, the income would have been generated through field crop i.e. *nagli* is compared with the income generated through cashew.

In is seen from Table 5 that, during the establishment period per hectare total increase in income through cashew plantation was zero. The per hectare total increase in income upto 15 year was Rs. 62,0655, which has resulted in generation of additional income to the tune Rs. 38,0655.

The study revealed that investment in cashew plantation is financially feasible and has resulted in generation of additional employment and income. The government should continue the programme in future to bring more and more uncultivable land under horticulture crop. Additional employment and income from horticultural crop will reduce rural-urban migration in Konkan region.

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Assessing Leaf Area Index of Wheat (*Triticum aestivum* L.) Crop with Hyperspectral Field Reflectance Measurements

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Abstract

The use of narrow band vegetation index: Normalized Difference Vegetation Index (NDVI) derived from hyperspectral measurements acquired by a field spectroradiometer was evaluated to estimate wheat (*Triticum aestivum* L.) leaf area index (LAI). A field study was conducted during the rabi season of 2012-2013 at Central Farm of the Mahatma Phule Krishi Vidyapeeth, Rahuri. The canopy spectral reflectance was measured using Spectroradiometer with spectral range from 350-2500 nm (1 nm interval) during the crop growth period. Plant Canopy Imager was used to measure leaf area index (LAI) using gap-fraction inversion procedure. The regression analysis was carried out for NDVI with LAI for wheat using linear, exponential, logarithmic and power relationships over crop growth period and R^2 values were found poor in 0.260-0.474 range for wheat. Exponential relationships were found significant with LAI when growth ($R^2=0.995$) and decline ($R^2=0.988$) phases were analysed independently. The developed exponential relationships could be used for the assessment of wheat LAI based on NDVI and in the crop evapotranspiration estimation algorithms applying remotely sensed observations.

Key words : Hyperspectral reflectance, spectroradiometer, NDVI, LAI, wheat.

Hyperspectral crop reflectance data are useful for several remote sensing applications in agriculture, but there is still a need for studies to define optimal wavebands to estimate crop biophysical parameters and spectral response of crops. The monitoring of agricultural crops during the development cycle is important to food security. Monitoring can be done observing the biophysical variables. One of

these biophysical variables that deserve attention is the leaf area index (LAI), that is related with crop evapotranspiration and crop yield (Sellers *et al.*, 1997; Xavier *et al.*, 2006). One way to estimate these biophysical parameters is by vegetation indices (VI). VI's are mathematical functions of reflected radiant flux in different spectral bands of remote sensing data (Jensen, 2007).

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Spectral vegetation behavior usually shows that plants absorb more solar energy in the

visible region with increasing biomass. The most frequently used bands for estimating VI are broad bands in red and near-infrared regions, because of the absorption of energy in the red region by leaves and reflectance and transmission of multiple energy scattering that occur on individual leaves and on plant canopy in near-infrared region (Goel, 1988). Therefore, vegetation indices such as normalized difference vegetation index (NDVI), the most frequently used vegetation index, are usually correlated with LAI and crop yield (Aparicio *et al.*, 2000; Serrano *et al.*, 2000; Thenkabail *et al.*, 2000; Elwadie *et al.* 2005; Eitel *et al.*, 2008; ; Raun *et al.*, 2008; Galvao *et al.*, 2009).

Hyperspectral remote sensing data has the potential to detect more variations on vegetation than multispectral data, because it uses narrow spectral channels of less than 10 nm (Thenkabail *et al.*, 2000; Stagakis *et al.*, 2010). These narrow channels allow the detection of detailed features, which could otherwise be disguised by broadband (Schmidt and Skidmore, 2003). Advances in the hyperspectral remote sensing technology are driving the development of new methods to analyze spectral reflectance data. Therefore, wheat spectral reflectance measurements were analyzed in terms of NDVI to estimate LAI during crop growth cycle for wheat crop.

Materials and Methods

The data required for this study were collected from Wheat (*Triticum aestivum* L.) field at located at 19°19'19.494" N and 74°39'16.873" E during *rabi* season of 2012-2013. Climatically the study area falls under the semi-arid and sub tropical zone with average annual rainfall of 566.5 mm. The annual average maximum and minimum temperature was 31.68°C and 15.48°C respectively. The annual average maximum and minimum

relative humidity was 61.13 and 34.63 %, respectively. The sunshine hours are in-between 4.40 to 9.10 hrs with annual average value of 7.81 hrs with annual average wind speed of 1.91 km hr⁻¹ during the crop growth period. The total rainfall during the crop growth periods was 260.40 mm. The pan evaporation varied from 4.40 to 9.10 mm day⁻¹ during the crop growth period. The average elevation of study area is 657m above the mean sea level. The prominent soil type is clay. The seed plot was selected for the study because all the standard cultivation practices were adopted during the crop growth period and the crop is maintained in unstressed condition. The wheat field was border-irrigated. The crop was sown in November 27, 2012 and harvested on March 26, 2013 and the data were recorded during this period.

Hyperspectral reflectance measurements : Spectroradiometers are widely used to collect spectral data and are designed to match the wavebands of different satellites' sensors (Agapiou *et al.*, 2010). Field reflectance measurements were performed over wheat field with the SVC HR-1024 spectroradiometer during the crop growth periods at an interval of seven days. The radiometric measurements were collected under clear-sky conditions between 12:00 and 14:00 hrs, at 60 to 80 cm above crop canopy, with the 25° field-of-view (FOV) optic fiber allowing 0.13 to 0.18 m spatial resolutions for each spectral measurement and all the measurements were taken from nadir view. Five spectral reflectance measurements from the most central part of each plot were taken with the spectroradiometer over the spectral range 350-2500 nm. A reference calibrated spectral on panel with 100 per cent reflectance was used to measure the incoming solar radiation as a reference one, while the measurement over the crops as 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 measurement to ensure reliable data collection. The same point was visited each time for taking observations over the crop growth period. These measurements were then used to simulate the narrow-bands and broad-bands from the spectral bands. Some bands in the spectral ranges 1350-1440 nm; 1790-1990 nm; and 2360-2500 nm were disconsidered due to atmospheric radiation absorption.

Leaf area index (LAI) measurements :

LAI is commonly used for monitoring crop growth. Instead of the traditional, direct and labor-consuming method of physically measuring the plant with a ruler (direct method), an optical instrument, Plant Canopy Imager CI-110 (CID Bio- Science Inc., USA) was used (indirect method). The CI-110 uses a fish eye camera, ceptometer and proprietary software to capture and analyze images of canopy data, PAR levels and GPS information. The gap-fraction inversion procedure (Norman and Campbell, 1989) was used to estimate LAI, canopy transmission coefficient and mean leaf angles. The software calculates the solar beam transmission coefficient using a user defined number of zenith and azimuth divisions. The output data is then displayed on the computer screen and can be saved into a file for further analysis. The LAI was estimated by analyzing the image with 5 zenith and azimuth divisions. The threshold contrast level was kept 95 with fish eye camera angle of 180°.

Normalized difference vegetation index and regression models : The reflectance measurements were re-sampled to 1nm wavelength and converted into in-band reflectance to make it comparable to the

reflectance that one should find after applying atmospheric and radiometric corrections to the satellite images. The data was converted into in-band reflectance so as to have the average values of the corresponding IRS LISS-III bands. After transforming the data into 'in band' reflectance of IRS LISS-III (B3: 620-680nm and B4: 770-860nm), the NDVI was calculated by using the equation proposed by Rouse *et al.* (1974).

$$\text{NDVI} = \frac{(B4 - B3)}{(B4 + B3)}$$

The regression analysis between leaf area index (LAI) and Normalized Difference Vegetation Index (NDVI) was carried out over the crop growth period (CGC) for wheat to

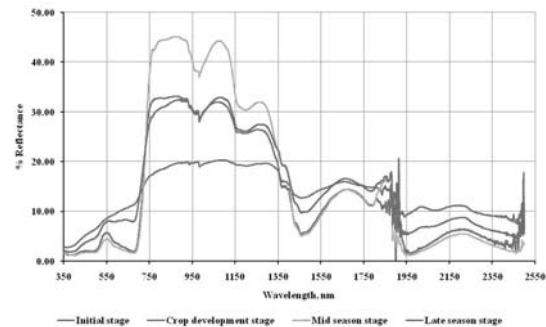


Fig. 1. Spectral reflectance of wheat at distinct growth stages

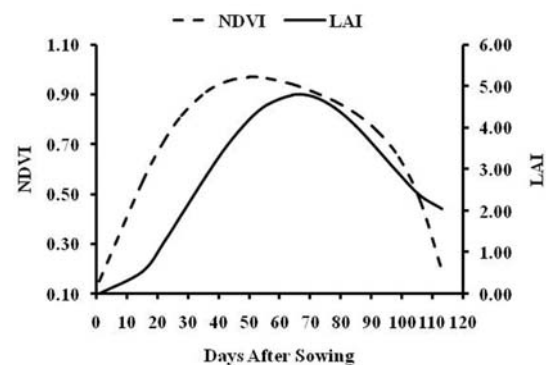


Fig. 2. LAI and NDVI profile for wheat during crop growth period

develop the relationship between LAI and NDVI. The regression relationships used were:

$$\text{LAI} = a (\text{NDVI}) + b \text{ (Linear)}$$

$$\text{LAI} = a e^{b(\text{NDVI})} \text{ (Exponential)}$$

$$\text{LAI} = a \ln(\text{NDVI}) + b \text{ (Logarithmic)}$$

$$\text{LAI} = a (\text{NDVI})^b \text{ (Power)}$$

where, 'a' is slope and 'b' is intercept.

The best fit regression relationship was found out based on the coefficient of determination (R^2), Root Mean Square Error (RMSE), Chi-square (χ^2) and Percent Error Modulus (PEM) values.

Results and Discussion

Spectral reflectance of wheat : The stagewise spectral reflectances of wheat crop between the wavelengths of 350 to 2500 nm are shown in Fig.1. Figure 1 shows the average spectral reflectance behavior at each growth stage for wheat. Spectral variations among

curves are mainly due to differences in crop growth stages. Lowest reflectance values in near infrared wavelengths (NIR: 700-1300 nm) were observed for the initial stage, where biomass is low and reflectance is influenced mainly by soil. Maximum reflectance in the NIR was observed for the crop development stage followed by mid-season stage, which is coincident with highest values of green leaf area index, consequently low reflectance of solar radiation in red wavelengths and high scattering of solar radiation in NIR (Moreira *et al.*, 1999). At late-season stage, reflectance in visible (VIS:350-700 nm) and NIR regions increase and decrease, respectively, when compared to the previous growth stages, which is mainly caused by the increase of senescent leaves. The visible region shows maximum reflectance at approximately 550 nm and lower reflectance in the blue region at 450 nm and red region at 680 nm. In general the spectral signatures of wheat crop shows low reflectance in visible and red region and the high reflectance in near infrared region.

Table 1. Results of regression analysis of LAI with NDVI for wheat over (a) whole crop growth period, (b) growth phase and (c) decline phase of LAI

Regression relationship	Slope 'a'	Intercept 'b'	R ²	RMSE	χ^2	PEM
(a) Whole crop growth period						
Linear	4.513	-0.288	0.474	-	-	-
Exponential	0.740	1.727	0.340	-	-	-
Logarithmic	2.491	3.945	0.381	-	-	-
Power	3.716	0.929	0.260	-	-	-
(b) Growth phase						
Linear	10.08	-5.729	0.938	3.605	1.617	3.075
Exponential	0.026	5.306	0.995	0.823	0.021	0.786
Logarithmic	7.594	4.174	0.902	3.536	7.017	13.024
Power	4.863	4.077	0.997	0.825	0.030	0.795
(c) Decline phase						
Linear	4.339	0.505	0.975	2.945	0.075	0.028
Exponential	1.340	1.321	0.988	0.389	0.003	0.002
Logarithmic	2.512	4.627	0.915	2.854	0.279	0.085
Power	4.725	0.777	0.957	0.393	0.016	0.038

NDVI and LAI for wheat : The NDVI values for wheat crop varied from 0.14 to 0.97 during the crop growth period. The LAI values for wheat crop varied from 0.52 to 4.78 during the crop growth period. Figure 2 shows the profile of variation of NDVI and LAI during the crop growth period of wheat.

Relationships between NDVI and LAI :

The regression analysis between leaf area index (LAI) and Normalized Difference Vegetation Index (NDVI) was carried out over the crop growth period (CGC) for wheat to develop the relationship between LAI and NDVI. The LAI-NDVI relationships developed are presented in Table 1 (a, b, c). The part 'a' of Table 1 presents the results of regression analysis carried out considering total crop growth period. The R^2 values were found poor in 0.26-0.47 range for wheat when total crop growth period is considered. In general, R^2 values were not significant, as temporal profile of LAI and NDVI were nonlinear. The regression relationships could be improved if growth and decline phases be analysed separately (Gupta *et al.* 2006). The part 'b' and 'c' of Table 1 gives the results of regression analysis for growth and decline phases, respectively. The R^2 values were in 0.90-0.99 range and 0.91-0.98 range for growth and decline phase respectively.

It is observed from Table 1(b) that, the exponential relationships developed for wheat crop during growth phase indicated the goodness of fit as per the lower value of χ^2 (0.021). It is observed that the value of coefficient of determination ($R^2 = 0.995$) is maximum, RMSE (0.823) and PEM (0.786) are minimum for exponential relationship. Hence, exponential relationship is best fit for estimation of LAI from the NDVI during growth phase. The exponential relationship developed for wheat crop during decline phase indicated the goodness of fit as per the lower value of χ^2 (0.003). It is observed that the value of

coefficient of determination ($R^2 = 0.988$) was maximum, RMSE (0.389) and PEM (0.002) is minimum for the exponential relationship. Hence, exponential relationship is best fit for estimation of LAI from the NDVI during decline phase for wheat.

The exponential relationships were found best suitable for the estimation of the LAI from NDVI during growth ($LAI=0.026e^{5.306(NDVI)}$) and decline ($LAI=1.340e^{1.321(NDVI)}$) phases for wheat. The developed exponential relationships could be used for the assessment of wheat LAI based on NDVI and in the crop evapotranspiration estimation algorithms applying remotely sensed observations.

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Modelling of mass transfer during osmotic dehydration of aonla slices (*Emblica officinalis* Gaertn.) Cv. NA-7

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Abstract

The study on osmotic dehydration of aonla slices of NA-7 variety was carried out in order to remove partial moisture prior to mechanical drying. Three sugar syrup concentration levels (50, 60 and 70°Brix), three temperatures levels of osmotic solution (40, 50 and 60°C) and constant solution to fruit ratio of 6:1 (v/w) were selected and observations on water loss and solute gain were taken at an interval of 15, 30, 60, 90, 120, 180 and 240 min. A two parameter mathematical model developed by Azuara *et al.* (1992) was used for describing the mass transfer in osmotic dehydration of aonla slices. The effect of immersion time on mass transfer was investigated and constants of two parameter model and final equilibrium points for water loss and solute gain were determined. The water loss from and solute gain by the aonla slices increased non-linearly with the duration of osmosis at all sugar syrup concentrations and both were higher in the initial period of osmosis than the later period. Further, both were increased with increasing sugar concentration. Model was able to predict mass transfer data of osmotic dehydration up to the equilibrium point using data of relatively short duration of osmosis.

Key words : Aonla, modelling, equilibrium water loss, equilibrium solute gain.

Osmotic dehydration (OD) of food got attention due to its importance in food processing industries. OD is a process for the partial removal of water from plant tissues such as fruits and vegetables by immersion in an aqueous concentrated solution of soluble salts. A driving force for the diffusion of water from the tissue into the solution is provided by the difference in osmotic pressure or concentration gradient between the food and surrounding osmotic solution. A diffusion of water is accompanied by the simultaneous counter diffusion of solute from the osmotic solution into the tissue. Since the membrane responsible for the osmotic transport is not perfectly selective, other solutes such as sugar, organic acids, minerals, salts and vitamins present in the cells can also be leached into the osmotic solution (Giangiacomo *et al.*, 1987 and Tortoe

et al., 2007). But this flow can be quantitatively neglected.

The rate of mass transfer (water loss and solute gain) was found to be a function of many variables such as solution temperature, solution concentration, composition of osmotic solution, immersion time, nature of food and its geometry, solution to fruit ratio. A large number of studies are available in literature regarding the influence of different osmotic parameters on the rate and amount of mass transfer based on specific food geometry for fruits and vegetables such as banana (Pokharkar and Prasad, 1998), radish (Herman-Lara *et al.*, 2012), apple, banana and potato (Tortoe *et al.*, 2011), papaya (Jain *et al.*, 2011). They have developed and reported several equations based on Fick's second law of diffusion. Further the equations developed for osmotic dehydration (Beristain *et al.*, 1990; Ertekin and Cakaloz, 1996 and Chenlo *et al.*,

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2006) were usually for specific processing conditions and geometric considerations and can't predict the end equilibrium point of the process. Several proposed equations based on Fick's second law are not useful practically due to the fact that some of the assumptions are unrealistic and also due to complexity of equations. Mathematical modelling of mass fluxes during osmotic dehydration process gives invaluable information to have clearer understanding of dehydrated material composition and operational design. Azuara *et al.* (1992) recommended simpler empirical equation including parameters with physical meaning. This empirical equation has been used to model the rate of dehydration of different plant-based materials (Schmit *et al.*, 2009 and Mercali *et al.*, 2010). However, in literature, the suitability of this equation to model the osmotic dehydration rate of aonla is scarce. Aonla is known for exceptionally high amount of ascorbic acid and is important fruit also highly valued among Indian medicines. Therefore, the present study was undertaken to investigate the effect of osmotic process parameters on mass transfer kinetics of aonla slices and to develop the mathematical model for water loss and solute gain in the form of Azuara *et al.* (1992).

Materials and Methods

Fresh aonla fruits of variety NA-7 (Neelam) were procured from an orchard of Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri (India). The aonla fruits were sorted for uniform size (32.5 ± 1 mm), colour, maturity and physical damage; washed with potable water and then wiped with a muslin cloth to remove surface moisture. Fruits were blanched in boiling water for 5 min and cut to 5 mm thick uniform slices with specially designed radial type aonla cutter. Cut slices were separated with a sharp stainless steel knife and held in water until the entire batch was

prepared to prevent enzymatic browning. Slices were then removed from the water and gently blotted with tissue paper prior to osmotic drying and determination of moisture content. Moisture content of the fresh as well as osmotically dehydrated aonla slices were determined by vacuum oven method. A pre weighed 3-5 g sample of aonla slices was kept in pre-dried and weighed petri-dishes. The

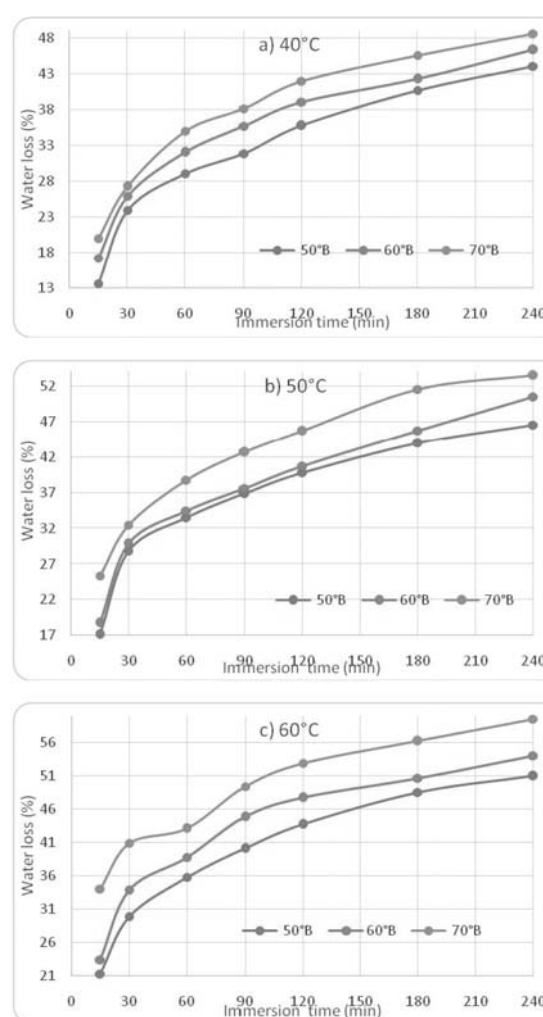


Fig. 1. Effect of immersion time and sugar concentration on water loss (%) at 6:1 STFR (v/w) during osmotic dehydration of aonla slices at a) 40; b) 50 and c) 60°C

petri-dishes with samples were placed in vacuum oven at 70°C maintaining vacuum between 85 to 100 mm of Hg till it attained constant weight. Petri-dishes were then cooled in desiccators for one hour and weighed. Average moisture content of three replicated samples was recorded (Ranganna, 2005).

Preparation of sugar syrup as osmotic agent : Sugar syrups of three concentrations (50, 60 and 70°B) were prepared by dissolving known quantity of sugar in distilled water using glass rod as stirrer. Concentration of sugar syrup was checked by using hand refractometer (Erma Japan make) of appropriate range (0-32, 28-62 and 58-92°B). Sugar was procured from local market and used as osmotic agent as it prevents food discolouration to a large extent and imparts good taste to the final product.

Experimental procedure : In osmotic dehydration, a sample of aonla slices of 5 mm thickness each weighing 75 g were prepared. Constant syrup to fruit ratio (STFR) of 6:1 (v/w) was used. The 500 mL capacity glass beakers containing sugar syrup (50, 60 and 70°B) were placed inside the constant temperature circulatory water bath (Make: Classic Scientific India, Thane) at (40, 50 and 60 °C) and slices were put into the syrup after attainment of desired temperature. Sodium metabisulphite (0.1%) was added to each beaker containing the syrup. For every 15, 30, 60, 90, 120, 180 and 240 minutes interval of time, one glass beaker was removed from the water bath and the aonla slices were immediately rinsed with distilled water to remove the solute adhered to fruit surface. Then slices were spread on the tissue paper for 5 min to remove the surface moisture. The weight of osmotically dehydrated aonla slices was recorded. Slices were then put in pre-weighed petri-dish for moisture determination by vacuum oven method. Each treatment replicated thrice and average moisture content was recorded.

Osmotic dehydration parameters : Water loss and solute gain were calculated using the equations given by Pokharkar and Prasad (1998).

$$WL = \frac{W_i X_i - W_0 X_0}{W_i} \quad \dots(1)$$

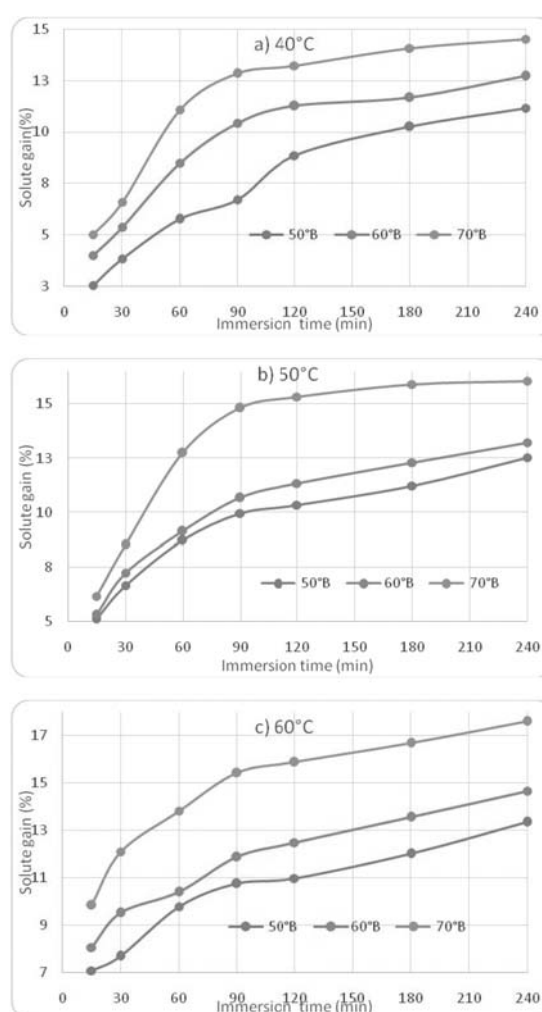


Fig. 2. Effect of immersion time and sugar concentration on solute gain (%) at 6:1 STFR (v/w) during osmotic dehydration of aonla slices at a) 40; b) 50 and c) 60°C

$$SG = \frac{W_\theta (1 - X_\theta) - (W_i - X_i)}{W_i} \dots (2)$$

Where, WL = Water loss (% or g per 100 g mass of sample), SG = Solute gain (% or g per 100 g mass of sample), W_θ = Mass of slices after time θ , g, W_i = Initial mass of slices, g, X_θ = Water content as a fraction of mass of slices at time θ and X_i = Water content as a fraction of initial mass of slices, fraction.

Modelling of mass transfer kinetics :

Azuara *et al.* (1992) developed a two-parameter model for water loss and solute gain, which was able to estimate the equilibrium point using data, obtained during a relatively short period of osmosis and was successfully used to predict the entire osmotic dehydration process up to the equilibrium point. Further, the model could characterize osmotic dehydration of different types of foodstuffs without restrictions of geometric considerations. Therefore, it was decided to develop the mathematical model for osmotic dehydration of aonla slices in the form of equation proposed by Azuara *et al.* (1992) based on experimental mean data of three replications for water loss and solute gain.

Water loss : A two-parameter equation developed by Azuara *et al.* (1992) for water loss could be written as,

$$WL_t = \frac{Kt (WL_\infty)}{1 + kt} = \frac{(WL_\infty) t}{(1/k) + t} \dots (3)$$

Where, WL_t = Fraction of water lost by sample at any time t (%), k = Constant related to the rate of water diffusion out from the product, t = Time (min) and WL_∞ = Fraction of water lost by sample at equilibrium.

During the osmotic dehydration of aonla slices, the constants k and water loss at

equilibrium could be determined by linear regression, using experimental data. The linear form is

$$\frac{t}{WL_t} = \frac{1}{k(WL_\infty)} + \frac{t}{WL_\infty} \dots (4)$$

Solute gain : A two-parameter equation developed by Azuara *et al.* (1992) for solute gain could be written as,

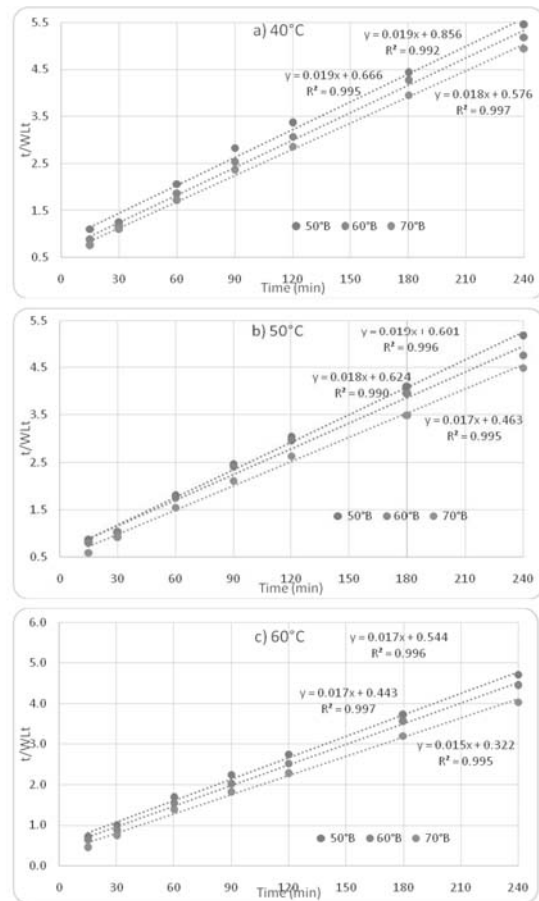


Fig. 3. Linear plots of Azuraet al. model for determination of WL_∞ and k at different sugar syrup concentrations at 6:1 STFR during osmotic dehydration of aonla slices (at a) 40; b) 50 and c) 60°C.

$$SG_t = \frac{kt(SG_\infty)}{1 + kt} = \frac{(SG_t) t}{(1/k) + t} \dots (5)$$

During the osmotic dehydration of aonla slices, the constants k and solute gain at equilibrium could be determined by linear regression, using experimental data obtained. The linear form is,

$$\frac{t}{SG_t} = \frac{1}{k(SG_\infty)} + \frac{t}{SG_\infty} \text{ (linear form). (6)}$$

Where, SG_t = Solute gain fraction at any time (%), k = Constant related to the rate of solute diffusion in the product, t = Time (min), SG_∞ = Fraction of solute gain by the sample at equilibrium.

Furthermore, as the time (t) becomes much greater than the values of $1/k$ (i.e. $t = \infty$), the water loss or the solute gain (WL_t or SG_t) approaches equilibrium value (WL_∞ or SG_∞) asymptotically. Thus, if the experimental plot of t/WL_t and t/SG_t respectively against t shows linearity, then the parameter values could be determined from the intercept and the slope. The model (Eqn. 4 and 6) were used to predict the mass transfer kinetics.

Verification of model for osmotic mass transfer kinetics : Model was validated by fitting the experimental water loss ratio (WL_t/WL_∞)_{expt.} at different immersion times to the water loss ratio (WL_t/WL_∞)_{pred.} predicted by the proposed model. Model was assessed for goodness of fit on the basis of highest coefficient of determination (R^2), adjusted coefficient of determination (Adj. R^2), lowest chi-square statistic, root mean square error (RMSE), mean bias error (MBE) and per cent error modulus. According to Deng and Zhao (2008) a model with per cent error modulus less than 10 per cent is considered acceptable. Similar procedure was adopted in validating the solute gain ratio.

Results and Discussion

Effect of osmotic dehydration process parameters on water loss and solute gain : Average initial moisture content of fresh aonla fruits of variety NA-7 was found 86.101 (% w. b.). Water loss and solute gain both were found in the range of 13.60 to 59.52 and 2.53 to 17.10 per cent, respectively during 4 hr osmosis.

Data of water loss and solute gain as influenced by various sugar syrup

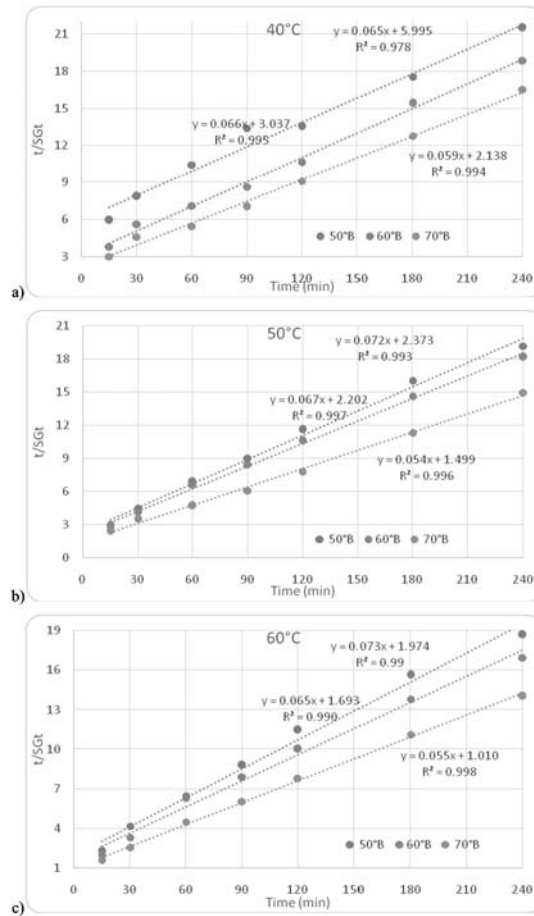


Fig. 4. Linear plots of Azuraet al. model for determination of SG_∞ and k at different sugar syrup concentrations at 6:1 STFR during osmotic dehydration of aonla slices at a) 40; b) 50 and c) 60°C

concentrations, sugar syrup temperatures (40, 50 and 60°C) and immersion time (15, 30, 60, 90, 120, 180 and 240 min) during osmotic dehydration of aonla slices is plotted in Fig. 1 and 2. Water loss and solute gain increased non-linearly with immersion time at all concentrations (50, 60 and 70°B). Similar trends were also observed for other temperatures (40, 50 and 60°C). Water loss and solute gain were very fast at the beginning of the process and rate was gradually decreased with the increase of immersion time for all the treatment combinations. It can be further seen that as the immersion time increased the water loss was increased; however, the equilibrium point could not be reached after short duration (4 h) of the osmotic dehydration process. This result is in confirmation with Lenart and Flink (1984); Alam and Singh (2008) and Jain *et al.* (2011).

This may be due to rapid water loss or solute uptake near the surface in the beginning might have resulted in structural changes leading to compaction of these surface layers and increased mass transfer resistance for solutes uptake (Lenart and Flink, 1984). Similar trends have been reported for other fruits and vegetables during osmosis by Sutar and Gupta (2007) and Ertekin and Cakaloz (1996).

Modelling of mass transfer on the basis of immersion time :

Inadequate control of product characteristics results in major difficulties regarding process Modelling. Raw material variability is probably the most crucial source of deviations. Variety, maturity level, even cultivation practices drastically affect the composition and barrier properties of a specific fruit or vegetable. The complex non-homogeneous structure of natural tissues seriously complicates any effort to study and understand the mass transport mechanisms of several interacting counter flows (water, osmotic solutes and soluble product solids). Further several factors like solution concentration, temperature, immersion time, sample size and shape, solution to sample ratio and applied pre-treatments affect the kinetics of mass transport.

A two parameter equation based on mass balance developed by Azuara *et al.* (1992) was used to predict the dehydration kinetics during osmosis process and to determine final equilibrium point. This empirical equation have been used to model the water loss and solute gain obtained experimentally at temperatures (40, 50 and 60°C), concentrations (50, 60 and 70°B) and immersion time (15, 30, 60, 90, 120, 180 and 240 min) at STFR 6:1 (v/w)

Table 1. Azura *et al.* model parameters and goodness of fit for water loss

Temp. (°C)	Conc. (°B)	k	WI _∞ (%)	R ²	Adj R ²	P	χ ²	RMSE	MBE	% error modulus
40	50	0.0230 ± 0.0008	50.72	0.992	0.991	2.00E-06	0.053	0.154	-3.00E-17	1.3943
	60	0.0292 ± 0.0006	51.48	0.996	0.995	4.00E-07	0.029	0.116	-6.00E-16	1.3414
	70	0.0322 ± 0.0004	53.85	0.997	0.997	1.00E-07	0.022	0.086	-2.00E-16	1.3543
50	50	0.0322 ± 0.0005	51.66	0.997	0.996	2.00E-07	0.027	0.099	1.70E-16	1.1029
	60	0.0288 ± 0.0008	55.59	0.990	0.988	3.00E-06	0.062	0.159	-2.00E-16	2.1843
	70	0.0368 ± 0.0005	58.58	0.995	0.994	5.00E-07	0.041	0.106	-2.00E-16	2.2986
60	50	0.0324 ± 0.0005	56.66	0.996	0.996	3.00E-07	0.031	0.096	2.40E-16	1.6829
	60	0.0383 ± 0.0004	58.89	0.998	0.997	8.00E-08	0.018	0.072	1.30E-16	1.2157
	70	0.0491 ± 0.0005	63.19	0.995	0.994	6.00E-07	0.048	0.099	1.70E-16	3.1671

during osmotic dehydration. Mean data of the three replications was fitted by regression analysis to this equation using statistical package SAS 9.3. The representative experimental graphs of t/WL_t and t/SG_t as calculated from the water loss and solute gain for different sugar syrup concentrations at different temperatures were plotted against immersion time as and parameter values k and WL_∞ for water loss and k and SG_∞ for solute gain were estimated from intercept and slope of the respective plots (Fig. 3 and 4) and presented in Table 1 and 2 including regression diagnostic criteria.

Predictions by proposed model : The proposed model was able to predict mass transfer kinetics up to the equilibrium point using data for relatively short period of osmosis. Model was validated by fitting the experimental water loss ratio (WL_t/WL_∞) expat different immersion time to the water loss ratio (WL_t/WL_∞) pred by the proposed model and goodness of fit was checked using regression diagnostic criteria. Similar procedure was adopted in validating the solute gain ratio.

Evaluation and validation of model for water loss : Model parameters k and WL_∞ and criteria for goodness of fit are presented in Table 1. The value of constant k is function of

immersion time and rate of water loss. Value of k was increased with increase in concentration at constant temperature except for few treatments hence did not show any specific trend with respect to temperature and concentration. Equilibrium water loss (WL_∞) was increased with increase in temperature at constant concentration and also with increase in concentration at constant temperature. Estimated equilibrium water loss varied from 50.72 to 63.19 per cent for different temperature-concentration combinations. Further, high R^2 (0.990 to 0.998), adjusted R^2 (0.988 to 0.997), lowest probability (8×10^{-8} to 3×10^{-6}), χ^2 (0.018 to 0.062), RMSE (0.072 to 0.1593), MBE (3.2×10^{-17} to 5.6×10^{-16}) and per cent error modulus (1.1029 to 3.1671) between experimental and predicted values were found suggesting Azuara *et al.* (1992) model fulfilled regression diagnostics criteria for all the treatment combinations. Per cent error modulus between experimental and predicted value is less than 10 per cent also revealed the model could be used successfully to predict the entire osmotic dehydration process up to the equilibrium point for water loss.

Evaluation and validation of model for solute gain : The value of constant k is function of immersion time and rate of solute

Table 2. Azura et al. model parameters and goodness of fit for solute gain

Temp. (°C)	Conc. (°B)	k	SG _∞ (%)	R ²	Adj R ²	P	χ ²	RMSE	MBE	% error modulus
40	50	0.0111 ± 0.0038	15.19	0.984	0.981	1.00E-05	0.299	0.752	-1.00E-15	1.0057
	60	0.0218 ± 0.0021	15.07	0.995	0.994	6.00E-07	0.122	0.415	-6.00E-16	0.1671
	70	0.0276 ± 0.0020	16.92	0.994	0.993	8.00E-07	0.155	0.394	7.60E-16	0.3
50	50	0.0307 ± 0.0026	13.73	0.994	0.992	1.00E-06	0.154	0.519	-6.00E-17	1.7714
	60	0.0308 ± 0.0015	14.72	0.997	0.997	1.00E-07	0.08	0.309	-5.00E-16	1.2657
	70	0.0366 ± 0.0015	18.22	0.996	0.996	3.00E-07	0.085	0.295	-2.00E-16	0.79
60	50	0.0370 ± 0.0033	13.69	0.99	0.988	3.00E-06	0.313	0.658	-4.00E-16	3.5057
	60	0.0417 ± 0.0023	15.09	0.994	0.993	9.00E-07	0.167	0.456	-3.00E-16	2.6214
	70	0.0547 ± 0.0010	18.09	0.998	0.998	4.00E-08	0.049	0.203	1.60E-16	1.5486

gain. Value of k was increased with increase in concentration at constant temperature for all the treatments. Equilibrium solid gain (SG_{∞}) was increased with increase in concentration at constant temperature. Predicted equilibrium solid gain varied from 13.69 to 18.22 per cent for different temperature-concentration combinations. Further, high R^2 (0.984 to 0.998), adjusted R^2 (0.981 to 0.998), lowest probability (4×10^{-8} to 1×10^{-5}), χ^2 (0.049 to 0.313), RMSE (0.2032 to 0.752), MBE (6.3×10^{-17} to 1.3×10^{-15}) and per cent error modulus (0.1671 to 3.5057) between experimental and predicted values were found suggesting Azuara *et al.* model fulfilled regression diagnostics criteria for all the treatment combinations (Table 2). Per cent error modulus between experimental and predicted values is less than 10 per cent also revealed that the model could be used successfully to predict the entire osmotic dehydration process up to the equilibrium point for solute gain. Similar finding for modelling were reported by Sutar and Gupta (2007) for onion slices; Ganjloo *et al.* (2011) for seedless guava cubes and Kaur and Singh (2013) for beetroot slices.

Conclusions

Water loss from and solute gain by aonla slices increased non-linearly with duration of osmosis at all concentrations and both increased at faster rate in the initial period of osmosis than later stage. Water loss and solute gain both increased with increasing sugar concentration and temperature. They can lose 13.60 to 59.52 per cent water and gain 2.53 to 17.10 per cent sugar depending upon the sugar syrup concentration (50-70°Brix) and temperature (40-60°C) in 4 hr duration of osmosis. The two parameter model developed by Azuara *et al.* described the mass transfer kinetics in the osmotic dehydration process of

aonla slices at any time satisfactorily when other conditions of osmosis are kept constant. Model can predict the equilibrium points on the basis of short duration of osmosis without conducting experiments for several hours.

Acknowledgements

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Hyperspectral reflectance based Leaf Area Index of Chickpea (*Cicer arietinum* L.)

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Abstract

The use of narrow band vegetation index: Normalized Difference Vegetation Index (NDVI) derived from hyperspectral measurements acquired by a field spectroradiometer was used to estimate Chickpea (*Cicer arietinum* L.) leaf area index (LAI). A field study was conducted during the *rabi* season of 2012-2013 at Central Farm of Mahatma Phule Krishi Vidyapeeth, Rahuri. The canopy spectral reflectance was measured using spectroradiometer with spectral range from 350-2500 nm (1 nm interval) during the crop growth period. Plant Canopy Imager was used to measure leaf area index (LAI) using gap-fraction inversion procedure. The regression analysis was carried out for NDVI with LAI for chickpea using linear, exponential, logarithmic, power and polynomial relationships over crop growth period considering growth and decline phases of LAI independently. Exponential relationships were found significant with NDVI for growth phase ($R^2=0.979$) and decline phase ($R^2=0.866$) when analysed independently. The developed exponential relationships could be used for the assessment of chickpea LAI based on NDVI and in the crop evapotranspiration estimation algorithms applying remote sensing observations.

Key words : Hyperspectral reflectance, spectroradiometer, NDVI, LAI, chickpea.

Recently high spectral resolution sensors have been developed, which allow new and more advanced applications in agriculture. Motivated by the increasing importance of hyperspectral remote sensing data, the need for research is important to define optimal wavebands to estimate biophysical parameters of crop. Hyperspectral crop reflectance data are useful for several remote sensing applications in agriculture, but there is still a need for studies to define optimal wavebands to estimate crop biophysical parameters and spectral response of crops. The monitoring of agricultural crops during the development cycle is important to food security. Monitoring can be done observing the biophysical variables. One of these biophysical variables that deserve attention is the leaf area index (LAI), that is related with crop evapotranspiration and crop

yield (Sellers *et al.*, 1997; Xavier *et al.*, 2006). One way to estimate these biophysical parameters is by vegetation indices (VI). VI's are mathematical functions of reflected radiant flux in different spectral bands of remote sensing data (Jensen, 2007).

Spectral vegetation behavior usually shows that plants absorb more solar energy in the visible region with increasing biomass. The most frequently used VI are broad band's which uses red and near-infrared regions, because of the absorption of energy in the red region by leaves and reflectance and transmission of multiple energy scattering that occur on individual leaves and on plant canopy in near-infrared region (Goel, 1988). Therefore, vegetation indices such as normalized vegetation index (NDVI), the most frequently used vegetation index, are usually correlated with LAI and crop yield (Aparicio *et al.*, 2010; Eitel *et al.*, 2008; Elwadie *et al.*, 2005;

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Galvao *et al.*, 2009; Raun *et al.*, 2008; Serrano *et al.*, 2000; Thenkabail *et al.*, 2000).

Hyperspectral remote sensing data has the potential to detect more variations on vegetation than multispectral data, because it uses narrow spectral channels of less than 10 nm (Stagakis *et al.*, 2010; Thenkabail *et al.*, 2000). These narrow channels allow the detection of detailed features, which could otherwise be disguised by broadband (Schmidt and Skidmore, 2003). Advances in the hyperspectral remote sensing technology are driving the development of new methods to analyze spectral reflectance data. Therefore, chickpea spectral reflectance measurements were analyzed in terms of NDVI to estimate LAI during crop growth cycle for chickpea crop.

Materials and Methods

Study area : The data required for this study were collected from Chickpea (*Cicer arietinum* L.) field at located at 19°19'19.494"N latitude and 74°39'16.873"E longitude during *rabi* season of 2012-2013. Climatically the study area falls under the semi-arid and sub tropical zone with average annual rainfall of 566.5 mm. The average maximum and minimum temperature was 31.68°C and 15.48°C, respectively. The average maximum and minimum relative humidity was 61.13 and 34.63 per cent, respectively. The sunshine hours are in-between 4.40 to 9.10 hrs with average value of 7.81 hrs with average wind speed of 1.91 km hr⁻¹ during the crop growth period. The total rainfall during the crop growth periods was 260.40 mm. The pan evaporation varied from 4.40 to 9.10 mm. The prominent soil type is clay. The seed plot was selected for the study because all the standard cultivation practices were adopted during the crop growth period and the crop is maintained in unstressed condition. The chickpea field was border-irrigated. The crop was sown in September

29th, 2012 and harvested in February 4th, 2013 and the data were recorded during this period.

Hyperspectral reflectance measurements : Spectroradiometers are widely used to collect spectral data and are designed to match the wavebands of different satellite sensors (Agapiou *et al.*, 2010). Field reflectance measurements were performed over chickpea field with the SVC HR-1024 spectroradiometer during the crop growth periods at an interval of seven days. The radiometric measurements were collected under clear-sky conditions between 12:00 and 14:00 hrs, at 60 to 80 cm above crop canopy, with the 25° field-of-view (FOV) optic fiber allowing 0.13 to 0.18 m spatial resolutions for each spectral measurement and all the measurements were taken from nadir view. Five spectral reflectance measurements from the most central part of chickpea field were taken with the spectroradiometer over the spectral range 350-2500 nm. A reference calibrated spectral on panel with 100% reflectance was used to measure the incoming solar radiation as a reference one, while the measurement over the crops as a target. The reflectance was calculated using the equation, Reflectance = (Target Radiance / Panel Radiance) x calibration factor of the panel. In order to avoid any errors due to significant changes in the

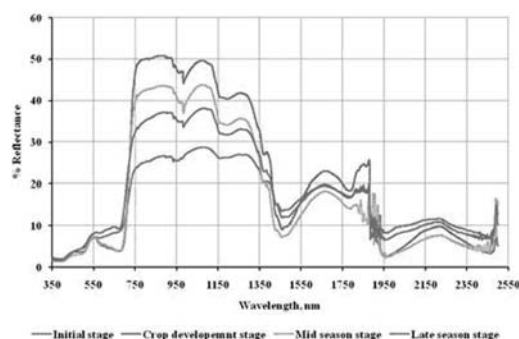


Fig. 1. Spectral reflectance of chickpea at distinct growth stages

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 measurement to ensure reliable data collection. The same point was visited each time for taking observations over the crop growth period. These measurements were then used to simulate the narrow-bands and broad-bands from the spectral bands. Due to atmospheric radiation absorption, some bands in the spectral ranges 1350-1440 nm, 1790-1990 nm and 2360-2500 nm were disconsidered.

Leaf area index (LAI) measurements :

LAI is commonly used for monitoring crop growth. Instead of the traditional, direct and labor-consuming method of physically measuring the plant with a ruler (direct method), an optical instrument, Plant Canopy Imager CI-110 (CID Bio- Science Inc., USA) was used (indirect method). The CI-110 uses a fish eye camera, ceptometer and proprietary software to capture and analyze images of canopy data, PAR levels and GPS information. The gap-fraction inversion procedure (Norman and Campbell, 1989) was used to estimate LAI, canopy transmission coefficient and mean leaf

angles. The software calculates the solar beam transmission coefficient using a user defined number of zenith and azimuth divisions. The output data is then displayed on the computer screen and can be saved into a file for further analysis. The LAI was estimated by analyzing the image with 5 zenith and azimuth divisions. The threshold contrast level was kept 95 with fish eye camera angle of 180°.

Normalized difference vegetation index and regression models :

The hyperspectral reflectance measurements were re-sampled to 1nm wavelength and converted into in-band reflectance of the corresponding IRS LISS-III bands (IR: 620-680 nm and NIR: 770-860 nm) and NDVI was calculated by using the equation proposed by Rouse *et al.* (1974).

$$\text{NDVI} = \frac{(\text{NIR} - \text{IR})}{(\text{NIR} + \text{IR})}$$

The regression relationships used were:

Linear : LAI= a (NDVI) + b

Exponential : LAI= a e^{b (NDVI)}

Logarithmic : LAI= a ln (NDVI) + b

Table 1. Results of regression analysis of LAI with NDVI for chickpea over (a) growth phase and (b) decline phase of LAI

Regression relationship	R ²	RMSE	χ ²	PEM
(a) Growth Phase				
LAI = 3.414 (NDVI) - 1.360	0.784	1.838	0.246	1.951
LAI = 0.012 e ^{5.687 (NDVI)}	0.979	1.329	0.074	0.072
LAI = 1.886 ln (NDVI) + 1.791	0.706	1.745	0.482	2.084
LAI = 2.555 (NDVI) ^{3.304}	0.975	1.327	0.211	4.548
LAI = 9.213 (NDVI) ² - 8.075 (NDVI) + 1.834	0.896	1.389	0.629	1.424
(b) Decline Phase				
LAI = 2.163 (NDVI) + 0.617	0.828	0.916	0.0020	0.002
LAI = 0.959 e ^{1.115 (NDVI)}	0.866	0.205	0.0007	0.005
LAI = 1.279 ln (NDVI) + 2.631	0.819	0.911	0.0019	0.005
LAI = 2.713 (NDVI) ^{0.662}	0.866	0.205	0.0007	0.015
LAI = -0.705 (NDVI) ² + 3.047 (NDVI) + 0.362	0.829	0.648	0.0119	0.002

Power : $LAI = a (NDVI)^b$

Polynomial : $LAI = a (NDVI)^2 + b(NDVI) + c$

where, 'a', 'b' and 'c' are the coefficients of the regression relationships.

The best fit regression relationship was found out based on the coefficient of determination (R^2), Root Mean Square Error (RMSE), Chi-square (χ^2) and Percent Error Modulus (PEM) values.

Results and Discussion

Spectral reflectance of chickpea : The stagewise spectral reflectances of chickpea crop between the wavelengths of 350 to 2500 nm are shown in Fig.1, shows the average spectral reflectance behavior at each growth stage for chickpea. Spectral variations among curves are mainly due to differences in crop growth stages. The lowest reflectance values in near infrared wavelengths (NIR: 700-1300 nm) were observed for the initial stage, where biomass is low and reflectance is influenced mainly by soil. Maximum reflectance in the NIR was observed for the crop development stage followed by mid-season stage, which is coincident with highest values of green leaf area index, consequently low reflectance of solar radiation in red wavelengths and high scattering of solar radiation in NIR (Moreira *et al.*, 1999). At late-season stage, reflectance in visible (VIS: 350-700 nm) and NIR regions increase and decrease, respectively, when compared to the previous growth stages, which is mainly caused by the increase of senescent leaves. The visible region shows maximum reflectance at approximately 550 nm and lower reflectance in the blue region at 450 nm and red region at 680 nm. In general the spectral signatures of chickpea crop shows low reflectance in visible and red region and the high reflectance in near infrared region.

NDVI and LAI for chickpea : The profile of variation of NDVI and LAI during the crop growth period of chickpea is shown in Fig. 2.

Relationships between NDVI and LAI : The regression analysis between leaf area index (LAI) and Normalized Difference Vegetation Index (NDVI) was carried out over the crop growth period (CGC) for chickpea to develop the relationship between LAI and NDVI. The LAI-NDVI relationships developed are presented in Table 1. The part 'a' and part 'b' of Table 1 gives the results of regression analysis for growth and decline phases, respectively. The R^2 values were in 0.706-0.979 range and 0.819-0.866 range for growth and decline phase respectively. It is observed from Table 1 that, the exponential relationships developed for chickpea crop during growth phase indicated the goodness of fit as per the lower value of χ^2 (0.072). It is observed that the value of coefficient of determination ($R^2 = 0.979$) is maximum, RMSE (1.329) and PEM (0.072) are minimum for exponential relationship. The exponential relationship developed for chickpea crop during decline phase indicated the goodness of fit as per the lower value of χ^2 (0.0007). It is observed that the value of coefficient of determination ($R^2 = 0.866$) was maximum, RMSE (0.0.205) and PEM (0.005) is minimum for the exponential relationship.

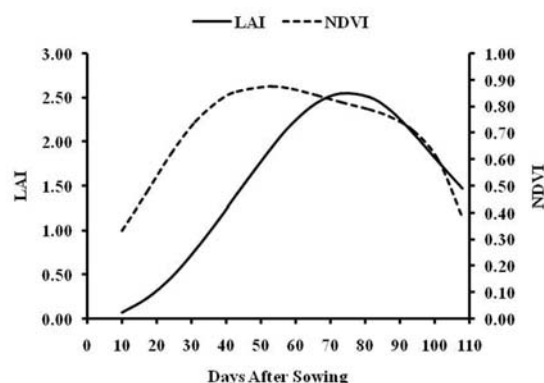


Fig. 1. Spectral reflectance of chickpea at distinct growth stages

Thus exponential relationships were found best suitable for the estimation of the LAI from NDVI during growth ($LAI = 0.012 e^{5.687 (NDVI)}$) and decline ($LAI = 0.959 e^{1.115 (NDVI)}$) phases for chickpea. The developed exponential relationships could be used for the assessment of chickpea LAI based on NDVI and in the crop evapotranspiration estimation algorithms applying remotely sensed observations.

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Standardization of Protocol for Preparation of Guava (*Psidium guajava* L.) Burfi

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Abstract

The experiment was undertaken to standardize the process for preparation of guava burfi and to study the storage behaviour at room temperature (ambient condition) during 2013-16. The pulp was extracted from the guava fruit by cold method of extraction. The guava burfi prepared with different recipes and stored at ambient temperature ($27 \pm 2^\circ\text{C}$) up to 30 days. The guava burfi were periodically evaluated for chemical, sensory and microbial parameters. The data regarding chemical composition of guava burfi prepared with different treatment combinations revealed that, there was significantly decrease in moisture content and ascorbic acid while TSS, titratable acidity and sugars content were found to be increased during 30 days of storage. In context to sensory qualities, a gradual decrease was observed in score for colour and appearance, texture, flavour, taste and overall acceptability during ambient storage of 30 days. Amongst the different treatment combinations, treatment T₁ (S₁B₁) i.e. 1 kg cold extracted pulp, 550 g sugar, 50 g Bengal Gram Flour (BGF), 50 g cow ghee, 50 g skim milk powder, 5 g salt, 2 g citric acid and 1 per cent pectin for preparation of general purpose guava burfi was found to be superior in respect of chemical analysis and sensory parameters. The microbial count in all the treatment combinations of guava burfi was within the permissible limit (not greater than 1×10^3 cfu g⁻¹ sample). The cost of production of best treatment of guava burfi was Rs.127.20 kg⁻¹.

Key words : Guava burfi, chemical composition, sensory, Bengal Gram Flour (BGF), microbial count.

Guava (*Psidium guajava* L.) belonging to the family myrtaceae and originated in tropical America. Guava is considered as important fruit because of its hardy nature, high vitamin C content and thus it is regarded as "Apple of Tropics". Guava is widely cultivated throughout the tropical and subtropical regions of the world and is widely grown for its fruit in tropics (Joseph and Mini, 2011). Guava is one of the most effective edible fruit, has long been used as a traditional medicine. It has been demonstrated to have several biological activities such as antidiabetic, anticough, antibacterial and antispasmodic actions (Abdelrahim *et al.*, 2002). Recently, it has been

reported to possess high potential for antioxidant activity.

In India, guava occupies an area of 2.36 lakh ha with an annual production of 31.98 lakh MT. The major guava producing states in India are Maharashtra, Madhya Pradesh, Uttar Pradesh, Karnataka, Tamil Nadu, Gujarat and Bihar. In Maharashtra, guava occupies an area of 0.40 lakh ha with an annual production of 3.24 lakh MT (Anon., 2015). Maharashtra is leading in both area and production. The largest guava producing districts in Maharashtra are Ahmednagar, Pune, Beed, Satara, Aurangabad and Amravati.

Guava fruits have characteristic quality texture due to presence of stone cells with good sweet aroma and refreshing acidic flesh. The

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guava fruits are an excellent source of vitamin C (299 mg 100⁻¹ g pulp). The fruit is also rich in minerals like phosphorus (23-37 mg 100⁻¹ g), iron (0.6-1.4 mg 100⁻¹ g) and calcium (14-30 mg 100⁻¹ g) as well as vitamins like niacin, thiamine, riboflavin and vitamin A. The fruit has the composition of 76 per cent water content, 1.5 per cent protein, 0.2 per cent fat, 14.55 per cent carbohydrates, 6.9 per cent fibre, 66.00 calories per 100 g fruit, 0.55 per cent titratable acidity and 0.81 per cent pectin (Yadav, 2005).

Guava is highly perishable fruit after ripening. The fully ripened guava fruits are mostly deteriorate before reaching to market. Such fully ripened guava fruits can be processed into good quality value added products, like *burfi*s. Thus, preparation of guava pulp by simple technology and its utilization for *burfi* making has great scope. Owing to the lack of information on processing of *burfi*, the present research work on standardization on preparation of guava *burfi* was undertaken with the objectives to standardize the process parameters for preparation of guava *burfi* and to study the storage behaviour of guava *burfi* at room temperature.

Material and methods

Guava fruits of Cv. Sardar (L-49) were obtained from Horticultural Farm and Central Nursery, Department of Horticulture, MPKV, Rahuri. Fully ripened and sound guava fruits were brought to the laboratory, cleaned and used for experimental purpose. Other food materials like sugar, bengal gram floor, fat (cow ghee), salt, skim milk powder, citric acid, pectin were procured from local market. The flow chart for preparation of guava *burfi* (Fig.1) is given below

Treatment details : For preparation of guava *burfi* for general purpose, three levels of sugar viz., S1-550 g, S2- 650 g and S3 - 750

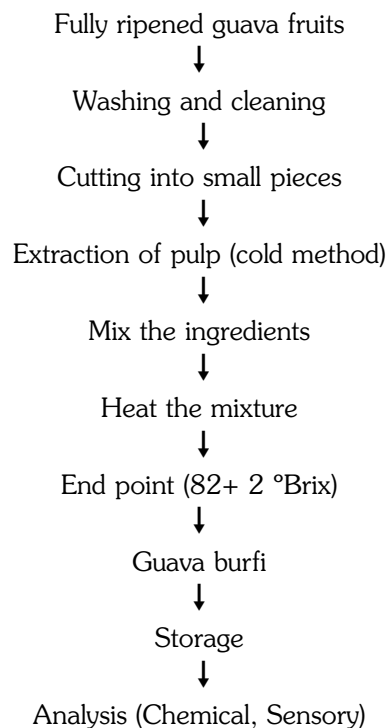


Fig. 1. Flow chart for Preparation of general purpose guava *burfi*

g and three levels of Bengal gram flour viz., B1- 50 g, B2- 75 g, B3- 100 g were used with three replications and nine treatment combinations. The details of treatment combinations were used to make *burfi* by using cold method extracted guava pulp are shown in Table 1.

Cold extracted pulp 1 kg + 50 g fat (cow ghee) + 50 g skim milk powder + 5 g salt + 2 g citric acid + 1 % pectin were common ingredients for all the treatments finalized on the basis of preliminary trials.

Chemical analysis of guava *burfi* :

Guava *burfi* was analyzed for moisture content, total soluble solids, acidity, total sugars, reducing sugars, non-reducing sugars and ascorbic acid content.

Sensory evaluation of guava *burfi* :

Sensory evaluation of guava *burfi* was carried

out according to method given by Amerine *et al.* (1979) on 9-point hedonic scale. The sensory evaluation was performed by a panel of judges for overall acceptability of *burfi*.

Statistical analysis : The data recorded in the present investigation were analyzed for the statistical significance as suggested by Panse and Sukhatme (1985).

Results and Discussion

Physico-chemical composition of fresh guava fruits : The results of physico-chemical composition of fresh guava Cv. Sardar (L-49) are presented in Table 2. The guava fruits were round in shape and greenish yellow in colour. The average weight of the fruit was 142.55 g. The average recovery of pulp was 71.56 per cent. The average values of seed and processing losses were 8.12 per cent and 20.32 per cent, respectively. The guava pulp obtained had 13.90 °B TSS, 0.45 per cent acidity, 13.10 per cent total sugars, 4.90 per cent reducing sugars, 8.20 per cent non-reducing sugars and 250.50 mg 100⁻¹ g ascorbic acid. The results obtained in the present investigation are similar to values recorded by Sharma *et al.* (2010); Haji *et al.* (2012); Sevda *et al.* (2012) and Athmaselvi *et al.* (2014) in guava fruits.

Chemical composition of general purpose guava *burfi* during storage

Total soluble solids (TSS) (°B) : The data regarding changes in TSS (°B) content of guava *burfi* is presented in Table 3. The TSS (°B) of guava *burfi* increased during storage in all the treatment combinations at the end of 30 days under ambient condition.

The TSS of fresh guava *burfi* was found to be maximum in treatment T₇ (82.75 °B) and minimum in treatment T₃ (80.12 °B). Similarly, at the end of 15th day of storage period,

treatment T₇ (82.88 °B) recorded maximum TSS followed by treatment T₈ (82.67 °B) while the minimum TSS was found in treatment T₃ (80.72 °B). At the end of 30th day of storage period, treatment T₈ (83.32 °B) recorded maximum TSS followed by treatment T₉ (83.01 °B) while the minimum TSS was found in treatment T₃ (81.46 °B). Similar results were also observed in guava toffee (Kad, 2010), jackfruit bar (Khadtar, 2012) and guava *burfi* (Jejurkar, 2014).

Moisture content (%) : The moisture content of guava *burfi* decreased during storage in all the treatment combinations at the end of 30 days under ambient condition (Table 3). The

Table 1. Details of treatment combinations for preparation of guava *burfi*

Treat-ments	Treatment combinations	Treatment details
T ₁	S ₁ B ₁	550 g sugar + 50 g BGF
T ₂	S ₁ B ₂	550 g sugar + 75 g BGF
T ₃	S ₁ B ₃	550 g sugar + 100 g BGF
T ₄	S ₂ B ₁	650 g sugar + 50 g BGF
T ₅	S ₂ B ₂	650 g sugar + 75 g BGF
T ₆	S ₂ B ₃	650 g sugar + 100 g BGF
T ₇	S ₃ B ₁	750 g sugar + 50 g BGF
T ₈	S ₃ B ₂	750 g sugar + 75 g BGF
T ₉	S ₃ B ₃	750 g sugar + 100 g BGF

Table 2. Physico-chemical composition of fresh guava fruits

Parameters	Content
Average weight of fruit (g)	142.55
Seed (%)	8.12
Recovery of pulp (%)	71.56
Processing losses (%)	20.32
Total soluble solids (OB)	13.90
Moisture content (%)	79.24
Ascorbic acid (mg 100 ⁻¹ g of pulp)	250.50
Acidity (%)	0.45
Reducing sugars (%)	4.90
Total sugars (%)	13.10
Non- reducing sugars (%)	8.20

moisture content of fresh guava *burfi* was found to be minimum in treatment T₃ (18.16%) and maximum in treatment T₇ (18.42%). At the end of 15th day of storage period, treatment T₉ (17.94%) recorded minimum moisture content followed by treatment T₈ (17.98%) while the maximum moisture content was found in treatment T₇ (18.28%). At the end of 30th day of storage period, treatment T₈ (17.23%)

recorded minimum moisture content followed by treatment T₉ (17.25%) while the maximum moisture content was found in treatment T₇ (17.99%). Kad (2010) found that the moisture content of guava toffee decreased from 11.93 to 9.07 per cent at the end of 60 days of storage period. The decrease in moisture content was also reported by Kaushal *et al.* (2001) in apple pomace toffee, Mahajan *et al.*

Table 3. Effect of various treatments combinations on physico-chemical composition of guava *burfi*

Particulars	Storage period (days)	Treatments									S.E.±	CD at 5%
		T ₁	T ₂	T ₃	T ₄	T ₅	T ₆	T ₇	T ₈	T ₉		
Total soluble solids (°B)												
	Initial (0)	81.20	80.65	80.12	82.22	81.27	80.36	82.75	82.16	81.78	0.254	NS
	15	81.44	81.01	80.72	82.53	81.85	81.04	82.88	82.67	82.32	0.318	NS
	30	81.80	81.50	81.46	82.95	82.57	81.85	83.15	83.32	83.01	0.260	NS
Moisture content (%)												
	Initial (0)	18.35	18.28	18.16	18.39	18.32	18.20	18.42	18.35	18.25	0.069	NS
	15	18.14	18.13	18.01	18.21	18.05	18.02	18.28	17.98	17.94	0.087	NS
	30	17.74	17.91	17.69	17.72	17.40	17.45	17.99	17.23	17.25	0.092	0.274
Acidity (%)												
	Initial (0)	0.342	0.330	0.320	0.330	0.320	0.320	0.310	0.300	0.292	0.007	NS
	15	0.349	0.336	0.329	0.337	0.328	0.326	0.317	0.313	0.310	0.008	NS
	30	0.358	0.343	0.338	0.343	0.333	0.330	0.324	0.320	0.319	0.010	NS
Ascorbic acid (mg 100⁻¹ g)												
	Initial (0)	105.80	106.10	106.80	105.10	105.40	106.20	104.40	105.00	105.80	0.231	NS
	15	102.78	102.86	103.22	101.59	101.70	102.47	101.22	101.21	101.97	0.283	NS
	30	98.27	98.15	98.19	96.62	96.52	97.26	96.55	95.94	96.67	0.306	NS
Total sugars (%)												
	Initial (0)	64.99	64.42	64.34	65.98	65.76	65.36	67.92	66.53	66.32	0.167	0.497
	15	67.08	67.11	67.47	68.00	69.00	68.97	71.10	69.29	69.97	0.179	0.532
	30	70.11	69.83	70.14	71.47	71.67	71.23	73.39	72.39	72.12	0.202	0.600
Reducing sugars (%)												
	Initial (0)	41.66	41.48	41.32	42.37	42.18	42.01	44.56	44.24	43.47	0.167	NS
	15	42.46	42.36	42.38	43.33	43.39	43.07	45.04	45.33	44.58	0.162	NS
	30	43.47	43.42	43.64	44.47	44.81	44.31	45.73	46.62	45.90	0.173	NS
Non-reducing sugars (%)												
	Initial (0)	23.33	22.94	23.02	23.61	23.58	23.35	23.36	22.29	22.85	0.162	NS
	15	24.63	24.76	25.10	24.68	25.62	25.91	26.07	23.97	25.40	0.173	0.515
	30	26.64	26.41	26.50	27.00	26.86	26.92	27.66	25.77	26.22	0.191	0.566
Microbial quality												
	30	1.50	0.60	1.80	0.55	0.55	0.78	0.81	0.79	0.85	0.073	0.216

(2011) in pineapple bar and Jejurkar (2014) in guava *burfi*.

Titrateable acidity (%) : The titrateable acidity of guava *burfi* increased during storage in all the treatment combinations at the end of 30 days under ambient condition (Table 3).

The titrateable acidity of fresh guava *burfi* was found to be minimum in treatment T₉ (0.292) and maximum in treatment T₁ (0.342%). Similarly, at the end of 15th day of storage period, treatment T₉ (0.310%) recorded minimum titrateable acidity followed by treatment T₈ (0.313%) while the maximum titrateable acidity was found in treatment T₁ (0.349%). At the end of 30th day of storage period, treatment T₉ (0.319%) recorded minimum titrateable acidity followed by treatment T₈ (0.320%) while the maximum titrateable acidity was found in treatment T₁ (0.358%). Kad (2010) found that, the titrateable acidity of toffee prepared from guava increased from 0.46 to 0.54 per cent at the end of 60 days of storage. Jejurkar (2014) reported that, the titrateable acidity of guava *burfi* was found to be increased from 0.30 to 0.40 per cent at the end of 30 days of storage period. Similar results were also reported in apple pomace toffee (Kaushal *et al.*, 2001), guava-papaya fruit bar (Venilla, 2004) and pineapple fruit bar (Mahajan *et al.*, 2011).

Ascorbic acid (mg 100⁻¹ g) : The ascorbic acid content of guava *burfi* decreased during storage in all the treatment combinations at the end of 30 days under ambient condition (Table 3).

The ascorbic acid content of fresh guava *burfi* was found to be maximum in treatment T₃ (106.80 mg 100⁻¹ g) and minimum in treatment T₇ (104.40 mg 100⁻¹ g). Similarly, at the end of 15th day of storage period, treatment T₃ (103.22%) recorded maximum ascorbic acid content followed by treatment T₂

(102.86 mg 100⁻¹ g) while the minimum ascorbic acid was found in treatment T₈ (101.21 mg 100⁻¹ g). At the end of 30th day of storage period, treatment T₁ (98.27 mg 100⁻¹ g) recorded maximum ascorbic acid followed by treatment T₃ (98.19 mg 100⁻¹ g) while the minimum ascorbic acid was found in treatment T₈ (95.94 mg 100⁻¹ g). The guava *burfi* prepared by Pol (2001) and Sivakumar *et al.* (2007) registered ascorbic acid up to 88.57 mg 100⁻¹ g and 98.20 mg 100⁻¹ g, respectively. Similar results were also noticed in conformity with the observations recorded by Domale *et al.* (2008) for aonla toffee, Kad (2010) for guava toffee, Vidhya and Narain (2010) for wood apple bar and Jejurkar (2014) for guava *burfi*.

Total sugars (%) : The total sugars of guava *burfi* increased during storage in all the treatment combinations at the end of 30 days under ambient condition (Table 3).

The total sugars of fresh guava *burfi* was found to be maximum in treatment T₇ (67.92%) and minimum in treatment T₃ (64.34%). Similarly, at the end of 15th day of

Table 4. Effect of storage of guava *burfi* on overall acceptability score

Particulars	Storage period at ambient conditions (days)			
	0	15	30	
Treatments				
T ₁	S ₁ B ₁	8.70	8.26	7.95
T ₂	S ₁ B ₂	8.65	8.21	7.84
T ₃	S ₁ B ₃	8.54	8.09	7.65
T ₄	S ₂ B ₁	8.49	8.00	7.56
T ₅	S ₂ B ₂	8.38	7.87	7.34
T ₆	S ₂ B ₃	8.44	7.93	7.49
T ₇	S ₃ B ₁	8.59	8.17	7.78
T ₈	S ₃ B ₂	8.27	7.60	7.10
T ₉	S ₃ B ₃	8.32	7.75	7.22
	S.E. ±	0.040	0.048	0.025
	CD at 5%	0.120	0.143	0.074

storage period, treatment T₉ (69.97%) recorded maximum total sugars followed by treatment T₈ (69.29%) while the minimum total sugars was found in treatment T₁ (67.08%). At the end of 30th day of storage period, treatment T₇ (73.39%) recorded maximum total sugars followed by treatment T₈ (72.12) while the minimum total sugars was found in treatment T₂ (69.83%). The total sugars increased in guava *burfi* might be due to lower temperature and higher relative humidity which resulted in slower rate of respiration, lower enzymatic activities which helps in slow build up of sugars or might be due to the fact that the high temperature and low humidity during room temperature storage resulted in faster hydrolysis of starch and other insoluble carbohydrates into soluble sugars.

The values of total sugars mentioned by Jejurkar (2014) were increased from 69.76 to 84.90 per cent in guava *burfi* at the end of 30 days of storage. The custard apple toffee had total sugars from 32.20 to 41.40 per cent reported by Dhumal *et al.* (2003). Kad (2010) found that the total sugars of toffee prepared from guava increased during 60 days of storage. Similar results were also reported in apple pomace toffee (Kaushal *et al.*, 2001), guava-papaya fruit bar (Venilla, 2004) and jackfruit bar (Ukkuru and Pandey, 2007).

Reducing sugars (%) : The reducing sugars of guava *burfi* were found to be increased during storage in all the treatment combinations at the end of 30 days under ambient condition (Table 3).

The reducing sugars of fresh guava *burfi* was found to be maximum in treatment T₇ (44.56%) and minimum in treatment T₃ (41.32%). Similarly, at the end of 15th day of storage period, treatment T₈ (45.33%) recorded maximum reducing sugars followed by treatment T₇ (45.04%) while the minimum reducing sugars was found in treatment T₂

(42.36%). At the end of 30th day of storage period, treatment T₈ (46.62%) were recorded maximum reducing sugars as followed by treatment T₉ (45.90%) while the minimum reducing sugars was found in treatment T₂ (69.83%). The reducing sugars was increased in all the treatment combinations of guava *burfi* might be due to the gradual decrease in moisture content or gradual inversion of non-reducing sugars into reducing sugars.

Jejurkar (2014) reported increase in reducing sugars content of guava *burfi* from 44.93 to 53.04 per cent during 30 days of storage. Kad (2010) found that the reducing sugars of toffee prepared from guava increased during 60 days of storage. Similar results were also reported in apple pomace toffee (Kaushal *et al.*, 2001), guava-papaya fruit bar (Venilla, 2004) and custard apple toffee (Dhumal *et al.*, 2003).

Non-reducing sugars (%) : The non-reducing sugars of guava *burfi* were found to be increased during storage in all the treatment combinations at the end of 30 days under ambient condition (Table 3).

Table 5. Economics of guava *burfi* *

Particular	Quantity	Rate (Rs.)	Cost (Rs.)
Guava	1.0 kg	20 kg ⁻¹	28.00
Sugar	550 g	32 kg ⁻¹	17.60
BGF	50 g	80 kg ⁻¹	4.00
Cow ghee	50 g	400 kg ⁻¹	20.00
Skim milk powder	50 g	440 kg ⁻¹	22.00
Salt	5 g	12 kg ⁻¹	0.60
Citric acid	2 g	120 kg ⁻¹	0.24
Pectin	5g	1200 kg ⁻¹	6.00
Yield	1.300 kg		
Grand total			98.44
Overhead charges (@ 40 %)			39.37
Cost of production			137.81
Profit (@ 20 %)			27.56
Total cost (Rs.) for 1.300 kg			165.37
Total cost (Rs.) for 1 kg			127.20

* For best treatment

The non-reducing sugars of fresh guava *burfi* was found to be maximum in treatment T₄ (23.61%) and minimum in treatment T₈ (22.29%). Similarly, at the end of 15th day of storage period, treatment T₇ (26.07%) recorded maximum non-reducing sugars followed by treatment T₆ (25.91%) while the minimum non-reducing sugars was found in treatment T₈ (23.97%). At the end of 30th day of storage period, treatment T₇ (27.66%) recorded maximum non-reducing sugars followed by treatment T₄ (27.00%) while the minimum non-reducing sugars was found in treatment T₈ (25.77%). The non-reducing sugars values mentioned by Jejurkar (2014) increased from 24.83 to 32.83 per cent in guava *burfi* at the end of 30 days of storage. Similar result was also reported by Pol (2001), that the values of non-reducing sugars were increased from 27.27 to 30.22 per cent during 90 days of storage.

Microbial quality of general purpose guava burfi : The data in respect of mean microbial count (bacterial colonies in cfu g⁻¹) of prepared guava *burfi* are presented in Table 3. The microbial count in *burfi* was nil initially and increased during storage period in all the treatment combinations. The interactions effect of microbial count was statistically significant during the storage period of 30 days. The microbial count was in the range of 6.10 x 10⁶ to 8.00 x 10⁶ cfu g⁻¹ at the end of 30 days of storage in all the treatment combinations. However, it is important to note that this microbial count was within the safer permissible limits. The bacterial count after the end of the storage period as noted by Sivakumar *et al.* (2007) was 3 x 10⁶ cfu g⁻¹, which was negligible in number and was within the safer limit for human consumption. Aruna *et al.* (1999) reported that the papaya toffee stored at room temperature showed 3 x 10³ cfu g⁻¹ bacterial counts after six months of storage.

The results obtained in the present investigation corroborated with the findings of Misra and Kuila (1988) in plane *burfi*; Kad (2010) in guava toffee and Selvi *et al.* (2013).

Overall acceptability of general purpose guava burfi : The data regarding changes in overall acceptability score of guava *burfi* during storage are presented in Table 4. As the storage period advanced, there was continuous decrease in overall acceptability score.

The organoleptic score of fresh guava *burfi* was found to be maximum in treatment T₁ (8.70) followed by treatment T₂ (8.65) and minimum in treatment T₈ (8.27). Similarly, at the end of 15th day of storage period, treatment T₁ (8.26) recorded maximum organoleptic score followed by treatment T₂ (8.21) while the minimum organoleptic score was found in treatment T₈ (7.60). At the end of 30th day of storage period, treatment T₁ (7.95) recorded maximum organoleptic score followed by treatment T₂ (7.84) while the minimum organoleptic score was found in treatment T₈ (7.10). Gradual decrease in taste score from 8.62 to 7.90 over 60th days of storage period was reported by Sivakumar *et al.* (2007) in guava fruit toffees. Further, it was reported that, the taste score decreased during storage of carrot toffees (Jagtap, 1994) and banana toffees (Dhoke, 1999). The results obtained in the present investigation are concurrent with the literature reported by Khadtar (2012) in jackfruit bar; Kad (2010) in guava toffee and Jejurkar (2014) in guava *burfi*.

Economics of guava burfi : The economics for the preparation of 1 kg guava *burfi* is shown in Table 5. The results obtained in the investigation indicated that, better quality of guava *burfi* for general purpose could be prepared by using cold extracted pulp 1 kg, 550 g sugar, 50 g bengal gram flour, 50 g fat (cow ghee), 50 g skim milk powder, 5 g salt, 2 g citric acid and 1 per cent pectin and the cost

was found to be Rs. 127.20 kg⁻¹. These costs are for laboratory (small) scale preparation of guava burfi.

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Drainage Coefficients for Plain Zone through Rainfall Analysis: A Case Study

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Abstract

The drainage coefficient of agricultural land was estimated by rainfall analysis of daily data of 31 years (1982-2012) for Satara District. The drainage coefficients (DC) for combinations of different durations (1 to 5 consecutive days) and different recurrence intervals (RI) of 2, 5 and 10 years were determined by subtracting basic infiltration rate from estimated consecutive days maximum rainfall. The drainage coefficients (DC) were estimated by considering 1, 2, 3, 4 and 5 mm hr⁻¹ basic infiltration rates of the soil. The drainage coefficient (DC) varies from 4.56 mm to 82.56 mm for 2 years RI, 7.44 mm day⁻¹ to 114.69 mm day⁻¹ for 5 years RI and 9.56 to 132.31 mm/day for 10 years RI for 1 day maximum rainfall. It was also observed that the drainage coefficient increases with increase in recurrence interval and decreases with increase in infiltration rate of the soil. Similar trend was observed for the drainage coefficients estimated for the combinations of 2, 3, 4 and 5 consecutive days rainfall and 2, 5 and 10 RI considering 1, 2, 3, 4 and 5 mm hr⁻¹ basic infiltration rates of the soil. The drainage coefficient maps showing the spatial distribution were developed by using GIS technique for the selected combinations of the basic infiltration rate (BIN), recurrence interval in years (RI) and tolerance period in days (TR). These maps can be used to get the location specific drainage coefficients for the proper design of surface drainage systems for the agricultural lands.

Key words : Drainage coefficient, rainfall analysis, recurrence interval, GIS.

Drainage removes excess water from the soil and helps to create a well-aerated root environment that enhances plant uptake of nutrients. Drainage on wet agricultural soils allows timely field operations, and helps plant growth to begin early, continue vigorously, and achieve improved levels of productivity. The purpose of drainage is to provide better root environment suitable for growth of plants (Sharma et al., 1997). For proper drainage it is necessary to know the desirable drainage rate (drainage coefficient), which depends on the rainfall intensity and amount of surface water admitted to drainage system. Drainage coefficient is the designed value in centimeters at which water has to be removed from a drainage area in 24 hrs. Drainage coefficient is also important in designing the small and

medium hydraulic structures and is a key factor in establishing the desired capacity of a drainage system. The drainage coefficient for any region varies with the geographical location, land use, size of area, rainfall intensity, frequency and duration and other climatic factors. The primary objective of irrigation and drainage for successful crop production is the development and maintenance of an environment in the plant root zone in which, soil moisture-oxygen-salt balance is favorable for plant growth. It is essential to design the drainage system properly. The excess water in the root zone is removed by the subsurface drainage system and that above the land surface is removed by surface drainage system. The standing water over the land surface deteriorates the crop growth. The sensitivity of different crops to surface waterlogging is different. Some crops can withstand surface

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water logging up to 5 days. While some crops can withstand surface water logging for 24 hours only. Accordingly the surface drainage systems need to be depends to drain off the excess water from the field with in the tolerance period of a specific crop. This needs the information on water that is expected to stand over the land surface and removed with in tolerance period. Drainage coefficient depends on rainfall, infiltration rate of soil, recurrence interval of rainfall and tolerance period of specific crops. Direct measurement of drainage coefficient is location specific and difficult for large areas hence an indirect method of its estimation using rainfall analysis is the most suitable approach. Rainfall analysis serves as indirect method of estimation of drainage coefficient. Rainfall is the most important factor influencing the value of drainage coefficient and large number of rainfall data is required for its depth duration frequency analysis. Remote sensing and GIS techniques offers several advantages over conventional methods used to map drainage coefficients and monitor waterlogging, soil salinity and alkalinity by virtue of synoptic viewing capability, repetitiveness and spectral sensitivity to water and salt, it is a valuable tool for obtaining dynamic information on waterlogging and soil salinity / alkalinity commonly associated with irrigated commands. Keeping in view the above facts the study is planned to determine the surface drainage coefficient using rainfall data analysis and to develop the spatial distribution maps of drainage coefficients by using the GIS techniques for Satara district of Maharashtra for the Plain Zone.

Materials and Methods

Study area : Satara district lies between 17.5° and 18.11° N latitude and 73.33° and 74.54° E longitude. The district is completely landlocked being surrounded by Ratnagiri

district on the West, Sangli district on the south, Solapur on the east, Pune on the north and Raigad on the North West. It covers 10,480 sq. kms. Most of the central Satara district's area falls in the Krishna basin and remaining in the Bhima basin.

Data and data analysis : Daily rainfall data for the period of 31 years (1982 to 2012) for Satara district form 16 weather stations well spread over the study area *viz.*, Dhahiwadi, Aundh, Karad, Khandala, Koregaon, Mahabaleshwar, Medha Jaoli, Mhaswad, Panchgani, Patan, Phaltan, Pusesauli, Vaduj and Wai was collected from Indian Metrological Department (IMD) at Pune. The maximum rainfalls of one, two, three, four, and five consecutive days were determined.

Probability analysis : Probability analysis of rainfall data provides useful tool for determining expected rainfall amount and to estimate the runoff volumes, this will help in designing the surface drainage (Nangare, 1994). The probabilities of occurrence of rainfall were estimated by using Weibull's formula. The seven probability distributions *viz.* Normal, Lognormal, Exponential, Gamma, Pearson type-III, Log Pearson type-III and Gumbel (maxima) were used for probability distribution analysis. The best fit probability distributions were decided by Chi-square test for their goodness of fit.

$$\chi^2 = \sum_{i=1}^k \frac{(O_i - E_i)^2}{E_i} \quad \dots(1)$$

The best fit probability function was determined by comparing Chi-square values obtained from each distribution and selecting the functions that gave the lowest Chi-square value (Agrawal *et al.*, 1998). If $2 \leq \chi^2 \leq 5$ per cent > 2 tab for (n-1) degrees of freedom then difference between observed and theoretical

values is considered to be significant. The lowest value of Chi-square test was taken as the best for selecting the best probability distribution (Bhatt, 1996). The best fit probability distribution was run to find out the probability values of rainfall at 50 per cent, 80 per cent, 90 per cent with the help of VITFIT computer program and the rainfall values for 2, 5 and 10 years recurrence interval were calculated.

Estimation of drainage coefficient :

The drainage coefficient was estimated for 2, 5 and 10 years recurrence interval (R.I.) by subtracting the basic infiltration rate from estimated consecutive day's rainfall (Sharma *et al.*, 1997).

$$DC = \frac{1}{n} [R - I] \quad \dots(2)$$

Where, DC = Drainage rate (drainage coefficient) in mm day⁻¹, R = Rainfall at a given probability for the duration under consideration in mm, I = Basic infiltration rate in mm day⁻¹, n = Number of days of crop tolerance

The drainage coefficient for different recurrence interval was estimated by considering the fact that soils are saturated and evapotranspiration, surface retention and raindrop interception are negligible as far as land drainage is considered.

The drainage coefficient maps were developed in ArcGIS by using the spatial analyst tools. The Inverse Distance Weighted (IDW) interpolation technique which interpolates the surface from the points in GIS was used to develop the spatial distribution maps of drainage coefficients.

Results and Discussion

The drainage coefficient was estimated for agricultural land through analysis of daily rainfall data of 31 years (1982-2012) for 16 stations from Satara using depth- duration-frequency analysis. The drainage coefficients (DC) were estimated by using one to five consecutive days rainfall values for 2, 5, and 10 years recurrence and considering 1, 2, 3, 4 and 5 mm hr⁻¹ basic infiltration rates of the soil. The estimated drainage coefficients for are given in Table 1. Table 1 shows that the DC varies between 4.56 mm to 82.56 mm for 2 years RI, 7.44 mm day⁻¹ to 114.69 mm day⁻¹ for 5 years RI and between 9.56 to 132.31 mm day⁻¹ for 10 years RI for 1 day maximum rainfall. However, for two consecutive days maximum rainfall the estimated values of DC varies between 6.06 mm day⁻¹ to 107.75 mm day⁻¹ for 2 years RI, 9.19 mm day⁻¹ to 148.25 mm day⁻¹ for 5 years RI and between 11.44 to 170.56 mm day⁻¹ for 10 years RI. For three consecutive days maximum rainfall the corresponding values of DC were 6.94 mm

Table 1. Estimated drainage coefficient (mm day⁻¹) for Satara district

Basic infiltration rate (mm hr ⁻¹)	DC for one day rainfall for R.I. (years)			DC for two day rainfall for R.I. (years)			DC for three days rainfall for R.I. (years)			DC for four days rainfall for R.I. (years)			DC for five days rainfall for R.I. (years)		
	2	5	10	2	5	10	2	5	10	2	5	10	2	5	10
1	82.6	114.7	132.3	107.8	148.3	170.6	128.0	181.4	210.8	140.4	203.9	237.6	147.3	212.4	247.5
2	29.7	45.5	54.3	36.7	54.9	65.8	42.4	60.3	72.6	47.1	66.4	77.9	50.2	69.1	80.5
3	13.3	22.7	28.3	18.1	25.9	30.8	20.6	30.1	35.3	21.4	33.3	39.7	21.6	33.6	40.3
4	7.5	12.0	15.8	9.8	15.1	18.0	10.9	17.0	20.9	11.9	17.5	22.1	12.4	16.8	20.8
5	4.6	7.4	9.6	6.1	9.2	11.4	6.9	9.7	12.3	7.1	10.6	12.5	6.9	10.4	12.4

day⁻¹ to 128 mm day⁻¹ for 2 years RI, 9.69 mm day⁻¹ to 181.38 mm day⁻¹ for 5 years RI and between 12.31 to 210.81 mm day⁻¹ for 10 years RI. For four consecutive days maximum rainfall the corresponding values of DC were between 7.13 mm day⁻¹ to 140.44 mm day⁻¹ for 2 years RI, 10.56 mm day⁻¹ to 203.88 mm day⁻¹ for 5 years RI and between 12.50 to 237.56 mm day⁻¹ for 10 years RI. For five consecutive days maximum rainfall the corresponding values of DC were between 6.94 mm day⁻¹ to 147.25 mm day⁻¹ for 2 years RI, 10.38 mm day⁻¹ to 212.44 mm day⁻¹ for 5 years RI and between 12.38 to 247.50 mm day⁻¹ for 10 years RI.

Further, the spatial distribution maps of drainage coefficients were developed by using the GIS technique for the selected combinations of the basic infiltration rate (BIN), recurrence interval in years (RI) and tolerance period in days (TR) are presented in Fig. 1 to 5. These maps can be used to get the location specific drainage coefficients for the proper design of surface drainage systems for the agricultural lands.

The drainage coefficient increases with

increase in recurrence interval and decreases with increase in infiltration rate of the soil. The soils with basic infiltration rate between 1 to 4 mm hr⁻¹ may necessarily be provided with surface drainage as per the tolerance period of the different crops. The spatial distribution drainage coefficient maps can be used to get the location specific drainage coefficients for the proper design of surface drainage systems. This analysis will also provide an idea regarding appropriate, safe and economic planning and designing of surface drainage systems.

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Performance Evaluation of Custard Apple (*Annona squamosa* L.) Pulp-Flakes Extractor

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Abstract

The research work was carried out to evaluate the performance of newly developed custard apple pulp-flakes extractor. The central wire mounted roller along with outer casing is the key component of the machine. The effect of roller speed and angle of inclination on core recovery, flakes recovery, machine capacity and seed separation was studied. As per the response contours for core recovery, working capacity, seed separation efficiency and flakes recovery, the optimum value of core recovery, working capacity, seed separation efficiency and flakes recovery is 91 per cent, 48 kg h⁻¹, 80 per cent and 60 per cent, respectively. The best combination of RPM of roller and inclination angle of drum is 77 RPM and 42°, respectively for said optimum values of core recovery, working capacity, seed separation efficiency and flakes recovery.

Key words : custard apple, flakes recovery, core recovery, seed separation efficiency, roller.

The custard apple (*Annona squamosa* L.) is one of the tropical fruits. It is usually eaten as a dessert fruit and finds immense applications in the preparations of beverages and ice creams Chikhalikar, (2000). The fruit has gained considerable importance because of its sweet pulp being medicinally valuable. The fruit is good source of carbohydrates (23.5 %), minerals (0.9 %) and proteins (1.6 %) Gopalan *et al.*, (1991). The pulp is also used in different processed products such as jam, jelly, rabadi, shake. However retention of flakes is of more important during pulp extraction to have good organoleptic properties of processed products. The manual extraction on custard apple pulp is tedious, cumbersome and time consuming job. The custard apple pulp-flakes extracting machine has been developed to overcome this problem. The machine was tested in the present research to study the effect of roller speed and angle of inclination on performance of the machine in terms of core

recovery, flakes recovery and seed separation efficiency. Khawaja *et al.* (2010) developed a pulping machine for tomato and tested it to study the effect of roller speed and clearance on pulp recovery. Camillo (1997) studied the effect of speed of shaft provided with spatulas on pulp recovery.

Materials and Methods

The custard apple pulp flakes extracting machine was tested to study the effect of roller speed and angle of inclination on core recovery, flakes recovery and seed separation efficiency. The custard apple fruits of Cv. Balanagar were procured from the research farm, Department of Horticulture, MPKV, Rahuri and trials were conducted in the laboratory, Department of Agril. Process Engineering, MPKV, Rahuri.

Independent variables

1. Revolution per minutes of roller
2. Angle of inclination of drum

1. Assistant Professor, 2. Head, 3. Ph. D. Scholar and 4. Ex. Director of Extension Education.

Dependent variables

1. Core recovery
2. Flakes recovery
3. Seed separation efficiency

Core recovery : The core recovery is the amount of pulp of the fruit coming out of the machine after separation. The total material at seed and pulp outlet was collected and weighed. The core recovery was calculated as $\text{Core recovery (\%)} = \frac{\text{Material at pulp outlet (g)} + \text{Material at seed outlet (g)}}{\text{Weight of core material feed (g)}}$

Flakes recovery : The retention of the flakes was one of the features of the machine. Flakes recovery is the percent weight of the extracted pulp without crushing of the pulp. The uncrushed flakes were separated manually and were weighed to calculate the flakes recovery as, $\text{Flakes recovery (\%)} = \frac{\text{weight of flakes only (g)}}{\text{Weight of pulp and flakes (g)}}$

Seed separation efficiency : This indicates the percent separation of the seeds from pulp. The total pulp collected at both seed and pulp outlet was collected and the separated and un-separated seeds and pulp was weighed. The seeds separation efficiency was calculated as $\text{Seed separation efficiency (\%)} = \frac{\text{Unseparated seeds at seed outlet (g)} + \text{Unseparated seeds pulp outlet (g)}}{\text{Total weight of seed material (g)}}$

Response surface methodology : Understanding the relationship between machine parameters and their response to product development is essential for optimization of roller speed (rpm) and inclination angle of drum to get the best possible output from the machine. In this regard response surface methodology is considered as one of the most accurate methods amongst the available methodologies.

Therefore, the response surface methodology was used in the present study to obtain an optimum value. Response surface methodology was best handled by Statistical Analysis System (SAS). The SAS 9.1 was used to develop code and understand the behavior of each parameter separately and their combinations.

Results and Discussion

Testing of custard apple pulp-flakes extractor : The developed machine was tested to see the effect of roller speed varied from 30 to 90 RPM and inclination angle of drum varied from 20° to 45° on core recovery, working capacity, seed separation efficiency and flakes recovery as shown in Table 1 to 6.

Response contour for core recovery : The core recovery was found to be increasing with increase in RPM of roller and inclination angle of drum. Maximum core recovery of 94.76 per cent was found for roller speed of 90 RPM and inclination angle of 45°.

The increased core recovery with increase in RPM of roller and inclination angle of drum was due to increased in centrifugal force, which forced the pulp-flake material away from the roller wires at pulp-flakes outlet and also due to increased in vibrations of the machine with increase in roller speed.

Response contour for working capacity : The minimum working capacity of 16.54 kg h⁻¹ was recorded at roller speed of 30 RPM and 20° inclination angle of drum, while maximum of 60.40 kg h⁻¹ was for a roller speed of 90 RPM and 45° inclination angle of drum. It was observed that with increase in RPM of roller and inclination angle of drum, the working capacity was increased.

The increased working capacity with increase in RPM of roller and inclination angle of drum was due to increased in centrifugal

Table 1. Effect of roller speed at 20° angle of inclination on core recovery, seed separation efficiency and flakes recovery

RPM	Time required (min)	Weight of fruits (g)	Weight of peel (g)	Weight of core (g)	Weight of material at pulp flakes outlet (g)	Weight of unseparated seed at pulp flakes outlet (g)	Weight of flakes only (g)	Weight of gritty pulp only (g)	Weight of material at seed outlet (g)	Weight of unseparated seed at seed outlet (g)	Working capacity (kg ha ⁻¹)	Seed separation efficiency (%)	Core recovery (%)	Flakes recovery (%)
30	20.24	10000.00	4422.12	5577.88	2583.67	73.63	2510.05	1226.02	1284.03	1348.73	102.63	16.54	70.50	48.84
40	19.54	10000.00	4447.88	5552.12	2741.64	76.62	2665.02	1179.83	1485.19	1385.25	103.82	17.05	74.33	44.27
50	18.56	10000.00	4531.98	5468.02	2802.91	80.93	2721.98	1130.79	1591.19	1391.61	104.44	17.68	76.71	41.54
60	18.16	10000.00	4612.00	5388.00	2870.73	86.75	2783.98	1080.83	1703.15	1389.03	103.99	17.80	79.06	38.82
70	17.26	10000.00	4497.92	5502.08	3004.14	123.25	2880.89	1079.51	1801.38	1445.95	107.29	19.13	80.88	37.47
80	14.58	10000.00	4338.20	5661.80	3171.74	137.58	3034.16	1027.62	2006.54	1509.44	110.97	23.30	84.91	33.87
90	12.44	10000.00	4640.94	5359.06	3066.45	131.83	2934.62	945.87	1988.75	1446.95	108.25	25.85	84.79	32.23

Table 2. Effect of roller speed at 25° angle of inclination on core recovery, seed separation efficiency and flakes recovery

RPM	Time required (min)	Weight of fruits (g)	Weight of peel (g)	Weight of core (g)	Weight of material at pulp flakes outlet (g)	Weight of unseparated seed at pulp flakes outlet (g)	Weight of flakes only (g)	Weight of gritty pulp only (g)	Weight of material at seed outlet (g)	Weight of unseparated seed at seed outlet (g)	Working capacity (kg ha ⁻¹)	Seed separation efficiency (%)	Core recovery (%)	Flakes recovery (%)
30	19.56	10000.00	4287.20	5712.80	2722.15	97.12	2625.03	1415.63	1209.40	1435.06	111.40	17.52	72.77	53.93
40	19.04	10000.00	4528.12	5471.88	2778.62	94.12	2684.50	1372.35	1312.16	1410.65	109.98	17.24	76.56	51.12
50	18.08	10000.00	4618.25	5381.75	2835.11	96.87	2738.23	1321.22	1417.01	1421.86	113.55	17.86	79.10	48.25
60	17.12	10000.00	4464.90	5535.10	3009.99	109.59	2900.39	1320.12	1580.27	1494.48	117.34	19.40	85.85	45.52
70	14.08	10000.00	4398.00	5602.00	3127.04	142.29	2984.75	1286.22	1698.53	1539.43	120.44	23.87	83.30	43.09
80	12.24	10000.00	4638.10	5361.90	3067.01	141.55	2925.45	1194.63	1730.82	1506.69	116.89	26.28	85.30	40.84
90	11.24	10000.00	4540.95	5459.05	3203.37	147.39	3055.98	1197.72	1858.26	1553.10	121.19	29.14	87.13	39.19

Table 3. Effect of roller speed at 30° angle of inclination on core recovery, seed separation efficiency and flakes recovery

RPM	Time required (min)	Weight of fruits (g)	Weight of peel (g)	Weight of core (g)	Weight of material at pulp flakes outlet (g)	Weight of unseparated seed at pulp flakes outlet (g)	Weight of flakes only (g)	Weight of gritty pulp only (g)	Weight of material at seed outlet (g)	Weight of unseparated seed at seed outlet (g)	Working capacity (kg ha ⁻¹)	Seed separation efficiency (%)	Core recovery (%)	Flakes recovery (%)	
30	19.1	10000.00	4287.10	5712.90	2782.18	113.12	2669.07	1657.88	1011.18	1484.21	123.97	17.95	85.16	74.68	62.11
40	18.36	10000.00	4627.95	5372.05	2778.42	112.81	2665.61	1537.48	1128.13	1442.40	122.48	17.56	84.87	78.57	57.68
50	17.52	10000.00	4700.25	5299.75	2831.13	112.35	2718.77	1490.29	1228.48	1440.47	124.54	18.15	84.74	80.60	54.81
60	15.24	10000.00	4565.20	5434.80	3011.97	128.26	2883.70	1502.18	1381.53	1506.53	129.35	21.40	84.24	83.14	52.09
70	12.36	10000.00	4286.40	5713.60	3257.89	158.84	3099.06	1543.81	1555.24	1616.95	138.84	27.74	83.24	85.32	49.82
80	9.24	10000.00	4577.70	5422.30	3178.55	155.08	3023.47	1423.35	1600.12	1549.69	133.93	35.21	83.05	87.20	47.08
90	8.24	10000.00	4526.00	5474.00	3285.49	159.84	3125.65	1396.96	1728.69	1591.84	137.40	39.86	83.03	89.10	44.69

Table 4. Effect of roller speed at 35° angle of inclination on core recovery, seed separation efficiency and flakes recovery

RPM	Time required (min)	Weight of fruits (g)	Weight of peel (g)	Weight of core (g)	Weight of material at pulp flakes outlet (g)	Weight of unseparated seed at pulp flakes outlet (g)	Weight of flakes only (g)	Weight of gritty pulp only (g)	Weight of material at seed outlet (g)	Weight of unseparated seed at seed outlet (g)	Working capacity (kg ha ⁻¹)	Seed separation efficiency (%)	Core recovery (%)	Flakes recovery (%)	
30	18.30	10000.00	4368.00	5632.00	2781.08	134.04	2647.04	1840.54	806.50	1474.46	136.29	18.47	83.19	75.56	69.53
40	16.04	10000.00	4545.80	5454.20	2858.00	135.26	2722.74	1745.34	977.39	1475.36	137.99	20.40	83.03	79.45	64.10
50	13.40	10000.00	4384.30	5615.70	3048.20	146.01	2902.19	1749.85	1152.34	1551.06	147.69	25.14	82.69	81.90	60.29
60	10.20	10000.00	4450.50	5549.50	3112.16	154.28	2957.88	1691.49	1266.40	1567.18	148.73	32.64	82.40	84.32	57.19
70	8.50	10000.00	4380.15	5619.85	3242.65	169.72	3072.93	1670.22	1402.71	1621.33	153.42	39.67	81.96	86.55	54.35
80	6.10	10000.00	4375.00	5625.00	3332.81	192.38	3140.44	1611.56	1528.88	1647.00	156.94	55.33	81.01	88.53	51.32
90	6.02	10000.00	4460.35	5539.65	3361.46	198.32	3163.14	1559.97	1603.17	1655.25	162.31	55.21	80.54	90.56	49.32

Table 5. Effect of roller speed at 40° angle of inclination on core recovery, seed separation efficiency and flakes recovery

RPM	Time required (min)	Weight of fruits (g)	Weight of peel (g)	Weight of core (g)	Weight of material at pulp flakes outlet (g)	Weight of unseparated seed at pulp flakes outlet (g)	Weight of flakes only (g)	Weight of gritty pulp only (g)	Weight of material at seed outlet (g)	Weight of unseparated seed at seed outlet (g)	Working capacity (kg ha ⁻¹)	Seed separation efficiency (%)	Core recovery (%)	Flakes recovery (%)
30	18.18	10000.00	4710.45	5289.55	2704.02	145.99	2558.03	1880.44	677.59	1438.76	17.46	81.88	78.32	73.51
40	16.00	10000.00	4415.15	5584.85	3010.23	166.43	2843.81	1957.49	886.32	1570.46	20.94	81.58	82.02	68.83
50	13.00	10000.00	4640.50	5359.50	2968.09	161.86	2806.23	1853.32	952.92	1534.96	24.74	81.43	84.02	66.04
60	10.04	10000.00	4485.00	5515.00	3156.79	180.89	2975.89	1861.31	1114.58	1605.97	32.96	80.68	86.36	62.55
70	8.24	10000.00	4632.10	5367.90	3156.33	183.58	2972.74	1777.85	1194.89	1595.34	39.09	80.51	88.52	59.80
80	6.04	10000.00	4467.85	5532.15	3340.31	216.86	3123.45	1806.25	1317.20	1662.96	54.96	79.31	90.44	57.83
90	6.00	10000.00	4650.00	5350.00	3305.23	216.14	3089.09	1701.30	1387.79	1651.01	53.50	79.03	92.64	55.07

Table 6. Effect of roller speed at 45° angle of inclination on core recovery, seed separation efficiency and flakes recovery

RPM	Time required (min)	Weight of fruits (g)	Weight of peel (g)	Weight of core (g)	Weight of material at pulp flakes outlet (g)	Weight of unseparated seed at pulp flakes outlet (g)	Weight of flakes only (g)	Weight of gritty pulp only (g)	Weight of material at seed outlet (g)	Weight of unseparated seed at seed outlet (g)	Working capacity (kg ha ⁻¹)	Seed separation efficiency (%)	Core recovery (%)	Flakes recovery (%)
30	17.40	10000.00	4589.55	5410.45	2855.64	162.85	2692.78	2097.09	595.69	1501.40	18.66	81.05	80.53	77.88
40	15.20	10000.00	4550.65	5449.35	2977.52	168.93	2808.59	2093.64	714.95	1556.88	21.51	80.93	83.21	74.54
50	12.30	10000.00	4445.95	5554.05	3142.48	178.84	2963.64	2114.98	848.66	1613.45	27.09	80.57	85.63	71.36
60	9.50	10000.00	4354.85	5645.15	3287.74	189.68	3098.06	2130.48	967.58	1700.32	35.65	80.65	88.36	68.77
70	8.04	10000.00	4538.75	5461.25	3271.29	203.16	3068.13	2025.03	1043.10	1686.43	40.76	79.86	90.78	66.00
80	6.00	10000.00	4548.35	5451.65	3353.86	226.24	3127.61	1994.21	1133.40	1710.73	54.52	78.98	92.90	63.76
90	5.40	10000.00	4564.00	5436.00	3418.16	229.40	3188.76	1950.44	1238.32	1733.00	60.40	78.73	94.76	61.17

force, which forced pulp-flake material away from the roller wires at pulp-flakes outlet and also due to increased vibrations of the machine with increase in roller speed.

Response contour for seed separation efficiency : The developed machine was tested for efficiency of seed separation of the core material feed in the hopper by changing RPM of roller and inclination angle of drum. It was found that the seed separation efficiency was decreasing with increase in inclination angle of drum and RPM of roller. A seed separation efficiency of 87.66 per cent was found at 20° inclination angle of drum and 40 rpm speed of roller, while it was decreased to 78.73 per cent at an inclination angle of drum of 45° and 90 rpm of roller. This was because of decreased residential time in the clearance between roller and outer casing with increase in inclination angle of drum.

Response contour for flakes recovery : The recovery of the flakes was found to be depending mainly on the RPM of roller (central wire mounted roller), since the clearance between stainless steel wires cylinder and outer casing varying from 6 mm at feed end to 4 mm at the discharge end.

It was observed that the flakes recovery was increasing with increase in inclination angle of drum and was decreasing with increase in RPM of roller. The maximum flakes recovery of 77.88 per cent was found for a roller speed of 30 rpm and 45° inclination angle of drum; whereas minimum flakes recovery of 32.23 per cent was for a speed of 90 rpm and 20° inclination angle of drum. The decrease in flakes recovery was due to increased momentum and inertial forces resulting in more impact action for squeezing out the pulp-flakes.

Response contour for core recovery, working capacity, seed separation efficiency and flakes recovery : The custard

apple pulp-flakes extractor was tested for core recovery, working capacity, seed separation efficiency and flakes recovery by changing the RPM of roller varying from 30 to 90 RPM and inclination angle of drum varying from 20° to 45°. The response contours map shown in Fig. 1 was drawn for core recovery, working capacity, seed separation efficiency and flakes recovery while considering RPM of roller and inclination angle of drum.

As per the response contours for core recovery, working capacity, seed separation efficiency and flakes recovery, the optimum value of core recovery, working capacity, seed separation efficiency and flakes recovery are 91 per cent, 48 kg h⁻¹, 80 per cent and 60 per cent, respectively. The best combination of RPM of roller and inclination angle of drum is 77 RPM and 42°, respectively for said optimum values of core recovery, working capacity, seed separation efficiency and flakes recovery.

The results obtained in the present investigation are in agreement with Pawar,

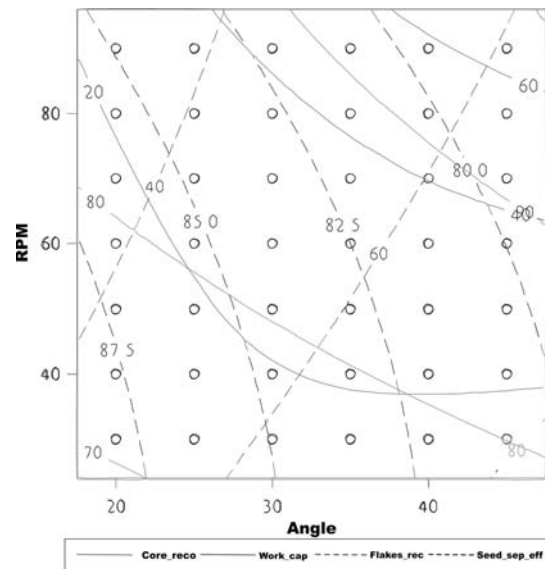


Fig. 1. Contour map for core recovery, working capacity, seed separation efficiency and flakes recovery

(2012) for the testing of custard apple pulp-flakes extracting machine.

The best combination of developed custard apple pulp-flakes extractor for core recovery, working capacity, seed separation efficiency and flakes recovery are 91 per cent, 48 kg h⁻¹, 80 per cent and 60 per cent, respectively. The best combination of RPM of roller and inclination angle of drum is 77 RPM and 42°, respectively.

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Engineering Properties of Pomegranate (*Punica granatum* L.) Fruits

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Abstract

The engineering properties are important to characterize pomegranate fruit with a view to understand the properties that may affect the design and development of equipments for processing, transportation, sorting, separating, packaging and storage. Thus in the present study several engineering properties such as fruit weight, major, intermediate and minor diameter, geometric mean diameter, fruit volume, surface area and aspect ratio were determined. Pearson correlations were determined to find out associations among the engineering properties of pomegranate fruit. Results indicated that fruit major diameter, intermediate diameter, minor diameter, geometric mean diameter, surface area and fruit volume were strongly correlated to fruit weight with high correlation coefficient ($r = 0.984, 0.984, 0.977, 0.988, 0.986$ and 0.978 , respectively). Any of these properties could be utilized as an indicator of fruit size. The sphericity and aspect ratio showed poor correlation to fruit weight with minimum coefficient of determination ($r = 0.615$ and 0.553 , respectively).

Key words : Pomegranate, engineering properties, correlation, sphericity, fruit size.

Pomegranate (*Punica granatum* L.) is one of the most important and commercial

horticultural fruit crop belongs to the family Punicaceae. It is native to Iran but has been cultivated and naturalized since ancient times over the entire Mediterranean region (Barman *et al.*, 2013). Pomegranate fruits are available

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throughout the year in India. Among arid and semiarid fruits of India, pomegranate ranks first in area and production. Maharashtra, the pomegranate basket of India, also ranks first in area with 1.28 lakh ha and production of 12.86 lakh tonne and productivity of 10.04 t ha⁻¹ (Anonymous, 2016). Ganesh, Bhagawa, Ruby, Arakta, Super Bhagawa and Mridula are different varieties of pomegranate produced in Maharashtra. In the world, production and consumption of pomegranate fruits is increasing rapidly due to its versatile adaptability, table and therapeutic values and better keeping quality. The fact that the pomegranate fruit has different industrial usages, such as fruit juice, conserve, vinegar, citric acid and medicine, lead to its gaining popularity in the world markets (Lal *et al.* 2013). The pomegranate fruit is referred to as 'superfruit' because of its high nutritive value, high antioxidant capacity, high potentially bioactive compounds, chemo-preventive properties having medicinal value and high consumers appeal (Hertog *et al.*, 1997). It has higher nutritional value due to the presence of natural bioactive compounds like phenolics, anthocyanins, vitamins, minerals and strong antioxidant activity (Barman *et al.*, 2013). The data obtained from modern science showed that the pomegranate fruit contains anti-carcinogenic (Bell and Hawthorne, 2008), anti-microbial (Reddy *et al.*, 2007) and anti-viral compounds (Kotwal, 2007).

The engineering properties of pomegranate are important to design equipment for processing, transportation, sorting, separating and also packing. Currently used system has been designed without taking these criteria into consideration; and the resulting designs lead to inadequate applications. This results in a reduction in work efficiency and an increase in product loss. Therefore determination and consideration of engineering properties of

agricultural materials are important to design machines and processes for harvesting, handling and storage of these materials and requires understanding for converting these materials into food and feed (Dineshkumar *et al.*, 2015). Fruit physical dimensions particularly shape are very important in sorting, sizing and determining the quantity of fruits can be placed in shipping containers or plastic bags of a given size (Keramat Jahromi *et al.*, 2008). Fruit volume and surface area could be beneficial in proper prediction of drying rates and hence drying time in the dryer. As an instance, slat conveyor system for conveying of fruits can be designed by fruit size and weight (Mansouri *et al.*, 2010). Many studies have revealed that the physical properties of fruits such as wild plum (Calisir *et al.*, 2005), cornelian cherry (Demir and Kalyoncu, 2003), fresh okra fruit (Owolarafe and Shotonde, 2004), cherry laurel (Calisir and Aydin, 2004), orange (Topuz *et al.*, 2005) used for designing of various post harvest equipments. Most of the research studies conducted to address quantitative evaluations of pomegranate fruit characteristics (Drogoudi *et al.*, 2005, Martinez *et al.*, 2006 and Dafny-Yalin *et al.*, 2010). However very limited literature is available on relationship between fruit characteristics. The knowledge of such relationship would be useful to breeding programs that requires awareness of fruit qualities in the selection of traits for improvement (Lal *et al.* 2013). Hence, the objective of present study is to determine engineering properties of pomegranate fruit of Cv. Bhagawa and correlations between major fruit characteristics.

Materials and Methods

Pomegranate fruits : Commercially well matured and healthy pomegranate fruits of Cv. Bhagawa were procured from the local market, Rahuri, Ahmednagar, Maharashtra for the determination of engineering properties.

Engineering properties : Hundred fruits of variable size were individually analyzed for engineering properties. Fresh fruit weight was determined by weighing the fruits on a precision digital balance (Make: Indosaw, Haryana) with an accuracy of 0.001 g. The major diameter (length, l), intermediate diameter (breadth, b) and minor diameter (thickness, t) of each fruit were measured using digital vernier caliper with least count of 0.01. Major diameter was measured from stalk base to the apex and was regarded as length. Intermediate diameter was measured in the direction perpendicular to the major diameter and was regarded as breadth. Minor diameter was regarded as thickness and was measured in the direction perpendicular to major and intermediate diameter.

Geometric mean diameter (GMD) : The geometric mean diameter was determined using the measured geometric dimensions of length (l), breadth (b) and thickness (t) for 100 fruits from the following equation:

$$\text{GMD} = (l \times b \times t)^{1/3} \quad \dots (1)$$

Where, l = length of fruit (Major diameter), b = breadth of fruit (Intermediate diameter) and t = thickness of fruit (Minor diameter).

Sphericity (Φ) : Sphericity (Φ) is defined as the ratio of the surface area of a sphere having

the same volume as the fruit to the surface area of the fruit. The shape of a food material is usually expressed in terms of its sphericity. Sphericity was determined from the measured geometric dimensions using following formula;

$$\Phi = \frac{\text{General mean diameter}}{\text{Major diameter}} \quad \dots (2)$$

Surface area (A) : The surface area of pomegranate fruits were calculated based on the geometric mean diameter (GMD) using the following equation

$$A = \pi(\text{GMD})^2 \quad \dots (3)$$

Where, GMD = Geometric mean diameter

Volume (V) : The volume of 100 pomegranate fruits were calculated based on the geometric mean diameter (GMD) using the following equations

$$V = \frac{\pi}{6} (\text{GMD})^3 \quad \dots (4)$$

Where, GMD = Geometric mean diameter

Aspect ratio (R) : Aspect ratio (R) describes about shape of the fruit and was determined from the following relationship

Table 1. Summary statistics of engineering properties of pomegranate fruit Cv. Bhagawa

Traits	Mean	Minimum	Maximum	Standard deviation	Sum
Weight of fruit (W) (g)	188.05	118.40	284.55	25.70	18804.57
Major diameter (l), cm	7.556	5.090	9.641	0.686	755.60
Intermediate diameter (b), cm	6.311	4.647	8.558	0.696	631.15
Minor diameter (t), cm	6.172	4.337	8.236	0.695	617.16
Geometric mean diameter (GMD), cm	6.651	4.681	8.792	0.690	665.11
Sphericity (Φ)	0.879	0.852	0.930	0.016	87.94
Surface area (A), cm ²	140.38	68.81	242.70	29.44	14038.39
Volume (V), cm ³	158.95	53.69	355.62	51.23	15895.42
Aspect ratio (R)	0.834	0.800	0.913	0.024	83.43

$$R = \frac{\text{Intermediate diameter}}{\text{Major diameter}} \dots (5)$$

Relationship between engineering properties of pomegranate fruits :

Correlation coefficients were worked out as per the method given by Al-jibouri *et al.* (1958) and Lal *et al.* (2013) and relations among the measured engineering properties and correlation matrix is established. All statistical analysis carried out by using SAS 9.2 software (SAS institute, Cary, NC).

Results and Discussion

The data given in Table 1 showed mean, minimum and maximum values for each engineering property recorded for 100 pomegranate fruits with its standard deviation. Fruits exhibited a wide range of sizes with minimum, maximum and average values for major, intermediate and minor diameter as 5.090, 9.641 and 7.556; 4.647, 8.558 and 6.311; 4.337, 8.236 and 6.172 cm, respectively. Fruit ranged widely in weight with smallest and largest fruit having 118.40 g and 284.55 g, respectively with mean value of

188.05 g. The average values of other dimensional properties such as geometric mean diameter, sphericity, surface area, volume and aspect ratio were 6.651 cm, 0.879, 140.384 cm², 158.954 cm³ and 0.834, respectively whereas minimum and maximum values were 4.681 and 8.792 cm; 0.852 and 0.930; 68.81 and 242.70 cm²; 53.69 and 355.62 cm³; 0.800 and 0.913, respectively.

Lal *et al.* (2013) also reported average values for length, width, weight and volume of pomegranate fruit as 7.569 cm, 7.735 cm, 242.0 g and 265.44 cm³, respectively. Dineshkumar *et al.* (2015) reported average values for length, width, thickness, mass, geometric mean diameter, sphericity, surface area and volume of pomegranate fruit as 5.804 cm, 7.206 cm, 7.008 cm, 208.06 g, 6.401 cm, 0.94, 219.90 cm² and 208.07 cm³, respectively.

Relationship between engineering properties of pomegranate fruits :

The correlation matrix related to different engineering properties of pomegranate fruit is presented in Table 2 and Fig. 1 (a to h). It showed the relationship between these various

Table 2. Engineering properties of pomegranate fruit (Cv. Bhagawa): correlation matrix

Traits	Fruit weight (W), g	Major axis (l) (cm)	Intermediate axis (b) (cm)	Minor axis (t), (cm)	Geometric mean diameter (GMD), (cm)	Sphericity (F)	Surface area (A), (cm ²)	Volume (V), (cm ³)	Aspect ratio ®
Weight of fruit (W), g	1	0.984**	0.984**	0.977**	0.988**	0.615**	0.986**	0.978**	0.553**
Major diameter (l), cm		1	0.971**	0.976**	0.988**	0.541**	0.972**	0.950**	0.456**
Intermediate diameter (b), cm			1	0.992**	0.995**	0.714**	0.998**	0.993**	0.654**
Minor diameter (t), cm				1	0.997**	0.705**	0.994**	0.982**	0.612**
Geometric mean diameter (GMD), cm					1	0.664**	0.995**	0.983**	0.585**
Sphericity (Φ)						1	0.710**	0.745**	0.964**
Surface area (A), cm ²							1	0.996**	0.643**
Volume (V), cm ³								1	0.689**
Aspect ratio (R)									1

* - significant at 5% and ** - significant at 1%

fruit characteristics. Among engineering properties, six characteristics i.e. major diameter, intermediate diameter, minor diameter, geometric mean diameter, surface area and fruit volume were strongly correlated to fruit weight with high correlation coefficients. Fruit weight and major diameter, fruit weight and intermediate diameter, fruit weight and geometric mean diameter and fruit weight and surface area indicate strong positive correlation (significant at 0.01 level) indicating that larger and longer fruits are heavier and having more fruit weight. The strong linearity of the relationship is evident in the strong correlation coefficients of 0.983, 0.984, 0.988 and 0.986, respectively (Table 2). Minor diameter i.e. thickness of fruit and volume are also strongly correlated with fruit weight with higher correlation coefficients of 0.977 and 0.978, respectively. This means that as fruit weight increased, the diameter and fruit volume also increased and was significant at the 0.01 level of significance. The extremely high correlation between fruit weight, fruit diameter, length, geometric mean diameter, surface area and volume indicates that weight can be interchangeably used to indicate size (Lal *et al.*, 2013). Thus, the development of a set of fruit characteristics for grading pomegranate fruit

destined for different purposes (e.g. fruit weight versus fruit size) is probably not necessary. Instead, any of the characteristics having higher correlation coefficient (fruit volume, fruit weight, major, intermediate and minor diameter, geometric mean diameter, surface area and volume) could serve as a measure. For example, crop breeders, farm managers, and marketing agents could use fruit weight, diameter, surface area or volume as the index of size. Lal *et al.* (2013) also observed the strong correlation among six characteristics of pomegranate fruit such as fruit diameter, fruit length, fruit volume, fruit weight, No. of seed + aril per fruit and weight of seed + aril per fruit. From Table 2 and Fig. 1(e and h) also observed that fruit characteristics like sphericity and aspect ratio were poorly correlated with fruit weight having correlation coefficient of $r = 0.615$ and 0.553 , respectively.

Conclusion

The results concluded that fruit weight, major, intermediate and minor diameter, geometric mean diameter, surface area and volume are closely correlated, any single character can be used as common indicator of fruit size. This is in contrast to sphericity and aspect ratio, which had poor relation to fruit

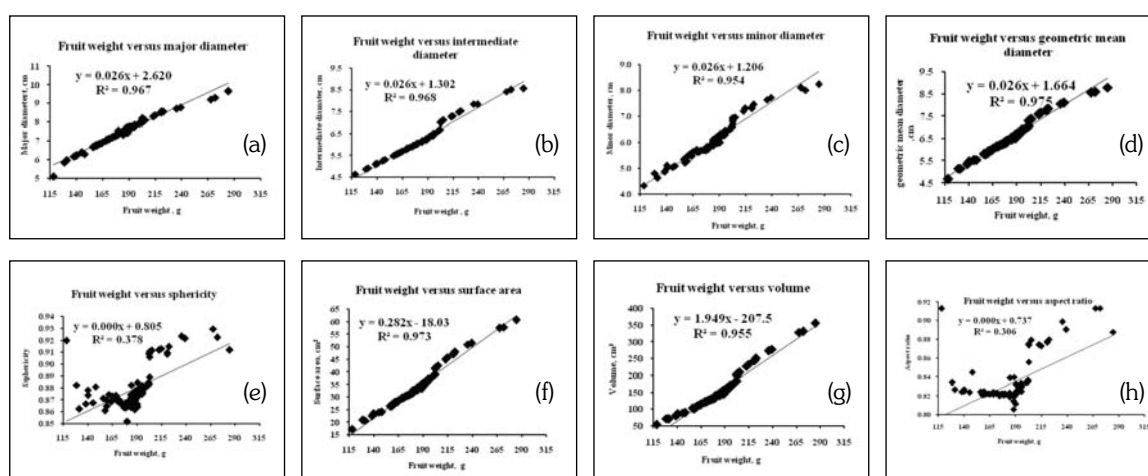


Fig. 1. Relationship between engineering properties of pomegranate fruit (Cv. Bhagawa)

size. The results of this study will be useful for designing and development of process machineries, feed hoppers, storage structures, material handling equipment and packaging purposes with minimum damage to the products. The correlation study will be helpful to crop breeders and pomegranate producers for deciding crop production strategies and farm management practices.

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Establishment of Soil Erodibility Factor 'K' for Soybean crop at Rahuri (M.S)

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Abstract

The study was undertaken to determine the Soil erodibility (K-factor) to assess the potential of soil being vulnerable to the vagaries of erosion so as to plan against its incipience or progress. The field experiment was conducted on the Instructional Farm of the Department of Soil and Water Conservation Engineering, Dr. A. S. College of Agricultural Engineering, Mahatma Phule Krishi Vidyapeeth, Rahuri during 2009. In the study two treatments, viz., cultivated fallow and soybean crop were considered. Daily rainfall during the crop growth period measured throughout the season with automatic rain gauge and analyzed for rainfall erosivity index. The soil loss in gram liter⁻¹ was estimated and then converted to soil loss in tones hectare⁻¹ for respective plot of a particular treatment. The kinetic energy for different intensities was computed and used for the erosivity indices (EI₃₀) of corresponding storm. The soil erodibility factor is the mean annual soil loss per unit erosivity index from field of 9 per cent slope and 22.13 m as field length. The erodibility factor (K) was determined by considering the soil loss from continuous cultivated fallow land without influence of crop cover or management. The Observed soil loss from cropped plot was found to be 0.989 t ha⁻¹. The total rainfall erosivity for the season was found to be 112.13 metric ton ha⁻¹. The maximum rainfall erosivity was found in the month of October. The value of soil erodibility factor (K) was found to be 0.1281.

Key words : Soil erodibility factor, erosivity index, runoff, soil loss.

Soil erosion is a major soil degradation threat in most vulnerable ecological systems especially in the fragile semi-arid environments. It is the vagaries from environmental agents (rainfall, runoff, streams, and wind) solely or coupled with anthropogenic factors. While nature builds the land, its agencies along with human and animal factors, destroy the land surface by erosion and, in many cases, destroy down the soil sub layer by gully and tunnel erosion. The need for environmental sustainability of land for agricultural resource productivity informed the formulation of the program of soil conservation such as composed by Revised Universal Soil Loss Equation, RUSLE (R. Suresh, 2006) in which conservation practices evaluated the K- factor, called erodibility factor, to assess the potential

of soil being vulnerable to the vagaries of erosion so as to plan against its incipience or progress. Soil erodibility (K-factor) has been used recently erosion and hydrological processes. The K factor is one of the key parameters required for soil erosion prediction across the world. Therefore assessment of erosional soil losses is the basis for effective conservation planning and management of the vulnerable ecosystems. By definition, the soil erodibility factor is the average soil erosion in terms of ton ha⁻¹ due to one unit of erosivity factors (EI) m from a control plot (Standard plot). A control plot would be 22.13 m long with a 9% uniform slope and two consecutive years in fallow, without any plant cover and plowed down slopes.

Material and Methods

Study area : The experiment was

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conducted in *Kharif* season during 2009, on the Instructional farm of the Department of Soil and Water Conservation Engineering, Dr. A. S. College of Agricultural Engineering and Technology, Mahatma Phule Krishi Vidyapeeth, Rahuri. It is located at 19° 24' N latitude and 74° 39' E longitude and at average height of 657 m above mean sea level. The experimental field of size 48 x 28 m was divided into four plots of size 12 x 28 m each. At the end of each plot runoff mulslot divisor was constructed for measurement of runoff and soil loss. The slope of each plot was 1.20%. Field plot was divided into four treatment plots, in which two plots were cultivated with soybean (T₁) and two plots were kept cultivated fallow treatment plot (T₂). The representative soil samples were obtained from different depths and locations for determination of physico-chemical properties of soil of experimental plot. The rainfall was measured throughout the season with automatic rain gauge installed in the adjoining field. The mulslot divisor provided at the end of each plot was used to measure the runoff from the plot. Knowing the dimensions of sedimentation storage tank and measuring the depth of water in water channel and sedimentation tank, runoff volume was calculated. The volume was then converted into depth of runoff by taking average value of two plots of a particular treatment.

The 500 ml runoff sample bottle was used for the determination of soil loss. Three runoff samples were collected from the water channel of each plot after stirring the water in the channel prior to sampling. These runoff samples were kept in laboratory for 48 hours for settlement and clear water was removed from the sample bottle. Remaining water in the soil was removed by filtration method. Then that soil was transferred into aluminium boxes and dried in hot air oven at 105 °C temperature for 24 hours. The soil loss in gram litre⁻¹ was estimated and then converted to soil loss in

tones per hectare for respective plot of a particular treatment.

Determination of Rainfall erosivity index, R : The recording rain gauge charts were analyzed for determination of rainfall erosivity index. The erosion index values for all the storms were computed. The differing slopes of rainfall line corresponding to time intervals were separated for period of storm. Rainfall intensities for these time intervals were worked out. The kinetic energy for all such segments was computed in metric units using following equation (Singh *et al.*, 2004) and totaled for a single storm.

Table 1. Physico-chemical properties of soil

Property	Values
Silt + very fine sand (0.002 to 0.1mm)	14.20%
Sand (0.1 to 2.0mm)	42.45%
Clay	42.84%
Organic Matter content	
Before harvesting	0.51%
After harvesting	0.46%
Soil type	Clay loam
Field Capacity	38.6%
Bulk density	1.43 g cc ⁻¹
Soil Structure	Sub angular blocky
Soil pH	7.8
Basic infiltration rate	6.3 cm h ⁻¹

Table 2. Runoff producing storms

Date	Rainfall amount (mm)	Rainfall duration (hr)	Average intensity (mm h ⁻¹)
22.08.2009	24.50	4.15	5.903
23.08.2009	23.50	5.12	4.585
25.08.2009	13.50	2.25	6.00
1.09.2009	7.00	1.50	4.660
2.09.2009	4.50	1.50	3.00
3.09.2009	6.25	3.25	1.923
11.09.2009	13.00	5.12	2.536
13.09.2009	17.00	2.54	6.692
15.09.2009	14.00	1.00	14.00

$$K.E_s = 210.3 + 89 \log I \quad \dots (1)$$

Where, $K.E_s$ = Kinetic energy of Storm, Mt ha^{-1} -cm and I = Rainfall intensity, $cm h^{-1}$.

On determination of kinetic energy, the erosivity index (EI_{30}) was worked out by using following equation (Singh *et al.*, 2004). These erosivity indices values were further considered as rainfall erosion index (R) for each storm.

$$EI_{30} = \frac{K.E_s \times I_{30}}{100} \quad \dots (2)$$

Where, EI_{30} = Rainfall Erosivity, Mt-cm ha^{-1} -h, $K.E_s$ = Kinetic energy of Storm, Mt ha^{-1} -cm and I_{30} = Maximum 30 min. rainfall intensity of the storm ($cm hr^{-1}$).

Soil erodibility factor, K : The soil erodibility factor is the mean annual soil loss per unit erosivity index from field of 9 per cent slope and 22.13 m as field length. The erodibility factor (K) was determined by considering the soil loss from continuous cultivated fallow land without influence of crop cover or management. The value of soil erodibility factor (K) can be determined for a particular location, using a set of runoff plots. The equation used for determination of erodibility factor.

$$K = \frac{A_0}{EI_{30} \times LS} \quad \dots (3)$$

Where, K = Soil Erodibility factor, A_0 = Observed soil loss, ($t ha^{-1}$), EI_{30} = Total rainfall erosivity index, Mt-cm ha^{-1} h and LS = Steepness of Slope factor.

Topographic factor, LS : The factors of slope length (L) and slope steepness (S) are combined in a single index. Wischmeier and Smith (1978) developed the equation for evaluating the LS values for uniform slope. The

following equation is given as,

$$LS = (\lambda/22.13)^m [65.41 \sin^2 \theta + 4.58 \sin \theta + 0.065] \quad \dots (4)$$

Where, LS = Topographic factor, λ = Slope length, m, m = Constant depending upon per cent slope, varying from 0.2 to 0.5 and θ = Angle of slope, degree

Results and Discussion

The experimental findings of different

Table 3. Observed rainfall and runoff data in cultivated fallow treatment plot and cropped area

Date	Rainfall (mm)	Runoff, mm in cropped area	Runoff, mm in fallow plot
22.08.2009	24.25	6.617	8.302
23.08.2009	23.50	6.883	9.047
25.08.2009	13.50	4.266	8.557
1.09.2009	7.00	1.787	2.626
2.09.2009	4.50	1.748	1.969
3.09.2009	6.25	1.720	2.340
11.09.2009	13.00	0.152	0.303
13.09.2009	17.00	2.260	2.626
15.09.2009	14.00	2.180	2.330

Table 4. Observed rainfall and soil loss data from cropped area and cultivated fallow treatment

Date	Rainfall (mm)	Soil loss ($t ha^{-1}$) from cropped plot	Soil loss ($t ha^{-1}$) from cultivated fallow plot
22.08.2009	24.50	0.105	0.209
23.08.2009	23.50	0.473	0.847
25.08.2009	13.50	0.156	0.462
1.09.2009	7.00	0.140	0.167
2.09.2009	4.50	0.020	0.056
3.09.2009	6.25	0.045	0.136
11.09.2009	13.00	0.001	0.038
13.09.2009	17.00	0.015	0.040
15.09.2009	14.00	0.034	0.064

treatments, properties of soil, estimation of soil loss and runoff is given below.

Physico-chemical properties of soil :

Various properties of soil of experimental field were determined as detailed in above section are reported in Table 1. The proportion of sand, silt and clay indicated that the soil is clay loam. The basic infiltration rate of the soil is 6.3 cm h⁻¹. The mean values of bulk density and field capacity are 1.43 g cc⁻¹ and 38.6 per cent, respectively.

Runoff : Only nine storms were effective in producing runoff. Event wise runoff data are given in Tables 2 and 3. From Table 2, it is observed that the maximum runoff occurred on 23.8.2009. The rainfall received on this day was 23.5 mm with average intensity of 4.58 mm h⁻¹. The crop was sown on 17.07.2009 and as such the soil was not much under crop cover which caused the maximum runoff (6.883 mm). This was followed by another high runoff (6.617 mm) on 22.08.2009 from 24.50 mm with an intensity of 5.903 mm h⁻¹. The runoff recorded from cultivated fallow treatment was 9.0475 mm (38.39 %) whereas from the cropped area it was 6.883 mm (29.28%) on 23/8/2009 (Table 3). Verma *et al.* (1990) have reported 37 per cent runoff from cultivated fallow treatment plot on 1 per cent slope of Kota clay soil.

Soil loss : The event wise soil loss is given in Table 4. It is observed that maximum soil loss was found to be 0.847 t ha⁻¹ from cultivated fallow and 0.473 t ha⁻¹ from cropped area. The total soil loss during the crop growth period was found to be more in cultivated fallow treatment (2.019 t ha⁻¹) followed by cropped area (0.989 t ha⁻¹).

Determination of Soil erodibility factor, K : The Soil erodibility (K) factor was determined by using Universal Soil Loss Equation by adopting the procedure mentioned

in previous section. The values of Rainfall erosivity factor (R) and topographic factor (LS) were computed as discussed earlier.

Rainfall erosivity factor, R : Rainfall erosivity factor (R) was found out by the formula

Table 5. Rainfall erosivity values during crop growth period

Date	Erosivity (R)	Month	R, value for month	% R value
20/6/2009	5.8514	June	5.85	5.21
3/7/2009	0.5180	July	10.72	9.56
7/7/2009	9.5838			
8/7/2009	0.2143			
15/7/2009	0.0942			
20/7/2009	0.0221			
21/7/2009	0.2128			
22/7/2009	0.0764			
17/8/2009	0.8669	August	20.28	18.08
18/8/2009	3.1378			
19/8/2009	0.9530			
20/8/2009	1.7815			
21/8/2009	0.7463			
22/8/2009	5.7304			
23/8/2009	5.2412			
24/8/2009	0.0606			
25/8/2009	1.5253			
27/8/2009	0.2389			
1/9/2009	1.4340	September	30.773	27.45
2/9/2009	0.2990			
3/9/2009	3.438			
4/9/2009	0.4334			
10/9/2009	0.0154			
11/9/2009	1.0434			
13/9/2009	16.271			
15/9/2009	7.824			
30/9/2009	0.0154			
3/10/2009	26.525	October	26.52	23.66
9/11/2009	2.7040	November	17.99	16.04
10/11/2009	2.893			
11/11/2009	3.362			
13/11/2009	0.1399			
14/11/2009	0.2961			
15/11/2009	8.575			
16/11/2009	0.0239			

suggested by Wischmeier and Smith (1978). The rainfall erosivity values during the season are presented in Table 5. From the Table 5, it is seen that the total rainfall erosivity for season was 112.13 metric t ha⁻¹. The month wise rainfall erosivity values were 5.85, 10.72, 20.28, 20.84, 30.77 and 17.99 metric t/ha for June, July, August, September, October and November respectively. The value of erosivity index was found to be maximum on 13.9.2009 (30.777) followed by (26.525) on 3.10.2009 and (9.5838) metric units on 7.7.2009.

Topographic factor (LS) and Soil erodibility factor (K) : The value of topographic factor, LS was computed and found to be 0.1418. The value of erodibility factor (K) was found to be 0.1281.

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RESEARCH NOTES

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Yield, Quality and Nutrient Uptake of Soybean as Influenced by Water Soluble Fertilizer, Micro-nutrient and Plant Growth Regulators

Soybean is one of the important oil seed grown in the temperate and tropical climate. The crop being pulse and oil seed plays three dimensional role as pulse, oilseed and legume. In Maharashtra, it was grown on 3.07 million ha area with production of 4.30 million tonnes and productivity 1076 kg ha⁻¹ (Anonymous, 2012). The soils of Maharashtra are deficient in zinc, low in nitrogen and medium in phosphorus and potassium (Patil, 2001). However, soil application of high analysis fertilizers are costly affairs to the farmers. To overcome this constrains, the present investigation was planned to fulfill the nutrient requirement of soybean through foliar application for harvesting potential yield and reduced the cost of fertilizer.

The field experiment on effect of foliar sprays of water soluble fertilizers, growth regulator and micronutrients on growth, yield and quality of soybean cv. JS-335 sowing on 21.07.2012 was conducted at Post Graduate Institute, MPKV, Rahuri during *Kharif* season 2012. The treatments consist of foliar sprays of T₁ - foliar sprays of 19:19:19 (0.5%) at 30 and 40 DAS, T₂ - foliar sprays of ZnSO₄ (0.5%) at 30 and 40 DAS, T₃ - foliar sprays of NAA (50 ppm) at 30 and 40 DAS, T₄ - foliar spray of H₃BO₃ (0.5%) at 30 and 40 DAS, T₅ - foliar sprays of 19:19:19 (0.5%) + ZnSO₄ (0.5%) at 30 and 40 DAS, T₆ - foliar sprays of 19:19:19 (0.5%) + H₃BO₃ (0.5%) at 30 and 40 DAS, T₇ - foliar sprays of 19:19:19 (0.5%) + NAA (0.5%) at 30 and 40 DAS, T₈ - foliar sprays of 19:19:19 (0.5%) + H₃BO₃ (0.5%) + ZnSO₄ (0.5%) at 30 and 40 DAS, T₉ - foliar sprays of

ZnSO₄ (0.5%) + H₃BO₃ (0.5%) + NAA (50 ppm) at 30 and 40 DAS and T₁₀ - only GRDF (50:75:00 kg ha⁻¹ N, P₂O₅ and K₂O). These treatments were replicated thrice in randomized block design. All the sprays was given at 30 and 40 DAS. The experimental soil was clayey with medium in soil available nitrogen, phosphorus and high in potassium. The DTPA-Zn and hot water soluble boron was deficient in soil (0.452 and 0.430 µg g⁻¹). The initial and harvest soil samples were analysed for soil available nutrients and plant samples for their nutrient concentration at harvest. The standard analytical methods Alkaline KMnO₄, 0.5 M NaHCO₃, NNNH₄OAc, atomic absorption spectrophotometer, 0.01 M CaCl₂, N analyzer, Vanadomolybdate-yellow colour method in nitric acid system, flame photometer, atomic absorption spectrophotometer and Azomethine-H colorimetric method were followed for estimation of nutrients from soil and plants.

Yield : The grain, straw, biological yield and harvest index of soybean was significantly influenced by spray treatments of water soluble fertilizers micronutrients and plant growth regulators (Table 1). The spraying of 19:19:19 (0.5%) + ZnSO₄ (0.5%), 19:19:19 (0.5%) + NAA (50 ppm) and 19:19:19 (0.5%) + H₃BO₃ (0.5%) + ZnSO₄ (0.5%) at 30 and 40 DAS were statistically at par with each other for grain yield of soybean (22.0, 22.3 and 22.7 q ha⁻¹, respectively). This might be because of spraying of 19:19:19, ZnSO₄ and H₃PO₄ provides balance nutrition to soybean, zinc act as reducing agent in plant metabolic activities as

well as co-enzyme. The boron accelerated the protein synthesis and translocation of sugar from source to sink by formation of sugar borate. Similarly, boron improves the pollen viability which may reflected in higher grain yield of soybean. These results are conformity with Dixit and Elamathi (2007) and Tate (2010).

The highest straw yield was noticed in treatment 19:19:19 (0.5%) + H₃BO₃ (0.5%) + ZnSO₄ (0.5%) at 30 and 40 DAS (21.0 q ha⁻¹). Similar trend was observed biological

yield and harvest index.

Quality : The protein and oil content of soybean was not significantly influenced by foliar application of 19:19:19, boric acid and zinc sulphate. However, numerically it was higher in 19:19:19 (0.5%) + H₃BO₃ (0.5%) + ZnSO₄ (0.5%) spray to soybean at 30 and 40 DAS (38.54 and 19.14%). Similar trend was observed for protein and oil yield. Similar observations were also reported by Dhakane (2005) and Vahedi (2012). Nutrient uptake.

Table 1. Effect of foliar sprays of water soluble fertilizers, micronutrients and plant growth regulators on yield and nutrient uptake of soybean

Treatment	Yield (q ha ⁻¹)			Harvest index	Nutrient uptake (kg ha ⁻¹)			Micronutrient uptake (kg ha ⁻¹)	
	Grain	Straw	Biological		N	P	K	Zn	B
T ₁ : 19:19:19 (0.5%) at 30 and 40 DAS	21.00	20.10	41.10	51.09	160.05	21.74	134.93	65.18	55.78
T ₂ : ZnSO ₄ (0.5%) at 30 and 40 DAS	20.30	19.70	40.00	50.75	151.09	19.37	131.52	63.29	53.67
T ₃ : NAA (50 ppm) at 30 and 40 DAS	20.70	19.90	40.60	50.98	153.70	20.46	133.24	64.58	54.54
T ₄ : H ₃ BO ₃ (0.5%) at 30 and 40 DAS	19.80	19.40	39.20	50.51	147.39	17.68	129.49	62.27	52.27
T ₅ : 19:19:19 (0.5%) + ZnSO ₄ (0.5%) at 30 and 40 DAS	22.00	20.50	42.50	51.74	169.35	24.46	141.36	68.38	58.38
T ₆ : 19:19:19 (0.5%) + H ₃ BO ₃ (0.5%) at 30 and 40 DAS	21.75	20.40	42.15	51.60	166.89	24.11	138.84	67.24	57.42
T ₇ : 19:19:19 (0.5%) + NAA (50 ppm) at 30 and 40 DAS	22.30	20.70	43.00	51.85	171.90	26.14	143.46	69.17	59.57
T ₈ : 19:19:19 (0.5%) + H ₃ BO ₃ (0.5%) + ZnSO ₄ (0.5%) at 30 and 40 DAS	22.70	21.00	43.70	51.94	188.50	27.06	145.46	70.13	60.18
T ₉ : ZnSO ₄ (0.5%) + H ₃ BO ₃ (0.5%) + NAA (50 ppm) at 30 and 40 DAS	21.50	20.30	41.80	51.43	163.90	23.12	136.57	66.76	56.26
T ₁₀ : Only GRDF	18.73	19.10	38.10	49.86	133.68	15.03	128.32	61.74	51.72
S.Em ±	0.27	0.08	0.22	0.31	4.21	2.56	0.01	1.24	1.34
CD at 5 %	0.80	0.24	0.66	0.94	12.54	7.63	0.03	3.70	4.02

Total uptake of nitrogen, phosphorus, potassium, zinc and boron were significantly influenced by foliar application (Table 1). The highest uptake of nitrogen, phosphorus and potassium was observed in 19:19:19 (0.5%) + H₃BO₃ (0.5%) + ZnSO₄ (0.5%) at 30 and 40

DAS (188.50, 27.06 and 145.46 kg ha⁻¹, respectively). Similar treatment recorded the highest zinc and boron uptake (70.13 and 60.18 g ha⁻¹). This might be because of boron sprays improves the protein synthesis, photosynthesis by translocating the photo-

Table 2. Effect of foliar sprays of water soluble fertilizers, micronutrients and plant growth regulators on protein and oil content of soybean

Treatment	Protein content (%)	Oil content (%)
T ₁ : 19:19:19 (0.5%) at 30 and 40 DAS	35.71	18.40
T ₂ : ZnSO ₄ (0.5%) at 30 and 40 DAS	35.44	18.10
T ₃ : NAA (50 ppm) at 30 and 40 DAS	35.56	18.20
T ₄ : H ₃ BO ₃ (0.5%) at 30 and 40 DAS	35.41	18.00
T ₅ : 19:19:19 (0.5%) + ZnSO ₄ (0.5%) at 30 and 40 DAS	37.37	18.77
T ₆ : 19:19:19 (0.5%) + H ₃ BO ₃ (0.5%) at 30 and 40 DAS	37.11	18.63
T ₇ : 19:19:19 (0.5%) + NAA (50 ppm) at 30 and 40 DAS	37.47	18.87
T ₈ : 19:19:19 (0.5%) + H ₃ BO ₃ (0.5%) + ZnSO ₄ (0.5%) at 30 and 40 DAS	38.54	19.14
T ₉ : ZnSO ₄ (0.5%) + H ₃ BO ₃ (0.5%) + NAA (50 ppm) at 30 and 40 DAS	36.01	18.50
T ₁₀ : Only GRDF	34.69	17.87
S.Em ±	0.77	0.27
CD at 5%	N.S.	N.S.

Note : GRDF was uniformly applied from T₁ to T₁₀ treatments

Table 3. Gross monetary returns, cost of cultivation, net monetary returns and benefit : cost ratio of soybean as influenced by different treatments

Treatment	Gross monetary returns	Cost of cultivation	Net monetary returns	B:C ratio
T ₁ : 19:19:19 (0.5%) at 30 and 40 DAS	67020.20	35020.25	32000.45	1.91
T ₂ : ZnSO ₄ (0.5%) at 30 and 40 DAS	64840.60	34720.30	30120.40	1.87
T ₃ : NAA (50 ppm) at 30 and 40 DAS	66080.45	34790.40	31290.70	1.90
T ₄ : H ₃ BO ₃ (0.5%) at 30 and 40 DAS	63280.20	34480.70	28800.65	1.84
T ₅ : 19:19:19 (0.5%) + ZnSO ₄ (0.5%) at 30 and 40 DAS	70100.30	35470.75	34630.30	1.98
T ₆ : 19:19:19 (0.5%) + H ₃ BO ₃ (0.5%) at 30 and 40 DAS	69330.30	35230.65	34100.75	1.97
T ₇ : 19:19:19 (0.5%) + NAA (50 ppm) at 30 and 40 DAS	71040.20	35540.25	35500.50	2.00
T ₈ : 19:19:19 (0.5%) + H ₃ BO ₃ (0.5%) + ZnSO ₄ (0.5%) at 30 and 40 DAS	72300.30	35680.45	36620.70	2.03
T ₉ : ZnSO ₄ (0.5%) + H ₃ BO ₃ (0.5%) + NAA (50 ppm) at 30 and 40 DAS	68560.60	35450.60	33110.60	1.93
T ₁₀ : Only GRDF	60020.35	34270.65	25750.40	1.75
S.Em ±	806.11	-	806.11	0.22
CD at 5 %	2394.17	-	2394.17	0.68

Note : GRDF was uniformly applied from T₁ to T₁₀ treatments

synthate from source to sink. It was reflected in enhancing the growth and nutrient uptake.

The spray application of 19:19:19 + H₃BO₃ + ZnSO₄ of 0.5 per cent each at 30 and 40 DAS to soybean was beneficial for increasing the grain yield and nutrient uptake. Gross monetary returns, net monetary returns and B:C ratio were found to be highest with GRDF + foliar application of 19:19:19 NPK 0.5% + H₃BO₃ 0.5% + ZnSO₄ 0.5% which was Rs. 72300.25 ha⁻¹, Rs. 36620.68 and 2.03, respectively and the cost of cultivation was Rs. 35680.45 ha⁻¹.

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Economics of Green Chilli as Influenced by Organic Sources of Nitrogen

Chilli is an important spice cum vegetable crop cultivated extensively in India. Generally, excessive amounts of inorganic fertilizers are applied to vegetables in order to achieve a higher yield and maximum value of growth. However, the use of inorganic fertilizers alone may cause problems for human health and the environment. In recent times, consumers are demanding higher quality safe food and highly interested in organic products. The sustainable agricultural practice can effectively prevent entry of pesticides and toxicants in the food chain. The organic materials such as poultry

manure, green leaf manures and FYM can substitute for inorganic fertilizers to maintain productivity and environmental quality (Chaudhary *et al.*, 2002). Although the organic manures contain plant nutrients in small quantities as compared to the fertilizers, the presence of growth promoting principles like enzymes and hormones, besides plant nutrients make them essential for improvement of soil fertility and productivity on long term basis (Bhuma, 2001). With these considerations in view, the present experiment was planned.

The field experiment was carried out during summer 2014 at Organic Farm, Agronomy Division, College of Agriculture, Pune in randomized block design with three replications. The eight treatments consisted of 100% N through FYM, 100% N through vermicompost, 100% N through poultry manure, 100% N through neem cake, 50% N through FYM + 50% N through vermicompost, 50% N through FYM + 50% N through poultry manure, 50% N through FYM + 50% N through neem cake, 25% N through FYM + 25% N through vermicompost + 25% N through poultry manure + 25% N through neem cake. Chilli variety Sitara was transplanted at spacing of 60 x 45 cm² on 21st February, 2014. All organic manures were applied 15 days before sowing. A total of nine pickings were considered for total fruit yield per hectare.

Fruit yield of green chilli (1.373 t ha⁻¹) was statistically higher with the application of 100% N through vermicompost and it was superior over rest of treatments (Table 1). The next best treatment was application of 100% N through poultry manure (1.359 t ha⁻¹). The increase in nutrient availability from vermicompost might have increased various endogenous hormonal

levels in plant tissues, which were responsible for enhanced pollen germination and tube growth, which ultimately increased the yield as compared to other sources. Further, increased vegetative growths has provided more sites for translocation of photosynthates which ultimately resulted in increased yield (Kumar *et al.*, 2012). Vermicompost also contains more number of nitrogen-fixing, phosphate-solubilizing and other beneficial microbes, antibiotics, vitamins, hormones, enzymes, etc. which has better effects on growth and yield of plants (Bhawalkar, 1992).

The cost of cultivation was maximum in application of 100% N through vermicompost (Rs. 78234 ha⁻¹). The higher value of cost of cultivation owing to more cost of vermicompost. The application of 100% N through vermicompost gave maximum gross monetary returns of Rs. 109024 ha⁻¹, which was significantly superior over rest of the treatments. The statistically higher net returns and benefit cost ratio of Rs. 67334 ha⁻¹ and 2.63, were recorded with 100% N through poultry manure, which was significantly more than rest of the treatments. The higher value of net monetary returns and benefit cost ratio

Table 1. Effect of organic sources of nitrogen on yield and economics of green chilli

Treatment	Fruit yield (t ha⁻¹)	Gross monetary returns (Rs. ha⁻¹)	Cost of cultivation (Rs. ha⁻¹)	Net monetary returns (Rs. ha⁻¹)	Benefit: cost ratio
T ₁ - 100% N through FYM	1.16	92808	48234	44574	1.92
T ₂ - 100% N through Vermicompost	1.373	109024	78234	30790	1.39
T ₃ - 100% N through Poultry manure	1.359	108768	41434	67334	2.63
T ₄ - 100% N through Neem cake	1.231	98496	48234	50262	2.04
T ₅ - 50% N through FYM + 50% N through vermicompost	1.353	108288	63234	45054	1.71
T ₆ - 50% N through FYM + 50% N through poultry manure	1.303	104264	44834	59430	2.33
T ₇ - 50% N through FYM + 50% N through neem cake	1.112	88944	48234	40710	1.84
T ₈ - 25% N through FYM + 25% N through vermicompost + 25% N through poultry manure + 25% N through Neem cake	1.274	101928	54034	47894	1.89
S.E.m±	0.0034	486	-	274	-
CD at 5%	0.0104	1476	-	833	-

recorded with application of 100% N through poultry manure owing to lower cost of cultivation and somewhat higher fruit yield. Though treatment receiving 100% N through vermicompost recorded higher total fruit yield as well as gross monetary returns among organic nitrogen treatments, but because of higher cost of vermicompost, net monetary returns and benefit cost ratio were lower when compared with other organic treatments. Naik *et al.* (2007) and Mandloi *et al.* (2008) reported that the higher B:C ratio (2.36) was recorded with the application of poultry manure when compared to FYM and vermicompost.

Based on the present study it can be concluded that highest fruit yield of green chilli of 1.373 t ha⁻¹ can be obtained with application of 100% N through vermicompost treatment, followed by application of 100% N through poultry manure. The same treatment also recorded the highest gross monetary returns (Rs. 109024 ha⁻¹). The statistically higher net returns of Rs. 67334 ha⁻¹ were recorded with treatment *viz.*, application of 100% N through poultry manure, which was significantly more than rest of the treatments. Similar trend was also noticed in case of benefit cost ratio (2.63) as that of net monetary returns.

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Propagation of Potato by Stem Cuttings

Potato seed tubers are an important ingredient in successful potato cultivation. About 60 per cent of cost of potato cultivation is incurred on seed alone. Several recommendations were brought out to economize on cost of seed by using suitable seed size and spacing but yet the cost of quality

tuber seed is still high. Keeping this in view the present experiment was undertaken in shade net house equipped with foggers and misters at NARP, Ganeshkhind, Pune during Rabi season 2015-16 so that the farmers can prepare their own planting material on their field itself and cut short on the expenses of tuber seed

material. The area under production in Maharashtra is showing a decreasing trend and one of the major reason is high cost of quality seed tubers.

Propagation tests were made with varieties Pukhraj, Jyoti and Ashoka which are usually preferred by potato growers. Cuttings with three internodes were prepared and treated with fungicide solution Bavistin @ 2.5 g lit⁻¹ for 10 mins. These cuttings were taken at 75 days growth stage of Rabi crop and planted in three different media *viz.*, vermiculite, coco pit and sand. Before planting the bottom end of cuttings was dipped in Keradex paste or Iondole Butyric Acid (50 ppm) and then planted in different media.

The shade net was fitted with foggers and misters. The plastic trays containing the cuttings were placed under the misters to ensure that the cuttings were kept moist.

From the results it was observed that the sprouting percentage of potato cuttings was very low in case of vermiculite (15%) and coco peat (25%). However the cuttings planted in sand showed a better sprouting percentage (50%). One month after planting the cuttings were uprooted and the root count was taken. On an average there were 5-6 roots/cutting in each variety. It was observed that almost 50% of the cuttings of each variety rooted equally

well in sand. Cole (1967) reported that rooted cuttings planted in soil in the green house produced vigorous growth from which more cuttings can be taken. He further reported that rooted cuttings can be transplanted in the field and tubers can be harvested if proper cultivation practices are undertaken.

From the results it can be concluded that sand is a good media for rooting of potato cuttings. Further studies on transplanting cuttings in the field to see if they tuberize or not is essential. Potato being a temperature sensitive crop these studies should be undertaken in regions which have an ideal climate for potato cultivation. There was no significant difference in the rooting percentage of cuttings treated with IBA and those treated with Keradex paste.

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Morphological traits and fibre yield of newly released jute (*C. olitorius*) genotypes

The jute (*Corchorus olitorius* L.) known as 'golden fibre' is grown mostly by small and marginal farmers. Jute plant is an annual shrub with basic chromosome number $n = 7$. It was

proposed that *Corchorus olitorius* originated from South China from where, it was introduced to India and Pakistan. It was found wild in many parts of India as well as China and

many parts of Australia and Africa especially in South-western Nigeria. In India, jute plays a vital role in the economy of West Bengal and also very important role in economy of Eastern Indian states such as Assam, Bihar, Orissa and Uttar Pradesh. It is cultivated on 0.80 m ha of area in the eastern India, provides livelihood support to 4 million farm families, 0.25 million industrial workers and 0.5 million traders.

Jute is a multipurpose crop, its fibres are primarily composed of cellulose and lignin that is partially textile fibre and partially wood, which is obtained from stem of the plant, its of great commercial importance in the world for

the fabrication of bags, carpets, fabrics and in manufacture of paper. The fibres are also woven into curtains, hessians cloth and backing for linoleum. Jute fibre is also used in automobile, pulp and paper, furniture and bedding industries. Jute fibre is cheaper than synthetic fibre and contributes largely to the income of countries, where, it is cultivated. Formerly, India and Bangladesh were the principal exporting countries. Jute leaves are consumed in various parts of world. It is popular vegetable in West Africa. It is made into slimy soup of sauce in some West African cooking tradition as well as in Egypt and Philippines, where, it is often considered the

Table 1. Morphological, yield attributing parameters and seed yield of Jute at harvest during 2014

Treatments	Plant height (cm)	Basal diameter (cm)	Dry matter of stem plant ⁻¹ (g)	Length of fibre (cm)	Fibre yield plant ⁻¹ (g)
JRO-524	252.00	2.41	51.61	192.50	12.25
JRO-8432	248.38	2.42	54.14	189.50	11.38
OIN-142	240.00	2.26	47.32	187.00	9.90
OIN-61	226.63	2.25	43.91	178.00	8.00
OEX-05	234.75	2.13	41.52	184.50	8.75
OIN-73	239.00	2.15	45.03	185.50	9.30
OIN-471	205.38	2.08	37.28	159.00	5.85
OIN-138	216.13	2.13	38.66	161.50	6.35
OIN-148	210.50	2.36	42.08	160.00	5.80
OIJ-276	219.13	2.27	41.00	168.00	6.50
OIJ-63	230.88	2.25	45.08	180.50	8.40
OIN-141	226.38	2.33	46.09	177.50	7.95
OIJ-211	217.63	2.23	39.55	163.50	6.45
OEX-09	232.63	2.26	45.79	179.50	8.05
OIJ-296	236.88	2.40	49.92	186.00	9.15
OIN-93	219.38	2.38	45.35	168.00	6.50
OIN-149	223.75	2.20	40.11	169.50	7.05
OIJ-656	227.38	2.07	38.71	180.00	8.20
OIN-71	234.38	2.32	48.48	181.00	8.55
JRO-204	267.88	2.55	55.66	196.00	13.80
OEX-13	224.13	2.24	42.15	171.00	6.93
OIJ-226	225.38	2.38	46.75	173.50	7.45
Mean	229.93	2.27	44.83	176.89	8.30
S.E. (±)	9.81	0.08	2.19	7.28	0.56
CD at 5%	28.85	0.25	6.44	21.42	1.65

national dish. The leaves of jute are rich in - carotene, iron, calcium and vitamin C. The plant has an anti oxidant activity with significant X-tocopheral equivalent to vitamin C.

Significant increase in production of high yielding varieties of jute crops along with improved production technologies and appropriate policy interventions. India's export market share is estimated at around 30 per cent of the global market valued at Rs 12,000 million. Incidentally, India earned Rs 1,200 crores as foreign exchange by exporting jute goods during 2005-06 as against Rs. 233 crores in the early 1960s (Saha and Hazra 2008 and Kumar *et al.* 2014).

In spite of the multipurpose use and wide distribution of jute, much attention has not been paid to this crop. In view, the investigation was undertaken to study "Morphological traits and fibre yield of newly released jute (*C. olitorius*) genotypes"

The experimental site was located in the farm of Jute and Allied Fibre crops, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra (between 19° 48' N - 19° 57' N latitude -74° 32' E and 74° 19' E longitude). The altitude varies from 495 to 569 meter above mean sea level. The soil was medium black, having pH 8.2, medium in organic C (0.52%), low in available N (179.03 kg ha⁻¹) and medium in available P (16.60 kg ha⁻¹) and available K (411.50 kg ha⁻¹). Climatologically, this area falls in the semi-arid tract with an annual rainfall varying from 307 to 619 mm. The average annual rainfall at Rahuri is 520 mm. The mean annual maximum and minimum temperature ranges from 33° to 43°C and 6° to 18°C, respectively. The relative humidity during morning and evening hours are 59 and 35 per cent, respectively.

The field experiment was conducted during June to November with total twenty-two jute

genotypes *viz.*, JRO-524, JRO-8432, OIN-142, OIN-61, OEX-05, OIN-73, OIN-471, OIN-138, OIN-148, OIJ-276, OIJ-63, OIN-141, OIJ-211, OEX-09, OIJ-296, OIN-93, OIN-149, OIJ-656, OIN-71, JRO-204, OEX-13 and OIJ-226 were laid out in Randomized Block Design and replicated thrice. The gross plot size and net plot sizes were 4.5 m x 3.6 m and 3.6 m x 2.4 m and fertilizer @ 60 -30 -30; N, P₂O₅ and K₂O kg ha⁻¹ were applied with maintain dose, respectively. N was applied in two equal split & one as basal and another was top dressed at 30 days after sowing (DAS) at the time of hand weeding. Data collection on growth and yield attributing characters from five randomly selected plants in each plot. The observations recorded on morphological parameters like plant height, basal diameter, dry matter of stem (g), fibre length (cm) and fibre yield plant⁻¹ (g). The data collected were analysed as suggested by Panse and Sukhatme (1954).

Morphological traits : Data regarding of growth attributes *viz.*, plant height (cm), basal diameter (cm) and stem dry matter plant⁻¹ (g) was recorded at harvest and presented in Table 1.

Results revealed that, the highest plant height was recorded by genotype JRO-204 (267.88 cm) over rest of the genotypes and it was at par with genotypes JRO-524 (252.00 cm), JRO-8432 (248.38 cm) and OIN-142 (240.00 cm). The genotypes OIN-471 (205.38 cm), OIN-148 (210.50 cm), OIN-138 (216.13 cm), OIJ-211 (217.63 cm) and OIJ-276 (219.13 cm) without differing from one another recorded the lowest plant height. Similar findings were reported by Ali *et al.* (2002) and suggested that the values of plant height at one stage predict the values at other stages as the values showed linear increasing trend from lower to higher stages. *i.e.* from 50 to 110 days.

The genotype JRO-204 gave the higher basal diameter (2.55 cm) and was at par with the genotypes, JRO-8432 (2.42 cm), JRO-524 (2.41 cm), OIJ-296 (2.40 cm), OIN-93 (2.38 cm), OIJ-226 (2.38 cm), OIN-148 (2.36 cm), OIN-141 (2.33 cm) and OIN-71 (2.32 cm), while, the genotype OIJ-656 (2.07 cm) recorded the lowest basal diameter followed by the genotype OIN-471 (2.08 cm). The basal diameter is one of the parameters affecting the fibre yield per plant. The highest basal diameter in combination with plant height gave the maximum fibre yield plant⁻¹. Similar results corroborated with the results of Islam (2002).

The genotype JRO-204 (55.66 g) recorded significantly higher stem dry matter plant⁻¹ over all rest of the genotypes and it was at par with JRO-8432 (54.14 g), JRO-524 (51.61 g) and OIJ-296 (49.92 g). The genotype OIN-471 produced significantly the lowest stem dry matter plant⁻¹ (37.28 g) than others and followed by the genotypes OIJ-276 (41.00 g), OEX-05 (41.52 g), OIN-148 (42.08 g) and OEX-13 (42.15 g). Similar results were also reported by Kumar *et al.* (2006).

Yield and yield attributing characters :

Data regarding the yield attributes viz., fibre length was recorded at harvest and differed significantly among genotypes (Table 1). The genotype JRO-204 recorded significantly higher fibre length (196.00 cm) than rest of all the genotypes but, it was at par with the genotypes, JRO-524 (192.50 cm), JRO-8432 (189.50 cm), OIN-142 (187.00 cm), OIJ-296 (186.00 cm), OIN-73 (185.50 cm), OEX-05 (184.50 cm), OIN-71 (181.00 cm), OIJ-63 (180.50 cm), OIJ-656 (180.00 cm), OEX-09 (179.50 cm) and OIN-61 (178.00 cm). The genotype 'OIN-471' recorded the lowest fibre length (159.00 cm) over rest of the genotypes which was followed by OIN-148 (160.00 cm), OIN-138 (161.50 cm) and OIJ-211 (163.50 cm). Similar results reported by Palit (1993) and

Palit *et al.* (2006).

The maximum growth and yield attributes were ultimately reflected into yield plant⁻¹. The fibre yield in jute was significantly correlated with various yield contributing characters viz., plant height, basal diameter and dry weight of stem. The genotype 'JRO-204' recorded the highest fibre yield plant⁻¹ (13.80 g) and closely followed by the genotypes, JRO-524 (12.25 g) and JRO-8432 (11.38 g), while the genotypes of OIN-148 (5.80 g) and OIN-471 (5.85 g) recorded the lowest fibre yield plant⁻¹ due to their lower values of plant height, basal diameter and dry weight of stem.

On the basis of results, it could be concluded that the genotype 'JRO-204' and 'JRO-524' were the best in respect to higher growth and yield of jute fibre which are beneficial for commercial cultivation.

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