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Forewarning Model For Aphid

J. D. Jadhav[1] , D. V. Indi[2], S. K. Shinde[3], S. D. Gorantiwar[4] and V. M. Amrutsagr[5]
Zonal Agricultural Research Station, Solapur - 413002 (India)

Abstract

Field experiments were carried out with two safflower varieties A-1/Bhima (tolerant) and CO-1 (susceptible) to study the effect of various weather factors on aphid (*Uroleucon compositae* T.) at the AICRP (Safflower), ZARS, Solapur (M. S.) during five consecutive rabi seasons of 2014-15 to 2018-19. The two varieties were sown at two sowing dates viz., normal (Second fortnight of September to first week of October) and late (Second fortnight of October to first week of November) during each season. Observations on aphid incidence and spread/trend and weather parameters were recorded to develop the suitable forewarning models. The late sown safflower crop with susceptible cultivar CO-1 found to be infested more by aphids. The maximum average aphids to the tune of 165 aphids/5 cm on apical twig plant^{-1} were observed during 2nd MW as compared to 145 aphids/5 cm on apical twig/plant in the normal sown CO-1 observed during 1st MW. The maximum average aphid population recorded in the normal and late sown A-1 was 94 and 105 aphids/5 cm apical twig plant^{-1} during 1st and 2nd MW, respectively. A thumb rule was developed to forewarn the incidence of safflower aphid and model equations were developed using weekly weather data of past five years to assess the pest intensity quantitatively. The studies also revealed that the maximum and minimum temperatures contributed significantly for the aphid incidence and its spread under two sowing situations and on both the cultivars. Safflower crop was susceptible to aphids at elongation stage, however susceptibility increased up to branching also. Further, the aphid population was negatively correlated with maximum and minimum temperatures and rainfall, while it was positively correlated with relative humidity both at morning and evening. The prediction models developed for aphid incidence under two sowing situations and for two different cultivars with high R^2 values (non-linear) *viz*., 0.78 (normal sown A-1), 0.82 (late sown A-1), 0.79 (normal sown CO-1) and 0.80 (late sown CO-1).

Key words : Weather parameters, forewarning models, safflower aphid, Linear equations.

Safflower (*Carthamus tinctorius* L.) is one of the important rabi edible oilseed crop of the country. Safflower oil is rich in linoleic polyunsaturated fatty acid (70-80%), which plays an important role in reducing the blood cholesterol level. Besides, safflower is more productive and more remunerative oilseed crop than many other conventional rainfed *rabi* crops popularly grown in different parts of the country. Apart from high yield and monetary returns, cultivation of safflower was either less expensive than other competitive crops or its cultivation involves very marginal or no additional investment.

Its cultivation is now spreading over various parts of the world both in tropics and temperate zone. Worldwide it is cultivated in area of 8.2 lakh ha with a production of 5.8 lakh tones and productivity of 709 kg ha^{-1}. In India, it is grown in 2.29 lakh ha with production of 1.42 lakh tones and productivity of 623 kg ha^{-1} (Anonymous, 2012). Maharashtra state is largest producer of safflower having 1.56 lakh ha area with production of 0.93 lakh tones and productivity 596 kg ha^{-1}. Besides use in the herbal tea, the safflower petals also have medicinal and therapeutic values as antifungal and antiviral because of gamma linoleic acid. Thus, safflower is gaining importance amongst

1., 2. and 3. Associate Professor, 5. and 6. Professor.

all the oilseeds. In spite of its utility and importance the fact remains that area and production of safflower is declining drastically. Low productivity of safflower in M. S. (India) may be attributed to several biotic and abiotic stresses.

Among the biotic stresses, safflower aphid (Uroleucon compositae Theobald) plays a major role (Akashe *et al*., 1999) in reducing the seed yields particularly under delayed sowing condition and in case of non-spiny varieties. Losses to the extent of 20 to 80% have been reported (Singh *et al*., 2000). Srinivas *et al*. (2012) studied the response of aphids to climate change and reported that the safflower aphid is economically important pest in India which however, is more sensitive to weather factors particularly temperature. They also reported that the predicted future changes such as increased temperature and elevated CO_2 may directly affect aphids' infestation on safflower and indirectly by bringing changes in plant chemical composition in the host plant. Thus, very few attempts were studied relating the aphid population with various weather parameters. No attempt has been made to quantify the effect or to develop weather based forewarning models. Hence, an attempt was made to study the role of different weather parameters *viz*., rainfall, relative humidity and temperature on infestation and development of safflower aphid and secondly to develop weather based forewarning models for predicting the aphid incidence in advance.

Materil and methods

Field experiment was conducted at the research farm of All India Co-ordinated Research Project on Safflower, ZARS, Solapur (MS), India (longitude of 75°56', latitude of 17°41 and at an altitude of 483.6 m above sea level) during five consecutive *rabi* seasons of 2014-15 to 2018-19. The untreated seeds of two cultivars of safflower *viz*., A-1/Bhima (tolerant) and CO-1 (susceptible) were sown under two sowing situations i. e. normal (Second fortnight of September to first week of October) and late (Second fortnight of October to first week of November) with a 45 x 20 cm spacing in non-replicated blocks of 200 m2 each. The crop was grown with all standard agronomic recommended practices under protective irrigation. These two cultivars morphologically differ in their plant habits. A-1 identified as a national aphid tolerant check is spiny in nature whereas CO-1 has been considered as non-spiny highly susceptible check to aphid reaction.

Five plants in each treatment block were selected and tagged to monitor the aphid incidence and development. The observations on aphid count commencing from 46^{th} MW up to 7^{th} MW were recorded on 5 cm apical twig plant^{-1} on five randomly selected plants in each treatment block at weekly interval during cropping seasons. The observations on maximum and minimum temperatures (TMax and TMin, respectively), relative humidity at morning and evening (RH-I and RH-II) and rainfall were recorded daily for the same corresponding crop period.

Averages of the meteorological week (MW) wise weather parameters over the same period were used in the determination of correlation coefficient (r) and regression coefficient (R2) of the average aphid population in relation to the different weather parameters. The data was again subjected to step down regression and linear and non-linear regression equations for both sowing dates and two varieties to develop the equations separately for the prediction of aphid population.

Results and discussion

The results (average of last 5 years from 2014-15 to 2018-19) presented in Table 1 reveled that under both the sowing conditions the safflower aphid occurrence was started on 46th-47th MW which survived on the crop up to 6th-7th MW. However, weather factors during 50th-3rd MW favored the more aphid multiplication and its further spread as well (31-165 aphids/5 cm apical twig/plant). Aphid population was maximum in case of late sown crop and also on susceptible variety CO-1, touching a maximum of 165 aphids/5 cm apical twig/plant observed during 2nd MW as compared to 145 aphids/5 cm apical twig/plant in the normal sown CO-1 observed during 1st MW. In A-1, the maximum aphid population observed was 105 aphids/5 cm apical twig/plant in 2nd MW in the late sown crop while in the normal sown crop, it was only 94 aphids/5 cm apical twig/plant observed during 1st MW. Thus, in both the cultivars aphid population was observed to be maximum in the late sown plots. Interestingly, the aphid incidence was first initiated and confined to the tender apical twig only at border side and later on spreads over the other leaves, branches and stem over the whole plot. The increased trend of aphid infestation in late sown safflower crop was also observed by Mane *et al*. (2012a). Based on Aphid Infestation Index (A. I. I.) the susceptibility of non-spiny safflower variety (CO-1) associated with dark green leaf colour, thick leaf and soft stem was reported by Mane *et al*. (2012b). The data on weather parameters and aphid population was subjected to the statistical analysis and correlation coefficient (r), linear and non-linear regression coefficient (R^2) and regression equations were worked out for predicting the aphid incidence on safflower for two sowing situations and two different varieties under scarcity zone of Maharashtra, India (Table 2, 3, 4 and 5).

Correlation Coefficient (r) : The aphid population was negatively correlated with maximum and minimum temperature and rainfall under both the sowing conditions (Table

Table 1. Effect of weather on Aphid population of safflower during 2007-08 to 2011-12 (average of five years)

MW	Aphids plant^{-1}	Rainfall (mm)	T_{max} (°C)	T_{min} (°C)	RH-I (%)	RH-II (%)
Normal sowing Cv.A-1						
46	3.8	5.9	31.2	18.7	75	42
47	9.4	4.7	31.5	16.1	73	43
48	13.4	0.3	31.1	16.1	72	45
49	18.0	0.4	31.3	15.2	73	39
50	37.2	2.5	30.8	15.6	79	41
51	51.0	0.0	31	13.9	74	40
52	75.8	0.1	31.2	13.8	70	36
1	93.6	0.0	31	15.2	75	42
2	82.0	6.4	30.8	14.1	71	38
3	68.2	0.0	31.3	13.3	70	36
4	31.4	0.0	31.9	13.3	70	34
5	10.2	0.0	32.5	15	67	38
6	1.2	0.0	32.9	15.9	59	30
7	0.0	0.8	33.2	21.3	58	28
Late sowing Cv.A-1						
46	0.6	5.9	31.2	18.7	75	42
47	5.6	4.7	31.5	16.1	73	43
48	11.4	0.3	31.1	16.1	72	45
49	15.2	0.4	31.3	15.2	73	39
50	31.2	2.5	30.8	15.6	79	41
51	54.0	0.0	31	13.9	74	40
52	68.0	0.1	31.2	13.8	70	36
1	95.4	0.0	31	15.2	75	42
2	104.8	6.4	30.8	14.1	71	38
3	83.6	0.0	31.3	13.3	70	36
4	49.4	0.0	31.9	13.3	70	34
5	22.8	0.0	32.5	15	67	38
6	8.8	0.0	32.9	15.9	59	30
7	3.0	0.8	33.2	21.3	58	28
Normal Sowing Cv.CO-1						
46	7.2	5.9	31.2	18.7	75	42
47	13.4	4.7	31.5	16.1	73	43
48	17.0	0.3	31.1	16.1	72	45
49	29.0	0.4	31.3	15.2	73	39
50	56.0	2.5	30.8	15.6	79	41
51	80.2	0.0	31	13.9	74	40
52	132.4	0.1	31.2	13.8	70	36
1	145.2	0.0	31	15.2	75	42
2	140.4	6.4	30.8	14.1	71	38
3	133.0	0.0	31.3	13.3	70	36
4	31.0	0.0	31.9	13.3	70	34
5	8.4	0.0	32.5	15	67	38
6	4.6	0.0	32.9	15.9	59	30
7	0.4	0.8	33.2	21.3	58	28
Late sowing Cv.CO-1						
46	1.2	5.9	31.2	18.7	75	42
47	9.6	4.7	31.5	16.1	73	43
48	15.6	0.3	31.1	16.1	72	45
49	24.0	0.4	31.3	15.2	73	39
50	49.6	2.5	30.8	15.6	79	41
51	79.0	0.0	31	13.9	74	40
52	117.4	0.1	31.2	13.8	70	36
1	150.2	0.0	31	15.2	75	42
2	165.2	6.4	30.8	14.1	71	38
3	155.2	0.0	31.3	13.3	70	36
4	73.8	0.0	31.9	13.3	70	34
5	38.2	0.0	32.5	15	67	38
6	13.6	0.0	32.9	15.9	59	30
7	4.0	0.8	33.2	21.3	58	28

2 and 3), while it was positively correlated with relative humidity (morning and evening). Minimum and maximum temperatures contributed significantly for the aphid incidence and its further spread under normal and late sowing situations as well as for cultivating either spiny (tolerant) and/or non-spiny (susceptible) cultivars of safflower.

Regression coefficient (R^2) : Coefficient of determination (R^2) was calculated for both linear and non-linear regression models to be

Table 2. Correlation (r) and Regression coefficient (R^2) for Aphid population of safflower during 2007-08 to 2011-12 (average of five years) Cv.A-1

Parameter	Correlation coefficient (r)		Regression coefficient (with significant parameters)			
	Normal	Late	Linear Model		Non-linear Model	
			Normal	Late	Normal	Late
Constant (Y)	-	-	2118.85	2148.35	21242.73	-1889.71
Tmax	-0.609*	-0.497	-55.59	-0.20	-1216.23	-107.91
Tmin	-0.610*	-0.648*	-2.80	-52.91	-81.45	-16.71
RH-I	0.422	0.298	-2.14	-6.19	-27.49	-0.20
RH-II	0.158	0.035	-3.47	-2.77	14.33	-24.51
Rainfall	-0.043	-0.033	-2.09	-3.90	-16.93	29.56
Tmax^2	-	-	-	-	18.65	2.83
Tmin^2	-	-	-	-	2.21	0.13
RH-I^2	-	-	-	-	0.19	0.02
RH-II^2	-	-	-	-	-0.17	4.36
Rainfall^2	-	-	-	-	2.66	-1889.71
R^2	-	-	0.68	0.66	0.78	0.82

Table 3. Correlation (r) and Regression coefficient (R^2) for Aphid population of safflower during 2007-08 to 2011-12 (average of five years) Cv.CO-1

Parameter	Correlation coefficient (r)		Regression coefficient (with significant parameters)			
	Normal	Late	Linear Model		Non-linear Model	
			Normal	Late	Normal	Late
Constant (Y)	-	-	4293.26	3679.42	11192.95	31352.52
Tmax	-0.593*	-0.483	-3.17	-0.60	-20.70	-32.41
Tmin	-0.581*	-0.650*	-111.55	-90.33	-322.98	-1694.59
RH-I	0.374	0.277	-4.02	-10.30	-185.56	-212.37
RH-II	0.122	0.015	-5.98	-5.08	-123.18	-73.61
Rainfall	-0.016	-0.048	-6.00	-6.49	82.12	37.34
Tmax^2	-	-	-	-	3.15	5.75
Tmin^2	-	-	-	-	3.64	26.05
RH-I^2	-	-	-	-	5.24	5.74
RH-II^2	-	-	-	-	0.81	0.50
Rainfall^2	-	-	-	-	-1.00	-0.42
R^2	-	-	0.70	0.67	0.79	0.80

*Table value r at 5 % = 0.532, ** Table value r at 1 %= 0.661

fitted for predicting the aphid incidence. The models were calculated with the averages of day weather factors and correlated with the aphid populations of two sowing conditions and two varieties (Table 2 and 3). Some of the models are with high R^2 values i. *e*. high degree of precision in the aphid prediction, as compared to the models which are based only on the weather factors.

Regression equations (APH) : The regression model equations (linear and non-linear) were developed for two sowing conditions i.e. normal and late (Table 4 and 5). Coefficient of determination (R^2) was improved significantly when non-linear regression models were fitted for predicting the aphid incidence. By employing step down linear regression models, the incidence of aphids on safflower can be predicted to an extent of 68%, 66%, 70% and 67% accuracy under normal and late sowing conditions for tolerant (A-1) and susceptible (CO-1) varieties, respectively while with non-linear models the prediction rate for the aphid population under above sowing situations was improved to 78%, 82%, 79% and 80%, respectively (Table 2, 3, 4 and 5).

Observed and predicted values of aphids on safflower are also calculated for fitting the ETL with an exposure period considered to undertake spray schedule (Table 6, 7, 8 and 9). The standard residual values estimated based on deviation between observed and predicted aphids are less than 3.00 which indicated the suitability of models for aphid prediction irrespective of weather parameters (Table 6, 7, 8 and 9). Hence, the equations are best fitted for aphid prediction. The high R^2 values under regression models (non-linear) confirm the validity of the models in estimating the percent aphid index and graphical representation also.

Earlier workers Akashe *et al*. (1995 and 2010) reported that the minimum temperature of 10.5 to 13.5°C and RH of 47 to 70 per cent

Table 4. Regression (Linear and Non-linear) equations for Aphid population of safflower under two sowing situations (A-1)

Sowing condition	Multiple regression	Equation	R^2 value
Normal	Linear	APH= 2118.85-55.59*Tmax -2.80 * Tmin -2.14*RHI-3.47*RHII-2.09*RF	0.68
	Non-linear	APH= 21242.73-1216.23*Tmax -81.45 * Tmin -27.49*RHI+14.33*RHII-16.93*RF +18.65*Tmax ^2 +2.21 * Tmin ^2+0.19*RH-I^2-0.17*RHII^2 +2.66*RF^2	0.78
Late	Linear	APH= 2148.35-52.91*Tmax -6.19 * Tmin -2.77*RH-I-3.90*RHII-0.20*RF	0.66
	Non-linear	APH= 31717.24-1889.71*Tmax -107.91 * Tmin -16.71*RHI-0.20*RHII-24.51*RF +29.56*Tmax^2+2.83*Tmin^2+0.13*RHI^2+0.02*RHII^2+4.36*RF^2	0.82

Table 5. Regression (Linear and Non-linear) equations for Aphid population of safflower under two sowing situations (CO-1)

Sowing condition	Multiple regression	Equation	R^2 value
Normal	Linear	APH= 4293.26-111.55*Tmax -4.02 * Tmin -5.98*RHI-6.00*RHII-3.17*RF	0.70
	Non-linear	APH= 11192.95-322.98*Tmax -185.56 * Tmin -123.18*RHI+82.12*RHII-20.70*RF +3.64*Tmax ^2 +5.24 * Tmin ^2+0.81*RH-I^2- 1.00*RHII^2+ 3.15*RF^2	0.79
Late	Linear	APH= 3679.42-90.33*Tmax -10.30 * Tmin -5.08*RHI-6.49*RHII-0.60*RF	0.67
	Non-linear	APH=31352.52-1694.59*Tmax-212.37*Tmin-73.61*RHI+37.34*RHII-32.41*RF +26.05*Tmax^2+5.74*Tmin^2+0.50*RH-I^2-0.42*RHII^2+5.75*RF^2	0.80

APH=Aphid population (in equation)

were found congenial for aphid multiplication during December and January at Solapur and concluded that low temperatures with high RH were conducive for the multiplication of aphid.

Table 6. Observed and predicted Aphid population of safflower under two sowing situations using linear regression equations. (A-1)

MW	Aphid population							
	Normal				Late			
	Observed	Predicted	Deviation	Standardized residual	Observed	Predicted	Deviation	Standardized residual
46	3.8	13.4	-9.6	-0.406	0.6	9.8	-9.2	-0.340
47	9.4	8.0	1.4	0.057	5.6	12.7	-7.1	-0.262
48	13.4	33.6	-20.2	-0.852	11.4	28.4	-17.0	-0.627
49	18.0	43.3	-25.3	-1.066	15.2	43.7	-28.5	-1.051
50	37.2	45.6	-8.4	-0.356	31.2	42.9	-11.7	-0.433
51	51.0	58.8	-7.8	-0.330	54.0	61.0	-7.0	-0.259
52	75.8	69.1	6.7	0.283	68.0	76.4	-8.4	-0.309
1	93.6	44.3	49.3	2.081	95.4	40.3	55.1	2.033
2	82.0	69.6	12.4	0.523	104.8	85.4	19.4	0.717
3	68.2	67.8	0.4	0.016	83.6	77.4	6.2	0.228
4	31.4	42.5	-11.1	-0.469	49.4	54.8	-5.4	-0.199
5	10.2	-4.8	15.0	0.635	22.8	3.1	19.7	0.726
6	1.2	13.5	-12.3	-0.518	8.8	27.6	-18.8	-0.693
7	0.0	-9.5	9.5	0.402	3.0	-9.8	12.8	0.470

Standard Residual > 3 is outleter

Table 7. Observed and predicted Aphid population of safflower under two sowing situations using Non-linear regression equations (A-1)

MW	Aphid population							
	Normal				Late			
	Observed	Predicted	Deviation	Standardized residual	Observed	Predicted	Deviation	Standardized residual
46	3.8	12.3	-8.5	-0.265	0.6	9.4	-8.8	-0.277
47	9.4	-4.6	14.0	0.434	5.6	-5.5	11.1	0.350
48	13.4	29.1	-15.7	-0.486	11.4	25.1	-13.7	-0.431
49	18.0	28.9	-10.9	-0.337	15.2	22.4	-7.2	-0.226
50	37.2	43.2	-6.0	-0.186	31.2	35.4	-4.2	-0.132
51	51.0	75.5	-24.5	-0.760	54.0	83.3	-29.3	-0.922
52	75.8	58.8	17.0	0.529	68.0	60.3	7.7	0.243
1	93.6	55.2	38.4	1.192	95.4	57.3	38.1	1.198
2	82.0	81.4	0.6	0.020	104.8	102.7	2.1	0.067
3	68.2	65.8	2.4	0.075	83.6	72.7	10.9	0.342
4	31.4	38.0	-6.6	-0.206	49.4	56.1	-6.7	-0.211
5	10.2	9.8	0.4	0.012	22.8	21.5	1.3	0.039
6	1.2	5.4	-4.2	-0.131	8.8	13.5	-4.7	-0.149
7	0.0	-3.5	3.5	0.109	3.0	-0.5	3.5	0.110

Standard Residual > 3 is outleter

Singh (2007) also reported the minimum and maximum temperatures of 15-17°C and 31-35°C, respectively coupled with minimum and maximum RH of 21-30 and 69-81 per cent,

Table 8. Observed and predicted Aphid population of safflower under two sowing situations using linear regression equations (CO-1)

MW	Aphid population							
	Normal				Late			
	Observed	Predicted	Deviation	Standardized residual	Observed	Predicted	Deviation	Standardized residual
46	7.2	19.4	-12.2	-0.307	1.2	12.2	-11.0	-0.249
47	13.4	7.4	6.0	0.152	9.6	17.6	-8.0	-0.180
48	17.0	57.5	-40.5	-1.019	15.6	46.1	-30.5	-0.689
49	29.0	67.4	-38.4	-0.964	24.0	70.4	-46.4	-1.047
50	56.0	68.1	-12.1	-0.305	49.6	67.2	-17.6	-0.397
51	80.2	95.3	-15.1	-0.380	79.0	99.6	-20.6	-0.464
52	132.4	118.6	13.8	0.346	117.4	126.5	-9.1	-0.204
1	145.2	68.5	76.7	1.928	150.2	64.5	85.7	1.932
2	140.4	126.5	13.9	0.350	165.2	140.3	24.9	0.562
3	133.0	115.8	17.2	0.432	155.2	128.3	26.9	0.607
4	31.0	63.3	-32.3	-0.811	73.8	89.4	-15.6	-0.351
5	8.4	-20.1	28.5	0.718	38.2	3.3	34.9	0.786
6	4.6	23.9	-19.3	-0.486	13.6	46.9	-33.3	-0.750
7	0.4	-13.4	13.8	0.347	4.0	-15.7	19.7	0.444

Standard Residual > 3 is outleter

Table 9. Observed and predicted Aphid population of safflower under two sowing situations using Non-linear regression equations (CO-1)

MW	Aphid population							
	Normal				Late			
	Observed	Predicted	Deviation	Standardized residual	Observed	Predicted	Deviation	Standardized residual
46	7.2	21.6	-14.4	-0.264	1.2	14.6	-13.4	-0.237
47	13.4	-8.6	22.0	0.401	9.6	-5.6	15.2	0.269
48	17.0	42.5	-25.5	-0.466	15.6	36.8	-21.2	-0.375
49	29.0	46.3	-17.3	-0.316	24.0	38.7	-14.7	-0.260
50	56.0	64.9	-8.9	-0.162	49.6	53.5	-3.9	-0.069
51	80.2	125.5	-45.3	-0.828	79.0	135.8	-56.8	-1.005
52	132.4	108.0	24.4	0.446	117.4	106.7	10.7	0.190
1	145.2	79.6	65.6	1.200	150.2	84.8	65.4	1.159
2	140.4	138.6	1.8	0.033	165.2	161.4	3.8	0.067
3	133.0	123.9	9.1	0.166	155.2	130.6	24.6	0.436
4	31.0	42.3	-11.3	-0.206	73.8	84.8	-11.0	-0.194
5	8.4	7.0	1.4	0.026	38.2	33.8	4.4	0.077
6	4.6	12.1	-7.5	-0.138	13.6	22.1	-8.5	-0.150
7	0.4	-5.5	5.9	0.108	4.0	-1.2	5.2	0.092

Standard Residual > 3 is outleter

respectively and rainfall of 31 mm during 5th MW were more congenial for aphid population built up on safflower. The ETL of safflower aphid numerically varied from 30 to 48 aphids on 5 cm apical twig/plant (Akashe *et al*., 1997; Mallapur *et al*., 2002; Patil, 2007 and Patil and Kamath, 2012). Besides, the numerical ETL for safflower aphid control Akashe *et al*. (1997), Patil (2007) and Patil and Kamath (2012) also reported the exposure period of about 2-3 weeks from first aphid occurrence in order to realise safflower as a profitable crop. These findings are in the agreement with the findings of present investigation. However, predictive model for mustard aphid infestation for eastern plains of Rajasthan was studied by Bapujirao *et al*. (2012). They developed the DSS (development of a decision support system) and also reported the negative correlation of minimum and maximum temperature and positive correlation of morning relative humidity and rainfall with the aphid population. Srivastava and Prajapati (2012) validated the temperature based mustard aphid forewarning model of Chakravarti and Gautam (2002) and calculated the growing degree day (GDD) from 1st to 15th January in two seasons (2009-10 and 2010-11) which has capability to forewarn the peak aphid population in Bundelkhand Agro-climate zone of M. P. The weather based forewarning models for diseases were developed by some workers i. e. for white rust in Brassica (Kumar and Chakravarthy, 2008) and for Alternaria leaf spot of safflower (Suresh, 2012).

Conclusions

Higher aphid population intensity in late sown safflower crop and also on non-spiny cultivar was probably due to more succulency/susceptible foliage available for longer time as well as more favorable microenvironment after pest occurrence. It indicates the importance of plant and environmental factors in the development of pest and its severity. Hence, it is advisable to have the sowing of safflower crop at the normal sowing time (second fort night of September mostly up to first week of October) to avoid yield losses due to aphid.

Fore casted the models/quadratic/regression equations to forewarn the incidence of safflower aphid to undertake the control action as soon as it's population reaches the ETL (on an average 30-40 aphids/5 cm apical twig/plant mostly in 48th MW). The correlation and regression analysis clearly indicated the importance of weather factors in the prediction of aphids on safflower. Both the regression models (linear and non-linear) were found to be precise for the prediction of incidence and further spread of safflower aphid. Thus, these models can be utilized in Agro-Advisories for aphid prediction on safflower after validation. However, the high R^2 values under non-linear regression models confirm the validity of the models in estimating the percent aphid index.

Forewarning/Forecasting models for safflower aphid : After occurrence, the aphid population and its spread is governed by weather conditions and plant morphology. In both the dates of sowing and cultivars, the rate of increase in aphid population depended on weather/microenvironment conditions and plant factor as well (succulent plant stage). Once aphid has occurred it is important to observe and forecast its intensity. Various following combinations of weather parameters were worked out to relate with the progress of aphid incidence. Thus, these weather based forewarning regression models developed at Solapur, M. S. (Anonymous, 2012) are considered to be highly useful in forewarning about the possible incidence of safflower aphid at an early stage for taking preventive steps.

Four linear regression equations *viz.*,

1) $APH=2118.85-55.59^{*}T_{max}-2.80^{*}T_{min}-$

2.14*RHI-3.47*RHII-2.09*RF for normal sown A- 1, R^2 = 0.68.

2) APH=2148.35-52.91*T_{max}-6.19*T_{min}-2.77*RH-I-3.90*RHII-0.20*RF for late sown A-1, R^2 = 0.66.

3) APH=4293.26-111.55*T_{max}-4.02*T_{min}-5.98*RHI-6.00*RHII-3.17*RF for normal sown CO-1, R^2 = 0.70.

4) APH=2148.35-52.91*T_{max}-6.19*T_{min}-2.77* RH-I-3.90*RHII-0.20*RF for late sown CO-1, R^2 = 0.67.

Four non-linear regression equations viz.,

1) APH= 21242.73 - 1216.23 * T_{max}-81.45 * T_{min} - 27.49 * RHI + 14.33 * RHII-16.93 *RF +18.65*T_{max}^2 + 2.21 * T_{min}^2 + 0.19* RH-I^2 - 0.17 * RHII^2 + 2.66* RF^2 for normal sown A-1, R^2 = 0.78.

2) APH= 31717.24 - 1889.71* T_{max}-107.91* T_{min} - 16.71* RHI - 0.20* RHII-24.51* RF + 29.56* T_{max}^2 + 2.83* T_{min}^2 + 0.13* RHI^2 + 0.02* RHII^2 + 4.36* RF^2 for late sown A-1, R^2 = 0.82.

3) APH= 11192.95 - 322.98* T_{max}-185.56* T_{min} - 123.18* RHI + 82.12* RHII-20.70* RF + 3.64* T_{max}^2 + 5.24* T_{min}^2 + 0.81* RH-I^2 - 1.00* RHII^2 + 3.15* RF^2 for normal sown CO-1, R^2 = 0.79.

4) APH= 31352.52 - 1694.59* T_{max}-212.37* T_{min} - 73.61* RHI + 37.34* RHII-32.41* RF+26.05* T_{max}^2 + 5.74* T_{min}^2 + 0.50* RH-I^2 0.42* RHII^2 + 5.75* RF^2 for late sown CO-1, R^2 = 0.80.

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Effect of Conservation Agriculture Through Land Configuration and Irrigation Management on Economics of Chickpea (*Cicer arietinum* L.)

P. D. Dudhade , P. S. Bodake and K. A. Chavan
Department of Agronomy,
Mahatma Phule Krishi Vidyapeeth, Rahuri - 413 722 (India)

Abstract

A field experiment was conducted during rabi season in the year 2011-12 at the farm of All India Co-ordinated Research Project on Pulses Improvement Project, Mahatma Phule Krishi Vidyapeeth, Rahuri (Maharashtra), India. The layout consisted of total 36 experimental units in three replications. Each experimental unit was with gross plot size of 4.20 x 3.60 m^2 and net plot size of 4.00 x 3.00 m^2. The fertilizer dose of 25 kg N and 50 kg P_2O_5 ha^{-1} was given as basal application before sowing. The ridges and furrow with two irrigations scheduled at branching and pod development stages produced the highest yield attributes and seed yield of chickpea. Irrigation scheduled at branching and flowering stage recorded significantly more total cost of cultivation (Rs. 32161 ha^{-1}), gross return (Rs. 78542 ha^{-1}), net return (Rs. 46381 ha^{-1}) and benefit cost ratio (2.44) than rest of treatments. The grain and straw yield was significantly higher 24.79 q ha^{-1} and 38.19 q ha^{-1} respectively, when chickpea was sown on ridges and furrow followed by broad bed furrow and flat bed.

Key words : conservation agriculture, irrigation, Chickpea, yield.

Among the grain legumes, Chickpea (*Cicer arietinum* L.) is the premier pulse crop of Indian subcontinent. It is an important winter season grain legume, popularly known as Chana or Gram or Bengal gram. It is a major pulse crop in India and accounts for 40 per cent of total pulse production. Water is the basic input for increasing crop production. Agricultural Productivity can be maintained with the assured supply of moisture to the plant, which is accomplished by irrigation. Even though chickpea thrives well under scarcity moisture conditions it responds well to irrigation (Saxena, 1984) each crop has certain critical growth stages, at which adequate moisture required for proper growth. Hence, efficient water management is the key factor for boosting the crop production. Knowledge about critical growth stages of the crop is essential for the judicious application of water. The importance

Table 1. Grain yield and straw yield influenced by land configuration and irrigation management in chickpea

Treatments	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})
Land configuration		
Flat Bed	21.51	35.26
Ridges & Furrow	24.79	38.19
Broad Bed Furrow	22.76	36.17
S. E. m ±	0.32	0.61
C.D. at 5 %	1.10	1.82
Irrigation management		
Branching	23.64	39.88
Flowering	21.07	34.09
Pod development	18.12	29.52
Branching & Pod development	29.26	42.68
S. E. m ±	0.71	2.15
C.D. at 5 %	2.12	6.46

of critical stages of crop growth for irrigation needs of the crop. Chickpea in India is usually grown on conserved soil moisture, though the crop responds to supplemental irrigation. chickpea pod development stage is the most critical in respect of soil moisture but irrigation at early vegetative growth (branching) also benefit the crop in light soil. Thus irrigation schedules have to be modified to suit to the requirement of gram. Proper irrigation layout plays vital role in scientific crop management technologies. Water logging can affects nitrogen fixation due to anoxia (Sprent *et al.* 1983). Excessive moisture may also induce excessive vegetative growth and the crop becomes prone to biotic stresses, which ultimately results in poor yield. The prospect of improving chickpea productivity seems to be bright, agrotechnologies for natural resource management of soil and water by land configuration and irrigation at critical growth stages etc. Considering the above facts the present investigation has been planned.

The experiment was conducted during rabi season in the year 2011-12 at the farm of All India Co-ordinated Research Project on Pulses Improvement Project, Mahatma Phule Krishi Vidyapeeth, Rahuri (Maharashtra), India. The experiment was laid out in split plot design during rabi season. There were twelve treatments comprised of three main plots viz., 1. Flat bed 2. Ridges and furrow 3. Broad bed furrow and four sub plots *viz.*, 1. Irrigation at branching 2. Irrigation at flowering 3. Irrigation

Table 2. The gross monetary returns, net monetary returns and B:C ratio as influenced by land configuration and irrigation management in chickpea

Treatments	Cost of cultivation (Rs ha^{-1})	Gross returns (Rs ha^{-1})	Net returns (Rs ha^{-1})	B:C
Land configuration				
Flat Bed	30099	57301	27202	1.90
Ridges & Furrow	32911	65794	32883	2.00
Broad Bed Furrow	32911	60517	27606	1.84
S. E. m ±		902	902	0.03
C.D. at 5 %		3120	3120	0.10
Irrigation management				
Branching	31911	63088	31177	1.98
Flowering	31911	56084	24173	1.76
Pod development	31911	48252	16341	1.51
Branching & Pod development	32161	77418	45257	2.41
S. E. m ±		1788	1788	0.06
C.D. at 5%		5361	5361	0.17

at pod development 4. Irrigation at branching and pod development. The layout consisted of total 36 experimental units in three replications. Each experimental unit was with gross plot size of 4.20 x 3.60 m^2 and net plot size of 4.00 x 3.00 m^2. The fertilizer dose of 25 kg N and 50 kg P_2O_5 ha^{-1} was given as basal application before sowing.

The result indicated that the seed and straw yield were significantly increased under chickpea crop grown on ridges and furrow (24.79 and 38.19 q ha^{-1} respectively) as compared to other land configuration. Grain yield was increased by 13.23 per cent, with ridges and furrow as compared to land configuration of flat bed owing to favorable environment for optimum soil water equilibrium due to loose, friable seed beds created in root zone of the crop throughout growth period. Similar results were reported by Nimbalkar (2008). Better conservation of soil moisture and efficient utilization of stored soil moisture were also reported to have favorably influenced these characters. The grain and straw yield (29.16 and 42.68 q ha^{-1}) were significantly more under irrigation given at branching and pod development stage as compared to other irrigation management. The ridges and furrow significantly increased gross and net monetary returns as compared to other land configuration. The gross monetary returns (Rs. 66794 ha^{-1}), net monetary returns (Rs. 32883 ha^{-1}) and B:C ratio (2.00) were recorded with ridges and furrow. Ridges and furrow system yielded better results than other land configurations. Better conservation of soil moisture and efficient utilization of stored soil moisture reflected in higher values of dry matter production and yield contributing characters. The gross (Rs. 77418 ha^{-1}) and net monetary returns (Rs. 45257 ha^{-1}) and B:C ratio (2.41) were significantly more under irrigation management at branching and pod development stage followed by branching stage. This may be attributed to significant increase in micro climatic parameters growth attributes, yield contributing and efficient utilization of stored soil moisture reflected in higher values.

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Thermal Indices in Relation to Seed Yield of Safflower

D. R. Murumkar[1], S. V. Khadtare[2], J. D. Jadhav[3] and S. K. Shinde[4]
Zonal Agricultural Research Station, Solapur - 413002 (India)

Abstract

Safflower (*Glycine max* L. Merrill) is an important oilseed crop. Photoperiod affects flowering time and the relative humidity affects initiation and development of pod. Though its growth and development are influenced by many weather parameters, the temperature is identified as one of the most important factors which affect its growth and development. The rate of growth and development of crop is function of the energy receipt and thermal regime in any given crop growth season. Field experiments were conducted on farm area of Dry farming research station ,Solapur with five varieties of safflower for two rabi seasons (2006-07 and 2007-08). It was observed that in the first crop season all the varieties matured within 107 to 122 days, while in the second crop season. The mean GDD accumulation from sowing to maturity ranged from 1760.9 to 2213.10 D. The varieties, NH-1 and PHULE KUSUMA consumed the lowest and highest GDD for attaining physiological maturity in different sowing dates among all varieties. The photoothermal Index (PTI) in all the varieties and seasons varied form 17.74 to 19.46 °D day^{-1} and 17.44 to 18.47 °D day^{-1} in vegetative and reproductive stage respectively.

Key words : Safflower, GDD, PTI and HUE.

The duration of a particular stage of growth was directly related to temperature and this duration for particular species could be predicted using the sum of daily air temperatures Wang (1960). Thus air temperature based indices like growing degree days (GDD), Phenothermal units (PTU), Phenothermal index (PTI), Heat use efficiency (HUE) etc. can successfully be used for describing phenological behavior and other growth parameters like leaf area development, biomass production, seed yield. Oil content etc. in relative terms (Hundal and Kingra, 2004; Neog and Chakravarty, 2007; Neog et al., 2007 and Singh et al., 2007)

Materials and methods

The experiments were conducted in two rabi seasons (2016-07 and 2017-08) on the farm area of Dry farming research station ,Solapur (17°41N latitude, 75°-45E longitude at an altitude of 476 meters above sea level) under rainfed situation.

Five safflower varieties, *viz*., Bhima, NH-1, DCH-129, GIRNA and PHULE KUSUMA were sown on three different dates at 15 days interval starting viz; 1st fortnight of September (S1), 2nd fortnight of September, (S2) and 1st fortnight of October (S3) to enable the crops to get exposed to different weather conditions during their various phenological stages. The experiments were laid out with randomized block design with three replications following recommended cultural practices. Based on visual observations two important phenological events, namely, Bud Initiation and physiological maturity were identified. Growing degree days accumulated for attaining different phonological events were calculated with base temperature as 80C following Hundal and Kingra (2000). Phenothermal Index (PT), expressed as degree

1. Assistant Professor, 2., 3. and 4. Associate Professsor.

days per growth days for vegetative (from sowing to Bud Initiation) and reproductive growth (Bud Initiation to physiological maturity) stages of the crop were calculated following (Chakravarty and Sastry, 1983).

Heat use efficiency (HUE) defined as the biomass accumulation during the given period per day was also calculated for seed yield as:

$$HUE = \frac{\text{Seed yield/Biomass yield}}{\text{Accumulated heat units}}$$

Results and Discussions

Crop phenology : Number of days taken to attain any phonological events varied in all the varieties, in different sowing dates and crop seasons (Table 1). On an average the crop took 42.3 (CV=9.2%) and 109.8 (CV=6.7) days to attain Bud Initiation and physiological maturity in all varieties, sowing dates and seasons. In both the seasons NH-1 took minimum days to mature as compared to other varieties in different sowings. This variety matured between 107 to 117 and 96 to 110 days in 2006-07 and 2007-08 respectively. On the other hand, PHULE KUSUMA took the maximum days (114 to 122 during 2006-07 and 01 to 115 during 2007-08) to mature in all sowings in both the seasons. Number of days to reach both the Bud Initiation and physiological maturity was reduced with successive delay in sowing in both the crop seasons. It was observed that the first flower appeared in 4 to 11 days earlier (with CV 54%) and the crop matured in 3 to 14 days in advance (with CV 48%) in all the varieties in both the seasons as sowing was delayed. Reduction of duration of phenophases in each successive delay in sowing may be attributed to gradual increase in air temperature from Septembr to October in both the season. The very high coefficient variation for number of days reduced to attain any phenological events due to delay in sowing indicates that it is not only the temperature which affect the phenology of the crop, but also there might be some other factor(s) that contribute towards phenological development of the crop. All the varieties took 7 to 14 more days to attain maturity in first season than in the second season. Possible reason for difference in crop duration in all the varieties and sowing dates in two crop seasons could be due to the prevalence of higher temperature during most time of crop growth in the second season as compared to first season. Moreover less rainfall and less number of rainy days in the second crop season enable the air temperature in raise more which ultimately contributed to reduction of crop growth

Table 1. Days to attaining Bud Initiation and physiological maturity of Safflower cultivars at different sowing dates during Rabi 2016-07 (I) and 2017-08 (II)

Cultivars	Crop season	Days to Bud Initiation				Days to physiological maturity			
		S1*	S2	S3	Mean	S1*	S2	S3	Mean
Bhima	*rabi* 2016-17	43	38	36	39.0	117	113	109	113.0
	rabi 2017-88	45	42	35	40.7	110	101	99	103.3
NH-1	*rabi* 2016-17	45	43	37	41.7	117	112	107	112.0
	rabi 2017-88	47	43	36	42.0	110	101	96	102.3
DCH-129	*rabi* 2016-17	47	44	43	44.7	121	116	110	115.7
	rabi 2017-88	45	42	38	41.7	112	105	99	105.3
GIRNA	*rabi* 2016-17	47	45	43	45.0	119	116	112	115.7
	rabi 2017-88	49	47	41	45.7	112	102	98	104.0
PHULE KUSUMA	*rabi* 2016-17	45	41	39	41.7	122	119	114	118.3
	rabi 2017-88	46	42	36	41.3	115	109	101	108.3

duration. The duration of different phonological events was in good agreement with those reported by Dhingra *et al*. (1995).

Growing degree days (GDD) : The GDD or thermal time concept assumes that the amount of heat would be more or less same for a crop to reach a particular phonological stage or maturity. The accumulated GDD to reach Bud Initiation and physiological maturity varied in all varieties in different sowings in both the seasons (Table 2). The total GDD requirement for attaining first flower and maturity ranged from 666.7 to 937.5 0D (with mean 801 0D) and CV=9.3%) and 1760.9 to 2213.1 0D (with mean 1998.2 0D and CV=6.4%), respectively, among all sowing dates, varieties and seasons. In both season, NH-1 and PHULE KUSUMA consumed the lowest and highest GDD for attaining physiological maturity in different sowing dates in all varieties. Further, crops sown on early dates accumulated higher GDD for attaining any phonological event as compared to late sown crop in both seasons. All the varieties consumed fewer amounts of thermal units for attaining physiological maturity in the second crop season which might be attributed to shortening of the crop duration in this season due to prevailing high temperature and dry weather as compared to the first crop season. Our results are supported by the findings of Deosthali *et al*., (2006-07) and Singh *et al*., (2007).

Phenothermal index (PTI) : The Phenothermal index gives an idea about the rate of development of the various phenological events with reference to heat units, which will eventually help in evaluating relative performance of different varieties. In both the crop seasons, the PTI varied from 17.74 to 19.50 °D day^{-1} during vegetative stage, while in the reproductive growth stage it was slightly lower and ranged from 17.42 to 18.47 °D day^{-1} in all varieties in different sowing dates (Table 3). The PTI during vegetative stage in all varieties was more variable (CV=2.2%) than reproductive stage (CV=1.5%), which might be attributed to the more sensitivity of vegetative growth period of all varieties to the prevailing weather conditions. In reproductive growth period of all varieties, the PTI was maximum in crop sown on early condition and gradually decreased as sowing was delayed, whereas, in the vegetative growth stage of the crop this index was decreased in few cases, but in most of the cases it increased slightly. During vegetative growth of the crop, there was gradual increase in both day and night temperatures which resulted an increase in the values of PTI of that

Table 2. Heat unit accumulation at Bud Initiation and physiological maturity of safflower cultivars at different sowing date during *Rabi* 2016-17 (I) and 2017-18 (II)

Cultivars	Crop season	Bud Initiation				Physiological maturity			
		S1*	S2	S3	Mean	S1*	S2	S3	Mean
Bhima	*rabi* 2016-17	801.0	706.1	666.7	724.6	2148.5	2057.2	1959.4	2055.0
	rabi 2017-18	854.5	811.6	678.1	781.4	2025.0	1865.7	1809.5	1900.1
NH-1	*rabi* 2016-17	838.7	801.4	686.3	775.5	2148.5	2042.5	1933.2	2041.4
	rabi 2017-18	894.7	832.9	698.8	808.8	2025.0	1865.7	1760.9	1883.9
DCH-129	*rabi* 2016-17	875.3	861.0	762.9	833.1	2177.1	2080.5	1950.0	2069.2
	rabi 2017-18	854.5	811.6	737.8	801.3	2057.0	1899.2	1809.5	1921.9
GIRNA	*rabi* 2016-17	875.3	841.2	799.0	838.5	2177.1	2080.5	2000.8	2086.1
	rabi 2017-18	937.5	914.7	799.5	883.9	2057.0	1882.6	1793.7	1911.1
PHULE KUSUMA	*rabi* 2016-17	838.7	761.3	725.0	775.0	2213.1	2135.0	2034.8	2127.6
	rabi 2017-18	874.2	811.6	698.8	794.9	2121.1	1995.2	1840.4	1985.6

phenophase in all varieties in both the seasons as sowing was delayed. On the other hand, in the later part of reproductive stage, air temperature decreased gradually in both the seasons which resulted in decline of values of PTI of that growth period in all the varieties when sowing was delayed. All the values of PTI in vegetative stage and most of the cultivars and the sowing dates of reproductive stage were higher in second crop season as compared to first crop season. The prevailing high day and night temperature in the second crop season resulted in higher PTI values in second season.

Seed yield : Seed yield of all the cultivars of safflower in different sowing dates and seasons is presented in Table 4. The lowest and the highest average yield of different sowing dates (over two seasons) were 14.46 and 19.11 q ha^{-1} in NH-1 and PHULE KUSUMA, respectively. On an average, there was 1.1 and 11.4% reduction in the seed yield in case of the crop sown on 2nd and 3rd date of sowing as compared to the crop sown on 1st Date in all varieties and seasons. In all the varieties, the average seed yield was higher in 2006-07 than in 2007-08 indicating that second season which was warmer and drier than the first season was not favorable for growth and development of the crop.

Table 3. Phenothermal Index (Degree day/growth day) at vegetative and reproductive stages of safflower cultivars at different sowing dates during *rabi* 2016-17. (I) and 2017-08 (II)

Cultivars	Crop season	Vegetative stage				Reproductive stage			
		S1*	S2	S3	Mean	S1*	S2	S3	Mean
Bhima	*rabi* 2016-17	18.63	18.58	18.52	18.58	18.21	18.01	17.71	17.98
	rabi 2017-18	18.99	19.32	19.37	19.23	18.01	17.87	17.68	17.85
NH-1	*rabi* 2016-17	18.64	18.64	18.55	18.61	18.33	17.99	17.81	18.04
	rabi 2017-18	19.04	19.37	19.41	19.27	18.47	17.81	17.70	17.99
DCH-129	*rabi* 2016-17	18.62	18.66	17.74	18.34	17.59	17.49	17.72	17.60
	rabi 2017-18	18.99	19.32	19.42	19.24	18.22	17.83	17.57	17.87
GIRNA	*rabi* 2016-17	18.62	18.69	18.58	18.63	18.08	17.45	17.42	17.65
	rabi 2017-18	19.13	19.46	19.50	19.36	17.77	17.60	17.44	17.60
PHULE KUSUMA	*rabi* 2016-17	18.64	18.57	18.59	18.60	17.85	17.61	17.46	17.64
	rabi 2017-18	19.00	19.32	19.41	19.24	18.07	17.67	17.56	17.77

Table 4. Seed yield and Heat use efficiency of safflower cultivars at different sowing dates during rabi 2016-17 (I) and 2017-18 (II)

Cultivars	Crop season	Seed yield (q ha^{-1})				Heat use efficiency (g m^{-2} 0D^{-1})			
		S1*	S2	S3	Mean	S1*	S2	S3	Mean
BHIMA	*rabi* 2016-17	19.65	19.23	18.10	19.0	0.0915	0.0935	0.0924	0.0924
	rabi 2017-18	18.26	19.07	16.45	17.9	0.0902	0.1022	0.0909	0.0944
NH-1	*rabi* 2016-17	16.14	15.53	13.52	15.1	0.0751	0.0760	0.0699	0.0737
	rabi 2017-18	13.9	14.42	13.26	13.9	0.0686	0.0773	0.0753	0.0737
DCH-129	*rabi* 2016-17	20.75	19.8	17.55	19.4	0.0953	0.0952	0.0900	0.0935
	rabi 2017-18	20.00	19.35	17.05	18.8	0.0972	0.1019	0.0942	0.0978
GIRNA	*rabi* 2016-17	16.56	17.66	16.25	16.8	0.0761	0.0849	0.0812	0.0807
	rabi 2017-18	15.36	16.9	14.15	15.5	0.0747	0.0780	0.0789	0.0772
PHULE KUSUMA	*rabi* 2016-17	21.35	19.8	17.86	19.7	0.0965	0.0927	0.0878	0.0923
	rabi 2017-18	20.1	18.38	17.16	18.5	0.0948	0.0921	0.0932	0.0934

Heat use efficiency : Among different varieties and sowings, the heat use efficiency varied from 0.0699 to 0.965 g m^{-2} 0D^{-1} during 2006-07, while during 2007-08 it varied from 0.0686 to 0.1022 g m^{-2} 0D^{-1} with coefficient of variation of 10% as whole. The values of heat use efficiency were slightly higher in second crop season in most of the cases (60 %) as compared to the first season in different sowing dates and varieties, which indicate that the thermal environment was favorable in second season. But this was not reflected in seed yield probably due to less rainfall in that season. In case of NH-1 and GIRNA the values of heat use efficiency was less than 0.080 g m^{-2} 0D^{-1}, on the other hand, in other three varieties these values were more than 0.0923 g m^{-2} 0D^{-1} in different dates of sowing over the seasons. The heat use efficiency was the lowest in NH-1 in different sowing dates in two crop seasons. On an average the heat use efficiency was maximum in the crop sown on 2nd date in all the varieties in both the crop seasons. Lower heat use efficiency in the case of NH-1 and GIRNA was reflected in the lower seed yield of these two varieties. Therefore this index can be used to asses seed yield in relative term. The results are in the line of those obtained by Hundal *et al*. (2004) and Kaur *et al*. (2004). It may be inferred that growing degree days, Phenothermal index and heat use efficiency indices may be used to assess the crop performance in assessing suitability of the crop performance in assessing suitability of the variety to a particular locality depending on the thermal environment of the local condition.

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Effect of Resource Conservation Through Land Configuration and Fertilizer Management on Soil , Economics and Quality of Soybean (*Glycine max* (L.) Merrill) Under Protective Irrigation

Poonam Yadav, P. S. Bodake and K. A. Chavan
Department of Agronomy, Mahatma Phule Krishi Vidypeeth, Rahuri - 413 722 (India)

Abstract

A field experiment was carried out during *kharif* season, 2012-2013 at PGI farm Mahatma Phule Krishi Vidyapeeth, Rahuri Dist. Ahmednagar (Maharashtra). The field experiment was laid out in a split plot design with twelve treatments and three replications. A spacing of 30 cm between rows and 10 cm between plants was maintained. The gross and net plot sizes were 3 x 3.60 m^2 and 2.80 x 3.00 m^2 respectively. Gross monetary returns were significantly affected by different land configuration. Maximum gross monetary returns (Rs. 92965.00 ha^{-1}) were obtained under ridges and furrow than rest of the land configuration.Under different fertilizer management treatments, the benefit: cost ratio was higher with the application of 100% GRDF based on AST (2.55). And also Under different land configurations, the benefit: cost ratio of the ridges and furrows (2.71) registered significantly highest among rest of the treatments. It was being at par with BBF.

Key words : Resource conservation, Soybean, Fertilizer.

Soybean (*Glycine max* L.) is one of the important pulse and oilseed crops of the Leguminoceae, sub family Papiliononaceae and genus Glycin. Soybean is called as "poor man meat" It is richest, cheapest and easiest source of best quality protein and fats and having a multiplicity of uses as food and industrial products therefore it is also known as "Wonder crop". For getting a sustainable crop production system under rainfed condition, the conservation of rainwater and its efficient recycling are imperative. The rainwater can be conserved either in-situ or exsitu in natural or manmade structures for supplemental irrigation. In-situ rainwater conservation can be carried out either though tillage or land surface management. The landform management system essentially reduces the velocity of runoff water and consequently increases opportunity time for water to infiltrate and reduces sediment losses. The concept of fertilizer management is developed to minimize the unfavorable exploitation of soil fertility and plant nutrient and thus to maintain the soil health and plant nutrient at optimum level. However, the appropriate combination of mineral fertilizers and organic manure plays an important role and varies according to the cropping pattern, ecological, social and economical situations (Singh and Dixit, 1998). In the view of above facts, there is need to evolve an appropriate agro- technology for successful cultivation of kharif soybean that results in efficient rain water conservation through land configuration use and nutrient management through fertilizer for higher productivity of soybean crop. On this backdrop the present investigation was planned for the study.

The field experiment was carried out at Post Graduate Instructional Farm, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar (Maharashtra) to study resource conservation through land configuration and fertilizer management in soybean. The experiment consists of twelve treatment combinations in which four land configuration and three fertilizer levels. These treatments were replicated three times in a split plot design. The Twelve treatment combination were randomized within each replication. FYM as per treatment added before harrowing. Full dose of major plant nutrients was applied as basal application through, urea and single super phosphate. Sowing of seed was done manually by dibbling. Sowing of seeds in each plots was done by maintaining the spacing 30 x 10 cm depth of 3-4 cm and then seeds were covered with fine soil.

The result indicated that mean oil content did not show any significant effect due to different land configuration and fertilizer management and also mean protein content do not show any significant effect due to different land configuration and fertilizer management. Protein content is essentially the manifestation of N concentration in seed. Hence, increased concentration of N in seed might have increased the protein content. Application of nitrogen and phosphorus might have improved the nutritional environment in rhizosphere as well as in the plant system leading to increased uptake and translocation of the nutrients especially of N, P and K inreproductive structures that led to higher concentration and uptake Since, uptake of nutrient is the function of seed and stalk yield and their concentration, higher concentration of these nutrients coupled with increased seed and stalk yield enhanced the total uptake of N, P and K. The total N, P, K uptake by seed and straw was differ significantly due to different land configurationand fertilizer management . Gross monetary returns was significantly affected by different fertilizer management. Maximum gross monetary returns (Rs. 88971.33 ha^{-1}) was obtained with the application of 100% GRDF based on AST, which was superior over rest of the treatments. Similar findings were also reported by Muyayabantu *et al.* (2013).Gross monetary returns were significantly affected by different land configuration. Maximum gross monetary returns (Rs. 92965.00 ha^{-1}) were obtained under ridges and furrow than rest of the land configuration.Similar findings were also obtained by Billore *et al.* (1993).The cultivation on ridges and furrows registered numerically higher net monetary returns (Rs. 58734.22 ha^{-1}) when compared with the other treatments

Table 1. Total N, P and K uptake by soybean as influenced by different treatments

Treatment	Total nutrient uptake (kg ha-1)		
	N	**P**	**K**
Main plot treatments Land configuration			
L_1 : Flat bed	122.19	22.61	53.19
L_2 : Tied ridges and furrows	129.40	24.85	55.09
L_3 : Ridges and furrows	143.39	27.20	62.01
L_4 : BBF 2 rows	134.89	25.61	57.85
S.E.m ±	1.90	0.30	0.46
C.D. at 5%	6.58	1.04	1.58
Subplot treatments : Fertilizer management			
F_1 : 100%GRDF based on AST	139.40	26.44	59.54
F_2 : 75%GRDF based on AST	132.17	25.03	56.98
F_3 : 50%GRDF based on AST	125.83	23.73	54.59
S.E.m ±	2.55	0.46	0.56
C.D. at 5%	7.64	1.37	1.69

Table 2. Oil and Protein (%) of soybean as influenced by different treatments

Treatment	Quality	
	Oil (%)	**Protein (%)**
Main plot treatments Land configuration		
L_1 : Flat bed	20.38	37.50
L_2 : Tied ridges and furrows	20.40	37.51
L_3 : Ridges and furrows	20.42	37.54
L_4 : BBF 2 rows	20.40	37.52
S.E.m ±	0.02	0.16
C.D. at 5%	NS	NS
Subplot treatments : Fertilizer management		
F_1 : 100%GRDF based on AST	20.42	37.54
F_2 : 75%GRDF based on AST	20.41	37.53
F_3 : 50%GRDF based on AST	20.38	37.49
S.E.m ±	0.15	0.01
C.D. at 5%	NS	NS

Table 3. Economics studies of soybean as influenced by different treatments

Treatment	Monetary returns (Rs. ha^{-1})		
	Gross monetary (Rs. ha^{-1})	Net monetary (Rs. ha^{-1})	B:C ratio
Main plot treatments Land configuration			
L_1 : Flat bed	76147.22	45616.55	2.49
L_2 : Tied ridges and furrows	81776.72	49846.05	2.56
L_3 : Ridges and furrows	92965.00	60124	2.83
L_4 : BBF 2 rows	84571.44	50340.78	2.47
S.E.m ±	3012.566	3012.578	-
C.D. at 5%	10424.853	NS	-
Subplot treatments : Fertilizer management			
F_1 : 100%GRDF based on AST	88971.33	54093.33	2.55
F_2 : 75%GRDF based on AST	81164.38	48817.38	2.50
F_3 : 50%GRDF based on AST	76459.58	45535.08	2.47
S.E.m ±	2642.478	2642.482	-
C.D. at 5%	7922.147	NS	-

.It was at par with BBF. Net monetary returns were significantly affected by different fertilizer management. Maximum net monetary returns (Rs. 54093.33 ha^{-1}) were obtained when the fertilizer was applied at 100% GRDF based on AST, which was superior over the rest of the treatments at 100% GRDF based on AST, which was superior over the rest of the treatments. Under different fertilizer management treatments, the benefit: cost ratio was higher with the application of 100 % GRDF based on AST (2.55).Under different land configurations, the benefit: cost ratio of the ridges and furrows (2.71) registered significantly highest among rest of the treatments. It was being at par with BBF.

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Effect of Climate Change on Production of Major *Rabi* Cereals in Western Maharashtra: Consequences on Food Security

V. A. Shinde[1], J. D. Jadhav[2], J. B. Patil[3], V. R. Bavadekar[4] and P. B. Pawar[5]
Zonal Agricultural Research Station, Solapur - 413 002 (India)

Abstract

Climate change is likely to affect the agricultural production adversely and becomes more serious concern for developing countries because they do not have enough resources to mitigate the adverse effect of climate change. Regression analysis for a ten districts of western Maharashtra was employed during 1961-2018. Empirical results show that climatic factors have a statistically significant impact on productivity of most of food grain crops but this effect varies across crops. Productivity of wheat and sorghum crops will be selected for the present study. For climatic factors actual average minimum temperature, average maximum temperature, relative morning humidity, relative evening humidity and rainfall will be considered for the present study. A rise in maximum temperature has a negative and significant effect in yields of rabi crops. On the other hand, a rise in minimum temperature has a significantly positive impact on yield on wheat but negative impact on production of rabi sorghum. The effect of rainfall has been found non-significant in all the rabi cereal crops. The quadratic term of rainfall is negative and non-significant in rabi sorghum meaning thereby a damaging effect on the crop yield. By the year 2100, with a significant change in climate. The climate impacts on cereals will vary widely in rabi seasons.

Key words : Climate change, *rabi* cereals, crop production, food security, Western Maharashtra.

Climate change is likely to affect the agricultural production adversely and becomes more serious concern for developing countries because they do not have enough resources to mitigate the adverse effect of climate change. Statistics shows that the amount of undernourished people is still alarmingly in developing world. In India more than 700 million population directly depend on agriculture and allied activities of which 52 per cent directly dependent on climate-sensitive sectors like agriculture, forestry and fishery for their livelihood. Agriculture sector is most sensitive to climate change and it affects the food security of India. This study was estimated the impact of climatic factors on cereals food grain productivity to facilitate the development of appropriate farm policies to cope with climate change. Regression analysis for a ten districts of western Maharashtra was employed during 1961-2014. Empirical results shows that, climatic factors have a statistically significant impact on productivity of most of food grain crops but this effect varies across crops.

Productivity of wheat and sorghum crops will be selected for the present study. For climatic factors actual average minimum temperature, average maximum temperature and rainfall were considered for the present study.

Looking to the adverse climatic situation and persistent changes in area, production and productivity of cereal crops, the study on effect of climate change on production of *rabi* cereals in western Maharashtra was selected with the following objectives, to study the trends in area, production and productivity of major *rabi* cereals, to study the trends and variation in the

1. and 2. Associate Professor, 3. Agril. Asstt. 4. and 5. Assistant Professor.

rainfall and temperature to study the correlation between climatic factors and production of cereals and also the impact of changes in climatic situation on production of *rabi* cereals, to workout the marginal effects of climate change on productivity of *rabi* cereals and to examine the implications of climate change for food security.

Methodology

The main objective of the present study was to analyze the area, production and productivity of major cereals and its implication on climate change. For area, production and productivity the study was based on secondary data mainly collected from various government publications, reports and related websites. While for climatic data, it was collected from respective research stations and Agricultural colleges located in the ten districts in the jurisdiction of Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist: Ahmednagar (MS) for the 54 years from 1961-2018 was utilized for this study. Total two major *rabi* food grain crops were taken *viz.*; wheat and *rabi* jowar (sorghum). The primary data, collected was compiled and analyzed to fulfil the objectives of the present study.

Results and Discussion

Mean and standard deviations of monthly temperature and annual rainfall during *rabi* period of Western Maharashtra, 1961-2018.

Annual per cent change in maximum temperature, minimum temperature, mean temperature and rainfall for the *rabi* season of western Maharashtra and actually change in above parameters was worked out and presented in Table1.

It has been observed from the above table that in *rabi* period during 1961-2018, the maximum temperature was increased by 0.25°C

Particulars	Max. temp. (°C)	Mini. temp. (°C)	Mean temp. (°C)	Rain-fall (mm)
Mean	30.2 (0.15)	18.10 (0.07)	24.24 (0.09)	114.20 (7.16)
% Annual change	0.017**	0.011**	0.015**	-0.157**
Change (°C)	0.25	0.16	0.21	-0.08

Note: Figures in the parentheses are standard errors, ** and * denote significance at 1 per cent and 5 per cent, levels, respectively.

with annual percentage change was highly significant at 0.017 per cent, minimum temperature was increased by 0.16°C with annual percentage change was highly significant at 0.011 per cent and mean temperature was increased by 0.21°C with annual percentage change was highly significant at 0.015 per cent while in case of annual rainfall, it was decreased by -0.08 mm with annual percentage change was highly significant at -0.157 per cent,

Impacts of climate change on crop yields

Regression results : The estimated equations for *rabi* crops is presented in Table 2. The geographical or district fixed effect have been found significant in all the crops, indicating that inclusion of spatial fixed effects in climate mode is important for controlling time-invariant location specific characteristics, which might be correlated with the climate variables. The time fixed effects are also significant, suggesting the importance of farm-level adjustments in agronomic and cropping practice consequent to the climate change.

Regression results in respect of effect of weather variables on production of *rabi* crops reveal that, a rise in maximum temperature has a negative and significant effect in yields of *rabi* crops. On the other hand, a rise in minimum temperature has a significantly positive impact on yield on wheat but negative impact on production of *rabi* sorghum. The opposing effects of rise in minimum and maximum temperatures suggest that temperature has a non-linear effect on the crop yields.

The effect of rainfall has been found non-significant in all the *rabi* cereal crops. The quadratic term of rainfall is negative and non-significant in *rabi* sorghum meaning thereby a damaging effect on the crop yield.

Marginal effect : In the presence of non-linear and interaction effects, the interpretation of regression coefficients is not straightforward. Therefore, to quantify the effect of changes in temperature and rainfall, marginal effects were calculated at their mean variables that are changes in crop yield due to rise of 1°C mean temperature or 1 mm in rainfall. The expected marginal impact of a single climate variable 'X' on yield evaluated at the mean is presented in the Table 3.

Table 3 represents the marginal effect of climate change in terms of temperature and rainfall. A rise in the maximum temperature in *rabi* season reduces the yield of wheat by 2 per cent and of *rabi* sorghum by are 4 per cent. However, the effect of a similar increases the minimum temperature is opposite but is sufficient enough to fully compensate the loss due to rise in maximum temperature. The marginal effect of 1°C rise in minimum temperature on yield of wheat crop benefit more from the rise in minimum temperature.

The marginal effect of rainfall on *rabi* crops, has been found non-significant. The non-significant effect of rainfall in the *rabi* season is expected as the quantum of *rabi* rainfall is not only less but more variable also. In general, the marginal effect of rainfall is much smaller than that of temperature. These results suggest that, the effect of climate change on agriculture of western Maharashtra will be largely driven by temperature change.

Projected impacts of climate change : The effects of climate change on crop yields have been projected for four time-slices *viz*., 2025, 2050, 2075 and 2100 at minimum and maximum changes in temperature and rainfall (IPCC,2017). The IPCC has predicted the changes in temperature and rainfall for the quarters December-February. There is a lack of concordance between IPCC defined quarters and the growing periods used in this paper. For projecting crop yields, the change in climate during December- February as representative of the change in *rabi* season. Accordingly, by 2100 the *rabi* temperature is expected to increase in the range of 1.4-3.7C and *rabi* rainfall in the range to -14 per cent to 28 per cent. The changes in temperature and rainfall towards 2025 are not so severe. The crop yields

Table 2. Regression results for *rabi* crops, 1961-2018

Variable	Wheat	*Rabi* sorghum
Maximum temperature	-0.163* (0.067)	-0.048* (0.024)
Minimum temperature	0.16* (0.066)	-0.155* (0.063)
Rainfall	0.0000 (0.0006)	0.0000 (0.0003)
Rainfall (Square)	0.084 (0.0205)	-0.0036 (0.0176)
Constant	-4.88* (2.24)	5.025** (1.001)
District	Yes	Yes
Time	Yes	Yes
No. of observations	2160	1080

Table 3. Marginal effect of climate change on rabi crops, 1961-2018

Variable	Wheat	*Rabi* sorghum
Maximum temperature	-0.0208** (0.0066)	-0.0412** (0.0111)
Minimum temperature	0.2065** (0.0657)	-0.0486 (0.712)
Rainfall	0.0000 (0.0007)	0.0000 (0.0001)

Table 4. Projected change in *rabi* crop yields by 2025, 2050, 2075 and 2100

Crop	2025		2050		2075		2100	
	Min	Max	Min	Max	Min	Max	Min	Max
	ΔT and ΔR	ΔT and ΔR	ΔT and ΔR	ΔT and ΔR	ΔT and ΔR	ΔT and ΔR	ΔT and ΔR	ΔT and ΔR
Wheat	-0.41	-1.27	-1.35	-4.14	-2.29	-7.02	-3.23	-9.91
Rabi sorghum	-0.005	-0.02	-0.0-17	-0.05	-0.028	-0.09	-0.040	-0.12

at the minimum and maximum changes in temperature have been projected using equation.

Where, Y is the yield, R is the rainfall, T is the temperature, and ($\delta Y/\delta R$) and ($\delta Y/\delta T$) were determined by the model equations. The projected climate change impacts on crop yields are given in Table 4. By the year 2100, with a significant change in climate the climate impacts on cereals will vary widely in *rabi* seasons. In the *rabi* season, wheat yield will be less by about 10 to 11 per cent, while, *rabi* sorghum yield will be less by about 0.1 per cent only. If the climate does not change significantly, yield losses will be much smaller. The climate impacts will not be so severe in the short-run that is, towards 2025. It is also possible that in the long-run too, the climate impacts may not be so severe because of continuous adaptation.

Consequences on food security : Food security is an outcome of the food production process. The climate change will affect food security by influencing the availability of food, access to food, stability of food supplies and volatility in food prices. Wheat as well as *rabi* sorghum are the main *rabi* staple foods for a majority of western Maharashtra population, and our findings suggest a considerable decline in their yields with significant changes in climate.

Wheat is a main stable food of majority of Indians, due to decrease trend of wheat production, it will directly hamper to the population of India as well as Maharashtra and also its direct impact on major bakery industry, which is directly linked with the wheat production. By 2050 Maharashtra's population is likely cross 16.22 crores and India' population is likely to cross billion demanding more diversified for our findings indicate with climate change production more food with limited resources will be a big challenge. It is therefore imperative to promote up to sustainable agricultural practices to overcome potential threats to food security. Set important measures that hold promises of reduce harmful effect of climate change include intercropping afforestation, growing drought-to crops, changes in planting dates.

Conclusion

1. A rise in maximum temperature has a negative and significant effect in yields of *rabi* crops. On the other hand, a rise in minimum temperature has a significantly positive impact on yield on wheat but negative impact on production of *rabi* sorghum.

2. The effect of rainfall has been found non-significant in all the *rabi* cereal crops. The quadratic term of rainfall is negative and non-significant in *rabi* sorghum meaning thereby a damaging effect on the crop yield.

3. Marginal effect of climate change in terms of temperature and rainfall. A rise in the maximum temperature in *rabi* season reduces the yield of wheat by 2 per cent and of *rabi* sorghum by are 4 percent. However,

the effect of a similar increases the minimum temperature is opposite but is sufficient enough to fully compensate the loss due rise in maximum temperature. The marginal effect of 1°C rise in minimum temperature on yield of wheat crop benefit more from the rise in minimum temperature.

4. The marginal effect of rainfall on *rabi* crops, has been found non-significant. The non-significant effect of rainfall in the *rabi* season is expected as the quantum of *rabi* rainfall is not only less but more variable also. In general, the marginal effect of rainfall is much smaller than of temperature.

5. By the year 2100, with a significant change in climate. The climate impacts on cereals will vary widely in *rabi* seasons. In the *rabi* season, wheat yield will be less by about 10 to 11 per cent, while, *rabi* sorghum yield will be less by about 0.1 per cent only. If the climate does not change significantly, yield losses will be much smaller.

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Effect of Potassium on Nutrient Uptake, Yield and Economics of Cotton in Vertisols

R. N. Katkar[1], V. K. Kharche[2], P. N. Magare[3], S. R. Lakhe[4], D. B. Tamgadge[5] and N. M. Konde[6]
Department of Soil Science and Agricultural Chemistry,
Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola - 444 104 (India)

Abstract

The field experiment was conducted during *kharif* 2009-10 to 2011-12 on the Research Farm, Department of Soil Science and Agricultural Chemistry, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. There were seven treatments comprising of potassium application through soil viz., T1 - RDF (50:25:00), T2 - RDF + 12.5 kg K_2O ha^{-1}, T_3 - RDF + 25 kg K_2O ha^{-1}, T_4 - RDF + 37.5 kg K_2O ha^{-1} and foliar T_5 - RDF + 2 % KNO_3 foliar spray (one), T_6 - RDF + 2% KNO_3 foliar spray (two) and T_7 - Absolute control alongwith RDF (50 kg N+25 kg P_2O_5 ha^{-1}) laid out in Randomized Block Design with three replications. The soil of experimental site was clay in texture and classified as hyperthermic family of Typic Haplustert. The soil had medium organic carbon (6.0 g kg^{-1}), low in available nitrogen (157.27 kg ha^{-1}) and available phosphorus (12.23 kg ha^{-1}) and high in available potassium (313.60 kg ha^{-1}). The pooled data revealed that application of 25 kg K_2O ha^{-1} alongwith recommended dose of fertilizers (50:25:0 NPK kg ha^{-1}) recorded significantly highest seed cotton yield (14.15 q ha^{-1}) as compared to recommended dose of fertilizers + 12.5 kg K_2O ha^{-1} and at par with recommended dose of fertilizers + 37.5 kg K_2O ha^{-1}. The uptake of nutrients N (67.71 kg N ha^{-1}), P (18.71 kg P ha^{-1}) and K (71.80 kg K ha^{-1}) was also significantly higher due to application of potassium. The fiber quality was slightly improved due to application of potassium. Application of potassium alongwith recommended dose of N and P_2O_5 helped to improve the soil fertility status. The application of RD + 37.5 kg K_2O ha^{-1} recorded significantly highest available nitrogen (180 kg N ha^{-1}), phosphorus (17.13 kg P ha^{-1}) and potassium (334.3 kg K_2O ha^{-1}). It could be concluded that the application of 25 kg K_2O ha^{-1} along with recommended dose of fertilizer (50:25:0 NPK kg ha^{-1}) recorded significantly higher seed cotton yield (14.15 q ha^{-1}) and B : C ratio (2.37) respectively. The uptake of nutrients (NPK) and fiber quality was significantly improved due to potassium application, hereby improving the soil fertility status.

Key words : Potassium, cotton, fiber quality, fertility status.

Cotton (Gossypium hirsutum), is one of the most important commercial and industrial crop. It plays a key role in economical and social affairs of the world. The cotton production is influenced by various components of production technologies. Among them a significant role is played by fertilizer management. Adequate nutritional supply is essential. Three major elements are needed in balanced quantity. Nitrogen is necessary for development of vegetative and fruiting branches and thus increasing yield. Phosphorus is essential for optimum growth of roots aerial parts and reproductive development. It increases earliness in crop, like flowering and boll development. Adequate potassium is necessary for reducing the physiological diseases to facilitate normal development, maturity of bolls and to improve quality of fibre. The important issues in cotton production are moisture stress during the growth period, nutrient management and insect pest incidence under rainfed condition. The potassium has important role in retention within plant, it also control guard cells of stomata's which helps to reduce the water loss from plant leaves. This lead to sturdiness in plant under water stress and rainfed situation. Due to these

1. Associate Prof., 2. Director of Research, 3. SRA, 4. Research Associate, 5. Head, and 6. Asst. Prof.

constraints cotton yield have sharply declined for the last half a decade thus reducing the area among yield sustaining factors, balanced crop nutrition is of great significance. Nutrients are absorbed by the plants both through roots and foliage. The foliar application has an advantage as it helps to overcome the losses of fertilizers through leaching, volatilization, fixation, etc. Nitrogenous and phosphorus fertilizers are more frequently used by the farmers from several years leading to an imbalanced nutrient supply. As a result, potassium status in soil depleted remarkably. Potassium is an essential nutrient in crop nutrition and play important role in production and improving the quality. The beneficial effect of potassium on cotton was reported by several workers (Maninder Kaur *et al*., 2007). Further, foliar nutrition, when used as a supplement to the recommended soil fertilizer application is highly beneficial, as the crop gets benefited from foliar applied nutrients when the roots are unable to meet the nutrient requirement of the crop at critical growth stages (Ebelhar and Ware, 1998). Hence, the study was conducted to investigate the effect of soil and foliar application of potassium alongwith recommended dose of N and P on the yield and nutrient uptake of cotton.

Materials and Methods

The field experiment was conducted during kharif season of 2009-10 to 2011-12 at Research Farm, Department of Soil Science and Agricultural Chemistry, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola under rainfed situation. The soil of experimental site was clay in texture and classified as hyperthermic family of Typic Haplustert. Composite soil sample was collected at 0 to 20 cm depth from experimental site prior to start of field experiment. The soil pH was slightly alkaline and non-saline (8.20) (EC 0.12 dS m^{-1}) having medium organic carbon (6.0 g kg^{-1}), low in available nitrogen (157.27 kg ha^{-1}) and phosphorus (12.23 kg ha^{-1}), high in available potassium (313.60 kg ha^{-1}). The experiment was laid out in Randomized Block Design with seven treatments *viz*., T_1 - RDF (50:25:00), T_2 - RDF + 12.5 kg K_2O ha^{-1}, T_3 - RDF + 25 kg K_2O ha^{-1}, T_4 - RDF + 37.5 kg K_2O ha^{-1}, T5 - RDF + 2% KNO_3 Foliar spray (one), T_6 - RDF + 2% KNO_3 foliar spray (two) and T_7 - Absolute control with three replications. Two seeds of cotton cv. AKH-8828 were dibbled per hill at distance of 60 cm x 30 cm. The five plant samples were collected from each plot at harvest for recording dry matter accumulation. Soil pH was determined by using Systronics glass electrode pH meter using 1:2.5 soil : water suspensions and the clear supernatant extract obtained from the suspension used for EC measurement using a conductivity meter (Jackson, 1973). Organic carbon (OC) was determined by Walkley and Black method as described by Jackson (1973). Available nitrogen was determined by alkaline potassium permanganate method as described by Subbiah and Asija (1956). Available phosphorus was determined by Olsen's method using 0.5 M sodium bicarbonate pH (8.5) as extractant. Available potassium was determined by Flame photometer using Ammonium acetate (pH 7.0) as an extractant as described by Hanway and Heidel (1952). Plant samples were collected at harvest of cotton. The plant samples were oven dried and ground to powder in electric grinding machine and used for analysis of nitrogen, phosphorus and potassium content. Total nitrogen was determined by Kjeldahl method as described by Piper (1966). Total phosphorus was determined on Spectrophotometer by Vanadomolybdate yellow colour method using di-acid extract (Jackson, 1973). Total potassium was determined by Flame photometer as described by Piper (1966). The data were statistically analyzed by using standard analysis of variance methods and then means were tested against the critical difference of 5% level of significance (Panse and Sukhatme, 1967).

Results and Discussion

Seed cotton yield : The recommended dose of fertilizer with increased levels of potassium increased the seed cotton yield. The significantly highest seed cotton yield (13.67 q ha^{-1}) was recorded with the application of RD + 37.5 kg K_2O ha^{-1} which was at par with application of RD + 25 kg K_2O ha^{-1} (12.85 q ha^{-1}). In case of stalk yield highest stalk yield (34.61 q ha^{-1}) was observed in the treatment 37.5 kg K_2O ha^{-1} followed by application of 25 kg K_20 ha^{-1} (32.65 q ha^{-1}) which was at par with each other. The pooled data (Table 1) revealed that significantly highest seed cotton yield (14.64 q ha^{-1}) was recorded in the treatment of recommended dose of fertilizer + 37.5 kg K_2O ha^{-1} (T_4), followed by recommended dose of fertilizer + 25 kg K_2O ha^{-1} (14.15 q ha^{-1}) (T_3), lowest seed cotton yield (9.91 q ha^{-1}) was recorded in control treatment. The per cent increase in seed cotton yield was recorded 27.68 in the treatment of recommended dose of fertilizer + 37.5 kg K_2O ha^{-1} (T_4) over RDF and 27.02 per cent in treatment of RD + 25 kg K_2O ha^{-1}. Application of recommended dose of fertilizer + 37.5 kg K_2O ha^{-1} recorded significantly highest cotton stalk yield (35.50 q ha^{-1}) followed by RD + 25 kg K_2O ha^{-1} (34.79 q ha^{-1}) (T_3), RD + two spray of 2% KNO_3 (T_6), RD + 12.5 kg K_2O ha^{-1} (T_2). Sharma and Singh (2007) observed that, the positive effect of potassium on yield might be due to pronounced role of potassium in transport of photosynthates and cell elongation. Cassman *et al*. (1989) observed that, yield increases with K application on Vermiculite soils because of high K fixing capacity. Parvez *et al*. (2005) observed significant increase in seed cotton yield with increasing levels of potassium in soil because potassium is readily mobile nutrient within the plant tissue, its utilization is concerned with the formation of carbohydrate and proteins, synthesis of nucleic acid, chlorophyll and translocation of solutes which might have helped in increasing seed cotton yield. The per cent increase in yield of 27.67 and 25.12 was recorded in treatments RDF + 2% KNO_3 Foliar spray (one) and RDF + 2% KNO_3 foliar spray (two) over control.

Uptake of nutrients : The significantly highest N uptake (67.71 kg N ha^{-1}) was recorded with the application of 37.5 kg K_2O ha^{-1} alongwith recommended dose of fertilizer

Table 1. Yield of cotton (q ha^{-1}) as influenced by various treatments

Treatments	Seed cotton yield			Pooled mean	Cotton stalk yield			Pooled mean
	2009-10	2010-11	2011-12		2009-10	2010-11	2011-12	
T_1 - RDF 50:25:00 N:P:K kg ha^{-1}	12.14	11.93	10.53	11.53	32.11	28.28	26.81	29.06
T_2 - RD + 12.5 kg K_2O ha^{-1}	13.61	12.40	10.93	12.31	33.10	31.48	27.39	30.65
T_3 - RD + 25 kg K_2O ha^{-1}	15.42	14.19	12.85	14.15	35.96	35.78	32.65	34.79
T_4 - RD + 37.5 kg K_2O ha^{-1}	15.50	14.77	13.67	14.64	35.63	36.28	34.61	35.50
T_5 - RD + 2% KNO_3 (One spray)	15.19	12.10	10.74	12.67	34.47	30.48	29.34	31.43
T_6 - RD + 2% KNO_3 (Two spray)	15.28	12.60	11.39	13.09	34.88	32.13	28.56	31.85
T_7 - Absolute control	11.82	9.53	8.39	9.91	28.17	24.27	21.32	24.59
SE (m) ±	0.42	0.52	0.92	0.49	0.99	1.23	1.85	1.06
CD at 5%	1.25	1.54	2.74	1.47	2.96	3.66	5.49	3.15
C.V	5.18	7.21	14.24	6.83	5.16	6.83	11.17	5.90

Table 2. Uptake of nutrients by cotton as influenced by various treatments

Treatments	Nutrient Uptake ($kg\ ha^{-1}$) Pooled mean		
	Nitro-gen	Phos-phorus	Pota-ssium
T_1 - RDF 50:25:00 N:P:K kg ha^{-1}	55.86	14.55	58.96
T_2 - RD + 12.5 kg K_2O ha^{-1}	58.96	15.25	63.05
T_3 - RD + 25 kg K_2O ha^{-1}	65.98	18.38	70.21
T_4 - RD + 37.5 kg K_2O ha^{-1}	67.71	18.71	71.80
T_5 - RD + 2% KNO_3 (One spray)	60.83	16.45	64.93
T_6 - RD + 2% KNO_3 (Two spray)	61.70	16.74	66.67
T_7 - Absolute control	48.15	12.26	52.20
SE (m) ±	1.54	0.32	1.23
CD at 5%	4.60	0.95	3.66

which was at par with recommended dose of fertilizer + 25 kg K_2O ha^{-1} (65.98 kg N ha^{-1}) (Table 2). The increased uptake of N due to the potassium application indicated the synergistic effect of potassium in N absorption by plant. The foliar application of K also increased the content and uptake of nitrogen by cotton as compared to control. Thirumuragan *et al*. (1984) also noted increased uptake of nitrogen due to absorption of nutrients by cotton. Further the application of high levels of potassium increased the uptake of nitrogen at critical growth stage.

The application of RD along with 37.5 kg K_2O ha^{-1} recorded significantly highest P uptake (18.71 kg P ha^{-1}) followed by RD+25 kg P ha^{-1} was found at par. The probable reason for the increased P content and uptake with RDF + 37.5 kg K_2O ha^{-1} may due to the application of K increases the root activity of the growing plants considerably which resulted in the greater absorption and utilization of P, which ultimately increased the P uptake (Mayilsamy and Iruthayaraj, 1980).

The application of RD + 37.5 kg K_2O ha^{-1} recorded significantly highest uptake of potassium (71.80 kg K ha^{-1}) which was at par with RD + 25 kg ha^{-1} (70.21 kg K ha^{-1}). The increased K uptake by cotton might be due to higher doses of potassium in soil (Blaise *et al*., 2009). The addition of K probably increased the quantity which is immediately available to the plant, resulting into higher content and uptake of K (Mayilsamy and Iruthayaraj, 1980).

The nutrient use efficiency of nitrogen (Table 3) was increased due to application of recommended dose of fertilizer (50:25:00 N: P: K kg ha^{-1}) with 25 kg K_2O ha^{-1} and 37.5 kg K_2O ha^{-1}. Adarsha *et al*. (2004) concluded that increased rate of nitrogen and phosphorus in cotton fields improved efficiency. The apparent nutrient recovery (ANR) (%) of K decreased with increased dose of potassium, where in ANR was enhanced by spraying of 2% K_2O ha^{-1} and found to increase upto 127.30% , whereas it decreased with increase in number of sprayings. It was observed that agronomic efficiency (AEK) increased with increase in potassium application

Table 3. Nutrient use efficiency as influenced by various treatments

Treatments	Apparent Nutrient Recovery (%) K	Agronomic Efficiency (AE) (kg grain kg^{-1} nutrient applied) K
T1 - RDF 50:25:00 N:P:K kg ha-1	-	-
T2 - RD + 12.5 kg K2O ha-1	86.80	19.20
T3 - RD + 25 kg K2O ha-1	72.84	19.96
T4 - RD + 37.5 kg K2O ha-1	52.06	12.61
T5 - RD + 2 % KNO3 (One spray)	127.30	27.60
T6 - RD + 2 % KNO3 (Two spray)	72.35	15.90
T7 - Absolute control	-	-

Table 4. Fiber quality parameters of cotton as influenced by various treatments

Treatments	2.5% Span length (mm)	Uniformity ratio (%)	Fineness micronaire (10^{-6} g inch^{-1})	Bundle strength tenacity at 3.2 mm gauge (g tex^{-1})
T_1 - RDF 50:25:00 N:P:K kg ha^{-1}	27.07	52.67	3.80	20.53
T_2 - RD + 12.5 kg K_2O ha^{-1}	26.60	50.33	3.93	20.20
T_3 - RD + 25 kg K_2O ha^{-1}	27.20	48.67	4.00	20.13
T_4 - RD + 37.5 kg K_2O ha-1	27.63	50.67	4.10	20.57
T_5 - RD + 2% KNO_3 (One spray)	26.10	51.33	4.00	20.43
T_6 - RD + 2% KNO_3 (Two spray)	26.47	51.03	4.03	20.23
T_7 - Absolute control	25.54	51.00	4.07	19.20
SE (m) ±	0.48	1.05	0.22	0.44
CD at 5%	NS	NS	NS	NS

and was maximum at 25 kg K_2O ha^{-1}, and then decreased to lowest values at dose of 37.5 K_2O ha^{-1}, while it was found enhanced by single spraying of 2% K_2O ha^{-1}. Blaise and Singh (2004) reported that when K applied with N and P the efficiency of K increased though an apparent response to potassium was not seen in dry land cotton. It is better to adopt a balanced fertilizers schedule (NPK application), wherein K is applied as a prophylactic measure.

Fibre quality : The quality parameters were found non-significant however some fibre parameters were numerically higher with recommended dose of fertilizer alongwith increased levels of potassium (Table 4). The findings corroborates with the results reported by Raskar *et al*. (2001), Anonymous (2004) and Mehta *et al*. (2009).

Soil properties : The pH and electrical conductivity of soil after harvest of cotton was found to be non significant. The organic content of soil after harvest of cotton as influenced by various treatments and recorded with RD + 37.5 kg K_2O ha^{-1} significantly highest (6.57 g kg^{-1}) followed by RD + 25 kg K_2O ha^{-1} (6.43 g kg^{-1}). The organic carbon under all the treatments was improved as compared to initial status (6.00 g kg^{-1}) which might be due to increase in root biomass as a result of vigorous growth and yield of seed cotton. The increase in organic carbon content in soil over initial (6.0 g kg^{-1}) could be due to the balanced nutrition of the crop leading to increase in soil biomass.

The available N was found to be increased under all the treatments except control. The application of RD + 37.5 kg K_2O ha^{-1} recorded significantly highest available nitrogen (180 kg N ha^{-1}) followed by RDF + 25 kg K_2O ha^{-1} (Table 5). The decrease in available N in control

Table 5. Nutrient status of soil after harvest of cotton as influenced by various treatments

Treatments	Ava. Nitrogen (kg ha^{-1})	Ava. Phosphorus (kg ha^{-1})	Ava. Potassium (kg ha^{-1})
T_1 - RDF 50:25:00 N:P:K kg ha^{-1}	164.1	15.20	318.1
T_2 - RD + 12.5 kg K_2O ha^{-1}	166.2	16.02	325.2
T_3 - RD + 25 kg K_2O ha^{-1}	175.8	16.69	329.6
T_4 - RD + 37.5 kg K_2O ha^{-1}	180.4	17.13	334.3
T_5 - RD + 2% KNO_3 (One spray)	165.2	15.67	320.1
T_6 - RD + 2% KNO_3 (Two spray)	168.9	15.94	321.5
T_7 - Absolute control	152.1	12.19	306.7
SE (m) ±	2.39	0.44	0.73
CD at 5%	7.10	1.32	2.18
Initial value	157.27	12.23	313.6

Table 6. Monetary returns of cotton as influenced by various treatments (Pooled mean)

Treatments	Yield (q ha^{-1})	GMR (Rs.)	COC (Rs.)	NMR (Rs.)	B:C ratio
T_1 - RDF 50:25:00 N:P:K kg ha^{-1}	11.53	48799	24057	24742	2.02
T_2 - RD + 12.5 kg K_2O ha^{-1}	12.31	51656	24377	27279	2.11
T_3 - RD + 25 kg K_2O ha^{-1}	14.15	59512	25108	34404	2.37
T_4 - RD + 37.5 kg K_2O ha^{-1}	14.64	61621	25374	36247	2.42
T_5 - RD + 2% KNO_3 (One spray)	12.67	53050	25762	27288	2.05
T_6 - RD + 2% KNO_3 (Two spray)	13.09	54662	27216	27446	2.00
T_7 - Absolute control	9.91	41412	22353	19059	1.85
SE (m) ±	0.49	1661		1596	
CD at 5%	1.47	4936		4741	

treatment might be due to continuous cropping devoid of nitrogen. The increased available N content might be due to synergistic effect of potassium application resulted in increasing nitrogen availability in soil. Ghosh *et al*., (2001) also reported the favorable effect of potassium application on available nitrogen status of the soil.

The available phosphorus was significantly influenced with the application RD + 37.5 kg K_2O ha^{-1} (17.13 kg P ha^{-1}) followed by RDF + 25 kg K_2O ha^{-1} (16.69 kg P ha^{-1}). The increased in available phosphorus due to the application of potassium, it might be due to the balanced nutrients concentration in soil solution resulted in better phosphorus use efficiency. These results corroborates with the findings of Jamadagni and Birari (1994).

Application of RD + 37.5 kg ha^{-1} K_2O recorded significantly highest K (334.3 kg K_2O ha^{-1}) it was found at par with treatment receiving RDF+ 25 kg K_20 ha^{-1}, which improved under all the treatments with the continuous application of RDF along with different levels of K_2O and KNO_3 except control. The increasing availability of potassium in soil might be due to application of potassium. Joshi (1993) observed the increased available status of NPK due to application of 100% RDF.

The benefit cost ratio of cotton was influenced by various treatments (Table 6). The B:C ratio was found significantly higher in the treatment of recommended dose of fertilizer with 37.5 kg K_2O ha^{-1} (2.42) followed by RD with 25 kg K_2O ha^{-1} (2.37).

It is concluded that the application of 25 kg K2O ha^{-1} along with recommended dose of fertilizer (50:25 NP kg ha^{-1}) to obtain higher seed cotton yield (14.15 q ha^{-1}), B:C ratio (2.37), uptake of nutrients (NPK) and slight improvement in fiber quality besides improvement in soil fertility status under rainfed situation.

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Effect of Climate Change on Production of Major *Kharif* Cereals in Western Maharashtra: Consequences on Food Security

J. B. Patil[1], V. A. Shinde[2], J. D. Jadhav[3], V. R. Bavadekar[4] and P. B. Pawar[5]
Zonal Agricultural Research Station, Solapur - 413 002 (India)

Abstract

Climate change is likely to affect the agricultural production adversely and becomes more serious concern for developing countries because they do not have enough resources to mitigate the adverse effect of climate change. Regression analysis for a ten districts of western Maharashtra was employed during 1961-2018. Empirical results show that climatic factors have a statistically significant impact on productivity of most of food grain crops but this effect varies across crops. Productivity of wheat and sorghum crops will be selected for the present study. For climatic factors actual average minimum temperature, average maximum temperature, relative morning humidity, relative evening humidity and rainfall will be considered for the present study. A rise in maximum temperature has a negative and significant effect in yields of *kharif* crops. On the other hand, a rise in minimum temperature has a significantly positive impact on yield on wheat but negative impact on production of *kharif* sorghum. The effect of rainfall has been found non-significant in all the *kharif* cereal crops. The quadratic term of rainfall is negative and non-significant in *kharif* sorghum meaning thereby a damaging effect on the crop yield. By the year 2100, with a significant change in climate. The climate impacts on cereals will vary widely in *kharif* seasons.

Key words : Climate change, *kharif* cereals, crop production, food security, western Maharashtra.

Productivity of rice, maize and pearl millet crops will be selected for the present study. For climatic factors actual average minimum temperature, average maximum temperature and rainfall was considered for the present study. Looking to the adverse climatic situation and persistent changes in area, production and productivity of cereal crops, it is felt necessary to study the Impact of climate change on area, production and productivity of cereals in western Maharashtra with the following objectives, to study the trends in area, production and productivity of major *kharif* cereals, to study the trends and variation in the rainfall, temperature and humidity, to study the correlation between climatic factors and production of cereals and also the impact of changes in climatic situation, to workout the marginal effect of climate change on productivity of *kharif* cereals and to examine the implications of climate change for food security.

Materials and Methods

The main objective of the present study is to analyze the area, production and productivity of major cereals and its implication on climate change. For area, production and productivity the study was based on secondary data mainly collected from various government publications, reports and related websites. While for climatic data, it was collected from respective research stations and Agricultural colleges located in the jurisdiction of MPKV, Rahuri. A ten districts of western Maharashtra with 59 years of data from 1961-2018 was utilized for this study. Total three major *kharif* food grain crops are taken i.e. rice, maize and pearl millet (bajra). The

1. Agril. Asstt 2 and 3. Associate Professor 4 and 5. Assistant Professor.

primary data thus, collected was compiled and analyzed to fulfil the objectives of the present study.

Results and Discussion

Mean and standard deviations of monthly temperature and annual rainfall during *kharif* period of western Maharashtra, 1961-2018.

Annual per cent change in maximum, minimum, mean temperatures and rainfall for the *kharif* season of western Maharashtra and actually change is worked out and presented in Table 1.

It has been observed from the above table that, in the *kharif* period during 1961-2018 the maximum temperature was increased by 0.19oC with percent annual change was highly significant at 0.02 per cent, minimum temperature was increased by 0.10°C with annual percentage change was highly significant at 0.005 per cent and mean temperature was increased by 0.15 oC with annual percentage change was highly significant at 0.014 per cent while in case of annual rainfall, it was decreased by -2.49 mm with annual percentage change was highly significant at -0.027 per cent,

Trends in area, production and productivity : Summary statistics of trends in area, production and productivity of *kharif* season cereals i.e. rice, maize and pearl millet has been worked out during 1961 to 2018 (59 years) and during 1974 to 2018 for maize (45 years)

Impacts of climate change on crop yields

Regression results : The estimated regression equations were presented in Table 2 for *kharif* crops. The geographical or district fixed effect have been found significant in all the crops, indicating that inclusion of spatial fixed effects in climate mode is important for controlling time-invariant location specific characteristics, which might be correlated with the climate variables. The time fixed effects are also significant, suggesting the importance of farm-level adjustments in agronomic and cropping practice consequent to the climate change.

Returning to the effect of weather variables, we find a rise in maximum temperature has a negative and significant effect in yields of rice and maize crops. While, in case of pearl millet it was found negative but non significant. On the other hand, a rise in minimum temperature has a significantly positive impact on yield of rice crop, however effect of minimum temperature

Table 1. Mean and standard deviations of monthly temperature and annual rainfall during crop-growing periods, 1961-2018

Particulars	Max. temp. (°C)	Mini. temp. (°C)	Mean temp. (°C)	Rain-fall (mm)
Mean	33.5 (0.06)	24.8 (0.06)	29.20 (0.04)	793.15 (32.40)
% Annual change	0.02**	0.005**	0.014**	-0.027**
Change (°C)	0.19	0.10	0.15	-2.49

Note: Figures in the parentheses are standard errors, ** and * denote significance at 1 per cent and 5 per cent, respectively.

Table 2. Regression results for *kharif* crops, 1961-2018

Variable	Rice	Maize	Pearl millet
Maximum temperature	-0.0107* (0.04)	-0.1496** (0.157)	-0.0009 0.052
Minimum temperature	0.101* (0.04)	0.0285 (0.154)	0.068 (0.05)
Rainfall	-0.0002** (0.0000)	-0.0007* (0.0003)	-0.0001 (0.0001)
Rainfall (Square)	-0.00037 (0.00028)	-0.0026** (0.0008)	-0.0020 (0.0051)
Constant	-2.19 (1.82)	-19.78** (6.192)	2.155 (2.04)
District	Yes	Yes	Yes
Time	Yes	Yes	Yes
No. of observations	1512	1640	1944

on production of maize and pearl millet found positive but non-significant. The opposing effects of rise in minimum and maximum temperatures suggest that temperature has a non-linear effect on the crop yields. The experimental evidence suggests that a rise in day or night temperature beyond its optimum level has a harmful effect on production of *kharif* crops.

The effect of rainfall has been found negative and significant in rice crop, while there was negative effect on maize and positive and significant effect of rainfall on pearl millet crop. The quadratic term of rainfall is negative and significant in maize meaning thereby a damaging effect on the crop yield.

Marginal effect : In the presence of non-linear and interaction effects, the interpretation of regression coefficients is not straightforward. Therefore, to quantify the effect of changes in temperature and rainfall, marginal effects were calculated at their mean variables that are changes in crop yield due to rise of 1 oC mean temperature or 1 mm in rainfall using equivalent (2). The expected marginal impact of a single climate variable, X, on yield evaluated at the mean is:

Table 3 presents the marginal effect of climate change in terms of temperature and rainfall. Rise in the maximum temperature in *kharif* season significantly decreases the yield of maize by 14 percent. However, the effect of increase in the minimum temperature in rice significantly increases production by 11 to 12 per cent, while in case of pearl millet production significantly reduced by 17 to 18 per cent.

The marginal effect of rainfall has been found significantly negative in rice crop only while, in case of maize and pearl millet change in rainfall was negligible and non-significant. In general, the marginal effect of rainfall is much smaller than the temperature. These results suggest that the climate change impact on western Maharashtra agriculture will be largely driven by temperature change only.

Projected impacts of climate change : The effects of climate change on crop yields have been projected for three time-slices *viz.* 2025, 2050, 2075 and 2100 at minimum and maximum changes in temperature and rainfall (IPCC,2013). The IPCC has predicted the changes in temperature and rainfall for the quarters June-August. There is a lack of concordance between IPCC defined quarters and the growing periods used in this paper. For projecting crop yields, August to represent the change in climate during *kharif* season. Accordingly, by 2100 the *kharif* season temperature is expected to rise by a minimum of 0.7 C and a maximum of 3.3 C. The changes in rainfall during this period are projected to be in the range of -7 per cent to 37 per cent. The changes in temperature and rainfall towards 2025 are not so evident. The crop yields at the minimum and maximum changes in temperature have been projected using Equation.

$$\Delta Y = [(\delta Y/\delta R) * \Delta R + ((\delta Y/\delta T) * \Delta T * 100$$

Where, Y is the yield, R is the rainfall, T is the temperature, and $(\delta Y/\delta R)$ and $(\delta Y/\delta T)$ were determined by the model equations. The projected climate change impacts on crop yields are given in Table 4. By the year 2100, the climate impacts on cereals will vary widely in

Table 3. Marginal effect of climate change on kharif crops, 1961-2018

Variable	Rice	Maize	Pearl millet
Maximum temperature	-0.0866 (0.0498)	-0.1402* (0.159)	-0.0069 (0.0144)
Minimum temperature	0.1137* (0.0501)	0.303 (0.171)	-0.1792** (0.0594)
Rainfall	-0.0002* (0.0000)	-0.0003 (0.0003)	0.0001 (0.0001)

Table 4. Projected change in kharif crop yields by 2025, 2050, 2075 and 2100

Crop	2025		2050		2075		2100	
	Min	Max	Min	Max	Min	Max	Min	Max
	ΔT and ΔR	ΔT and ΔR	ΔT and ΔR	ΔT and ΔR	ΔT and ΔR	ΔT and ΔR	ΔT and ΔR	ΔT and ΔR
Rice	-0.24	-1.17	-0.80	-3.83	-1.35	-6.50	-1.90	-9.15
Maize	0.03	0.13	0.09	0.43	0.15	0.73	0.22	1.03
Pearl millet	-0.16	-0.36	-0.52	-1.19	-0.89	-2.01	-1.25	-2.85

kharif seasons. Among *kharif* cereals, rice will be affected more than maize and pearl millet by the climate change. The rice yield will decline by over 9 per cent with significant changes in climate as compared to loss of 3 per cent in pearl millet and gain of 1 per cent in maize. If the climate does not change significantly, yield losses will be much smaller. The climate impacts will not be so severe in the short-run that is, towards 2025. It is also possible that in the long-run too, the climate impacts may not be so severe because of continuous adaptation.

Implications for food security : Food security is an outcome of the food production process. The climate change will affect food security by influencing the availability of food, access to food, stability of food supplies and volatility in food prices. Rice and pearl millet are the major *kharif* staple foods for a majority of western Maharashtra population, and our findings suggest a considerable decline in their yields with significant changes in climate.

The effects of climate change on food production are not limited to crops. It will affect food production and food security via its direct or indirect impact other components of the agricultural production systems, especially livestock production which closely linked with crop production. Livestock in these area rose under farming systems. Any decline in crop or production will reduce folder supplies. Heat on animals will reduce rate of feed intake. The temperatures and changing rainfall patterns may be increased spread of the existing diseases and macro-parasites, give new diseases and affect reproduction behavior, these factors will affect performance of the livestock.

By 2050 Maharashtra's population is likely cross 16.22 crores and India' population is likely to cross billion demanding more diversified for our findings indicate with climate change production more food with limited resources will be a big challenge. It is therefore imperative to promote up to sustainable agricultural practices to overcome potential threats to food security. Set important measures that hold promises of reduce harmful effect of climate change include intercropping afforestation, growing drought-to crops, changes in planting dates. Important adaptations include water harvesting, its conservation and efficient use through micro-irrigation techniques such as sprinkler and drip irrigation. According to an estimate, micro-irrigation, watershed management and insurance cover can avoid 70 per cent of the avoidable loss due to drought.

Conclusions

1. Rise in maximum temperature has a negative and significant effect in yields of rice and maize crops. While, in case of pearl millet found negative but non-significant. On the other hand, a rise in minimum temperature has a significantly positive impact on yield of rice crop, however effect of minimum temperature on production of maize and

pearl millet found positive but non-significant.

2. The effect of rainfall has been found negative and significant in rice crop, while there was negative effect on maize and positive and significant effect of rainfall on pearl millet crop. The quadratic term of rainfall is negative and significant in maize meaning thereby a damaging effect on the crop yield.

3. Marginal effect of climate change in terms of temperature and rainfall. Rises in the maximum temperature in *kharif* season decreases the yield of of maize by 14 percent. However, the effect of increases in the minimum temperature is in rice increases production by 11 to 12 per cent, while in case of pearl millet production reduces by 17 to 18 per cent. The net effect of change in temperature is observed negligible in the case of maize.

4. The marginal effect of rainfall on *kharif* crops, except pearl millet, has been found negative and significant in rice only. In general, the marginal effect of rainfall is much smaller than of temperature. These results suggest that the climate change impact on western Maharashtra agriculture will be largely driven by temperature change.

5. By the year 2100, the climate impacts on cereals will vary widely in *kharif* seasons. Among *kharif* cereals, rice will be affected more than maize and pearl millet by the climate change. The rice yield will decline by over 9 per cent with significant changes in climate as compared to loss of 3 per cent in pearl millet and gain of 1 per cent in maize.

Suggestion

Impact of climatic factors *viz.*, increase in maximum temperature (0.19°C), minimum temperature (0.10°C) and decrease with uneven distribution in rainfall (2.5 mm) affecting the yield of rice, maize and pearl millet in *kharif* season. By the year 2100, climate change impact on maize and pearl millet is found negligible hence pearl millet crop is recommended as best contingent crop under changing climate and maize as a best alternative cereal crop in western Maharashtra for achieving sustainability and stability in cereal crop production.

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Crop Weather Relationships of Fodder Sorghum Varieties under Different Sowing Windows

K. Saimaheswari[1], T. Prathima[2], D. Subramanyam[3] and P. Latha[4]
Department of Agronomy, S. V. Agricultural College, Tirupati - 517 502 (India)
Email : saimaheswarikadiri@gmail.com1

Abstract

Field experiment was carried out during summer, 2018 at S.V. Agricultural College, Tirupati, Acharya N.G. Ranga Agricultural University to study the crop weather relationship of fodder sorghum varieties under different times of sowing. The experiment was in four dates of sowing (I FN of January, II FN of January, I FN of February and II FN of February) with varieties (CSV 21 F, CSV 30 F and CSV 32 F). Results are revealed that among the four times of sowing, different meteorological indices GDD, HTU, PTU, and TUE varied across the different growth stages. Early sowing (I FN of January) had favorable agro-climatic conditions particularly temperature, day length and sunshine hours interms of required accumulation of GDD, PTU and HTU from sowing to harvest compared to other dates of sowing. Total requirement of accumulated GDD, HTU and PTU showed increasing trend with extension of sowing time from I FN of January to II FN of February. The CSV 32 F variety accumulated maximum GDD from sowing to until harvest.

Key words : Times of sowing, Growing Degree Days (GDD), Heliothermal Units (HTU), Photothermal Units (PTU), Thermal use efficiency (TUE).

In India, animal husbandry is closely associated with crop production as a complementary enterprise, possessing the largest livestock population of 512 million heads (Livestock census, 2012). The availability of quality feed and fodder has been considered as the major bottleneck in harnessing the potential of the livestock sector in India. Further increasing area under fodder crops is not possible in the country due to lot of demand for food grain to meet the facing hardship for feeding the burgeoning human population. Increasing the fodder yield per unit area is with introduction of high yielding, better quality fodder varieties with suitable location specific agronomic practices. The only way to enhance the fodder production under the existing situation.

Sorghum is an important widely grown forage crop for dairy animals. It is fast growing, quick in recovery after cutting, palatable, nutritious and utilized as silage and hay besides fresh feeding. Sorghum crop is adaptive to vast environmental conditions in India and as well as in Chittoor district. Seasonal variation in production of fodder results in large gap between demand and supply of green fodder during crucial periods of the year such as summer. Development of location specific agrotechniques and identification of good quality genotypes of sorghum offer an excellent opportunity to provide good quality fodder for better nutrition to bovine population.

Among agronomic manipulations, sowing time and suitable cultivars are considered to be important for increased production potentials of fodder sorghum. The sowing time of the sorghum affects the fodder supply to considerable extent and hence, proper sequencing of the sowing time should be done

1. and 3. Department of Agronomy, S.V. Agricultural College, Tirupati, 517502, 2. Principal Scientist, Extension Agronomy, RARS, Tirupati and 4. Senior Scientist, Crop Physiology, RARS, Tirupati.

in order to achieve maximum fodder yield along with maintaining the regular supply of the green fodder. The identification of genotype for enhanced productivity and quality during summer to mitigate the present shortage of fodder requirement in summer season.

The critical agrometeorological variables associated with agricultural production are precipitation, air temperature and solar radiation (Hoogenboom, 2000). Phenological development of crop closely followed the changes in weather conditions occurring during crop growing period. The variation in planting dates modifies the microclimate to which the plants are exposed and it is responsible for biomass production and ultimately the yield. It is necessary to understand the knowledge of plant environment interaction for increasing yield of crop. The best genotype with suitable sowing time lead to changes in the crop microclimate which has a direct influence on the plant growth and development and resource utilization. Keeping above factors in view, the present experiments were designed to study the crop weather relationships (interactions) in fodder sorghum under different sowing windows and varieties.

Materials and Methods

A field experiment entitled "Optimization of Sowing Window for Summer Fodder Sorghum [*Sorghum bicolor* (L.) Moench] Cultivars" was carried out during summer, 2018 on sandy loam soils of dryland farm of S.V. Agricultural College, Tirupati, Acharya N.G. Ranga Agricultural University. The experiment was laid out in a split plot design and replicated thrice. The treatments consisted of four times of sowing *viz*., I FN of January, II FN of January, I FN of February and II FN of February assigned to main plots and three fodder sorghum varieties *viz*., CSV 21 F, CSV 30 F and CSV 32 F assigned to subplots.

Agro meteorological indices developed by utilizing various meteorological elements are found in literature to study the crop weather relationships. Agrometeorological indices like Growing Degree Days (GDD), Heliothermal Units (HTU), Photothermal Units (PTU) and Thermal use efficiency (TUE) were computed during different phenophases of sorghum (by adopting the procedure laid out by Rajput (1980).

Growing Degree Days : A degree day is the difference between the mean temperature of the day and base temperature. It is a weather based indicator for assessing crop development. It is a measure of heat accumulation used to predict plant developmental rates such as date that crop reaches maturity. Base temperature of 10°C was used for computation of GDD on daily basis for sorghum (Kumar, 2003).

$$\text{Growing degree days (°C)} = \Sigma \frac{\text{Tmax+Tmin}}{2} - T_b$$

Where, Tmin = minimum temperature (°C), Tmax= maximum temperature (°C) and Tb = Base temperature = 10°C

Helio Thermal Units : The helio thermal units for a given day represent the product of GDD and the actual hours of bright sun shine for that day. The sum of the HTU for the duration of each phenophase was determined by using the formula.

Accumulated HTU (°C day hour) = GDD x Duration of sunshine hour

Photo Thermal Units : The photo thermal units for each day represent the product of GDD and the day length. The accumulated PTU for each phenophase was determined by the following formula.

Accumulated PTU (°C day hour) = GDD x Day length hour

Thermal Use Efficiency : Thermal Use Efficiency for biomass yield was calculated using the following formula.

TUE (kg ha^{-1} °C day^{-1}) = Biomass yield / GDD

Results and Discussion

Weather parameters : The data pertaining to weather parameters recorded during the crop growth period of fodder sorghum as influenced by times of sowing and varieties are presented in Table 2. The variation in climate is especially related to solar radiation, day length, relative humidity, rainfall and temperature.

The temperature maximum and minimum increased by 4.8 and 5.3°C respectively during the crop growth period of fodder sorghum when sowing was extended from I FN of January to II FN of February. Similarly the morning relative humidity was reduced by 5 per cent when sowing was delayed to II FN of February. Daily evaporation was 5.6 mm during the crop growth period of I FN of January sown crop. It steadily increased with delayed sowing and reached maximum of 6.8 mm when the crop was sown during II FN of February. The duration of sunshine reduced from 8.5 hours day-1 to 7.9 hours day-1 with extended times of sowing from I FN of January to II FN of February. Significant increase or decrease was not observed in other weather parameters.

Growing Degree Days : The crop sown during I FN of January and I FN of February accumulated 104.3 and 102.1 growing degree days respectively for emergence of seedlings. The degree day accumulation was reduced when sowing was delayed and the crop sown very late during II FN of February required 91.6 growing degree days for its emergence. The degree day accumulation from emergence to 4th leaf stage was chiefly influenced by the adopted times of sowing. The crop sown during II FN of February accumulated maximum growing degree days (216.4°C days) followed by II FN of January (190.5°C days). The crop sown during I FN of February (157°C days) and I FN of January (155.3°C days) was exposed to least accumulation of GDD during this corresponding stage. The requirement of accumulated growing degree days to attain subsequent stage of Panicle initiation was gradually increased (187.0 to 331.1°C days) with extended times of sowing from I FN of January to II FN of February and the crop sown during II FN of February accumulated maximum GDD (331.1°C days) for panicle initiation. The trend was continued during the later stage of booting also. The GDD accumulation during 50 per cent flowering was remarkably influenced by the times of sowing and the crop was exposed to maximum of 224.2 growing degree days when it was sown

Table 1. Green fodder yield (t ha^{-1}) and dry fodder yield (t ha^{-1}) of fodder sorghum varieties as influenced by times of sowing

Treatments	Green fodder yield (t ha^{-1})	Dry fodder yield (t ha^{-1})
Times of sowing		
I FN of January	35	14
II FN of January	33	13
I FN of February	29	12
II FN of February	25	10
SEm±	1.3	0.4
CD (P= 0.05)	4.5	1.4
Varieties		
CSV 21 F	24	10
CSV 30 F	30	12
CSV 32 F	36	14
SEm±	0.9	0.3
CD (P= 0.05)	2.8	0.8
Times of sowing x Varieties		
S at M		
SEm±	1.88	0.53
CD (P= 0.05)	NS	NS
M at S		
SEm±	2.01	0.58
CD (P= 0.05)	NS	NS

very late during II FN of February. The accumulation of degree days (151.2°C days) during this corresponding period observed steep reduction with sowing of crop during II FN of January. The total requirement of accumulated growing degree days showed increasing trend (1021.8 to 1359.5°C days) with extension of sowing time from I FN of January to II FN of February. These results are in consonance with the findings of Ahmad *et al*. (2016), Prakash *et al*. (2017)

Among the varieties tested, CSV 21F accumulated maximum growing degree days for emergence. CSV 30 F and CSV 32 F were exposed to maximum growing degree days at 4th leaf and booting stages. The CSV 32 F variety required maximum degree day accumulation during Panicle initiation and 50 percent flowering. However, the variety CSV 30 F required maximum degree day accumulation at panicle initiation under late sown conditions. The total growing degree day accumulation was exceptionally influenced by the tested varieties and CSV 32 F variety recorded maximum growing degree day accumulation from sowing to until harvest. The above results were in conformity with the findings of Hemalatha et al. (2013), Prakash et al. (2017).

Helio Thermal Units : The crop sown during I FN of January I FN of February and II FN of February required 878.2, 811.6 and 869.2°C day hours respectively for emergence of seedlings. The HTU requirement was reduced to 603.4 when crop was sown during II FN of January. The HTU requirement from emergence to 4^{th} leaf stage was chiefly influenced by the adopted times of sowing.

Table 2. Mean weather parameters recorded during the crop growth period of fodder sorghum as influenced by time of sowing and varieties

	Temperature (°C)			Relative Humidity (%)			Wind velocity KMPH	Bright Sun shine	Rain-fall (mm)	Evapo-ration (mm)
	Max.	Min.	Mean	RH I	RH II	Mean				
S1 : I Fortnight of January (12.01.2018)										
V_1	32.1	16.3	24.2	86	37	61	4.6	8.7	28.4	5.6
V_2	32.6	17.2	24.9	86	38	62	4.5	8.4	41.2	5.6
V_3	32.8	17.5	25.1	85	38	61	4.5	8.4	41.2	5.6
Mean	32.5	17.0	24.7	85	37	61	4.5	8.5	36.9	5.6
S2 : II Fortnight of January (27.01.2018)										
V_1	33.4	17.9	25.7	85	35	60	4.4	8.4	41.2	5.9
V_2	33.9	18.9	26.4	84	36	60	4.4	8.3	41.2	6.0
V_3	33.9	19.0	26.5	84	36	60	4.4	8.3	41.2	6.0
Mean	33.7	18.6	26.2	84	36	60	4.4	8.3	41.2	5.9
S3 : I Fortnight of February (10.02.2018)										
V_1	34.7	20.0	27.4	83	36	60	4.3	8.2	0.2	6.3
V_2	35.2	20.8	28.0	82	36	59	4.4	8.3	12.8	6.5
V_3	35.4	21.0	28.2	82	36	59	4.4	8.3	15.0	6.5
Mean	35.1	20.6	27.9	83	36	59	4.4	8.3	9.3	6.4
S4 : II Fortnight of February (26.02.2018)										
V_1	36.5	22.4	29.4	80	35	58	4.2	8.1	15.0	6.8
V_2	36.9	23.1	30.0	80	36	58	4.3	7.8	99.2	6.8
V_3	36.9	22.9	29.9	81	36	58	4.3	7.8	99.2	6.9
Mean	36.8	22.8	29.8	80	36	58	4.3	7.9	71.1	6.8

The crop sown during II FN of February required maximum HTU (1637.9 °C day hours) followed by II FN of January (1510.7 °C day hours). The crop sown during I FN January required least accumulation of HTU (1361.8) during this corresponding stage. The accumulated HTU to attain subsequent stage of Panicle initiation was gradually increased with extended times of sowing from I FN of January to II FN of February (1535 to 2467.5°C day hours) and the crop sown during II FN of February accumulated maximum HTU (2467.5°C day hours) for panicle initiation. The crop sown very late during II FN of February was exposed to maximum HTU (4169.7°C day hours) during subsequent stage of booting followed by I FN of February (3672.7°C day hours). The HTU requirement during 50 per cent flowering was remarkably influenced by the times of sowing and the crop sown during I FN of February was exposed to maximum HTU (1764.6°C day hours) followed by II FN of February (1456°C day hours). The accumulation of HTU during this corresponding period observed steep reduction with sowing of crop during II FN of January (1045.6°C day hours). The total requirement of HTU showed decreasing trend with extension of sowing time from I FN of January to II FN of February.

The HTU required for the advancement of the crop through different stages to attain final harvest stage was remarkably influenced by the tested varieties. CSV 21 F required maximum HTU for emergence. CSV 30 F and CSV 32 F were exposed to maximum HTU at 4th leaf and booting stages. The CSV 32 F variety required maximum HTU during Panicle initiation and 50 percent flowering. However, the variety CSV 30 F required maximum HTU under late sown

Table 3. Agro meteorological indices at different growth stages of fodder sorghum as influenced by time of sowing and varieties

	Sowing to emergence			4^{th} leaf stage			Panicle initiation stage		
	GDD	**HTU**	**PTU**	**GDD**	**HTU**	**PTU**	**GDD**	**HTU**	**PTU**
I FN of January									
CSV 21 F	119.2	1012.3	1519.1	149.9	1304.3	1903.7	144.7	1190.9	1821.7
CSV 30 F	96.9	811.1	1235.0	160.6	1390.6	2041.8	186.2	1516.8	2344.1
CSV 32 F	96.9	811.1	1235.0	160.6	1390.6	2041.8	230.2	1900.0	2897.4
Mean	104.3	878.2	1329.7	157.0	1361.8	1995.8	187.0	1535.9	2354.4
II FN of January									
CSV 21 F	109.9	1018.2	1392.2	183.4	1440.4	2306.7	171.5	1088.5	2131.3
CSV 30 F	98.0	905.1	1242.4	195.3	1553.4	2456.5	203.3	1937.8	2522.4
CSV 32 F	87.0	795.1	1103.9	192.9	1538.3	2427.8	232.0	2214.9	2876.2
Mean	98.3	603.4	1246.2	190.5	1510.7	2397.0	202.2	1747.0	2509.9
I FN of February									
CSV 21 F	121.3	988.9	1522.5	156.2	1491.5	1941.1	188.1	1698.1	2309.1
CSV 30 F	92.6	723.0	1165.1	154.9	1497.8	1924.9	255.9	2107.4	3146.2
CSV 32 F	92.6	723.0	1165.1	154.9	1497.8	1924.9	294.9	2368.9	3622.0
Mean	102.1	811.6	1284.3	155.3	1495.7	1930.3	246.3	2058.1	3025.8
II FN of February									
CSV 21 F	107.5	1028.2	1326.7	217.8	1555.9	2667.7	279.2	2132.4	3370.7
CSV 30 F	91.3	865.7	1127.2	217.8	1651.8	2670.7	378.9	2807.8	4558.8
CSV 32 F	76.1	713.7	940.5	213.5	1706.1	2621.0	335.2	2462.4	4043.6
Mean	91.6	869.2	1131.5	216.4	1637.9	2653.1	331.1	2467.5	3991.0

conditions. The total HTU requirement was exceptionally influenced by the tested varieties and CSV 32 F variety recorded maximum HTU accumulation from sowing to until harvest. However, the variety CSV 30 F required maximum HTU under late sown conditions. This investigation corroborates with the findings of Thavaprakash *et al*. (2007), Prakash *et al*. (2017).

Photo Thermal Units : The crop sown during I FN of January and I FN of February required 1329.7, and 1284.3 PTU respectively for emergence of seedlings. The PTU requirement was reduced to 1131.5 °C day hours when crop was sown very late during II FN of February. The PTU requirement from emergence to 4thleaf stage was chiefly influenced by the adopted times of sowing. The crop sown during II FN of February required maximum PTU (2653.1°C day hours) followed by II FN of January (2397°C day hours). The crop sown during I FN February required least accumulation of PTU (1930.3°C day hours) during this corresponding stage.The accumulated PTU to attain subsequent stage of Panicle initiation was gradually increased with extended times of sowing from I FN of January to II FN of February (2354.4-3991.0 °C day hours) and the crop sown during II FN of February accumulated maximum PTU (3991.0 °C day hours) for panicle initiation. The crop was exposed to maximum PTU during the subsequent stage of booting when sowing was delayed to I and II FN of February. The PTU requirement during 50 per cent flowering was remarkably influenced by the times of sowing and the crop sown during II FN of February was exposed to maximum PTU (2597.0°C day hours) followed by I FN of January (2405.4°C

Table 3. Contd.

	Booting stage			50 per cent flowering stage			Total		
	GDD	**HTU**	**PTU**	**GDD**	**HTU**	**PTU**	**GDD**	**HTU**	**PTU**
I FN of January									
CSV 21 F	323.9	3000.6	4024.0	323.9	3000.6	4024.0	323.9	3000.6	4024.0
CSV 30 F	403.5	3713.7	4992.2	403.5	3713.7	4992.2	403.5	3713.7	4992.2
CSV 32 F	377.5	3416.8	4661.4	377.5	3416.8	4661.4	377.5	3416.8	4661.4
Mean	368.3	3377.0	4559.2	368.3	3377.0	4559.2	368.3	3377.0	4559.2
II FN of January									
CSV 21 F	354.4	1111.7	4331.2	120.1	639.8	1451.5	939.2	7772.6	11612.9
CSV 30 F	485.5	3734.3	5909.7	167.7	1211.5	1996.6	1149.6	9342.2	14127.6
CSV 32 F	513.2	3850.8	6237.9	166.0	1285.5	1971.9	1190.1	9684.6	14617.7
Mean	451.0	2899.0	5492.9	151.2	1045.6	1806.7	1093.0	8933.1	13452.7
I FN of February									
CSV 21 F	412.4	2885.5	4983.6	164.6	1362.7	1955.2	1042.4	8426.8	12490.5
CSV 30 F	519.8	3920.2	6244.8	215.7	1974.1	2545.9	1238.6	10222.4	15062.9
CSV 32 F	541.3	4212.3	6489.1	224.8	1957.1	2641.7	1308.4	10759.1	15842.8
Mean	491.1	3672.7	5905.8	201.7	1764.6	2380.9	1196.5	9802.8	14465.4
II FN of February									
CSV 21 F	401.0	3433.7	4747.7	161.5	1193.6	1888.5	1165.8	9343.9	14001.2
CSV 30 F	546.7	4613.6	6431.9	245.0	1519.8	2825.6	1479.5	11458.1	17699.8
CSV 32 F	542.2	4461.7	6396.1	266.2	1654.5	3077.0	1433.1	10998.3	17147.3
Mean	496.6	4169.7	5858.6	224.2	1456.0	2597.0	1359.5	10600.1	16282.8

day hours). The accumulation of PTU (1806.4) during this corresponding period observed steep reduction with sowing of crop during II FN of January. The total requirement of PTU showed increasing trend with extension of sowing time from I FN of January to II FN of February (12733-16282.8°C day hours). These results are in line with the earlier findings as reported Thavaprakash *et al*. (2007), Maurya *et al*. (2015).

The PTU required for the advancement of the crop through different stages to attain final harvest stage was remarkably influenced by the tested varieties. CSV 21 F required maximum PTU for emergence. CSV 30 F and CSV 32 F were exposed to maximum PTU at 4th leaf and booting stages. CSV 21 F required maximum PTU (2621.0) leaf at 4th leaf stage under delayed sown conditions. The CSV 32 F variety required maximum PTU during Panicle initiation and 50 percent flowering. The total PTU requirement was exceptionally influenced by the tested varieties and CSV 32 F variety recorded maximum PTU accumulation from sowing to until harvest. However, the variety CSV 30 F required maximum PTU (4558.8) under late sown conditions. This investigation corroborates with the findings of Prakash *et al.* (2017).

Thermal Use Efficiency : Variation in thermal use efficiency was significant during all the dates of sampling due to adopted times of sowing. The crop sown early during I FN of January recorded maximum thermal use efficiency (1.27 g m^{-2} °C day^{-1}) than the crop sown at later dates. The thermal use efficiency was progressively and significantly reduced with extended date of sowing from I FN of January to II FN of February (1.27- 0.71 g m^{-2} °C day^{-1}) where as lowest values of thermal use efficiency (0.71 g m^{-2} °C day^{-1}) were registered when sowing of the crop was delayed to II FN of February.

Among the fodder sorghum varieties tried, the highest thermal use efficiency was recorded by CSV 32 F which superior over rest of varieties. The variety CSV 21 F recorded the lower values of thermal use efficiency.

Fodder yield : The data on green and dry fodder yield presented in Table.1 indicated that crop sown during I fortnight of January recorded the maximum green and dry fodder yield which was comparable with crop sown on II fortnight of January. Sowing of the crop at later dates recorded the lower green fodder yields.

Optimum temperature and shorter day length resulted in higher dry fodder yield via optimum metabolic activities and thereby the early sown plants of all varieties had been recorded higher thermal use efficiency. Whereas higher temperatures, lower relative humidity and higher evaporation rates hampered the normal metabolic activities resulting in lower fodder yield as well as lower thermal use efficiency in late sown crop. Among the varieties, irrespective of sowing date CSV 32 F recorded maximum thermal use efficiency than rest of the varieties. It might be attributed to accumulation of more drymatter production due to long duration. (Leelarani *et al*. 2012).

Conclusions

It can be concluded that early sowing (I FN of January) had favorable agro-climatic conditions particularly temperature, day length and sunshine hours interms of required accumulation of GDD, PTU and HTU from sowing to harvest compared to other dates of sowing. Estimation of growing degree days, helio thermal units, photo thermal units, thermal use efficiency and radiation use efficiencies indicated that the I FN of January is more suitable for sowing of the fodder sorghum to explore full benefits of favourable weather conditions for best economic output.

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Categorization of Macronutrients, Micronutrients and Water Quality of BSP Farm of Parbhani for Rational Land Use Planning

S. S. Shilewant, V. D. Patil and P. H. Gourkhede
Department of Soil Science and Agriculture Chemistry
Vasantrao Naik Marathwada Krishi Vidyapeeth,Parbhani - 431 401 (India)
Email : pathrikar2012@gmail.com

Abstract

Categorization, Characterization of soil and water quality of BSP Farm (Khanapur Block-B) for Rational Land Use Planning, MKV, Parbhani was carried out during the year 2012. The total gross area of college farm is spread over 135.49 ha and it is divided into four blocks viz. Block A, B, C and D. These four blocks were surveyed by traversing along the bunds of farm plots and the data on natural resources were collected. From these 110 soil samples were drawn to study the properties and nutrient status.The water quality of BSP farm was assessed for irrigation. The results emerged out from the present investigation revealed that in all 88.28 per cent soil samples are low and 11.82 per cent are placed as very low in available N content. Available phosphorus content found to be low in 7.27% while 50 % medium and 42.73% soils moderately high. The availability of potassium found to be very high in BSP farm. The availability of sulfur is 81.82% soils are deficient and 18.18% soils are sufficient. The soils of farm found to be high and sufficient in calcium and magnesium. The DTPA-Fe and boron deficiency was major concern in all soil of BSP Farm (Khanapur Block-B). These soils are found to be low too high in DTPA-Zn content, and rich in available copper and manganese. All water samples of BSP farm (Khanapur Block-B) were slightly alkaline. On the basis of salinity, safe for irrigation but need moderate leaching. The SAR and RSC values of water samples were safe suitable for irrigation.These soils support the crop wheat, soybean sugarcane and cotton.

Key words : Micronutrient, Micronutrient, water quality, land use pattern.

Soil resource information plays a vital role in the management of natural resources and more specifically in the field of agriculture. Soil is a dynamic non-renewable natural resource whose proper husbandry is essential for both continued agriculture productivity and to prevent its degradation. To maintain the present level of soil productivity and meet the food, fodder needs and shelter demand of future management of soil resources on specific principles is of prime important (Sarkar *et al*., 2002). Soil is considered to be a store house of plant nutrient even though there is continuous removal by intensive cropping and losses through leaching and erosion which depleted content to great extent. Soil mapping is the process of classifying soil type and other soil properties in a given area and geo-encoding such information. To achieve sustainable yields of crops besides maintaining soil health needs knowledge on morphological, physical and characteristics and classification of soils which is essential requirement (www. Google.com/soil mapping and LUP).

Soil is a medium for plant growth and development that leads to crop productivity depends on many factors and soil fertility is major amongst all. Soil fertility has a direct relation with crop yields, provided other factors are at optimum level. Soil fertility must be periodically estimated because there is continuous removal of macro and micro nutrients by the crop intensively grown in every crop season. Due to continuous cropping system for periods without adequate supply of additional amounts of nutrients, there is every possibility of

1. Associate Professor, 2 Ex-Head, 3 and 4. Sr. Res. Asstt.

deficiencies of essential nutrients in due course of time. The productivity of soil depends equally on its physical properties and nutrients. Unless the soil is in appropriate structural conditions, the nutrient present in soil would not be in available to plants (Jibhakate *et al.* 2009).

Thus, soil resource thematic map and using data various soil properties and soil profile studies will focus light on the BSP farm soils of M.K.V., Parbhani. Till to date no effort are made in mapping of BSP farm (Khanapur Block-B) soils in general and fertility status in particular. Mapping of farm or agril research station is needed for making developmental farm, it is a basic source for utilization as economical management. Therefore, it was planned to map the farm. The emerged thematic maps will serve as a base for management of soils, crops and selection of other activity related to soil.Water is prime nutrient which sustains life, is often the listing factor for successful crop production in semiarid and arid regions. Water tends to be of varying qualities. Assured and good quality water supply is one of the important factors for increasing crop production.Irrigation with poor quality water modify the soil behaviors mainly by changing the ions associated with exchange complex (Pendke, 2009). Success of agriculture mainly depends upon the efficient use of irrigation water without allowing soil to develop saline, alkaline and water logging condition. So, it is important to study water quality for irrigation of BSP(Khanapur Block - B), Parbhani.

Materials and Methods

The soil, a natural resource even today is less understood and less recognized in comparison to plant and animals. The soil, an unconsolidated mineral matter on the surface of the earth, is influenced by parent material, climate, micro and macro-organisms, topography and time. Various soils forming factors and processes influence the variations in characteristics of different soils. In the present project efforts have been made to describe soils of BSP farm (Khanapur block-B), MKV Parbhani. Geographically The BSP farm (Khanapur Block- B) is situated at 409 m above mean sea level between 19018' N latitude and 76047' E longitude. The total area of BSP farm (Khanapur Block- B) is 135.49 ha. and its area is distributed in A, B, C and D Blocks. Climate of Parbhani district is characterized by hot and dry in summer and cold in winter agro climatically it is classified as assured rainfall zone. The BSP farm (Khanapur Block - B), Parbhani is supported with the variety of natural trees and shrubs which includes Neem, Acacia, Australian babul and Mango. The site was selected From UPRS and CCBP farm of MKV, Parbhani. The BSP farm (Khanapur Block-B) is spread over 135.49 net cultivated area. The soil samples were collected by digging the pit up to 0-15 cm depth as per procedure of guarding the soil and rejecting half of it, near about 500 gm. Nearly about 110 samples were collected from BSP Farm (Khanapur Block-B) Parbhani Collected soil samples were dried, pounded in wooden mortar and pastel and were passed through 2 mm sieve. Each sample was thoroughly mixed to make it homogenous and preserved in properly labeled polythene bags for a laboratory analysis (for determination of bulk density and free $CaCO_3$, soil samples were retained before pounding the soil). In all 110 representative surface soil samples were collected from 55 plots by adopting standard procedure outlined by Yadav and Khanna (1979). At BSP Farm (Khanapur Block - B), MKV, Parbhani there are six wells, the water samples from their wells are collected by using standard procedure (Richards, 1954) water samples were collected in clean plastic bottles of one liter capacity and tightly screwed and brought to the laboratory for further analysis.The pH of water sample was determined by using glass electrode pH meter (Jackson, 1973). Electrical conductivity of water sample was determined by using EC meter (Jackson, 1973) and irrigation samples were categorized as per the classification of the irrigation water based on salinity hazard (Richards, 1954).

Soluble Cations

Calcium and Magnesium (Ca++ and Mg++) : These were estimated by Versenate (EDTA) titration method (Richards, 1954).

Sodium and Potassium (Na+ and K+) : Sodium and potassium content in water samples were determined by using flame photometer (Jackson, 1973).

Soluble anions

Carbonates and Bicarbonates (CO3-- and HCO_3-) : The carbonates and bicarbonates from water samples were determined by titrimetric method (Richards, 1954).

Chlorides and Sulphate (Cl^- and SO_4--): Chlorides and sulphates were determined by the Mohr'stitration method and Turbidity method, respectively (Richards, 1954).

Sodium Adsorption Ratio (SAR) : It was computed by the formula (Richards, 1954) as given below. He suggested the following classes of water.

$$SAR = \frac{Na^+}{\sqrt{Ca^{++} + Mg^{++} / 2}}$$

Residual Sodium Carbonate (RSC) RSC was calculated by the following formula

$$RSC\ (me\ L^{-1}) = (CO_3^{--} + HCO_3^-) - (Ca^{++} + Mg^{++})$$

Where, all cations and anions are expressed in me L^{-1}.

Eaton (1950) introduced the concept of RSC keeping in view, the importance of relative proportion of Ca++ + Mg++ in bicarbonate rich water according to RSC values.

Results and Disscussion

Categorization of soils on the basis of ratings of macronutrients

Soils of BSP Farm (Khanapur Block- B) were categorized as per the ratings (Parker, 1951) in various categories and the related data are presented in Table 4.

Out of 110 soil samples evaluated for available nitrogen content, all soils showed low range of available nitrogen status. The critical

Table 1. Classification of irrigation water based on Salinity hazard

Salinity	EC (dSm-1)	Suitability
C_1	< 0.25	Safe for use
C_2	0.25 to 0.75	Need moderate leaching
C_3	0.75 to 2.25	Cannot be used on soils with restricted drainage
C_4	2.25 to 3.00	Unsuitable under ordinary condition
C_5	>3.00	Unsuitable for irrigation

Table 2. Classification of irrigation water based on SAR

Class symbol	Class of water	SAR values	Suitability
S_1	Low sodium	<10	Can be use safely
S_2	Medium sodium	10-18	May be used on course textured soil
S_3	High sodium	18-26	Ordinarily unsuitable water
S_4	Very high sodium	> 26	Unsuitable

Table 3. Classification of irrigation water based on RSC

Class	RSC (meL^{-1})	Suitability for irrigation
I	< 1.25	Suitable
II	1.25- 2.50	Marginal
III	>2.50	Unsuitable

appraisal showed that among 110 samples, thirteen samples (11.82 per cent) were categorized very low in available N content and 97 samples (88.28 per cent) low in available N content. Among the various soil groups, 88.64 per cent of soils and 11.36 per cent soil of Typic Haplusterts, respectively were categorized as low and very low in available N content. Further in VerticUstrochrepts 82.50 per cent and 17.50 per cent were low and very low in available N. In Lithic Ustorthents 96.15 per cent soils were low and 3.85 per cent soils are very low in available N content.

As regard to available phosphorus content categorized as 7.27 per centsoils were low, 50 per cent medium and 42.73 per cent soils moderately high in phosphate. All soil groups are rated as very high in potassium content.

Available potassium found to be very high on BSP Farm (Khanapur block -B). 96.36 per cent soils were very high in potassium content. 2.73 per cent soils were high in potassium content and only 0.91 per cent soils were moderately high in potassium content. Approximately all soil groups had very high potassium content.

This was because of transformation of monocalcium phosphours (water soluble P) in dicalcium and further tricalcium phosphate (water insoluble). These soils rated as high in K. However, the recent research finding showed that crops are responding the K application even though the K content is high in soils. This might be due to high clay content of soils. Moreover, to continuous cropping with limitation or no application of K, resulted in to exorbant mining of K from soil. Therefore, soils are responding for K deficient. Patil *et al.* (2001) reported that among all nutrients negative balance of K was highest (198174 t) in the soils of Maharashtra. There results suggest to provide optimum nutrient to the crops to be grown in their soils. Low status of nitrogen reported by Patil *et al.* (2008), Rajeswar *et al*. (2009) Same results of N, P, K status found by Chalwadeet al.(2006), Dhale and Jagdish Prasad (2009), and Vineeta and Malewar (2009).

The sulphur deficiency emerged is cautioning the soil health and crop productivity sustenance. The S deficiency came up to the extent of 85 per cent or more in all the soil orders, showed that these soils require urgent attention as must be supplied with sulphur. The present date

Table 4. Categorization of soils on the basis of ratings of macronutrients

Soil property	Soil groups			
	Typic haplu-sterts	Vertic ustoch-repts	Lithic ustor-thents	Total
Available N (Kg ha^{-1})				
Very low	5 (11.36)	7 (17.50)	1 (3.85)	13 (11.82)
Low	39 (88.64)	33 (82.50)	25 (96.15)	97 (88.18)
Medium	Nil	Nil	Nil	Nil
Moderately high	Nil	Nil	Nil	Nil
High	Nil	Nil	Nil	Nil
Very high	Nil	Nil	Nil	Nil
Very low	Nil	Nil	Nil	Nil
Available P_2O_5 (Kg ha^{-1})				
Very low	Nil	Nil	Nil	Nil
Low	1 (2.27)	5 (12.50)	2 (7.69)	8 (7.27)
Medium	15 (34.09)	24 (60.00)	16 (61.54)	55 (50.00)
Moderately high	28 (63.64)	11 (27.50)	8 (30.77)	47 (42.73)
High	Nil	Nil	Nil	Nil
Very high	Nil	Nil	Nil	Nil
Available K (Kg ha^{-1})				
Very low	Nil	Nil	Nil	Nil
Low	Nil	Nil	Nil	Nil
Medium	Nil	Nil	Nil	Nil
Moderately high	1 (2.27)	Nil	Nil	1 (0.91)
High	1 (2.27)	Nil	2 (7.69)	3 (2.73)
Very high	42 (95.45)	40 (100)	24 (92.31)	106 (96.36)

cropping is dominating with soybean which demand more sulphur. Patil *et al.* (2000) surveyed the oilseed giving soils of Parbhani and Latur district one and half decade before reported sulphur deficiency to the extent of 30-40 per cent, which now found to be increased. This might be due to more mining of sulphur from these soils as indicative of increasing S deficiency. The similar result reported by Mali and Raut (2002) and Singh *et al.* (2006). The soils of farm found to be high and sufficient in calcium and magnesium. Generally, it was observed that soils of basaltic origin are high in Ca + Mg. This was due to the ferromagnesium mineralogical make up basalt rock. The similar finding recorded Ashokkumar and Jagdish Prasad (2010) and Marewar (2009). Narle *et al.* (2015).

Wide range deficiency of available iron was found at BSP farm (Khanapur Block-B) i.e. 74.55 per cent soils are low, 19.09 per cent soils were medium and only 6.36 per cent soils are high in DTPA extractable iron. Lithic Ustorthents show higher deficiency (80.77%) followed by Typic Haplusterts (72.73%) and Vertic Ustochrepts (72.50%).

DTPA extractable manganeseobserved to be high in soil of BSP farm (Khanapur Block-B). Out of 110 samples, 21 (19.09 per cent) samples found low in zinc, 38 samples (35.55 per cent) were medium in zinc status and rest 51 (46.36 per cent) were high in zinc.

Table 5. Categorization of soils on the basis of ratings of secondary Macronutrients of differentsoil groups of BSP Farm (Khanapur Block -B), MKV Parbhani

Soil nutrients	Soil groups			
	Typic haplu-sterts	Vertic ustoch-repts	Lithic ustor-thents	Total
Available Sulphur (kg ha^{-1})				
Deficient	37 (84.09)	30 (75.00)	23 (88.46)	90 (81.82)
Sufficient	7 (15.91)	10 (25.00)	3 (11.54)	20 (18.18)
Exchangeable Ca (cmol (P+) kg^{-1})				
High	44 (100)	41 (100)	26 (100)	110 (100)
Medium	Nil	Nil	Nil	Nil
Low	Nil	Nil	Nil	Nil
Exchangeable Mg (cmol (P+) kg^{-1})				
High	44 (100)	41 (100)	26 (100)	110 (100)
Medium	Nil	Nil	Nil	Nil
Low	Nil	Nil	Nil	Nil

Table 6. Categorization of soils of BSP Farm (Khanapur block -B) on the basis of ratings of micronutrients

Soil nutrients	Soil groups			
	Typic haplu-sterts	Vertic ustoch-repts	Lithic ustor-thents	Total
Cu (mg kg^{-1})				
Low	Nil	1 (2.50)	Nil	1 (0.01)
Medium	Nil	Nil	Nil	Nil
High	44 (100)	39 (97.50)	26 (100)	109 (99.09)
Fe (mg kg^{-1})				
Low	32 (72.73)	29 (72.50)	21 (80.77)	82 (74.55)
Medium	9 (20.45)	8 (20.00)	4 (15.38)	21 (19.09)
High	3 (6.82)	3 (7.50)	1 (3.85)	7 (6.36)
Mn (mg kg^{-1})				
Low	Nil	Nil	Nil	Nil
Medium	Nil	Nil	Nil	Nil
High	44 (100)	40 (100)	26 (100)	110 (100)
Zn (mg kg^{-1})				
Low	8 (18.18)	9 (22.50)	4 (15.38)	21 (19.09)
Medium	11 (25.00)	17 (42.50)	10 (38.47)	38 (35.55)
High	25 (56.82)	14 (35.00)	12 (46.15)	51 (46.36)
Bo (mg kg^{-1})				
Low	31 (70.45)	32 (80.00)	22 (84.62)	85 (78.18)
Medium	13 (29.55)	8 (20.00)	4 (15.38)	25 (21.82)
High	Nil	Nil	Nil	Nil

Hot water-soluble boron found to be deficient 78.18 per cent soil samples while rest 21.82 per cent soils showed medium in boron availability.

The result revealed that available copper and manganese was high in BSP farm (Khanapur Block-B). The high content of copper in black soils is documented by many researchers (Malewar and Randhawa 1978,and Sarkar *et al*. 2002). The iron and boron deficiency were major concern in the soils of BSP farm (Khanapur Block-B). It was reviewed that lime included iron deficiency is a common feature of calcareous, black soils. The soils of BSP farm rated as calcareous. Hence, the calcium carbonate of the soil reacts with the iron and it became insoluble, reduce the availability as induce the chlorosis in crops. Boron is another micronutrient which found deficient in more than 75 per cent plots. The result opined that the BSP farm (Khanapur Block-B) soils must be fortified with Fe and B. Further, application of organic manure, compost found to be mitigated the effect of high calcium carbonate. The reduction in insolubility as increase in availability of iron in calcareous soils was also reported Patil (1997) due to application of higher doses of organic manures. The low availability of Fe was reported by Sayed Ismail (1999), Hundal *et al*. (2006).

Water quality parameters

Irrigation water samples collected from BSP farm (Khanapur block-B) were subjected to estimation of various component and quality parameters.

Cation's concentration

The concentration of different soluble cationsviz.calcium, magnesium, sodium and potassium in irrigation water samples of BSP farm (Khanapur block -B) are presented in Table.

The data revealed that the Na^+ content of irrigation water samples was ranged from 1.24 to 2.34 me L^{-1} with an average value of 1.49 me L^{-1}. Further data revealed that the Na+content of irrigation water samples was higher in well of B-3 block, andthe Na+content of irrigation water samples waslower in well of D-4 block.

Table 6. shows the categorization of water samples according to salinity. The all-water samples from BSP farm (Khanapur Block -B) was having good quality (C_2). Further data revealed that 100 per cent water samples were safe for irrigation but need moderate leaching. Data with respect to soluble Ca^{++} in BSP farm (Khanapur block -B) sample revealed that the Ca^{++} content of irrigation water ranged from 1.6 to 3.2 me L^{-1} with an average value of 2.34 me L^{-1}. Further data revealed that the Ca^{++}

Table 7. Categorization of water samples of BSP farm (Khanapur block -B) accordingto salinity

Salinity	Water samples	Suitability
C_1	Nil	Safe for use
C_2	7 (100)	Need moderate leaching
C_3	Nil	Cannot be used on soils with restricted drainage
C_4	Nil	Unsuitable under ordinary condition
C_5	Nil	Unsuitable for irrigation

Table 8. Concentration of soluble cations (meL-1) of irrigation water sample in BSP farm (Khanapur block-B)

Sample No.	Ca^{++} (meL^{-1})	Mg^{++} (meL^{-1})	Na^+ (meL^{-1})	K^+ (meL^{-1})
A-4-S_1	2.4	1.6	1.39	0.10
B-3-S_1	1.6	3.2	2.34	0.15
B-4-S_1	2.0	2.2	1.98	0.21
B-4-S_2	2.4	2.8	1.90	0.14
B-4-S_3	3.2	2.4	2.03	0.13
D-3-S_1	1.8	2.2	1.50	0.10
D-4-S_1	3.0	3.6	1.24	0.14
Average	2.34	3.14	1.49	0.14

content of irrigation water samples was higher in third well of B-4 block.

The Mg^{++} content of irrigation water samples of BSP farm (Khanapur block -B) were ranged from 1.6 to 3.6 me L^{-1} with an average value of 3.14 me L^{-1}.

The K+ content in irrigation water samples of BSP farm (Khanapur block -B) ranged from 0.14 to 0.21 me L^{-1} with an average value of 0.14 me L^{-1}.

Anions concentration

The result on contents of different anionsviz., carbonates, bicarbonates, chlorides and sulphates in irrigation water samples of BSP farm (Khanapur block -B)

The data revealed that, the CO_3-- content of water samples ranged from 0.4 to 1.6 me L^{-1} with an average value of 1.26 me L^{-1}. The highest CO_3-- content of water samples were found in well of B-3 block.

HCO_3- concentration in water samples ranged from 4.0 to 6.0 me L^{-1} with an average value of 6.46 me L^{-1}.

The Cl- contents in water samples from BSP farm (Khanapur block -B) ranged from 2.4 to 8.8 me L^{-1} with an average value of 5.32 me L^{-1}. The highest value observed in wells of A-4 and B-4-S3 blocks, and the lowest value observed in well of B-3 blocks. The SO_4-- content in irrigation water samples of BSP farm (Khanapur block -B) ranged from 1.17 to 2.82 me L^{-1} with an average value.

Sodium Adsorption Ratio (SAR) and Residual sodium carbonate (RSC)

The data obtained in respect of cations and anions subjected for various parameters are used for quality analysis of irrigation water. TheSAR and RSC values of water samples from BSP farm (Khanapur block -B).

It was observed from the data that SAR of irrigation water samples of BSP farm (Khanapur block -B) ranged from 0.98 to 1.51 with an average value of 0.82. The RSC value of irrigation water samples observed from range 0.40 to 1.20 me L^{-1} with an average 0.74 me L^{-1}. The highest value observed in wells of A-4

Table 9. Concentration of soluble anions (meL^{-1}) of irrigation water sample in BSP farm (Khanapur block-B)

Sample No.	CO_3- (meL^{-1})	HCO_3- (meL^{-1})	Cl- (meL^{-1})	SO_4- (meL^{-1})
A-4-S1	1.2	4.0	5.2	1.17
B-3-S1	1.6	3.6	4.4	2.64
B-4-S1	0.8	4.0	3.6	2.82
B-4-S2	0.4	5.2	4.4	2.27
B-4-S3	0.8	5.6	5.2	1.84
D-3-S1	0.4	4.8	4.8	1.70
D-4-S1	1.2	6.0	4.8	2.45
Average	1.26	6.46	4.63	2.13

Table 10. SAR and RSC (meL^{-1}) value of irrigation water sample in BSP farm Khanapur Block-B

Sample No.	SAR (meL^{-1})	RSC (meL^{-1})
A-4-S_1	0.98	1.20
B-3-S_1	1.51	0.40
B-4-S_1	1.36	0.60
B-4-S_2	1.18	0.80
B-4-S_3	1.21	0.40
D-3-S_1	1.06	1.20
D-4-S_1	1.15	0.60
Average value	1.20	0.74

Table 11. Categorization of irrigation water samples based on SAR values

Water quality class	Range of SAR	Suitability for irrigation	No. of irrigation water samples
S_1	<10	Safe	7 (100)
S_2	10 to 18	Moderately Safe	Nil
S_3	18 to 26	Moderately unsafe	Nil
S_4	>26	Unsafe	Nil

and D-3 blocks. Water samples show little variation in RSC content.

The data indicated that the categorization of irrigation water samples of BSP Farm (Khanapur Block-B). and the revealed that all water samples from farm were safe for irrigation. Also Similar result was found by Shilewant *et al*. (2020). Out of 110 samples 108 samples are safe in salt concentration and two samples are normal in salt concentration. Two samples from Typic Halpusterts were normal in salt concentration and others 42 samples are safe in salt concentration. Soil samples from other two groups are safe in salt concentration.

The data indicated the RSC values of irrigation water samples from BSP farm (Khanapur Block-B). The data revealed that 100 per cent water samples were suitable for irrigation.

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DNA Profiling of A, B and/or R Lines Using DNA Markers for Male Sterile Lines in Bread Wheat

Ashwin B. Dahake, A. K. Chabra, S. K. Sethi, Arun Kumar and Ravika
Department of Genetics and Plant Breeding,
CCS Haryana Agricultural University, Hisar - 125 004, Haryana (India)

Abstract

Wheat constitutes the world's most important food crop and its different properties have made this crop the most important staple food of 35 per cent population of the world. The research work on hybrid development in bread wheat which might put impact on productivity is going on. To assess the variability available among wheat genotypes, the DNA profiling was done by using RAPD marker. The average similarity across all parent genotypes was found out at 0.30 indicating a low level of genetic similarity among the genotypes studied. Maximum similarity value of 0.71 was observed between parents PBW-550 and PBW-343 followed by 0.60 between PBW-343 and HD-3058.

Key word : Wheat, hybrid, DNA profiling, RAPD marker.

India has emerged as second largest producer of the wheat after China. Wheat production has increased more than 14 times from 6.46 million tonnes in 1952 to 88.90 million tonnes in 2014-15 (Anonymous, 2016). The average yield has increased more than 4 times from 0.66 tonnes per hectare in 1950 to 2.872 tonnes hectare^{-1} in 2014-15 (Anonymous, 2016).

Keeping in view the rate of increase in population and the growth rate of wheat yields the concept of hybrid wheat emerged as an alternate to meet future demand. The wheat yield has already reached a plateau through conventional breeding approaches. The concept of hybrid wheat may bring breakthrough in the yield levels. The private and public hybrid seed industry in various cross pollinated and often cross-pollinated crops like pearl millet, maize, cotton etc., has already brought about significant improvements in production and productivity of these crop plants. Various treads of economic importance related to grain yield in wheat have shown heterosis in desirable direction. The availability of male sterile lines through *T.*

timopheevi cytoplasm may therefore be utilised in developing wheat hybrids. However, there are certain constraints associated with wheat being self-pollinated crop that need to be tackled before commercialisation of wheat hybrids. The present study has, therefore, been proposed in the same direction.

Several workers had studied on this aspect and reported accordingly time to time. Phenotypic markers are highly influenced by environment and to overcome this problem, DNA markers is one of the most successful tools. Chen et al., (2005) reported one 134 bp fragment that was amplified in the anthers of male sterile and male fertile wheat using one pair of primers based on the conserved domain of MNZ gene in Arabidopsis thaliana and a 160 bp male sterility gene homology which was present only in male fertile anthers.

Using SSR markers, a major fertility restoration gene, Rf3, was located on the 1B chromosome. This gene was partially dominant in conferring fertility restoration in the two restorer lines. Several SSR markers identified may be useful in marker assisted selection of new restorer lines with T. timopheeviicytoplasm. Two minor QTLs conferring fertility restoration were also identified on chromosomes 5A (in R18) and 7D (in R9034) in two R-lines (Zhou, 2005).

Li *et al*., 2010 has analysed male sterile lines and F1 hybrids by RAPD markers. They found that mtDNA variation existed in the cytoplasm donors and male sterile lines resulted from genetic interactions between common wheat nucleus and Aegilops cytoplasm, and have affected the structure of the mitochondrial genome. Similar results were also obtained in male sterile lines and fertility-restored F1 hybrids. These demonstrated the variation of mtDNA in fertility restoration by the combination of the fertility restorer gene(s), and fertility restoration involved a strong influence of nuclear restorer genes on mtDNA organization. The variation of mtDNA in Aegilops species, their respective CMS lines and fertility-restored F1 hybrids may reflect the fertility divergence.

Rongxia (2002) studied genetic analysis and identification of RAPD markers of fertility restorer gene Rf-6 for the T. timopheevii cytoplasmic male sterility of wheat. Bulked Segregan Analysis was employed to identify Random Amplified Polymorphic DNAs (RAPD) markers linked to the restorer gene (Rf-6) in the F2 population of ND44A/2114. Among the total 460 arbitrary l0-mer oligonucleotide primers screened, 10 produced polymorphisms between the parents. One of them, OPI18 was identified to be associated with Rf-6. The polymorphic band was designated OPI181260. Further RAPD analysis was conducted in l47 F2 plants of ND44A/2114 by primer OPI18. It was found that the distance between Rf-6 and OPIl81260. is 3.4 cM. Similar findings were reported during 2012 forwheat male sterility of NIAN type by using RAPD markers and the polymorphic band was amplified with primer S120 in BC1F1 population (Anonymous, 2012).

A systematic study on male sterility sources, their maintenance, fertility restoration, floral biology, extent of cross pollination and use of molecular markers are still lacking in wheat. The objective of the present study was focused on use of RAPD technique to evaluate polymorphism among male sterile lines, male fertile lines and their F_1 hybrids. The proposed research programme focused molecular characterization of A/B/R lines which would facilitate their registration in the national and international germplasm that in turn will help for further breeding programme.

The research was carried out at the laboratory of Department of Genetics and Plant

Breeding, CCS Haryana Agricultural University, Hisar, Haryana. Two field experiments were conducted during *rabi* season (November to April). One laboratory experiment was carried out at departmental laboratory.

Material and methods

The plant material for the present study comprised twenty-five pollen parents, three male sterile lines and their 59 F1 hybrids of wheat. The performance of RAPD markers was evaluated using various parameters such as percentage of polymorphism, similarity matrix data and clusters formed in the dendogram. The experiment was carried out in two stages. In the first stage, DNA isolated from eighty-seven genotypes of wheat was used for standardization of PCR amplification technique using sixty RAPD primers. In the second stage, the selected primers showing amplification were used to study genetic diversity among eighty-seven genotypes and identify specific molecular marker(s), if any.

Sixty RAPD primers were used for the present investigation, out of which forty-two primers showed amplification and 18 primers showed no amplification. These primers perhaps did not find any complementary binding sequence on the genomic DNA of these wheat genotypes. Moreover, some primers might have some special requirement for amplification as suggested by Weeden *et al*., (1992) and Ahmad (1999).

Result and Discussion

A total of 88 amplified products were obtained using 14 RAPD primers, out of which 87 were polymorphic and 1was monomorphic. Average polymorphism across all eighty-seven bread wheat genotypes was 60.32% which is quite consistent with that (64.3%) reported by Mukhtar *et al*., (2002) among 20 wheat genotypes. Cao *et al*., (2002) reported 45.3% polymorphic bands in 29 wheat genotypes. Teshale *et al*., (2003) observed 79.6% polymorphism among the selected genotypes. However, in some earlier reports, high level of polymorphism has been reported. Frietaset al., (2000) reported 83% polymorphism among 14 genotypes of Brazilian wheat. High level of polymorphism obtained in present study shows the genetic distinctness of eighty-seven wheat genotypes selected for the present study.

Size of amplified products ranged between 200bp to 11000bp.Teshale *et al*., (2003) obtained products ranging between 300 bp to 3000 bp and those obtained by Cao *et al*., (2002) ranged from 280 bp to 2800 bp.

Cluster analysis based on RAPD marker showed that the 27 wheat parent genotypes were grouped into seven clusters (Fig. A and table 1). Cluster I consisted of 15 genotypes. Cluster II consisted of only one genotype RAJ-4228 showing diverse genetic nature as compared to rest of the genotypes. Cluster III consisted of nine genotypes while three genotypes form their individual cluster with high genetic distance viz., Cluster IV; Kanchan-97, Cluster V; WH1063 and Cluster VI; JAVW-584.

Pooled RAPD analysis of both parent and hybrid showed an average of 0.31 genetic similarities. Maximum similarity was found between H-39 and H 38 (0.69) followed by H 37 and H 38 (0.68) while minimum similarity was found between JAVW-584 and H 2 (0.032) (Table 4.10). Cluster analysis of pooled RAPD data from both parent and hybrid formed eight clusters. Cluster I exhibited 51 genotypes including hybrids as well as parents while Cluster II 25 genotypes. Cluster III consisted of only two genotypes namely HJ-47 and WH-1063with 0.40 similarity index showing diverse nature among the rest of the individuals. Cluster IV contained only four Hybrids namely H 36, H 33, H 48 and H 22. Cluster V and VI contained

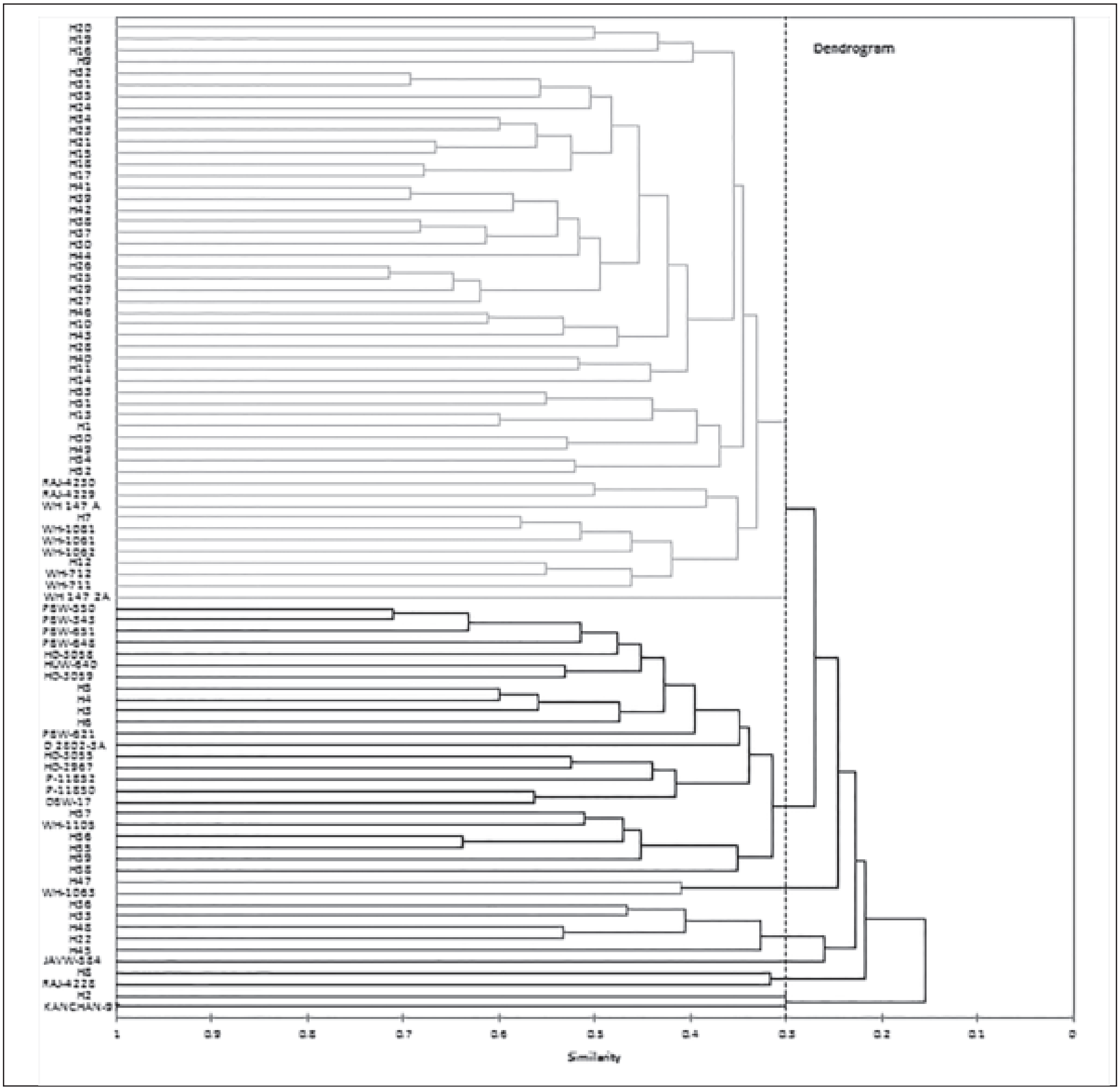

Fig. A. Dendrogram of A, B & R lines and their F1 hybrids of wheat base on RAPD marker analysis

only single genotype H 45 and JAVW-584 respectively. JAVW-584 parent genotypes consistently found diverse genotypes among the other parent and their hybrid when comparing with single dendogram of parent as well as pooled analysis. While Cluster VII exhibited only two genotypes containing one hybrid H8 and RJ-4228. Cluster VIII contained H2 and Kanchan parent genotypes.

The DNA was isolated from eighty-seven genotypes by CTAB method in the departmental laboratory. Sixty RAPD primers were used and standard protocols were followed for DNA isolation and RAPD analysis. 14 primers were found polymorphic and primer OPA 10 was most informative RAPD marker on the basis of polymorphism information content among all the primers used for the material under studied.

Table 1. Clustering of wheat genotypes (male and female parents and their hybrids) using RAPD analysis

Cluster	Total No.	Content
I	51	H 20, H 19, H 16, H 9, H 32, H 31, H 35, H24, H 34, H 23, H 21, H 15, H 18, H 17, H 41, H 39, H 42, H 38, H37, H 30, H 44, H 26, H 25, H 29, H 27, H 46, H 10, H 43, H 28, H 40, H 11, H 14, H 53, H 51, H 13, H 1, H 50, H 49, H 54, H 52, RAJ 4230, RAJ 4229, WH-147 A, H 7, WH 1081, WH 1061, WH 1062 , H 12, WH 712, WH 711, WH-147-2A.
II	24	PBW 550, PBW 343, PBW 651, PBW 648, HD 3058, HUW 640, HD 3059, H 5, H 4, H 3, H 6, PBW 621, D-2802-3A, HD 3055, HD 2967, P 11852, P 11850, DBW 17, H 57, WH 1105, H 56,H 55, H 59, H 58.
III	2	H 47, WH 1063,
IV	5	H 36, H 33, H 48, H 22, H 45.
V	1	JAVW 584.
VI	2	H 8, RAJ 4228.
VII	2	H2, KANCHAN 97.

All the three male sterile lines showed different banding patterns for 10 primers. A floral trait in relation to hybrid breeding that promotes outcrossing was studied and molecular characterization of A/B/R lines was done to facilitate their registration in the national genetic recourses.

In order to impart meaning to the results obtained and fully comprehend their implications, a statistical analysis is of utmost importance. Based on data on presence/absence of bands, genetic similarity was calculated to estimate all pair wise differences in the amplification product for all genotypes. Based on this data, cluster analysis was performed to establish relationship among genotypes.

Based on RAPD similarity matrix data, the value of similarity coefficient ranged from 0.042 to 0.89 was calculated. The average similarity across all genotypes studied was found at 0.30, indicating a low level of genetic similarity among these genotypes. The maximum similarity value of 0.71 was observed between parents PBW-550 and PBW-343 followed by 0.60 between PBW-343 and HD-3058. This may be due to high level of genetic relatedness between these 2 genotypes.

This shows that optimum level of variability exists among genotypes studied and can be used in crossing programme for hybrid wheat development.

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Forewarning Model and Correlation between Weather Parameters and Thrips of Sunflower on Different Varieties

S. B. Kharbade, N. D.Tamboli, J. D. Jadhav, V. A. Sthool and P. B. Pawar
Department of Agricultural Meteorology,
College of Agriculture, Pune - 411 005 (India)

Abstract

The experiment was conducted in a split-split plot design with three replications having eighteen treatment combinations formed considering different protection, varieties and sowing windows. The significantly highest yield and minimum infestation was observed in variety PhuleRaviraj than variety Bhanu and MSFH-17, sowing window 30th MW (S_2 : 23rd July - 29th July) was higher then S_3 and S_1 and under protected condition (P_1) as compared to unprotected condition (P_2). It would be, therefore, advisable to sow PhuleRaviraj variety of kharif sunflower during 30th MW (S_2 : 23rd July - 29th July) to get maximum returns with minimum infestation of thrips on sunflower. The incidence of thrips on sunflower can be predicted to an extent of 66% accuracy with help of forewarning model.

Key words : Forewarning model, Correlation, weather parameters, thrips, Sunflower.

Sunflower (*Helianthus annuus* L.) belongs to the family Compositae. It is a seasonal, erect and herbacious plant with leaves simple, alternate with stout petioles and lanceolate in shape. A single head produces 350 to 2000 seeds. Seeds are pointed at base and round at end.

In early 1970s, only about 0.1 million hectares were under sunflower cultivation, however, by 2012-13, it gone up to 5.5 million hectares. In India, it was used mainly as ornamental crop but in recent past it became an important source of edible and nutritious oil. Sunflower is a major source of vegetable oil in the world. It is used for a variety of cooking purposes. Sunflower seed contains about 48 - 53% edible oil. The sunflower oil is considered premium compared to other vegetable oils as it is light yellow in color, high level of linoleic acid and absence of linolenic acid, possesses good flavor and high smoke point. Sunflower oil is a rich source (64 %) of linoleic acid which is good for heart patients. Linoleic acid helps in washing out cholesterol deposition in the coronary arteries of the heart. The oil is also used for manufacturing hydrogenated oil. Recent study confirms that varieties differ extensively in the physiological process determining the yield. It has been also shown that the total yield per plant and per unit area is determined by the number of head and seed weight per plant. These physiological factors also determined by environmental factors.

Sunflower is photo and thermo-insensitive and day neutral plant. The sunflower oil has greater stability and quality under various climatic conditions. Incidence of pest is majorly influenced by date of sowing of crop. So it is necessary to identify suitable date of sowing for sunflower crop to minimize the damage due to thrips. Study of correlation of pest incidence with weather parameters very useful in Integrated Pest Management (IPM). Forewarning models were very important tool to predict insect pest infestation in advance .it is very useful for farmers to be ready for insect attack if formula containing values of weather are observed in particular period for sunflower.

Now days, attentions also paid on global warming and due to global warming climatic change are oftenly observed in India. Growth, yield, oil percent is greatly affected. To overcome this problem, there is necessity to study the response of different varieties of sunflower to different sowing times and incident of insect pest on it. With this view, to identify suitable variety and influencing sowing date and incidence of thrips on sunflower, present investigation has been undertaken.

Material and Methods

The field experiment was conducted during *kharif*, 2018 at Mulegaon Agricultural Farm, Zonal Agricultural Research Station, Solapur, Maharashtra State (India). Geographically the campus of Mulegaon Agricultural Farm is situated on 17°41' N latitude and 75°56'E longitude. The altitude is about 483.6 M above mean sea level.

The data revealed that during the crop growth period, the annual maximum and minimum temperature ranged between 25.0 to 43.2°C and 7.3 to 27.1°C, respectively. During the kharif season, the maximum temperature ranged between 29.0 to 40.8°C with an average of 34.7°C, whereas, the minimum temperature ranged between 18.0 to 26.2°C. The pan evaporation ranged between 1.8 to 12.8 mm with an average of 7.4 mm. The wind speed ranged between 2.1 to 18.3 Kmph with an average of 9.7 Kmph. In case of BSS which was ranged between 0.0 to 12.1 hrs with an average of 5.2 hrs. The morning RH ranged between 60 to 90 per cent with an average of 75 per cent and the afternoon RH ranged between 24 to 90 per cent during the crop growth period. Experiment details and treatment details was given below.

a)	Name of crop	:	Sunflower
b)	Cultivars	:	1. Bhanu
		:	2. MSFH-17
		:	3. PhuleRaviraj
c)	Season	:	*Kharif*, 2015
d)	Design	:	Split-split plot
e)	No. of replications	:	3
f)	Treatments	:	3 sowing windows
g)	Spacing	:	45 x 20 cm^2
h)	Seed rate	:	8-10 kg ha^{-1} (all Varieties)
i)	Fertilizer application	:	50 kg N + 25 kg P_2O_5 ha^{-1}
j)	Irrigation	:	NIL
k)	Pest/diseases observed, if any	:	Hairycaterpillar, thrips
l)	Plant protection measures taken, if any	:	Quinolphos
m)	Weed control	:	2 hand weeding's
n)	Plot size	:	Gross : 6.0 x 4.5 m^2
		:	Ne : 4.2 x 3.6 m^2
o)	Place of research work	:	Mulegaon Agricultural Farm, Zonal Agricultural Research Station, Solapur
p)	Commencement of Research work	:	*Kharif*, 2015

Treatment details:

Treatment	Combinations
T1-S1V1	S1-26MW (26 June-01 July), V1-Bhanu
T2-S1V2	S1-26MW (26 June-01 July), V2-MSFH-17
T3-S1V3	S1-26MW (26 June-01 July), V3-PhuleRaviraj
T4-S2V1	S2-30MW (23 July-29 July), V1-Bhanu
T5-S2V2	S2-30MW (23 July-29 July), V2-MSFH-17
T6-S2V3	S2-30MW(23 July-29 July), V3-PhuleRaviraj

T7-S3V1 S3-34MW(20 Aug.-26 Aug.), V1-Bhanu
T8-S3V2 S3-34MW(20 Aug.-26Aug.), V2-MSFH-17
T9-S3V3 S3-34MW(20 Aug.-26Aug.),V3-PhuleRaviraj

Then all treatments take (2 split plots) under treated and untreated plot by Quinolphos. Entomological observations

Pest incidence observations recorded from selected five plants from each plots of experimental field. Observation, were recorded from selected five plants and then number of thrips per 5 cm length of twigs of plant were counted. Two treatments that treated and untreated are differentiating by spraying of Quinolphose 1.5 ml/1 lit. water on treated treatments. No any control measure was applied on untreated treatment.

Correlation Studies : The weather elements play an important role in success or failure of the crop. The weather requirement varies differently in the different phenophase and hence the study of individual weather element prevailed during different phenopheses was conducted by studying the degree of association between seed yield and total biomass versus weather elements. The weather elements considered are maximum temperature (Tmax.), minimum temperature (Tmin.), morning time relative humidity (RH-I), noon time relative humidity (RH-II), bright sunshine hours (BSSH) and canopy temperature, wind speed, pan evaporation etc. were included in this study. The correlation coefficients for each treatment were estimated through pearsmans correlation techniques.

1:Correlation between weather parameters and incidence of thrips under treated condition On variety Bhanu

Correlation analysis of incidence of thrips with weather parameters revealed non-significant negative correlation with BSS and rainfall and non-significant positive correlation with temperature in 26^{th} MW. The similar result found by Akashe *et al.* (2010)

On variety MSFH-17 : Correlation analysis of incidence of thrips with weather parameters revealed non-significant negative correlation with BSS and non-significant positive correlation with minimum temperature in all sowing window. Similar results were reported by Banerjee and Bandopadhyaya *et al.* (2005).

On variety Phule Raviraj : Correlation analysis of incidence of thrips with weather parameters revealednon-significant negative correlation with BSS, maximum temperature and non-significant positive correlation with minimum temperature and rainfall in all sowing windows. The similar result found by Akashe *et al*. (2010).

Table 1. Effect of weather on thrips population of sunflower during year, 2018

MW	THIRPS	T-Max	T-Min	RH-1	RH-II	WS	RF	BSS
30	7.90	34.5	22.5	77	41	8.6	0	4.7
31	10.63	34.4	22.4	78	42	7.7	0	5.3
32	10.50	33.4	22.6	83	52	8.8	34.5	2.4
33	10.67	33.4	22.3	79	45	9.6	0.5	4.2
34	8.22	35.3	21.7	82	43	7.6	23.4	7.5
35	8.92	33.8	21.6	82	45	6.0	14.6	5.5
36	7.50	34.2	22.3	85	53	6.6	27.6	6.6
37	6.25	32.2	21.4	93	64	6.2	116	4
38	5.01	32.5	21.3	88	51	5.0	3.7	5.8
39	3.08	35.5	21.3	73	36	5.0	0.8	9.6

2: Correlation between weather parameters and incidence of thrips under untreated condition On variety Bhanu

Correlation analysis of Incidence of thrips with weather parameters revealed non-significant negative correlation with BSS and maximum temperature and non-significant positive correlation with minimum temperature, RH-I, rainfall in 30^{th} MW. The similar results were found by Akashe *et al*. (2010).

On variety MSFH-17 : Correlation analysis of incidence of thrips with weather parameters revealed highly significant negative correlation with rainfall, (0.995**) RH-I (0.930**) and RH-II (0.900**) non-significant negative correlation with Tmin and BSS in 26^{th} MW. When sunflower sown in 34^{th} MW produced non-significant negative correlation with rainfall and 32^{th} MW non-significant positive correlation with BSS, minimum temperature, humidity. The similarresults were found by Akashe *et al.* (2010).

On variety Phule Raviraj : Correlation analysis of incidence of thrips with weather parameters revealed significant positive correlation with RH-I (0.825*) and non-significant positive correlation with minimum temperature in 26^{th} MW and non-significant negative correlation with maximum temperature and BSS when sown in 30 MW and 34^{th} MW and non-significant positive correlation with RH, minimum temperature when sown in 34^{th} MW. The similar results were found by Akashe *et al*. (2010).

Pest forewarning model : Weather has a highly domineering impact on incidence of insect pests or diseases on all crops. Almost all insect pests are 'Meteotropic' i. *e.* influenced by weather conditions. Weather based pest forecast models (FORECASTERS) are used in the crop protection parlance. Forecasters, as a tool in the IPM, can be beneficially used for efficiently planning control measures well in time. For development of these models, both meteorological and biological data are required as input. The output is the 'anticipated outbreak' of insect pests or diseases. Predictive models can be used for insurance whereas Quantitative models are useful for good management of insect pests or diseases. Forewarning model forthrips (*Scirtothripsdorsalis*) on sunflower (*Helianthus annus* L.).

After calculation of available data sets on weather parameters and thrip population on sunflower during Kharif seasons of last 1 year (2015-16), the linear regression model is developed for the prediction of thrip incidence on sunflower during crop growth period. The standard procedure for regression analysis was used. Correlation of thrips with weather parameters for past years has been calculated with reference to maximum temperature (°C), relative humidity morning (%), relative humidity evening (%) and rainfall (mm) and summarized in Table-29 with corresponding significance for given years and central tendency of common weather parameters. Other parameters were non-significant. The further no data for

Table 2. Regression coefficient and R^2 for thrips population of sunflower in 2018

Parameter	Regression coefficient (with significant parameters)
Constant (Y)	-20.374
Tmim	1.168
W.S	0.536
B.S.S	-0.013
R^2	0.66

Table 3. ANOVA table

Source of variation	d. f.	SS	MS	'F'	Prob.
Regression	3	37.42	12.47	3.73	0.080
Residual	6	20.06	3.344		
Total	9	57.45			

validation purpose. The data on weather parameters and thrip population was subjected to the statistical analysis and correlation coefficient (r), linear regression coefficient, squared multiple correlation (R^2) and regression equation were worked out for predicting the thrip incidence on sunflower in the scarcity zone of Maharashtra, India.

$Y = -20.374 + 1.168 \times T_{min} + 0.536 \times W.S - 0.013 \times BSS.$

Where, Y = Thrip population (in equation), T_{min} = Min.Temp. (°C), WS = Wind speed (km/hrs), BSS = Bright sunshine hours (hrs) and R^2 = Squared multiple correlation.

Conclusions

1. incidence of thrips on sunflower can be forecasted by Forewarning model at 66% accuracy

2. The significantly highest yield and minimum infestation was observed in variety PhuleRaviraj than variety Bhanu and MSFH-17, sowing window 30th MW (S_2 : 23rd July - 29th July) was higher than S_3 and S_1 and under protected condition (P_1) as compared to unprotected condition (P_2).

3. It would be, therefore, advisable to sow PhuleRaviraj variety of kharif sunflower during 30th MW (S_2 : 23rd July – 29th July) to get maximum returns with less thrips infestation.

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Use of Models for Prediction of Rainfall

S. K. Upadhye, J. D. Jadhav, V. M. Londhe, V. T. Jadhav, P. B. Pawar and V. R. Bawdekar
Zonal Agricultural Research Station, Solapur - 413 002 (India)

Abstract

Solapur (17°48' N latitude and 75°48, E longitude and 457 m above mean sea leval altitude) located on the south east edge of the state ane lies entirely in Bhima and Seena basins. The entire district is drained by the Bhima River. The average rainfall of the station is about 732.4 mm. but the rainfall is highly erratic and irregular. All five probability distributions functions are compared by D-index, which is adopted for verifying fitness of rainfall probability distributions. The test statistic was calculated from the relationship. The D-index value of less than 0.20 is considered as a best fit, 0.20 to 0.30 is normal fit and above 0.30 will be an unfit distribution as adopted by earlier. The computation of observed and estimated rainfall at different probability of exceedence for maximum monthly, seasonal (i.e. kharif, rabi and zaid) and annual rainfall using different distribution namely normal, log-normal, exponential, Pearson type III and log-pearson type III are described The analysis indicated that normal (0.19), pearson type III (0.19) and log pearson Type III (0.19) distributions were best fitted for the maximum one day rainfall with minimum D-index values. Peatrsom type III distributions was best fit for the maximum weekly monthly, seasonal (kharif) and annual rainfalls but the distribution was unfit for the season of rabi and zaid. From the result it is concluded that exponential distribution is not fit for the study area.

Key words : Exponential, log-normal, Pearson type III, log-Pearson type III Distributions and rainfall prediction.

Probability analysis can be used for prediction of occurrence of future events from available records of rainfall with the help of statistical methods (Kumar and Kumar, 1989). Using the theoretical probability distributions, it would be possible to forecast the rainfall if various nagnitudes with different periods. Several distributions have been used for hydrological analysis as given by Chow *et al*. (1988).

Probability analysis of one day rainfall has been attempted for different places (Sharda and Bhushan, 1985; Agrawal *et al*. 1988; Monthly et al. 2000 and Pradeep and Maheshwara Babu, 2010). An attempt has been made in present study to estimate the probable maximum one day, weekly, monthly, seasonal (i.e. kharif' rabi and zaid) and annual rainfall for different per cent of probability for Solapur by five probability distribution functions so as to select the best one.

Material and methods

The daily rainfall data of last 32 years (1987-2018) collected at Dry Farming Research Station; solapur is used for this study The values of maximum daily, weekly, monthly, seasonal (i.e. kharif, rabi and zaid) and annual rainfall of 22 years from 1987 to 2018 were arranged in descending order and the probability of exceedence P was obtained using Weibulp s formula

$$P= m/N+1 \qquad \dots (1)$$

Where P is the probability, N is the total number of years of record and M is the rank of observed rainfall is the reciprocal of the calculated probability of exceedence. The maximum one day, weekly, monthly, seasonal (i.e. kharif' rabi and zaid) and annual rainfall of Solapur were fitted to five probability distribution functions i.e. normal, log-normal, exponential, pearson typeIII and log pearson type III to predict maximum one day, maximum weekly, maximum monthly, seasonal (i.e. kharif, rabi and zaid) and annual rainfall. One day maximum, weekly maximum, seasonal maximum and annual rainfalls were determined manually. Probability distribution at different levels has been determined through computer software package VTFIT.

All five probability distributions functions are compared by D-index, which is adopted for verifying fitness of rainfall probability distributions. The test statistic was calculated from the relationship.

$$\text{D-index} = \sum_{I=2}^{N} \frac{|\, xi \text{ Observed} - xi \text{ Extimated} \,|}{X} \quad ..(2)$$

Where, X = mean of the observed rainfall

Result and Discussion

The D-index value of less than 0.20 is considered as a best fit,0.20 to 0.30 is normal fit ane above 0.30 will be an unfit distribution as adopted by earlier investigators (Willmot 1981 and 1982 and Cohen,1988)

The computation of observed and estimated rainfall at different probability of exceedence for maximum monthly,seasonal (i.e. kharif, rabi and zaid) and annual rainfall using different distribution namely normal, log-normal, exponential, pearson type III and log-pearson type III are described below.

Mean standard deviation (S.D.) and coefficient of variation (C.V.) for one day maximum, maximum weekly, maximum monthly, seasonal (i.e. kharif rabi and zaid). And annual rainfall over the area, were calculated.

Maximum one day rainfall : The estimated one day maximum rainfall at different probabilities is presented in Table 1.the

Table 1. Comparison of observed and estimated maximum one day rainfall for different probability distribution functions

Probability of exceedance (%)	Observed rainfall (mm)	Estimated rainfall (mm)				
		Normal	Log normal	Exponential	Pearson type III	Log pearson type III
10	111.56	102.17 (9.39)	104.72 (6.84)	107.22 (59.66)	111.31 (0.25)	103.85 (7.71)
25	87.45	89.00 (1.55)	87.21 (0.24)	103.08 (15.63)	88.57 (1.12)	87.31 (0.14)
50	73.8	74.36 (0.56)	71.17 (2.63)	51.54 (22.26)	68.73 (5.07)	71.62 (2.18)
75	60.7	59.72 (0.98	58.08 (2.62)	21.39 (39.31)	54.08 (6.62)	58.40 (2.30)
90	46.44	46.55 (0.11)	48.37 (1.93)	7.83 (38.61)	44.76 (1.68)	48.37 (1.93)
Mean	75.99					
D-index		0.17	0.19	2.31	019.	0.19
Fitting condition		Best fit	Best fit	Unfit	Best fit	Best fit
SD		22.22	22.57	66.90	26.84	22.22
C.V.%		0.29	0.30	0.88	0.35	0.29

Note : the values in parenthesis represent the absolute deviation of observed and estimated rainfall.

Table 2. Comparison of observed and estimated maximum weekly rainfall for different probability distribution functions

Probability of exceedance (%)	Observed rainfall (mm)	Estimated rainfall (mm)				
		Normal	Log normal	Exponential	Pearson type III	Log pearson type III
10	203.95	187.36 (16.59)	158.54 (18.41)	290.99 (87.04)	207.55 (3.60)	187.55 (16.40)
25	157.00	158.48 (1.48)	150.09 (6.91)	175.20 (18.20)	147.36 (9.65)	149.00 (8.00)
50	111.90	126.38 (14.48)	118.58 (6.68)	87.60 (24.30)	104.64 (7.26)	116.90 (5.00)
75	89.43	94.28 (4.85)	93.69 (4.26)	36.36 (53.07)	82.43 (7.00)	92.92 (3.50)
90	74.95	65.39 (9.56)	75.79 (0.84)	13.32 (61.63)	74.21 (0.74)	76.42 (1.47)
Mean	127.45					
D-index		0.37	0.29	1.92	0.22	0.27
Fitting condition fit		Unfit	Normal fit	Unfit	Normal fit	Normal
SD		48.73	43.98	113.70	55.05	44.56
C.V.%		0.38	0.35	0.89	0.43	0.35

Note: the values in parenthesis represent the absolute deviation of observed and estimated rainfall.mm: and I = series of rainfall amounts at 10,25,50,75 and 90 per cent probability of exceedence (Weerasinghe,1989).

Table 3. Comparison of observed and estimated maximum Monthly rainfall for different probability distribution functions

Probability of exceedance (%)	Observed rainfall (mm)	Estimated rainfall (mm)				
		Normal	Log normal	Exponential	Pearson type III	Log pearson type III
10	380.17	351.15 (29.02)	343.73 (36.44)	549.26 (169.06)	383.02 (2.85)	348.26 (31.91)
25	260.98	297.81 (36.83)	281.32 (20.35)	330.69 (69.71)	283.21 (22.23)	275.19 (14.21)
50	212.40	238.54 (26.14)	225.17 (12.77)	165.34 (47.06)	206.13 (32.22)	127.08 (5.68)
75	191.58	179.28 (12.30)	180.23 (11.34)	68.62 (122.95)	159.36 (32.22)	177.95 (13.69)
90	140.86	125.94 (14.92)	147.51 (6.65)	25.13 (115.73)	137.07 (3.79)	151.73 (10.87)
Mean	237.20					
D-index		0.50	0.37	2.21	0.28	0.32
Fitting condition		Unfit	Unfit	Unfit	Normal fit	Unfit
SD		89.98	78.61	214.61	100.46	78.92
C.V.%		0.38	0.33	0.90	0.42	0.33

Note: the values in parenthesis represent the absolute deviation of observed and estimated rainfall.

Table 4. Comparison of observed and estimated seasonal (kharif) rainfall for different probability distribution function

Probability of exceedance (%)	Observed rainfall (mm)	Estimated rainfall (mm)				
		Normal	**Log normal**	**Exponential**	**Pearson type III**	**Log pearson type III**
10	918.74	815.66 (103.08)	811.00 (107.74)	1237.36 (318.62)	885.84 (32.90)	822.77 (95.97)
25	624.45	683.84 (59.39)	644.25 (19.80)	744.96 (120.51)	637.20 (12.75)	644.42 (19.97)
50	507.25	537.38 (30.13	498.86 (8.39)	372.48 (134.77)	452.22 (55.03)	494.23 (13.02)
75	336.925	390.92 (53.99)	386.29 (49.36)	154.59 (182.33)	347.24 (10.31)	381.46 (44.54)
90	320.6	259.10 (61.50)	306.86 (13.74)	56.62 (263.98)	302.28 (18.32)	303.78 (16.82)
Mean	541.59					
D-index		0.57	0.37	1.88	0.24	0.35
Fitting condition		Unfit	Unfit	Unfit	Normal fit	Unfit
SD		222.36	202.13	483.47	239.42	208.16
C.V.%		0.41	0.37	0.89	0.44	0.38

Note: the values in parenthesis represent the absolute deviation of observed and estimated rainfall

Table 5. Comparison of observed and estimated seasonal (*rabi*) rainfall for different probability distribution function

Probability of exceedance (%)	Observed rainfall (mm)	Estimated rainfall (mm)				
		Normal	**Log normal**	**Exponential**	**Pearson type III**	**Log pearson type III**
10	92.02	74.35 (17.67)	226.12 (134.10)	70.96 (21.06)	79.73 (12.29)	83.45 (8.57)
25	51.45	53.73 (2.28)	54.65 (3.20)	42.72 (8.73)	41.91 (9.54)	46.03 (5.42)
50	15.65	30.82 (15.17)	11.28 (4.37)	21.36 (5.71)	16.50 (0.85)	17.27 (1.62)
75	6.95	7.91 (096)	2.33 (4.62)	8.87 (1.92)	4.94 (2.31)	4.37 (2.58)
90	2.12	0.00 (2.12)	0.56 (1.56)	3025 (1.13)	0.98 (1.14)	0.87 (1.25)
Mean	33.64					
D-index		1.14	4.40	1.15	0.78	0.58
Fitting condition		Unfit	Unfit	Unfit	Unfit	Unfit
SD		31.08	95.98	27.73	32.69	34.57
C.V.%		0.92	2.85	0.82	0.97	1.03

Note: the values in parenthesis represent the absolute deviation of observed and estimated rainfall.

Table 6. Comparison of observed and estimated seasonal (ZAID) rainfall for different probability distribution function

Probability of exceedance (%)	Obse-rved rainfall (mm)	Estimated rainfall (mm)				
		Normal	Log normal	Expon-ential	Pearson type III	Log pearson type III
10	252.33	271.72 (19.39)	265.40 (13.07)	378.05 (125.72)	296.36 (44.03)	268.09 (15.76)
25	212.6	220.78 (8.18)	200.67 (11.93)	227.61 (15.01)	203.17 (9.43)	198.16 (14.44)
50	142.8	164.19 (21.39)	147.08 (4.28)	113.81 (28.99)	132.86 (9.94)	144.17 (1.37)
75	97.125	107.59 (10.47)	107.81 (10.68)	47.23 (49.89)	91.93 (5.20)	106.82 (9.69)
90	78.26	56.66 (21.60)	81.51 (3.51)	17.30 (60.96)	73.67 (4.59)	82.81 (4.55)
Mean	156.62					
D-index		0.52	0.28	1.79	0.47	0.29
Fitting condition		Unfit	Normal fit	Unfit	Unfit	Normal fit
SD		85.92	73.84	147.72	91.21	74.46
C.V.%		0.55	0.47	0.94	0.58	0.48

Note: the values in parenthesis represent the absolute deviation of observed and estimated rainfall.

Table 7. Comparison of observed and estimated annual rainfall for different probability distribution function

Probability of exceedance (%)	Obse-rved rainfall (mm)	Estimated rainfall (mm)				
		Normal	Log normal	Expon-ential	Pearson type III	Log pearson type III
10	1257.15	1059.19 (197.96)	1053.54 (203.61)	1686.37 (429.22)	1145.14 (112.01)	1061.15 (196.00)
25	881.88	904.38 (22.51)	863.92 (17.96)	1015.30 (133.42)	864.85 (17.02)	857.86 (24.02)
50	658.20	732.38 (74.18)	692.98 (34.78)	507.65 (150.55)	644.20 (14.00)	684.84 (26.64
75	526.90	560.38 (33.48)	555.87 (28.97)	210.69 (316.21)	505.81 (21.09)	552.89 (25.99)
90	450.87	405.58 (45.29)	455.87 (28.97)	210.69 (316.21)	436.35 (14.52)	460.46 (9.59)
Mean	755.00					
D-index		0.49	0.38	1.86	0.24	0.37
Fitting condition		Unfit	Unfit	Unfit	Normal Fit	Unfit
SD		261.14	239.44	658.92	288.88	240.75
C.V.%		0.35	0.32	0.87	0.38	0.32

Note: the values in parenthesis represent the absolute deviation of observed and estimated rainfall.

numerical value deviation was observed to be high in exponential distribution when compared to all other distributions. The D-index value was found to be minimum for normal (0.17) distributions followed by log-normal distribution (0.19) pearson type III (0.19) and log-pearson type III (0.19) Hence, normal, followed by log-normal distribution, pearson type III and log-pearson type III were found to be best fit and Considered reliable methods to estimate the one estimated maximum rainfall. The exponential distribution is unfit for the one day maximum rainfall.

Maximum weekly rainfall : The estimated maximum weekly rainfall at different probabilities is presented in table 2. it was observed that the Pearson type III (0.22) followed by log-Pearson type III (0.27) And log-normal (0.29) distribution are found to be normally fit for the maximum weekly rainfall and other two distribution were unfit for the maximum weekly rainfall.

Maximum monthly rainfall : The estimated maximum monthly rainfall is shown in Table 3. Pearson type III (0.28) distribution was identified as normally fit for the maximum monthly rainfall and other two distribution were unfit for the maximum monthly rainfall.

Seasonal rainfall : The estimated kharif, rabi and zaid seasonal rainfall at different probability is presented in Table 4, 5, and 6 respectively. It was observed that the Pearson type III (0.24) distribution was normally fit for the *kahrif* season, log-normal (0.28) and log-Pearson type III (0.29) distribution were normally fit for the zaid season but no one method fit for the *rabi* season.

Annual rainfall : The estimated annual rainfall at different probabilities is presented Table 7. The D-index was found to be minimum on Pearson type III (0.24) distribution. From the result, it could be inferred that the log-Pearson type III distribution normally fitted for annual rainfall to give the reliable estimates in the selected study area and also found that other four distributions namely normal, log-normal exponential and Pearson type III distribution are unfit for the study area.

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Computation of Heat use Efficiency and Radiation use Efficiency for Rainfed Groundnut (*Arachis hypogaea* L.)

S. T. Yadav[1] and M. M. Lunagaria[2]
Department of Agricultural Meteorology, BACA, Anand
Anand Agriculture University, Anand - 388001 (India)
*Corresponding author: styadav1975@gmail.com

Abstract

A field experiment was conducted on heat use efficiency and radiation use efficiency of rainfed groundnut in middle Gujarat, Anand Agricultural University, Anand (Gujarat) during 2019 and 2020. Results showed that first date of sowing recorded higher HUE (1.06 kg ha^{-1} °C day - 0.91 kg ha^{-1} °C day) as compared to second sowing date (0.82 – 0.84 kg ha^{-1}°C day) and third sowing date (0.72 - 0.72 kg ha^{-1} °C day) which could be attributed to higher pod yield. In varieties, GG 20 recorded higher HUE (0.91 kg ha^{-1} °C - 0.87 kg ha^{-1}°C day) and higher pod yield followed by GJG 34 and TAG 37A . In case HUE of biomass, first date of sowing recorded higher HUE (2.76 kg ha^{-1} °C day to 2.24 kg ha^{-1} °C day) compared to other dates of sowing. Among the varieties, GG 20 (2.36 kg ha^{-1} °C day to 2.05 kg ha^{-1} °C day) recorded higher HUE followed by GJG 34 and TAG 37A. Radiation use efficiency of pod yield first date of sowing recorded lower RUE (1.13 g MJ-1) compared to other sowing dates. TAG 37A observed higher RUE (1.74 g MJ-1) in respect with other two varieties.

Key words : Heat use efficiency, Radiation use efficiency, Groundnut, Yield.

Groundnut (*Arachis hypogaea* L.) is an important oilseed crop of tropical and subtropical regions of the world. In our country, it is one of the most important cash crop. The well-distributed rainfall at least 500 mm during crop growth period of groundnut and abundance of bright sunshine hours with relatively warm temperature. Sowing, emergence, germination, flowering, vegetative and pod development of groundnut requires well distribution of rainfall. However, well distributed rainfall ensures that the normal growth and development of the pods. Temperature in the range of 25 °C to 30 °C is optimum for plant development. Being a C3 crop, higher temperatures may affect its productivity and to some extent its distribution (Weiss, 2000). In India, groundnut occupies an area of 5.5 m ha producing 9.6 Mt with a productivity of 1750 kg ha^{-1} (Shwetha *et al*. 2017). It is grown mainly in rainy season i.e. *Kharif* season which accounts for about 80 percent of the total groundnut production. Gujarat stands first rank in area and production (Anonymous, 2012). It occupies 1.95 million hectares (28.93%) of the total area of the country producing 3.39 million tonnes (42.43%) of the total production of the country with a productivity of 1777 kg ha^{-1}. Owing to vagaries of monsoon yield of groundnut fluctuations are more in year to year (Anonymous, 2010). It is predominantly grown in monsoon (June-October) season and Junagadh is the most productive among all the districts in Gujarat (Sahu *et al*. 2004). In Gujarat, Anand district occupies area about 7000 ha, production 1200 MT and yield 1701 kg ha^{-1} of groundnut (Anonymous, 2011).

Heat use efficiency (HUE) and radiation use efficiency (RUE) can be used very effectively for the prediction of growth and yield of crops. Growing degree days is an independent variable to describe plant growth and development of

1. Ph. D Scholar and 2. Associate Professor and Head.

crop. It can be used as a tool for characterizing thermal responses in crops. Knowledge of accumulated GDD can provide an estimate of development stage as well as crop harvest date (Roy *et al*. 2005). The occurrence of different phenological stages during crop growth period in relation to temperature can be estimated by using accumulated heat units or growing degree days (Murthy, 1986). Although, the Heat use efficiency (HUE) and radiation use efficiency (RUE) has been used widely to evaluate the performance of many crops under different climatic situations, studies on heat units and RUE under rainfed condition are lacking. In this point of view, the study was planned to compute heat use efficiency and radiation use efficiency for rainfed groundnut.

Materials and Methods

The field experiment was conducted during kharif season during 2019 and 2020 at Anand Agricultural University, Anand, Gujarat, India. Anand is located at the latitude of 22° 35' N and longitude of 72° 55' E and at an altitude of 45.1m above the mean sea level. The soil type is sandy loam soil in texture with a field capacity of 15.4 to 15.8 at different depth. Bulk density was 1.52 g cm-3 to 1.55 g cm-3 in the 15 to 45 cm layer at the experimental site. The treatments consists of three dates of sowing viz; first date of sowing - onset of monsoon, second date of sowing - 10 days after onset of monsoon and third date of sowing - 20 days after onset of monsoon with three varieties GG 20, GJG 34 and TAG 37A. The experiment was replicated with four times in randomized block design (factorial). The crop was sown at a distance of 30 cm x 10 cm. Approximately 60 mm as heavy irrigation and 40 mm for light irrigation was given to the each plot as a life saving irrigations. The meteorological data were collected from the Agrometeorological observatory which is adjacent to the experimental site. All the package of practices was followed as per recommended. Heat use efficiency and radiation use efficiency were computed by using the weather parameters and crop growth data with the pertinent prescribed formula.

Growing degree days (GDD) : Growing degree days (GDD) is an arithmetic accumulation of daily mean temperature above certain threshold temperature (base temperature) and is calculated as

$$\text{GDD (°C)} = \frac{\text{Tmax} + \text{Tmin}}{2} - \text{Tbase}$$

Where, Tmax : Daily maximum temperature (°C) during a day, Tmin : Daily minimum temperature (°C) during a day and T_{base} : Base temperature 10°C.

Heat use efficiency (HUE) : Heat use efficiency (HUE) was also computed by following formula

$$\text{Heat use efficiency (kg ha}^{-1}\text{ °C)} = \frac{\text{Seed yield (kg ha}^{-1}\text{)}}{\text{Accumulated heat units (°C day)}}$$

Radiation use efficiency : Radiation use efficiency (RUE) was computed as the ratio of sum of biological yield to the sum of intercepted PAR by the crop plants as

$$\text{RUE (g MJ m}^{-2}\text{)} = \frac{\text{BY}}{\text{IPAR}}$$

Where, RUE = Radiation use efficiency, BY = Biological yield of groundnut and IPAR = Intercepted photosynthetic active radiation.

Results and discussion

Pod yield and above ground biomass production : Significantly high pod yield (2176 kg ha^{-1} and 1862 kg ha^{-1}) and above ground biomass production (5909 kg ha^{-1} and 4765 kg

Table 1. Pod yield and biomass of groundnut during 2019 and 2020

Treatments	Pod yield (kg ha^{-1})		Biomass (kg ha^{-1})	
	2019	2020	2019	2020
Date of sowing				
Onset of monsoon	2176	1862	5909	4765
10 days after onset of monsoon	1937	1592	4739	4193
20 days after onset of monsoon	1614	1369	4463	3519
Variety				
GG 20	2043	1701	1872	5341
GJG 34	1915	1612	1763	5071
TG 37A	1769	1511	1640	4699
SEm ±	46.7	47.9	33.4	43.4
CD at 5%	135.3	138.7	95.1	125.6
CV %	8.5	10.3	9.3	3.0

ha^{-1}) was recorded during both years under first date of sowing which was statistically at par with second date of sowing and significantly higher than the third date of sowing. Guled *et al.* (2013) recorded the highest yield (2244 kg ha^{-1}) in the first date of sowing as compared to other sowing dates. Effect of varieties on pod yield was significantly higher pod yield (2043 kg ha^{-1} and 1701 kg ha^{-1}) and above ground biomass production under GG 20 over varieties GJG 34 and TAG 37A (Table 1).

Growing degree days (GDD) : The accumulated GDD of onset of monsoon sowing was 2144°C day and 1906°C day, 10 days after onset of monsoon was 2368°C and 1894°C day and 20 days after onset of monsoon was 2264 C day and 1906°C day during 2019 and 2020, respectively (Table 2). The accumulated GDD from sowing to physiological maturity was highest (2368 oC days) in 10 days after onset of monsoon to other dates of sowing. It may be noticed that duration of crop growth period or number of days taken to physiological maturity was higher in 10 days after onset of monsoon in 2019. The accumulated GDD followed an increasing trend of GDD values from flower initiation to maturity. The highest accumulated GDD was observed in emergence, flowering and initiation of pod filling stage under first date of sowing followed by second and third date of sowing during both the years Guled (2013). Among the varieties, accumulation of GDD from sowing to physiological maturity were 2254°C days and 1951°C days during 2019 and 2020 respectively.

Heat use efficiency (HUE) for pod yield and biomass : HUE of pod yield decreased with decreasing the pod yield and biomass of groundnut crop during 2019 and 2020. Results showed onset of monsoon recorded higher HUE

Table 2. Phenophasewise accumulated growing degree day (°C days) of groundnut during 2019 and 2020

Crop growth stages	Emergence		Flowering		IPF*		Peak LAI		Maturity		Harvesting	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
Date of sowings												
Onset of monsoon	160	155	694	648	1435	1433	1607	1646	2125	1891	2145	1906
10 days after onset of monsoon	147	124	636	583	1448	1398	1636	1608	2351	1881	2368	1895
20 days after onset of monsoon	159	155	599	648	1182	1433	1596	1646	2245	1891	2264	1906
Varieties												
GG 20	151	140	637	637	1355	1424	1607	1634	2237	1937	2254	1951
GJG 34	164	140	655	637	1367	1431	1607	1634	2237	1937	254	1951
TG 37A	151	147	637	617	1343	1405	1607	1634	2237	1937	2254	1951

*IPF = Initiation of pod filling

(1.06 kg ha^{-1} °C day - 0.91 kg ha^{-1} °C day) as compared to 10 days after onset of monsoon (0.82 – 0.84 kg ha^{-1} °C day) and 20 days after onset of monsoon (0.72 - 0.72 kg ha^{-1} °C day) which could be attributed to higher pod yield. The lowest HUE for pod yield in third sowing might be due to the lowest pod yield. The results were in conformity with Meena et. al., (2015). In case of varieties, GG 20 recorded higher HUE (0.91 kg ha^{-1} °C - 0.87 kg ha^{-1} °C day) and higher pod yield followed by GJG 34 (0.85 kg ha^{-1} °C - 0.83 kg ha^{-1} °C day) and TAG 37A (0.79 kg ha^{-1} °C - 0.77 kg ha^{-1} °C day). The lowest HUE for pod yield in variety TAG 37A might be due to the lowest pod yield. These results are also enclosed agreement with the findings by Kingra and Kaur (2012). Meena *et. al*., (2015) also showed that higher heat unit efficiency was observed in HNG 10 variety compared with TG 37A variety (Table 3).

The HUE of biomass was found more in year 2019 as compared with year 2020. Among the dates of sowing, onset of monsoon sowing recorded higher HUE (2.76 kg ha^{-1} °C day to 2.24 kg ha^{-1} °C day) compared to 10 days after onset of monsoon sowing (2.00 kg ha^{-1} °C day to 1.92 kg ha^{-1} °C day) and 20 days after onset of monsoon sowing (1.98 kg ha^{-1} °C day to 1.62 kg ha^{-1} °C day) which could be attributed to higher biomass. The lowest HUE and lowest biomass was found in third sowing. Results were similar was found by Meena *et al*., (2015). Kingra and Kaur (2012) reported that late sown crop (July) availed less growing degree-days and accumulated less dry matter than the earlier sown (June) crop, thus indicating a decrease in dry matter and heat use efficiency. Among the varieties, GG 20 (2.36 kg ha^{-1} °C day to 2.05 kg ha^{-1} °C day) recorded higher HUE followed by GJG 34 (2.25 kg ha^{-1} °C day to 1.94 kg ha^{-1} °C day) and TAG 37A (2.08 kg ha^{-1} °C day to 1.81 kg ha^{-1} °C day). The lowest HUE in TAG 37A might be due to the lowest biomass (Table 3).

Radiation use efficiency (RUE) for pod yield and biomass : RUE of pod yield under the dates of sowing, onset of monsoon sowing recorded lower RUE (1.13 g MJ^{-1}) compared to second date of sowing (1.74 g MJ^{-1}) and third date of sowing (1.93 g MJ^{-1}). RUE of pod yield increasing with the dates of sowing of groundnut crop was delay in sowing during 2019 an 2020. The higher RUE for pod yield was observed during year 2019 compared year 2020. Similar findings were reported by Guled P. M. (2013). Among the varieties, TAG 37A observed higher

Table 3. Heat use efficiency of pod yield and biomass of groundnut using the GDD, HTU and PTU

Treatments	Heat use efficiency (kg ha^{-1} °C^{-1} day)											
	Pod yield						Biomass					
	GDD		HTU		PTU		GDD		HTU		PTU	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
Dates of sowing												
Onset of monsoon	1.02	0.91	0.23	0.18	0.08	0.08	2.76	2.24	0.62	0.39	0.22	0.17
10 days after onset of monsoon	0.82	0.84	0.17	0.18	0.07	0.08	2.00	1.92	0.41	0.34	0.16	0.15
20 days after onset of monsoon	0.72	0.72	0.15	0.16	0.06	0.08	1.98	1.62	0.42	0.26	0.16	0.13
Varieties												
GG 20	0.91	0.87	0.19	0.15	0.07	0.07	2.36	2.05	0.51	0.35	0.19	0.16
GJG 34	0.85	0.83	0.18	0.14	0.07	0.07	2.25	1.94	0.48	0.33	0.18	0.15
TG 37A	0.79	0.77	0.17	0.13	0.06	0.06	2.08	1.81	0.45	0.31	0.17	0.14

Table 4. Radiation use efficiency for pod yield and biomass of groundnut using the GDD, HTU and PTU

Treatments	Radiation use efficiency (g MJ^{-1})					
	Pod yield			Biomass		
	2019	2020	Mean	2019	2020	Mean
Onset of monsoon	1.13	1.42	1.28	0.42	0.58	0.50
10 days after onset of monsoon	1.74	1.44	1.59	0.73	0.60	0.67
20 days after onset of monsoon	1.94	1.66	1.80	0.50	0.74	0.62
Varieties						
GG 20	1.58	1.38	1.48	0.64	0.59	0.62
GJG 34	1.49	1.51	1.50	0.57	0.63	0.60
TG 37A	1.74	1.63	1.59	0.44	0.70	0.57

RUE (1.74 g MJ^{-1}) compared to other varieties during 2019 and 2020. Maximum RUE of biomass recorded in 10 days after onset of monsoon sowing (0.73 g MJ^{-1}) during year 2019 compared to other dates of sowings (Table 4). The results revealed that RUE of for biomass under the different varieties, GG 20 found more RUE (0.64 g MJ^{-1}) compared to GJG 34 and TAG 37A during year 2019 (Table 4).

It was concluded that the variey GG 20 recorded significantly higher pod yield irrespective of dates of sowing. Therefore, GG 20 could be considered as thermo tolerant under middle Gujarat.

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Stability Analysis for Yield Attributes in *Rabi* Sorghum*

S. A. Anarase[1], R. M. Gethe[2] and Prerna Bhosale[3]
Punyashlok Ahilyadevi Holkar College of Agriculture, Halgaon, Tal. Jamkhed, Dist. Ahmednagar, Mahatma Phule Krishi Vidyapeeth, Rahuri - 413 722 (India)

Abstract

The analysis of variance for phenotypic stability revealed that the variation due to genotype x environment was considerable for all the characters studied. The significance of G x E (linear) and pooled deviation for majority of the attributes suggested the importance of both linear and non-linear components in determining total genotype x environment interactions. Perusal of stability parameters revealed that eight parents were found to be average stable for grain yield. Nevertheless, it was noticed that the male parent RSV 1460 and RPOSV 3 exhibited bi value significantly greater than one, showed below average stability, which was suitable for favourable environments. Among hybrids twenty five hybrids exhibited high mean, unit regression (b_i) and least deviation from regression (S^2d_i) and therefore they were classified as stable with average response to environments. In general, the hybrids found stable for grain yield also showed stability for two or more component characters, which indicated that the stability of various component traits might be responsible for stability of these hybrids for grain yield plant^{-1}. The best three hybrids *viz*., 1543A x RSV 1297, 1343A x RSV 1200 and 1343A x SPV 1359 were found to have average stability over environments for grain yield per plant with one or more stable yield contributing attributes, signifying their potential for commercial exploitation for genetic improvement in *rabi* sorghum.

Key words : Genotype x Environment interaction, stability.

The relative performance of genotypes often changes from one environment to another. The occurrence of large genotype x environment interaction poses a major problem of relating phenotypic performance to genetic constitution and makes it difficult to decide which genotypes should be selected. It is important to understand the nature of genotype x environment interaction to make testing and ultimately selection of more efficient genotypes. Breeding genotype with wider adaptability has been ultimate aim of plant breeders. A variety is desirable for commercial exploitation over a wide range of environment, if adaptability in real sense is due to genetic make up. Although plant breeders have been unable to exploit them fully in breeding programme. This has been due to problems of measuring adaptability or other complexities of natural environments. Eberhart and Russell (1966) defined a stable genotype as one, which produced high mean yield and depicted regression coefficient (b_i) around unity and deviations from regression (S^2d_i) near zero. Present investigation aimed to study the interaction of 91 genotypes (five female sterile lines, fourteen testers, resultant seventy hybrids and two checks) of *rabi* sorghum with environments.

Material and methods

The experimental material consisted of five male sterile lines, fourteen testers, resultant seventy hybrids and two checks of rabi sorghum. The experiment consisted of 91 genotypes was conducted in randomized block design with three

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1. Assistant Professor of Agriculture Botany, 2. Associate Professor of Agronomy and 3. Assistant Professor of Agril. Chemistry and Soil Science.

replications during rabi 2012-13 at three different locations *viz.*, E_1 : College farm, Navsari Agricultural University, Navsari, E_2 : Main Sorghum Research Station, Athwa farm, NAU, Surat and E_3 : Agricultural Research Station, Achhalia, during *rabi* 2012-13. In individual experiment, each net plot had single row of 3 m each, the inter row spacing 45 cm apart. The border row was planted around each replication. Recommended package of practices was followed to raise good crop. For observations five plants were selected at random from each plot and were tagged. Observations were recorded on the randomly selected plants from each treatment in each replication for grain yield per plant, days to 50 per cent flowering, days to maturity, plant height, panicle length, primaries per panicle, panicle weight, harvest index, 1000-grain weight and protein content. Data were analysed following model proposed by Eberhart and Russel (1966)

Results and discussion

The analysis of variance for phenotypic stability (Table 1) revealed that mean squares due to genotypes as well as environments were highly significant for all the characters when tested against pooled deviation. The genotypes interacted significantly with environments for all the traits when tested against pooled error specifying that the genotypes interacted significantly to diverse environments.

The mean squares due to environments (linear) were highly significant for all the characters when tested against pooled deviation. However, the same was significant for all the characters when tested against pooled error. This indicated that variation among environments was linear and it signifies unit change in environmental index for each unit change in the environmental conditions.

The variances due to G x E were further partitioned in to components (i) G x E (linear) and (ii) G x E (non-linear) i.e. pooled deviation. The coincidence of genotypic performance with environmental values was observed for grain yield, panicle length, primaries per panicle and harvest index an evident from significant

Table 1. Analysis of variance (mean square) for phenotypic stability for different characters in *rabi* sorghum

Source of variation	d.f.	GY	DF	DM	PH	PL	PPP	PW	HI	TW	PC
Genotypes	90	++** 378.73	++** 20.24	++** 43.67	++** 2252.34	++** 28.51	++** 371.85	++** 480.70	++** 87.16	++** 50.62	++** 3.68
Environments	2	+* 147.39	++** 581.46	++** 757.01	++** 20869.66	++** 11.68	++** 565.65	++** 195.01	++** 127.38	++** 254.97	++** 4.44
G x E	180	++** 34.93	** 3.50	** 8.72	** 119.54	+** 2.25	+** 60.65	** 36.89	++** 5.11	** 6.91	** 0.73
Environments (Lin)	1	++** 294.78	++** 1162.92	++** 1514.03	++** 41739.33	++** 23.36	++** 1130.30	++** 390.02	++** 254.76	++** 509.94	++** 8.88
G x E (Lin)	90	++** 47.45	** 3.75	** 5.68	** 109.07	++** 2.97	++** 76.30	+** 43.80	++** 7.81	** 7.66	** 0.69
Pooled Deviation	91	** 22.16	** 3.23	** 11.63	** 128.58	** 1.51	** 44.51	** 29.66	2.38	** 6.100	** 0.75
Pooled Error	540	9.44	0.67	1.37	47.66	0.42	10.25	8.27	2.15	0.55	0.06

+, ++ : Significant against pooled deviation M.S. at 5% and 1% levels, respectively.
*, ** : Significant against pooled error M.S. at 5% and 1% levels, respectively.
GY : Grain yield per plant (g), DF : Days to 50 per cent flowering, DM : Days to maturity, PH : Plant height (cm), PL : Panicle length (cm), PPP : Primaries per panicle, PW : Panicle weight (g), HI : Harvest Index (%), TW : 1000-grain weight (g), PC : Protein content(%)

genotypes x environments (linear) mean squares when tested against pooled deviations. Although, G x E (linear) was found to be significant for all the characters when tested against pooled error indicating differential performance of genotypes under diverse environments but with considerably varying norms, i.e., the linear sensitivity of different genotypes is variable. The mean squares due to pooled deviations were significant for all the characters except harvest index, which suggested that performance of different genotypes fluctuated significantly from their respective linear path of response to environments.

On comparing relative magnitude of genotype x environment (linear) and pooled deviation from linearity (non-linear), it was found that the linear component was high for grain yield plant^{-1}, panicle length, primaries per panicle, panicle weight, and harvest index indicating that linear component contributed more towards the genotype x environment interactions. In case of days to 50 per cent flowering, 1000-grain weight and protein content both linear and non-linear components was almost equal indicating importance of both linear and non linear components in determining genotype x environment interactions for these attributes.

These results were in general, concurring with those of Muppidathi *et al.* (1995 a and b), Narkhede *et al.* (1998a & b), Muppidathi *et al.* (1999a & b), Patil *et al.* (1991), Shivanna *et al.* (1992), Das and Prabhakar (2003), Khandelwal *et al.* (2005) and Kale (2012).

The stability parameters *viz.*, mean performance (X), regression coefficient (bi) and individual squared deviation from linear regression (S^2d_i) for parents as well as hybrids were estimated for ten characters to assess the stability over the environments and are presented in Table 2.1-2.4. Total 91 genotypes were divided in to two groups; first comprising all hybrids with hybrid check CSH 15R and second comprising all parents with varietal check BP 53. Population means of these two groups were estimated separately and used for assessment of stability parameters.

For grain yield per plant significant deviation from regression were exhibited by 12 hybrids and 02 parents, revealing larger contribution of non-linear component is important than linear components towards G x E interaction. Among parents three females viz., 104A, 1343A and 1543A, eight males and varietal check BP 53 had higher mean than parental mean with bi magnitude not significantly deviating from unity and non-significant deviation from regression, hence they were considered stable for this trait. The male parent RSV 1460 and RPOSV 3 exhibited high mean, b_i value significantly greater than unity and non-significant deviation from regression, thus showing below average stability which was suitable for rich environments. Out of 70 hybrids and check (CSH 15R) tested, 25 hybrids exhibited high mean, along with regression coefficient near unity and non-significant deviation from regression and therefore they were classified as stable hybrids. In addition to these stable hybrids, four hybrids 1409A x RSV 1006, 1409 A x RSV 1704, 1543A x SPV 1359 and 1543A x SPV 1546 had high mean, regression coefficient greater than unity and non significant deviation from regression showed specific adaptability for favourable environments. While one hybrid, 1409A x RSV 1093 showed specific adaptability to poor environments for grain yield per plant. The superlative five stable hybrids were 1543A x RSV 1297, 1343A x RSV 1200, 1343A x SPV 1359, 1543A x SPV 1704 and 1543A x RSV 1188.

For days to 50% flowering, among parents, 8 male parents recorded low mean, non significant regression coefficient and non significant S^2d_i values showed average stability over environments. The top three most stable observed males are RSV 458, RSV 1006 and RSV 1427. The female parent 104A showed

Table 2.1 Stability parameters for grain yield plant^{-1}, days to 50 per cent flowering and days to maturity in *rabi* sorghum

Genotypes	Grain yield plant^{-1} (g)			Days to 50% flowering			Days to maturity		
	Mean	b_i	S^2d_i	Mean	b_i	S^2d_i	Mean	b_i	S^2d_i
104A x RSV 458	52.54	0.10	14.31	66.22	0.73	9.39**	124.00	1.51	-0.50
104A x RSV 1006	61.63	3.35	93.57**	67.89	-0.02	1.17	120.22	0.90	3.40
104A x RSV 1093	70.58	-0.575	25.36	68.67	0.79	-0.63	120.33	1.17	0.10
104A x RSV 1130	58.15	-4.32	-2.43	69.67	1.39	-0.65	124.11	1.43	48.90**
104A x RSV 1188	65.95	-4.17	-7.95	69.22	0.99	-0.53	123.89	0.78	-0.60
104A x RSV 1200	60.75	1.27	-0.93	70.67	1.45	-0.55	124.33	2.03	20.80 **
104A x RSV 1297	61.96	-0.66	-2.75	69.33	1.30	0.59	120.00	1.62	3.10
104A x SPV 1359	55.20	0.32	16.38	70.56	2.40	1.17	124.44	1.51	37.10 **
104A x RSV 1427	59.93	2.05	-7.99	68.33	0.70	1.27	117.56	0.38	34.10**
104A x RSV 1460	58.44	0.35	-9.05	69.89	1.90	-0.32	119.44	0.81	-1.30
104A x SPV 1546	60.83	3.31	-6.95	68.33	1.62	1.91	119.67	1.25	-1.30
104A x SPV 1704	54.75	0.23	-9.06	69.00	1.08	4.62 **	122.22	1.65	5.60*
104A x RPOSV 3	25.09	4.52	26.99	69.78	1.15	4.07 **	119.78	1.12	5.50 *
104A x RSSGV 43	45.87	-2.65	33.29 *	68.78	1.30	1.28	119.67	1.59*	-1.40
1343A x RSV 458	62.14	-0.92	-8.33	68.44	0.62	3.55 *	116.89	0.76	27.80 **
1343A x RSV 1006	62.45	1.48	-3.39	68.78	0.51	0.79	121.33	1.12	27.70 **
1343A x RSV 1093	71.79	-5.39	-5.99	71.56	0.38	-0.26	125.22	1.58*	-1.30
1343A x RSV 1130	63.22	-0.31	-3.56	74.22	0.96	2.18 *	125.33	1.32	-0.90
1343A x RSV 1188	70.05	1.33	-6.61	72.55	1.07	0.05	122.56	1.20	-0.80
1343A x RSV 1200	86.53	2.17	-8.46	75.37	1.22	8.57**	127.22	1.20	-0.80
1343A x RSV 1297	61.31	10.53	2.13	73.89	1.77	9.16**	129.22	0.38	18.60**
1343A x SPV 1359	84.87	2.42	-8.84	72.56	0.75	1.09	120.90	1.61	5.00*
1343A x RSV 1427	75.06	-0.38	16.49	72.89	1.745	1.60	126.74	1.47	-1.20
1343A x RSV 1460	68.48	2.62	26.96	72.44	1.39	-0.26	123.01	1.29	57.20 **
1343A x SPV 1546	64.72	7.74	63.94 **	71.67	1.20	-0.37	123.22	1.69	-1.30
1343A x SPV 1704	79.17	-0.08	3.02	70.33	0.31	1.02	119.99	1.07	12.50 **
1343A x RPOSV 3	43.35	0.22	0.95	71.33	0.92	-0.62	124.22	1.23	5.10 *
1343A x RSSGV43	60.49	-10.37	2.17	69.78	0.43	1.89	118.56	0.94	13.70**
1409A x RSV 458	48.26	0.08	135.73 **	67.00	1.77	0.01	122.67	1.73	19.10**
1409A x RSV 1006	61.73	8.47*	-9.26	67.67	1.50	-0.08	120.67	1.34	58.10**
1409A x RSV 1093	71.50	-6.08*	-8.69	68.89	1.14	5.33 **	121.56	1.84	2.90
1409A x RSV 1130	60.81	-0.59	-7.04	69.33	0.82	4.33 **	122.22	1.87	0.10
1409A x RSV 1188	59.12	-4.55	170.90 **	68.22	0.72	-0.57	123.22	2.56	1.70
1409A x RSV 1200	69.15	2.13	14.42	70.56	0.87	-0.43	122.11	1.56	-1.20
1409A x RSV 1297	67.58	4.37	40.44 *	68.56	1.70	0.23	122.56	1.39	-0.80
1409A x SPV 1359	65.69	-0.30	-1.04	69.67	1.49	1.82	121.78	1.33	3.40
1409A x RSV 1427	60.14	3.10	14.73	70.44	1.12	-0.65	122.44	0.84	-1.10
1409A x RSV 1460	60.26	6.35	12.05	70.00	1.42	3.20 *	123.67	1.90	21.10**
1409A x SPV 1546	59.85	5.25	16.86	67.33	0.83	1.35	120.56	1.28	27.60**
1409A x SPV 1704	62.13	9.86*	-9.42	68.56	1.73	-0.18	121.33	0.98	-1.30
1409A x RPOSV 3	35.36	-1.83	40.68 *	70.89	1.85*	-0.63	119.67	1.36	0.80
1409A x RSSGV43	47.93	-0.53	58.04**	69.67	1.17	0.53	121.00	1.36	6.00 *
1543A x RSV 458	58.27	-0.38	23.47	69.00	0.89	2.73 *	122.11	1.08	3.40
1543A x RSV 1006	58.66	4.24	24.45	69.56	1.19	-0.66	120.78	0.84	7.50 *
1543A x RSV 1093	70.20	2.84	2.77	71.89	1.06	-0.66	124.11	1.13	65.10**
1543A x RSV 1130	68.85	0.47	98.59 **	73.33	1.34	1.09	124.78	1.36	16.60**
1543A x RSV 1188	77.99	0.12	0.08	72.56	1.16	3.54 *	122.33	1.55	-0.80
1543A x RSV 1200	69.37	3.88	6.26	72.33	0.48	0.57	122.67	1.32	-0.90

* and ** Significant at 5% and 1% level of probability, respectively.

above average stability and suitability to poor environments. Out of 70 hybrids, 31 hybrids and check CSH 15R had low mean, non-significant regression coefficient and non-significant S^2d_i values which indicated their ideal stability over environments. The performance of 10 hybrids could not be predicted under variable environments in view of significant S^2d_i values.

Table 2.1 Contd…

Genotypes	Grain yield plant^{-1} (g)			Days to 50% flowering			Days to maturity		
	Mean	**b_i**	**S^2d_i**	**Mean**	**b_i**	**S^2d_i**	**Mean**	**b_i**	**S^2d_i**
104A x RSV 458	52.54	0.10	14.31	66.22	0.73	9.39**	124.00	1.51	-0.50
1543A x RSV 1297	87.82	2.58	-7.54	76.70	0.49	58.68 **	125.89	0.66	16.40**
1543A x SPV 1359	66.50	11.34*	-9.13	72.67	0.95	1.34	125.33	0.86	10.90 **
1543A x RSV 1427	65.67	-4.30	19.89	71.55	0.75	4.89 **	127.78	1.11	-1.40
1543A x RSV 1460	65.55	7.68	5.77	70.55	1.52	-0.55	122.33	1.58	24.10 **
1543A x SPV 1546	68.22	5.80*	-9.12	70.55	1.00	-0.46	122.78	1.22	11.00 **
1543A x SPV 1704	80.20	0.48	5.62	72.22	0.93	-0.66	121.44	0.50	9.00 **
1543A x RPOSV 3	34.17	-1.18	85.69 **	71.11	0.86	-0.66	122.44	1.74	11.20 **
1543A x RSSGV43	53.55	-4.04	-6.20	70.55	0.59	-0.59	118.11	0.39	1.40
9168A x RSV 458	50.47	-3.97	5.09	65.11	0.84	0.11	115.67	0.84	3.80
9168A x RSV 1006	54.51	-2.66	-4.74	67.89	0.71	0.59	115.22	0.25	-0.60
9168A x RSV 1093	56.25	-4.03	9.07	68.55	0.50	1.52	115.78	0.06	5.80 *
9168A x RSV 1130	62.04	-0.25	-7.05	69.89	0.33	-0.62	116.33	0.46	1.10
9168A x RSV 1188	55.73	-8.67	-6.34	68.89	0.56	2.95*	114.67	0.38	-0.90
9168A x RSV 1200	57.78	2.80	-6.97	69.67	0.72	-0.34	116.00	-0.33	3.70
9168A x RSV 1297	60.64	-5.60	33.77 *	68.11	0.04	1.61	115.33	-0.45	-0.50
9168A x SPV 1359	60.92	3.211	106.66 **	69.44	0.52	-0.51	116.44	0.28	6.70 *
9168A x RSV 1427	49.98	-3.60*	-9.43	67.89	0.05	0.26	115.00	0.19	3.60
9168A x RSV 1460	54.73	-0.39	-8.79	68.00	-0.07	-0.52	114.22	0.29	0.40
9168A x SPV 1546	60.55	-0.01	10.22	69.11	0.17	1.70	115.56	0.33	7.70 *
9168A x SPV 1704	54.73	-0.10	11.78	69.00	0.19	-0.46	116.33	0.01	12.60 **
9168A x RPOSV 3	32.22	0.89	13.70	70.11	0.58	0.00	116.78	-3.50	2.90
9168A x RSSGV 43	50.65	-0.91	6.24	68.78	0.96	2.30 *	114.89	8.60	-1.30
CSH 15 R (c)	56.53	3.96	-3.57	69.11	0.65	-0.48	118.89	0.25	-0.60
Mean (Hybrids)	60.81			70.04			120.98		
104A	53.17	2.07	5.14	71.67	0.39*	-0.66	125.33	1.17	0.10
1343A	57.10	1.51	4.85	70.39	1.72	3.85 **	125.30	1.41	59.30 **
1409A	41.31	-0.59	111.39 **	73.00	1.84	-0.47	128.89	1.38	9.30 **
1543A	53.81	2.43	-3.14	76.01	0.61	21.79 **	129.00	0.18	6.30 *
9168A	44.96	1.68	-7.34	73.33	0.93	-0.30	119.89	0.68	31.90 **
RSV 458	45.13	0.79	-8.59	66.89	1.86	-0.22	114.11	0.21	2.40
RSV 1006	47.79	2.07	-9.11	69.00	2.59	-0.26	118.22	1.12	-1.40
RSV 1093	65.52	2.35	-9.01	72.33	0.28	-0.10	126.56	0.07	4.40*
RSV 1130	56.09	4.96	-6.03	77.55	1.54	22.61**	127.67	0.57	7.10 *
RSV 1188	60.40	1.24	1.27	75.89	1.44	7.19 **	128.33	0.83	-0.30
RSV 1200	56.69	4.53	-8.89	75.11	1.15	1.60	122.61	0.12	40.20 **
RSV 1297	54.26	3.98	-7.12	72.00	0.68	-0.23	122.44	0.80	-0.50
SPV 1359	58.77	2.66	-8.51	73.33	1.05	11.15 **	124.00	0.95	-0.10
RSV 1427	45.87	2.47	-9.38	70.11	0.73	-0.66	120.56	1.00	6.00 *
RSV 1460	53.28	5.49*	-9.44	72.44	1.35	2.63 *	120.42	1.39	48.10 **
SPV 1546	54.15	1.14	5.06	72.33	0.47	-0.58	121.22	0.63	1.10
SPV 1704	53.75	-1.93	13.37	72.33	1.21	24.70 **	122.22	0.63	-1.30
RPOSV 3	57.35	4.04*	-9.41	72.78	0.14	-0.41	126.00	0.60	6.90 *
RSSGV 43	33.59	-0.52	27.09 *	71.33	1.72	-0.48	118.11	1.78	29.90 **
BP 53 (c)	60.46	0.46	-7.86	80.67	1.11	-0.21	128.89	1.30	15.8**
Mean (Parents)	52.67			72.92			123.49		

* and ** Significant at 5% and 1% level of probability, respectively.

The best five hybrids among the stable hybrids for this trait were 9168A x RSV 458, 1409A x RSV 458, 1409A x SPV 1546, 1409A x RSV 1006 and 9168A x RSV 1006.

Table 2.2 Stability parameters for plant height, panicle length and primaries panicle^{-1} in *rabi* sorghum

Genotypes	Plant height (cm)			Panicle length (cm)			Primaries panicle^{-1}		
	Mean	b_i	S^2d_i	Mean	b_i	S^2d_i	Mean	b_i	S^2d_i
104A x RSV 458	184.04	0.95	-45.80	21.80	1.43	10.63 **	55.00	-4.82	39.60 *
104A x RSV 1006	250.36	0.23*	-47.20	22.32	0.73	1.02	61.55	1.47	2.80
104A x RSV 1093	243.20	0.47	-19.60	23.93	5.28	-0.01	75.44	0.11	-3.67
104A x RSV 1130	244.43	0.17*	-48.30	22.38	3.74	-0.40	82.11	4.84*	-9.11
104A x RSV 1188	237.73	0.45	210.90*	20.89	-5.36	5.38 **	76.44	4.50	325.38 **
104A x RSV 1200	213.07	1.25	601.40**	23.35	4.83	-0.08	69.55	0.24	66.90 **
104A x RSV 1297	226.63	1.11	-37.20	24.40	4.35*	-0.42	71.44	-1.70	137.40 **
104A x SPV 1359	223.01	1.42	16.00	24.66	2.17	-0.36	63.44	2.59	14.42
104A x RSV 1427	230.97	1.13	214.10*	23.77	5.98	5.36 **	72.33	2.93	-9.77
104A x RSV 1460	217.34	1.19	6.40	22.79	5.34	5.10 **	72.00	1.17	-7.09
104A x SPV 1546	223.37	0.96	-48.40	23.05	5.19	2.16 *	62.44	3.61	5.58
104A x SPV 1704	223.15	1.08	-45.50	22.80	1.93	2.90 **	72.89	1.85	59.33**
104A x RPOSV 3	198.30	1.78	-13.30	17.08	-4.68	0.50	63.33	0.81	8.33
104A x RSSGV 43	212.95	1.09	-25.20	20.77	3.91	0.47	70.67	2.47*	-10.21
1343A x RSV 458	196.54	1.86	-36.00	19.00	1.99	0.07	67.89	3.38	19.18
1343A x RSV 1006	244.44	0.29	-37.40	20.19	0.01	-0.29	76.78	5.17	-0.55
1343A x RSV 1093	230.90	1.87	515.70**	21.11	1.61	2.22 *	75.33	4.70	-0.38
1343A x RSV 1130	224.81	1.78	552.30**	21.47	-0.42	0.91	78.82	1.39	12.54
1343A x RSV 1188	232.60	1.23	215.30*	20.94	-5.13*	-0.37	76.56	0.61	198.68 **
1343A x RSV 1200	249.07	0.23	-21.90	22.52	2.00	-0.05	95.55	0.97	-7.41
1343A x RSV 1297	249.40	0.37	-39.70	22.38	-0.63	-0.28	71.55	-2.61	37.27 *
1343A x SPV 1359	241.36	1.37	59.50	23.21	1.60	1.07	92.11	1.79	-9.03
1343A x RSV 1427	221.40	0.72	-42.90	21.71	1.40	-0.42	87.11	2.90	-3.56
1343A x RSV 1460	212.35	0.85	477.50**	21.38	1.91	1.08	75.67	0.00	3.31
1343A x SPV 1546	218.39	0.95	165.10*	20.71	1.55	0.89	84.55	3.15*	-10.23
1343A x SPV 1704	237.93	0.60	-43.00	22.13	1.57	-0.42	87.78	1.58	-8.11
1343A x RPOSV 3	189.01	1.64	-14.90	17.42	1.44	1.20	84.67	0.36	-8.93
1343A x RSSGV43	217.00	1.39	446.40**	18.25	0.26	1.66 *	84.33	6.94	-5.94
1409A x RSV 458	176.63	1.05	-47.30	23.14	0.29	-0.05	53.56	-3.70	-2.58
1409A x RSV 1006	221.53	1.39	130.50	26.56	-1.38	-0.25	64.33	-2.24	147.76 **
1409A x RSV 1093	226.55	0.82	-5.80	26.62	9.12	0.41	67.89	3.15*	-10.23
1409A x RSV 1130	210.93	1.64	56.10	25.54	-8.41	1.15	74.17	-3.70	94.23 **
1409A x RSV 1188	219.55	0.93	-16.90	25.36	-8.74	8.26 **	73.00	-1.45	13.15
1409A x RSV 1200	231.23	0.65	101.00	27.82	0.34	0.08	72.15	-1.49	15.12
1409A x RSV 1297	219.03	1.15	-27.30	28.40	1.73	0.16	76.26	1.34	-10.23
1409A x SPV 1359	220.99	1.22	11.60	28.39	-1.69	-0.13	72.55	2.50	10.93
1409A x RSV 1427	215.57	0.64	493.30**	27.19	-2.80	-0.39	66.44	2.02	-2.46
1409A x RSV 1460	185.90	1.07	-47.20	25.74	2.60	0.76	59.89	-1.32	82.85 **
1409A x SPV 1546	198.69	1.37	-16.00	26.30	5.91*	-0.42	68.44	-4.65	140.61 **
1409A x SPV 1704	218.67	1.11	-45.50	28.01	2.65	-0.30	74.44	2.56	-1.75
1409A x RPOSV 3	193.13	1.47	-35.40	19.99	2.49	-0.36	79.00	-2.61	41.09 *
1409A x RSSGV43	219.44	0.89	-5.50	23.18	0.65	0.40	71.11	-2.96	50.07 *
1543A x RSV 458	193.33	1.09	117.80	19.65	3.74	-0.17	62.11	5.47	-5.66
1543A x RSV 1006	204.98	1.30	14.00	19.45	1.21	-0.33	67.65	-1.38	-5.90
1543A x RSV 1093	227.95	1.17	5.70	21.74	-0.91	-0.02	70.11	0.39	49.48 *
1543A x RSV 1130	232.80	1.14	6.60	21.48	0.02	-0.21	79.91	1.35	3.21
1543A x RSV 1188	242.94	0.70	2.60	22.36	1.13	0.75	87.21	1.80	-10.07
1543A x RSV 1200	238.08	1.22	183.80*	21.85	1.75	1.29 *	82.00	1.11	24.30

* and ** Significant at 5% and 1% level of probability, respectively.

As regards to days to maturity, 5 male parents recorded low mean, non significant regression coefficient and non significant S^2d_i values showed average stability over environments. The top three most stable observed males are RSV 458, RSV 1006 and RSV 1297. Among the hybrids, 17 hybrids and check CSH 15R had low mean, non-significant regression coefficient and non-significant S^2d_i values which indicated their ideal stability over

Table 2.2 Contd…

Genotypes	Plant height (cm)			Panicle length (cm)			Primaries panicle^{-1}		
	Mean	b_i	S^2d_i	Mean	b_i	S^2d_i	Mean	b_i	S^2d_i
1543A x RSV 1297	256.39	0.75	120.10	24.30	2.92	0.35	99.67	0.86	-0.80
1543A x SPV 1359	245.01	0.77	700.30**	22.31	1.59	0.87	69.67	6.17	4.86
1543A x RSV 1427	227.37	1.40	124.20	21.60	4.34	-0.40	76.16	1.70	4.85
1543A x RSV 1460	204.43	1.62	-35.40	20.39	2.05	0.72	76.70	2.64	-8.40
1543A x SPV 1546	218.68	1.38*	-48.10	21.10	1.40	-0.40	80.67	0.88	47.05 *
1543A x SPV 1704	240.10	0.62*	-48.10	22.33	1.96	-0.39	90.33	2.02	-10.12
1543A x RPOSV 3	203.39	1.73	-5.60	15.98	0.44	-0.02	80.27	4.21	20.70
1543A x RSSGV43	212.34	1.39*	-48.30	19.01	2.31	-0.22	74.22	3.32	14.77
9168A x RSV 458	207.73	1.09	-27.80	20.59	5.62	0.49	50.11	4.10*	-9.57
9168A x RSV 1006	236.55	1.53*	-48.10	21.92	0.47	-0.07	68.00	0.74	47.52 *
9168A x RSV 1093	240.16	1.82	127.40	22.10	-0.77	-0.39	63.00	2.72	135.90 **
9168A x RSV 1130	237.07	0.70	19.40	21.75	1.43	-0.21	70.56	1.61	42.51*
9168A x RSV 1188	246.27	1.47	-40.40	22.08	0.62	-0.42	62.78	1.34	1.65
9168A x RSV 1200	242.24	1.23	35.00	22.31	1.12	0.55	59.89	0.73	5.66
9168A x RSV 1297	241.35	0.93	-18.70	23.26	0.95	-0.39	55.00	2.62	-9.85
9168A x SPV 1359	252.47	0.86	129.90	22.84	1.57	-0.00	59.00	0.44	65.35 **
9168A x RSV 1427	248.37	1.24	-30.10	22.48	-0.32	-0.30	56.78	3.78	-8.54
9168A x RSV 1460	234.80	1.78	32.60	19.86	4.81	0.61	57.89	-1.35	47.45 *
9168A x SPV 1546	231.47	1.29	-41.10	20.70	1.24	-0.42	50.22	-0.11	-3.67
9168A x SPV 1704	233.77	1.32	7.10	22.27	-0.14*	-0.42	59.78	1.42	277.72 **
9168A x RPOSV 3	229.13	1.11	-48.00	18.51	-4.97	3.49**	60.55	0.56	20.97
9168A x RSSGV 43	241.39	0.34*	-48.10	19.44	0.90	-0.10	58.22	2.84	14.08
CSH 15 R (c)	207.56	0.55	43.00	20.88	-0.58	0.13	69.62	0.52	-2.16
Mean (Hybrids)	224.36			22.30			71.53		
104A	144.28	0.24	52.00	22.57	3.93	1.63 *	74.44	-3.58	249.21 **
1343A	135.19	0.93	-30.70	18.94	2.52	0.44	68.91	0.32	1.14
1409A	113.77	-0.28*	-47.50	27.79	-2.54	6.24 **	58.78	-3.06	14.13
1543A	130.14	0.12	-37.80	19.56	1.13	0.03	69.44	0.06	34.23 *
9168A	163.75	0.64	203.70*	19.48	-0.61	0.09	41.67	3.83	49.07 *
RSV 458	163.05	1.33	374.70**	14.44	0.11	1.056	43.67	-2.90	25.67
RSV 1006	175.70	0.52	61.40	15.66	0.07	0.08	48.26	-3.10	-5.27
RSV 1093	218.83	1.74	139.60*	20.57	-2.56	0.33	69.11	-0.51	-5.41
RSV 1130	217.24	0.63	24.20	18.21	-0.84	2.58 **	54.44	-0.69	158.26 **
RSV 1188	204.79	1.72	755.40**	19.20	-2.88	3.47**	61.67	0.41	-9.72
RSV 1200	218.29	0.50	-34.50	19.67	0.42	0.17	60.67	-1.69	32.38 *
RSV 1297	228.57	0.22*	-48.30	20.01	-1.39	5.25 **	66.89	-1.06	7.40
SPV 1359	229.39	0.56	-40.70	21.50	4.09	-0.15	63.67	-0.07	38.42 *
RSV 1427	205.83	0.40	9.20	18.47	-1.47	1.34 *	71.89	0.81	296.31 **
RSV 1460	214.93	0.18	174.90*	17.76	-0.70	1.96 *	60.00	2.06	10.64
SPV 1546	211.16	1.57	204.70	17.30	11.32	7.39 **	74.22	4.35	39.24 *
SPV 1704	215.35	0.57	-44.60	18.85	5.86	2.07 *	61.33	1.53	-9.66
RPOSV 3	205.95	0.34	710.40**	16.24	-11.52	7.96 **	75.67	3.71	13.44
RSSGV 43	199.99	0.63	227.70*	13.76	3.21	-0.29	85.22	0.69	11.03
BP 53 (c)	175.98	0.83	-6.80	15.75	0.22	4.15**	65.64	-0.47	8.74
Mean (Parents)	188.61			18.79			63.78		

* and ** Significant at 5% and 1% level of probability, respectively.

environments. The best five hybrids among the stable hybrids for this trait were 9168A x RSV 1460, 9168A x RSV 1188, 9168A x RSSGV 43, 9168A x RSV 1427 and 9168A x RSV

Table 2.3 Stability parameters for panicle weight, harvest index and 1000- grain weight in *rabi* sorghum

Genotypes	Panicle weight(g)			Harvest index (%)			1000-grain weight(g)		
	Mean	b_i	S^2d_i	Mean	b_i	S^2d_i	Mean	b_i	S^2d_i
104A x RSV 458	65.82	-0.33	11.01	24.92	0.70*	-2.15	10.31	3.82	0.40 **
104A x RSV 1006	73.93	2.41	120.95**	22.17	1.41	2.84	9.33	2.35	2.71 **
104A x RSV 1093	83.14	1.12	0.45	23.74	0.78	1.63	8.64	-2.07	0.06
104A x RSV 1130	72.07	-1.52	38.94*	24.96	0.23	-1.28	9.86	3.46	0.35 *
104A x RSV 1188	77.84	-3.77	40.47*	27.74	-0.28	-1.26	9.83	0.62	1.45 **
104A x RSV 1200	73.17	1.63	-0.49	32.45	0.16	-1.92	9.08	4.43	0.04
104A x RSV 1297	73.23	0.54	-1.33	32.33	1.17	-2.15	9.29	3.22	-0.04
104A x SPV 1359	66.25	0.60	12.84	26.54	2.05	-1.51	10.11	0.16	0.06
104A x RSV 1427	71.79	1.87	-1.00	27.57	-0.21	-2.10	9.09	0.80	-0.05
104A x RSV 1460	72.24	0.77	-5.85	30.15	1.87*	-2.14	8.94	-1.37	0.17
104A x SPV 1546	76.97	2.63	-5.74	36.47	-1.37	-0.67	9.14	4.07	0.20 *
104A x SPV 1704	68.64	0.08	-1.83	26.07	2.88	-1.68	9.00	-2.66	0.13
104A x RPOSV 3	34.88	4.81	-5.55	24.61	1.80	4.85	9.05	-2.18	0.37 **
104A x RSSGV 43	57.06	-3.73	2.80	24.28	2.54	0.06	9.03	-2.40	1.84 **
1343A x RSV 458	75.74	-0.05	7.61	29.50	-3.86	4.52	8.25	-0.92	1.52 **
1343A x RSV 1006	75.89	2.64	-4.65	22.41	-0.48	1.54	8.21	2.89	0.25 *
1343A x RSV 1093	86.80	-4.26	69.40**	28.51	-3.22	3.21	8.85	1.74	-0.03
1343A x RSV 1130	76.21	0.17*	-8.34	29.15	-0.21	2.39	8.52	0.69	-0.06
1343A x RSV 1188	84.55	0.98	-0.76	29.52	-4.29	6.27*	9.37	2.64	0.33 *
1343A x RSV 1200	104.77	3.06	-6.27	37.94	0.55	-2.07	8.28	3.11	0.24*
1343A x RSV 1297	72.86	8.65	73.24**	21.93	1.57	-1.43	8.31	1.57	-0.01
1343A x SPV 1359	103.05	2.53*	-8.37	37.78	2.29	-1.92	9.77	4.01	0.36 **
1343A x RSV 1427	93.09	-0.92	1.49	36.93	2.24	1.17	6.67	-0.77	1.10 **
1343A x RSV 1460	85.47	2.03	8.27	35.77	2.21	1.55	8.01	1.11	1.46 **
1343A x SPV 1546	77.16	7.78	-1.69	31.44	-1.67	3.61	6.37	-0.18	1.31 **
1343A x SPV 1704	96.69	-0.09	6.42	36.95	1.19	0.10	8.10	2.42	0.59 **
1343A x RPOSV 3	53.53	0.43	15.97	21.78	0.74	-1.61	8.35	-3.69	-0.01
1343A x RSSGV43	72.76	-6.97	90.56**	27.69	-0.58	1.46	8.52	0.76	1.16 **
1409A x RSV 458	60.03	2.55	232.74**	35.60	-1.02	10.62*	9.94	-1.71	0.09
1409A x RSV 1006	75.77	7.02	58.32**	28.97	1.12	-1.84	8.53	0.34	0.53 **
1409A x RSV 1093	84.30	-3.50	23.73	36.26	2.26	-2.08	10.35	2.21	0.23 *
1409A x RSV 1130	73.49	0.90	-0.73	24.47	0.71	-1.56	9.67	-3.32	0.45 **
1409A x RSV 1188	73.94	0.31	214.17**	29.73	4.75	6.86*	9.60	-3.24	0.40 **
1409A x RSV 1200	84.78	1.44	4.27	39.29	-0.26*	-2.14	7.63	4.99	0.97 **
1409A x RSV 1297	79.68	5.39	-5.97	32.66	3.57	4.44	9.41	-2.98	-0.03
1409A x SPV 1359	78.00	-0.50	-1.35	34.59	2.30	-1.86	9.09	-3.04	0.24 *
1409A x RSV 1427	74.47	2.60	-6.69	34.32	2.61	0.46	7.96	3.11	0.15
1409A x RSV 1460	73.19	6.08	83.29**	30.44	-1.15	9.95*	8.22	2.44*	-0.06
1409A x SPV 1546	76.38	3.31	-6.82	33.43	0.74	1.31	8.79	2.97	0.91 **
1409A x SPV 1704	74.74	8.17	69.25**	33.75	-1.20	-2.06	10.57	1.14	0.01
1409A x RPOSV 3	45.00	-0.92	61.19**	17.75	1.24	-2.13	9.65	4.98	0.30 *
1409A x RSSGV43	58.64	-1.62	21.26	29.10	-0.10	-5.70	11.21	3.02	-0.01
1543A x RSV 458	70.23	-1.12	6.90	32.99	-0.99	4.73	8.28	2.03	0.07
1543A x RSV 1006	71.48	4.56	3.17	34.52	-0.28	-1.85	8.42	2.44	0.51 **
1543A x RSV 1093	86.66	1.99	-4.32	31.91	-0.89	-0.40	8.78	3.37	0.02
1543A x RSV 1130	82.04	0.48	34.01*	28.39	-0.68	0.34	8.76	3.65	0.20 *
1543A x RSV 1188	94.49	-0.13	-6.26	36.31	1.14	-0.87	9.29	0.54	1.03 **
1543A x RSV 1200	81.95	3.72	43.26*	33.16	1.14	-0.63	7.74	-2.33	0.25 *

* and ** Significant at 5% and 1% level of probability, respectively.

1006. Cross 104A x RSSGV 43 showed above average stability and suitability to rich environments due to their low mean, regression coefficient more than unity and non significant S^2d_i values.

For plant height, 6 males were found stable as evident from its high mean with regression coefficient near to unity and non-significant non-linear components. The male parent RSV 1297 exhibited high mean with bi value significantly

Table 2.3 Contd…

Genotypes	Panicle weight(g)			Harvest index (%)			1000-grain weight(g)		
	Mean	b_i	S^2d_i	Mean	b_i	S^2d_i	Mean	b_i	S^2d_i
1543A x RSV 1297	106.99	3.52	-3.38	37.07	1.13	-0.50	8.22	1.82	0.78 **
1543A x SPV 1359	79.76	9.90	97.67**	31.85	0.89*	-2.15	8.83	-2.89	0.78**
1543A x RSV 1427	77.60	-3.321*	-8.03	33.18	0.44	-1.37	8.31	1.46	1.42 **
1543A x RSV 1460	80.53	6.50	0.03	34.16	-0.07	-1.29	8.06	-1.57	0.17
1543A x SPV 1546	82.06	5.33	39.27*	32.65	1.15	-1.69	6.77	4.18	0.02
1543A x SPV 1704	94.27	1.44	9.93	37.19	1.80	1.08	8.76	-2.50	0.95 **
1543A x RPOSV 3	44.60	1.43	73.64**	16.88	2.56	-1.07	8.41	1.50	0.99 **
1543A x RSSGV43	67.12	-3.53	33.53*	27.94	4.16	-0.09	8.40	-1.45	0.09
9168A x RSV 458	62.82	-4.291*	-7.82	20.82	3.51	-0.58	10.56	-1.14	3.17 **
9168A x RSV 1006	67.31	-4.20	-4.37	22.22	1.92	-1.86	11.50	4.71	0.90 **
9168A x RSV 1093	69.37	-2.05	41.65*	24.66	2.04	-1.81	10.02	-1.04	1.13 **
9168A x RSV 1130	82.83	1.13	-7.74	32.77	4.62	1.90	10.25	0.29*	-0.06
9168A x RSV 1188	69.06	-7.13	64.79**	18.19	-0.14	-1.08	11.07	5.67	1.95 **
9168A x RSV 1200	71.91	2.95	-5.72	29.54	0.35*	-2.15	10.70	-1.68	3.33 **
9168A x RSV 1297	74.55	-3.18	92.78**	21.90	-0.73	-1.58	12.01	-4.19*	-0.05
9168A x SPV 1359	74.28	0.69	68.41**	21.38	-0.35	8.07*	11.02	1.66	0.54 **
9168A x RSV 1427	63.05	-3.90	28.87*	22.72	3.09	-0.72	10.72	2.39	0.88 **
9168A x RSV 1460	68.69	-2.23	-4.41	20.79	0.75	-1.33	10.06	3.29	-0.05
9168A x SPV 1546	75.11	0.68	-1.80	25.76	2.12	-1.23	9.48	0.09	-0.04
9168A x SPV 1704	67.18	0.06	33.63*	25.24	2.49	0.23	9.41	-1.11	0.69 **
9168A x RPOSV 3	40.75	-0.67	32.71*	23.43	2.98	2.51	9.83	2.15	0.78 **
9168A x RSSGV 43	63.05	-1.33	-3.66	18.94	2.84*	-2.12	9.44	3.82	-0.00
CSH 15 R (c)	72.42	1.65	-8.32	26.83	2.03*	-2.14	8.93	-1.67	4.70
Mean (Hybrids)	74.37			28.94			9.14		
104A	66.46	0.80	2.93	28.72	0.70	-1.81	8.29	2.17	1.95 **
1343A	71.05	1.67	2.33	30.05	1.79	-1.86	7.83	3.91	0.50 **
1409A	53.45	1.53	140.07**	32.22	-0.66	11.05*	8.11	3.88	0.46 **
1543A	66.43	2.29	1.20	31.16	0.54	4.32	8.27	3.68	-0.04
9168A	58.73	2.67	-8.25	28.06	2.11	0.55	8.36	4.20	-0.01
RSV 458	58.77	0.17	-2.82	27.57	1.74	-1.61	7.42	4.39	-0.02
RSV 1006	60.80	3.22	-2.23	24.63	1.64	-2.02	8.62	-4.24	2.06**
RSV 1093	78.41	1.15	-5.96	26.63	2.33*	-2.15	7.32	-4.11	0.08
RSV 1130	69.81	0.08	-7.81	25.69	0.56*	-2.14	6.99	-2.07	0.36**
RSV 1188	76.02	-0.41	-4.37	24.96	2.24	-1.59	7.21	2.63*	-0.06
RSV 1200	72.58	3.14	-3.91	23.60	-0.10	-2.05	7.18	-1.18	2.90**
RSV 1297	69.97	3.09	-5.35	24.85	0.87	-1.03	7.24	-2.35	0.80**
SPV 1359	74.15	1.84	-1.35	22.54	2.14	-1.90	8.30	4.59*	-0.06
RSV 1427	60.68	1.19	-5.36	24.51	3.00	-0.97	8.31	2.93	0.80**
RSV 1460	67.69	3.98	23.48	21.43	0.13	-1.86	8.39	6.60	0.29*
SPV 1546	68.59	2.23	-7.06	22.83	0.51	-1.15	8.45	-0.06*	-0.06
SPV 1704	66.66	-2.33	-5.83	23.08	0.12*	-2.15	8.59	1.77	-0.00
RPOSV 3	72.44	3.43	-2.01	24.19	4.02	0.14	8.19	0.79	0.66**
RSSGV 43	44.73	-1.77	3.41	24.85	3.04	3.68	8.19	1.88	3.76**
BP 53 (c)	73.87	-0.07	-5.03	28.84	0.40	-1.80	9.48	-0.51	3.11**
Mean (Parents)	66.56			26.02			8.04		

* and ** Significant at 5% and 1% level of probability, respectively.

less than unity and non significant S^2d_i values, showed above average stability which was suitable for poor environments. Among hybrids, 25 hybrids exhibited high mean along with regression coefficient near unity and non-significant deviation from regression and therefore they were classified as stable hybrids. The superlative five stable hybrids were 1543A

Table 2.4 Stability parameters for protein content in *rabi* sorghum

Genotypes	Protein content (%)			Genotypes	Protein content (%)		
	Mean	b_i	S^2d_i		Mean	b_i	S^2d_i
104A x RSV 458	10.31	3.82	0.40 **	1543A x RSV 1200	7.74	-2.33	0.25 *
104A x RSV 1006	9.33	2.35	2.71 **	1543A x RSV 1297	8.22	1.82	0.78 **
104A x RSV 1093	8.64	-2.07	0.06	1543A x SPV 1359	8.83	-2.89	0.78**
104A x RSV 1130	9.86	3.46	0.35 *	1543A x RSV 1427	8.31	1.46	1.42 **
104A x RSV 1188	9.83	0.62	1.45 **	1543A x RSV 1460	8.06	-1.57	0.17
104A x RSV 1200	9.08	4.43	0.04	1543A x SPV 1546	6.77	4.18	0.02
104A x RSV 1297	9.29	3.22	-0.04	1543A x SPV 1704	8.76	-2.50	0.95 **
104A x SPV 1359	10.11	0.16	0.06	1543A x RPOSV 3	8.41	1.50	0.99 **
104A x RSV 1427	9.09	0.80	-0.05	1543A x RSSGV43	8.40	-1.45	0.09
104A x RSV 1460	8.94	-1.37	0.17	9168A x RSV 458	10.56	-1.14	3.17 **
104A x SPV 1546	9.14	4.07	0.20 *	9168A x RSV 1006	11.50	4.71	0.90 **
104A x SPV 1704	9.00	-2.66	0.13	9168A x RSV 1093	10.02	-1.04	1.13 **
104A x RPOSV 3	9.05	-2.18	0.37 **	9168A x RSV 1130	10.25	0.29*	-0.06
104A x RSSGV 43	9.03	-2.40	1.84 **	9168A x RSV 1188	11.07	5.67	1.95 **
1343A x RSV 458	8.25	-0.92	1.52 **	9168A x RSV 1200	10.70	-1.68	3.33 **
1343A x RSV 1006	8.21	2.89	0.25 *	9168A x RSV 1297	12.01	-4.19*	-0.05
1343A x RSV 1093	8.85	1.74	-0.03	9168A x SPV 1359	11.02	1.66	0.54 **
1343A x RSV 1130	8.52	0.69	-0.06	9168A x RSV 1427	10.72	2.39	0.88 **
1343A x RSV 1188	9.37	2.64	0.33 *	9168A x RSV 1460	10.06	3.29	-0.05
1343A x RSV 1200	8.28	3.11	0.24*	9168A x SPV 1546	9.48	0.09	-0.04
1343A x RSV 1297	8.31	1.57	-0.01	9168A x SPV 1704	9.41	-1.11	0.69 **
1343A x SPV 1359	9.77	4.01	0.36 **	9168A x RPOSV 3	9.83	2.15	0.78 **
1343A x RSV 1427	6.67	-0.77	1.10 **	9168A x RSSGV 43	9.44	3.82	-0.00
1343A x RSV 1460	8.01	1.11	1.46 **	CSH 15 R (c)	8.93	-1.67	4.70
1343A x SPV 1546	6.37	-0.18	1.31 **	Mean (Hybrids)	9.14		
1343A x SPV 1704	8.10	2.42	0.59 **	104A	8.29	2.17	1.95 **
1343A x RPOSV 3	8.35	-3.69	-0.01	1343A	7.83	3.91	0.50 **
1343A x RSSGV43	8.52	0.76	1.16 **	1409A	8.11	3.88	0.46 **
1409A x RSV 458	9.94	-1.71	0.09	1543A	8.27	3.68	-0.04
1409A x RSV 1006	8.53	0.34	0.53 **	9168A	8.36	4.20	-0.01
1409A x RSV 1093	10.35	2.21	0.23 *	RSV 458	7.42	4.39	-0.02
1409A x RSV 1130	9.67	-3.32	0.45 **	RSV 1006	8.62	-4.24	2.06**
1409A x RSV 1188	9.60	-3.24	0.40 **	RSV 1093	7.32	-4.11	0.08
1409A x RSV 1200	7.63	4.99	0.97 **	RSV 1130	6.99	-2.07	0.36**
1409A x RSV 1297	9.41	-2.98	-0.03	RSV 1188	7.21	2.63*	-0.06
1409A x SPV 1359	9.09	-3.04	0.24 *	RSV 1200	7.18	-1.18	2.90**
1409A x RSV 1427	7.96	3.11	0.15	RSV 1297	7.24	-2.35	0.80**
1409A x RSV 1460	8.22	2.44*	-0.06	SPV 1359	8.30	4.59*	-0.06
1409A x SPV 1546	8.79	2.97	0.91 **	RSV 1427	8.31	2.93	0.80**
1409A x SPV 1704	10.57	1.14	0.01	RSV 1460	8.39	6.60	0.29*
1409A x RPOSV 3	9.65	4.98	0.30 *	SPV 1546	8.45	-0.06*	-0.06
1409A x RSSGV43	11.21	3.02	-0.01	SPV 1704	8.59	1.77	-0.00
1543A x RSV 458	8.28	2.03	0.07	RPOSV 3	8.19	0.79	0.66**
1543A x RSV 1006	8.42	2.44	0.51 **	RSSGV 43	8.19	1.88	3.76**
1543A x RSV 1093	8.78	3.37	0.02	BP 53 (c)	9.48	-0.51	3.11**
1543A x RSV 1130	8.76	3.65	0.20 *	Mean (Parents)	8.04		
1543A x RSV 1188	9.29	0.54	1.03 **				

* and ** Significant at 5% and 1% level of probability, respectively.

x RSV 1297, 9168A x SPV 1359, 1343A x RSV 1200, 9168A x RSV 1188 and 1343A x SPV 1359. Four hybrids were found above average stable and suitable for poor environments whereas, one hybrid 9168A x RSV 1006 was found below average stable for this trait.

As regards to panicle length, among the parents, three females *viz*., 1343A, 1543A and 9168A and three males *viz*., RSV 1093, RSV 1200 and SPV 1359 recorded higher mean than parental mean with bi magnitude not significantly deviating from unity and non-significant deviation from regression, hence were considered as stable. Out of 70 hybrids tested, 27 hybrids exhibited high mean, along with regression coefficient near unity and non-significant deviation from regression and therefore they were classified as stable hybrids. Among the hybrids, 2 hybrids *viz*., 1409A x SPV 1546 and 104A x RSV 1297 exhibited high mean, b_i value significantly greater than unity and non-significant deviation from regression showing below average stability and were found suitable for rich environments. The superlative five stable hybrids were 1543A x SPV 1359, 1343AxSPV 1359, 1343AxRSV 1200, 1543A x SPV 1704 and 1543A x RSV 1188.

For primaries per panicle the female 1343A along with 4 male parents and check BP 53 were stable as evident from their high mean, unit regression coefficient and non-significant non-linear component. Among the 70 hybrids and check (CSH 15R) tested, 27 hybrids exhibited high mean, along with regression coefficient near unity and non-significant deviation from regression and therefore they were classified as stable hybrids. The superlative five stable hybrids were 1543A x RSV 1297, 1343A x RSV 1200, 1343A x SPV 1359, 1543A x SPV 1704 and 1343A x SPV 1704. The two hybrids 104A x RSV 1130 and 1343A x SPV 1546 showed below average stability which were suitable for rich environments.

Among parents, one female (1343A), 10 males and check BP 53 had higher mean than parental mean with bi magnitude not significantly deviating from unity and non-significant deviation from regression, were considered stable for panicle weight. Among the hybrids, 23 hybrids exhibited high mean, along with regression coefficient near unity and non-significant deviation from regression and therefore they were classified as stable hybrids. Two hybrids, 1343A x RSV 1093 and 1543A x RSV 1427 recorded high mean, bi significantly less than unity, exhibited above average response and suitability for poor environments. One hybrid 1343A x SPV 1359 exhibited high mean, bi value significantly greater than unity and non-significant S^2d_i, showing below average stability and suitability for favourable environments. The superior five stable hybrids were 1543A x RSV 1297, 1343A x RSV 1200, 1343A x SPV 1704, 1543A x RSV 1188 and 1543A x SPV 1704.

For harvest index, 4 females, 01 male (RSV 458) and varietal check BP 53 recorded high mean, non significant regression coefficient and non-significant S^2d_i values showing average stability over environments. The male parent RSV 1093 was found suitable for favourable environments. Among 70 hybrids, 30 hybrids had high mean, non significant regression coefficient and non-significant S^2d_i values which indicated their ideal stability over environments. The performance of 4 hybrids (1343 A x RSV 1188, 1409A x RSV 458, 1409A x RSV 1188 and 1409A x RSV 1460) could not be predicted under variable environments in view of significant S^2d_i values. Three hybrids 1409A x RSV 1200, 1543A xS PV 1359 and 9168A x RSV 1200 exhibited high mean, b_i value significantly less than unity and non-significant deviation from regression showed above average stability which were suitable for poor environments, whereas hybrid 104A x RSV 1460 was suitable for rich environment. The best five hybrids among the stable hybrids for this trait 1343A x RSV 1200, 1343A x SPV 1359, 1543A x SPV 1704, 1543A x RSV 1297 and 1543A x SPV 1704.

As regards to 1000- grain weight, among the parents, 3 male along with check BP 53 had higher mean than parental mean with bi magnitude not significantly deviating from unity and non-significant deviation from regression, hence were considered as stable for this trait. Among all parents RSV 1188 and hybrids cross 9168A x SPV 1546 exhibited high mean, bi value significantly greater than unity and non-significant S^2d_i values, exhibiting below average stability which was suitable for rich environments, while male SPV 1704 has exhibited above average stability for this trait. Performance of 16 hybrid, 6 testers and 1 female was unpredictable behaviour due to high mean bi around unity and S^2d_i significantly deviating from zero. Out of 70 hybrids and check (CSH 15R) tested, 14 hybrids exhibited high mean, along with regression coefficient near unity and non-significant deviation from regression and therefore they were classified as stable hybrids. The superlative three stable hybrids were 1543A x RSV 1188, 1543A x RSV 1297 and 1343A x RSV 1200.

For protein content, females 1543A and 9168A along with one male parent SPV 1704 had higher mean than parental mean, bi magnitude not significantly deviating from one and non-significant deviation from regression, hence were considered stable for this trait. Among the males, SPV 1546 and among crosses, 9168A x RSV 1130 and 9168A x RSV 1297 exhibited bi value significantly less than one, showing above average stability which were suitable for poor environments. Among the hybrid group, 9 hybrids exhibited high mean, along with regression coefficient near unity and non-significant deviation from regression and therefore they were classified as stable hybrids. Performance of 20 hybrids was unpredictable due to high mean bi around unity and S^2d_i value significantly deviating from zero. The superlative five stable hybrids were 1409 A x RSSGV 43, 1409A x SPV 1704, 104A x SPV 1359, 9168A x RSV 1460 and 1409A x RSV 458.

When stability parameters as suggested by Eberhart and Russell (1966) were studied for different genotypes (5 females, 14 males, 70 hybrids and 2 checks), it was revealed that none of the genotype was found stable for all the traits. Any generalization regarding stability of genotypes for all the attributes was therefore not possible. Among these genotypes, 25 hybrids exhibited unit regression (bi) and least deviation from regression (S^2d_i) and therefore they were classified as stable with average response to environments. Perusal of stability parameters further revealed that 8 parents were found to be stable for grain yield for all the environments. In general, the female and male parents behaved differently in different environments as observed by Patel *et al.* (1984). However, it was noticed that the male parent RSV 1460 and RPOSV 3 exhibited bi value significantly greater than one, showed below average stability and suitability for rich environments for grain yield per plant. Instances where a few true breeding varieties were comparable in yield to hybrids under favorable environmental conditions have been reported by Rao and Harinarayana (1969) and Singhania and Rao (1976).

The hybrids (heterozygous entries) were in general, slightly more stable than the parents (homozygous ones), but the wide ranges found within both the parents and hybrids for stability parameters indicated that it should be possible to select stable entries at both levels of genetic structure. These results corroborated with the findings of Reich and Atkins (1970), Majisu and Dogget (1972), Patanothai and Atkins (1974), Rao *et al.* (1981), Patel *et al.* (1984), Haussmann *et al*. (2000) and Kale (2012).

From the stability analysis, it could be seen that the best three stable hybrids for grain yield per plant were 1543A x RSV 1297, 1343A x RSV 1200, 1343A x SPV 1359. In general, the hybrids found stable for grain yield also showed stability for two or more component characters, which indicated that the stability of various component traits might be responsible for the observed stability of various hybrids for grain yield per plant. In the present investigation, the best three hybrids *viz*., 1543A x RSV 1297, 1343A x RSV 1200, 1343A x SPV 1359 were found to have average stability over environments for grain yield per plant with one or more stable yield contributing attributes, signifying their potential for commercial exploitation for genetic improvement in rabi sorghum.

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Surface Runoff Estimation for Rainwater Harvesting in Godawari-Purna Sub-basin Using RS & GIS for Marathwada Region of Maharashtra

M. S. Pendke[1], D. P. Waskar[2] and S. H. Narale[3]
Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani - 431 402 (India)
Corresponding author : Email : mspendke1@rediffmail.com

Abstract

Water is a prime natural resource and considered as a precious national asset. It is also a basic need for agricultural planning and development. The goals of water resource management of any project may be achieved by planning suitable water harvesting structure at proper locations. Marathwada region of Maharashtra state has always been a water deficit area which calls for immediate remedial measures to address the critical water resources situation in the region. The entire Godawari-Purma sub basin is hard rock terrain. It suffers from growing water scarcity, which is aggravated by frequent droughts. The GP sub basin is located between 76°36' to 77°59' E and 19°07' to 19°17'N with an area of 34413.87 ha falls in assured rainfall region.The basin boundary is updated using the updated drainage and terrain information from high resolution satellite data of LISS-IVusing GIS tool. Based on the derived thematic maps of land use, hydrological soil group and land capability class, curve numbers for respective area of the sub watershed were determined. Based on the last 30 years rainfall records, the runoff potential was estimated using SCS curve number method. Out of the 11 sub catchments, the minimum runoff depth and runoff volume was found to be in sub catchment no IX. The maximum runoff depth and runoff volume was found to be in sub catchment no. IV. Overall in Godawari-Purna sub-basin, the runoff volume of 159.403 TCM was generated from an area of 34413.87 ha. The sub catchment wise runoff depth and runoff volume maps were generated using Arc-GIS software. The runoff estimation study indicated that there is a good scope for runoff harvesting and hence, many number of rainwater harvesting structures could be constructed for runoff harvesting which in future could be a source for supplemental irrigation to enhance the crop production.

Key words : Catchment, Curve number, Hydrological soil group, Rainfall, Runoff.

Rainfed agriculture in India faces persistent challenges which have a bearing on its potential contribution towards poverty reduction, food security and sustainable productivity growth. Of the 141 M ha of net sown area in the country, 80 M ha is rainfed. Rainfed agriculture contributes 40% of food grain production and supports 2/3rd of the livestock population. Though, impressive gains were noted in some of the rainfed crops in recent times, the gap between attainable and farmers' yields still remain high which is a major cause of concern. Small and marginal farmers who are the backbone of rainfed farming are resource poor and risk averse. Moreover, both public and private investments in technology adoption and infrastructure have been quite low in rainfed agriculture resulting in a vicious circle of low yields-low net returns-low investments in improved technologies. With several resource management problems emerging in irrigated regions, rainfed agriculture offers scope to contribute to the growing food needs of future particularly of pulses and edible oils.

Surface water is an important and a dependable source of water supplies in all climatic regions. Rainwater harvesting in water harvesting structures for supplemental irrigation is an important strategy for stabilizing yields of rainfed crops in Marathwada region of

1. Agricultural Engineer, AICRP on Dryland Agriculture, 2. Director of Research and 3. Agricultural Assistant, AICRP on Dryland Agriculture.

Maharashtra. Surface water harvesting structures are promoted in the Integrated Watershed Management Programme (IWMP) and under MGNREGS as a drought proofing strategy. More recently, farm ponds are integrated with micro irrigation programme under National Mission, particularly in states like Maharashtra and Andhra Pradesh. With continued over-exploitation of ground water, it is important to use surface water harvested as surplus runoff in water harvesting structures, either as stand-alone resource or in conjunction with ground water for enhancing water productivity, particularly in arid and semi-arid regions.

Marathwada region of Maharashtra state experiences wide district and intra district climate variability. The annual rainfall in the region ranges from 516 mm to 1109 mm. The agriculture in an area is mostly depend on rainfall as more than 85 % area is rainfed. Majority of the population depend upon rainfed agriculture and the productivity is uncertain due to deficiencies of rainfall, occurrence of frequent dryspells resulted to moisture stress.

The need for application of modern approaches like Remote Sensing and GIS techniques has been emphasized for efficient management of water resources. Rapid advances in the development of Geographical Information System (GIS) provides spatial data integration and tools for natural resource management and have enabled integrating the data in an environment which has been proved to be an efficient and successful tool for surface and ground water studies (Meijerink, 1996).In recent years, use of satellite remote sensing data along with GIS and topographical maps has made it easier to establish the base line information on water resource planning. (Sreenivasanand Krishna Murthy, 2018) In the present study, remote sensing and GIS tools were used for development of thematic maps and thereby, estimation of runoff potential.

Materials and Methods

The study on surface runoff estimation for assessing the rainwater harvesting was conducted Godawari-Purna sub basin, located between 76°36' to 77°59' E and 19°07' to 19°17'N. The geographical area of the basin is 34413.87 ha. Most of the area is under cultivation with no forest and only 0.4 % area is under waste land and GaothanThe basin area falls under assured rainfall zone of Marathwada region of Maharashtra. The average annual rainfall of the area is 885 mm.The location of the study area is shown in Fig 1.

The SOI toposheet (1:50000 scale) of the study area was collected from Regional Remote Sensing Centre-Central, NRSC, ISRO, Nagpur. The scientific data are listed as below and was procured from National Remote Sensing Centre (NRSC) ISRO, Hyderabad. In the present research work, the manual method of basin boundary delineation has been followed. The reference basin area was first delineated from the drainage and terrain information from 1:50 K topomaps. Further, this basin boundary was updated using the updated drainage and terrain information from high resolution satellite data.

Satellite data acquisition : The Resource sat 2, LISSIV data of 15th October 2011 and 24th April 2012 were used for undertaking this

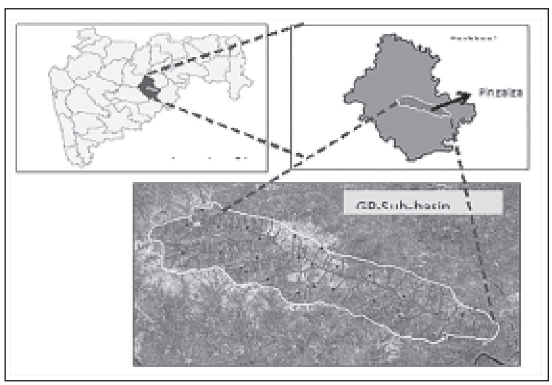

Fig. 1. Location of the Godawari-Purna sub basin (study area)

study. The recent data for of Resource sat 2 LISS IV of 25th March 2016 i.e. before monsoon season and of 20th November 2016 i.e. of post monsoon season were utilized for detailed study. The basic soil depth, soil texture and hydrological soil group maps on 1:250000 scales were procured from the NRIS project of ISRO. The layers on geomorphology, land use, drainage, water bodies and base layers have been prepared from satellite data interpretation. The rainfall data of last 30 years were collected from Department of Agricultural Meteorology, VNMKV, Parbhani and the rainfall data of the normal rainfall year was used to estimate the surface runoff potential using SCS curve number technique. The SCS curve number techniques is based on recharge capacity of the basin. (Mishra *et al*. 2006).The recharge capacity was determined by antecedent moisture condition and by physical characteristics of the watershed. Antecedent moisture condition (AMC) was used as an index of basin wetness. The selection of curve numbers was based on various hydrologic soil cover, land use, treatment or cultivation practices, hydrological condition of the area and hydrological soil group.

Using remote sensing and GIS tools, various thematic maps *viz*., land use / land cover, hydrological soil group and slope maps were developed. Based on the derived thematic maps of land use, hydrological soil group and land capability class using high resolution satellite image of LISS-IV and union of all these thematic maps, curve numbers for respective area of the sub watershed were determined. The curve numbers for each class of land and its respective hydrological soil group were worked out for AMC I, II, and III respectively and accordingly the weighted curve numbers for the sub catchments area were determined. Using SCS curve number method, runoff was determined following standard procedure.ERDAS IMAGINE software was used for satellite data processing, geo-referencing, digital image processing. ARC GIS 10.3.1 software package was used for generating the GIS database of thematic layers and their integration and analysis.

Basin boundary was delineated by manual method using DEM as input. In manual method, the drainage lines and contours were taken as the reference. Firstly, the point was chosen as the basin outlet, which will be the pore point for all the water draining out of that basin. Basin boundary was delineated by drawing lines perpendicular to the elevation contours for the land that drains to the point of interest.

Generation of thematic maps : Thematic maps *viz*., land use cover, has been interpreted using the visual interpretation techniques by heads-on digitization in the GIS environment using the enhanced high-resolution satellite imagery. Image interpretation element keys namely tone, texture, shape, size, pattern, association, etc. have been used for mapping these features. Other thematic layers namely soil depth, soil texture and hydrological soil groups have been sourced from the existing NRIS database and updated using the high-resolution satellite imagery. Slope map has been generated from CartoDEM using the surface tools of the spatial analyst toolbox in ArcGIS.

Assessment of Surface Runoff Potential : The rainfall data for the last 30 years was used to estimate the surface runoff potential using SCS curve number technique. The SCS curve number techniques is based on recharge capacity of the watershed. The recharge capacity was determined by antecedent moisture condition and by physical characteristics of the watershed. Antecedent moisture condition (AMC) was used as an index of watershed wetness. (Vinod Kumar and Rastogi, 1989; Shrivastav and Rao, 1993).

Using the thematic maps of land use/ land cover and hydrological soil group and integrating them in raster using UNION tool of arc tools, the area of each class of land was worked out. Assigning the suitable curve numbers for respective land use and HSG to each area, the weighted curve number was determined and used in estimation of runoff potential. The layer of surface runoff depth and surface runoff volume of each sub catchment were prepared. Kadam *et al*. 2012 estimated runoff using SCS CN method and various thematic layers. Similar procedure was adopted in the present study.

Results and Discussion

Various thematic layers *viz*., land use, land slope and hydrological soil groupwere generated using merged product of Cartosat-1 and high resolution satellite data of Resourcesat-2, LISS-IV images of March 25, 2016 and November 20, 2016 and shown in Fig. 2 to Fig. 4.

Land use mapping indicated that 85.68 per cent land is under cultivation with cropped area indicating a good vegetative cover in basin area. Digital Elevation Model (DEM) indicated that majority of the area of basin is having a slope in the range of 0 to 3 percent. The hydrological soil group map was generated and the basin area was classified in HSG II, HSG-III and HSG –IV group. The majority of the land was found to be under HSG-IV group. In the central upper part of the basin, the area was found to be under HSG-III group.

Surface runoff potential : Based on the derived thematic maps of land use, hydrological soil group and land capability class using high resolution satellite image of LISS-IV and union of all these thematic maps, curve numbers for respective area of the sub catchments were determined. The curve numbers for each class of land and its respective hydrological soil group were worked out for AMC I, II, and III respectively and accordingly the weighted curve numbers for the sub catchments were determined. Based on the last 30 years rainfall records, the runoff potential for the normal

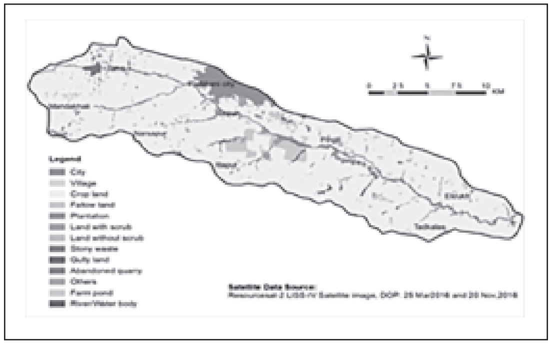

Fig. 2. Land use / land cover map of GP sub basin

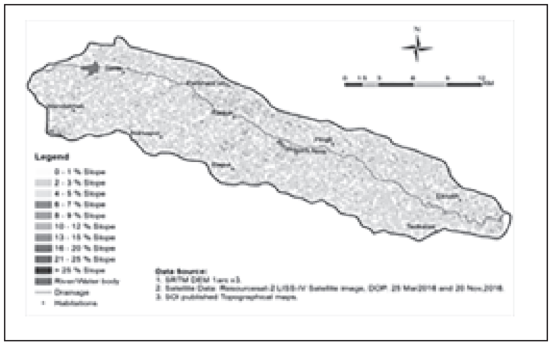

Fig. 3. Land slope map of GP sub basin

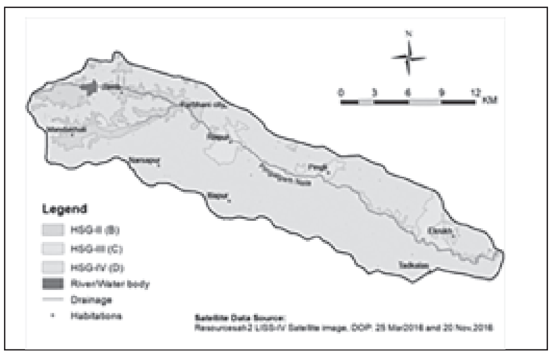

Fig. 4. Hydrological soil group map of GP sub basin

rainfall year was estimated for the basin area. The runoff depth and volume for each sub catchment was estimated and the data is presented in Table 1.

Out of the 11 sub catchments, the minimum runoff depth and runoff volume was found to be

Table 1. Runoff and runoff volume in sub catchments of GP basin

Sub catchment number	Area, ha.	Runoff depth, m	Runoff volume, Cu.m.
I	4913.06	0.43402	21323
II	4810.67	0.43795	21068
III	2310.90	0.45397	10490
IV	4924.70	0.47318	23302
V	2164.08	0.47672	10316
Vi	4079.51	0.48268	19691
VII	1948.58	0.47881	9330
VIII	2933.44	0.47963	14069
IX	1955.97	0.45586	8916
X	2341.60	0.48167	11278
XI	2031.35	0.47334	9615
Total	34413.87		159403

in sub catchment no IX. The maximum runoff depth and runoff volume was found to be in sub catchment no. IV. Overall in Godawari-Purna sub basin the runoff volume of 159.403 TCM was estimated to generate from an area of 34413.87 ha.The sub catchment wise runoff depth and runoff volume maps were generated using Arc-GIS software and shown in Fig. 5 and 6.

The storm-wise rainfall and runoff estimated by curve number method for each sub catchment for the normal rainfall year is presented in Table 2.

Out of the 11 sub catchment, the minimum runoff depth and runoff volume was found to be in sub catchment no IX. The maximum runoff depth and runoff volume was found to be in sub catchment no. IV. Overall in Godawari-Purna sub-basin, the runoff volume of 159.403 TCM was generated from an area of 34413.87 ha.

Table 2. Storm-wise rainfall and runoff for each sub-catchment

Date/ month	Rain-fall, mm	Runoff, mm										
		Sub cat-1	Sub cat-2	Sub cat-3	Sub cat-4	Sub cat-5	Sub cat-6	Sub cat-7	Sub cat-8	Sub cat-9	Sub cat-10	Sub cat-11
29/5	44.6	17.42	17.70	19.01	20.70	20.85	21.40	21.05	21.19	19.13	21.26	20.68
1/6	46.2	31.06	31.35	32.63	33.99	34.20	34.68	34.40	34.47	32.76	34.47	34.06
3/6	30.0	16.80	17.03	18.01	19.09	19.25	19.64	19.42	19.47	18.11	19.47	19.14
6/6	22.4	10.67	10.85	11.63	12.51	12.64	12.96	12.77	12.82	11.71	12.82	12.55
7/6	15.0	1.64	1.65	1.64	1.69	1.70	1.71	1.70	1.69	1.69	1.69	1.69
10/6	42.0	27.26	27.54	28.75	30.06	30.25	30.71	30.44	30.51	38.87	30.51	30.12
30/6	33.6	19.87	20.10	21.17	22.32	22.50	22.91	22.67	22.73	21.28	22.73	22.38
6/7	44.0	29.06	29.35	30.59	31.93	32.12	32.59	32.32	32.39	30.72	32.39	31.99
8/7	15.0	1.64	1.65	1.66	1.67	1.70	1.71	1.70	1.70	1.70	1.70	1.70
11/7	18.0	1.96	1.97	2.05	2.08	2.10	2.16	2.12	2.12	2.12	3.91	3.00
6/8	36.0	11.80	12.02	13.06	14.41	14.54	14.99	14.71	14.70	13.16	14.88	14.41
9/8	54.0	38.24	38.56	39.93	41.40	41.61	42.12	41.83	41.90	40.07	41.90	41.47
10/8	77.0	60.00	60.37	61.97	63.62	63.86	64.44	64.11	64.19	62.12	64.19	63.70
11/8	15.0	1.64	1.65	1.69	1.70	1.72	1.73	1.72	1.72	1.71	1.72	1.71
23/8	125.0	106.7	107.1	108.9	110.8	111.1	111.7	111.3	111.4	109.1	111.4	110.9
24/8	34.0	20.21	20.45	21.52	22.69	22.86	23.27	23.04	23.09	21.63	23.09	22.74
26/8	27.0	15.75	15.93	15.44	16.45	16.60	16.96	16.75	16.80	15.53	16.80	16.49
28/8	22.0	10.36	10.53	11.31	12.17	12.30	12.62	12.44	12.48	11.39	12.48	10.68
29/8	24.0	11.92	12.10	12.94	13.86	14.81	14.33	14.14	14.19	13.02	14.19	13.90
Total	434.02	437.95	453.97	473.18	476.72	482.68	478.81	479.63	455.8	481.6	473.3	

Kothyari *et al.* 2004 determined rainfall runoff relationship and results of this study confirms with the previous work. Borah, 1989and Capece *et al*. 1988 worked on runoff simulation for the watershed area. Similar results are obtained in this study. Kale *et al.* 1992 worked on effect of slope on runoff potential. In the present study, the slope map was used for estimation of runoff potential from the basin.

Conclusion

1. Remote Sensing coupled with GIS technique is proved as an efficient tool for runoff estimation from large area catchments.It also proved as a convenient method for fast extraction of information related to estimation of runoff potential.

2. The latest improvement in Remote Sensing technology like high spatial and temporal resolutions has made the micro level water resource planning more easy.

3. Estimation of runoff potential from Godawari_Purna sub basin will help for future planning of water harvesting structures.

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Influence of Enzyme Assisted Processing on Extraction and Antioxidant Activity of Dragon Fruit Juice

N. U. Thoke[1], V. S. Khandare[2] and D. P. Waskar[3]
Department of Horticulture,
Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani - 431 402 (India)
Email : dpwaskar@gmail.com

Abstract

The present investigation was undertaken to optimize a process for enhanced extraction of dragon fruit juice. The experiment was laid out in completely randomized design with four treatment replicated five times. The experimental results revealed that the enzyme assisted processing (EAP) using cell wall degrading enzyme pectinase T_3 - 0.15% pectinase remarkably improved the functional quality of dragon fruit juice resulting in enhanced juice yield, total phenols, betacyanin and total antioxidant activity.

Key words : Dragon fruit, enzyme, juice, yield, antioxidant activity.

Dragon fruit known to be rich in nutritional value, especially rich in betalins which meet the increasing trade interest for antioxidant products and natural food colorants. Among the red dragon fruit species *Hylocererus polyrhizus* (Red Flesh) fruits are edible and it has a great source of vitamin C and water soluble fiber (Mizrahi and Nerd, 1999). It is also reported that dragon fruit have health benefits including prevention of memory losses, prevention of cancer control of blood glucose level in diabetic patients, prevention of oxidation, aiding in healing of wounds etc. In addition, it has the ability to promote the growth of probiotics in the intestinal tract (Zainoldin and Baba, 2009).

Processing dragon fruit into juice is a difficult task of an industrial scale as no specialized equipment for extracting such a juice is currently available. Presently, juice extraction is done manually by halving the fruit and extracting the pulp with a spoon. The pulp behaves as a non-newtonian fluid with high apparent viscosity and it is suspected of having a strong shear thinning behavior like other mucilaginous material from cactus fruits. This makes it very difficult to remove the thousands of small soft seeds (diameter<1mm) by simple sieving, and juice without seeds can only be obtained by drastically reducing juice yield. Extraction of juice using the commercial pectinolytic enzymes and amylolytic enzyme will produce clearer fruit juice without cloudy appearance (Lee *et al.* 2006), enzymatic hydrolysis can be used to promote high yield, better viscosity and quality fruit juice (Qin *et al*. 2005). Therefore, research investigation on influence of enzyme assisted processing on extraction and antioxidant activity of dragon fruit juice was undertaken.

Material and Methods

The present investigation was undertaken at Department of Horticulture, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani during years 2018-2019 and 2019-2020.The experiment was laid out in completely randomized block design with five replications and four treatments. The treatments consisted of T_1 - 0.05 % pectinase, T_2 - 0.1% pectinase, T_3 - 0.15% pectinase and T_4 - control (without enzyme).

1. Ph. D (Hort.) Scholar, 2. Professor and 3. Director of Research.

Table 1. Effect of enzyme assisted processing on Juice Yield of dragon fruit

Treatment	Juice yield (%)		
	2018-2019	**2019-2020**	**Pooled mean**
T_1 - Pectinase 0.05%	79.60	79.13	79.36
T_2 - Pectinase 0.1%	82.67	82.91	82.79
T_3 - Pectinase 0.15%	84.91	87.19	86.05
T_4 - Control	60.00	61.84	60.92
C.D	4.68	4.84	4.84
S.E(m) ±	1.41	1.46	1.46

Freshly harvested dragon fruits washed, peeled and scooped out the flesh and were crushed coarsely by using laboratory scale blender. The crushed macerate subjected to HTST (80°C for 120 min.) for enzymatic liquefaction. The heated macerate was brought down to a temperature of 60°C and treated with the enzyme pectinase (EC 3.2.1.1 from *Aspergillus niger*, 1 U mg^{-1}) at four dosages level 0.05, 0.1 and 0.15%, respectively. The macerate was incubated at 60°C for 1h followed by pressing with hydraulic press by using nylon filter bags. The extracted juice was heat processed at 90°C for 1 min. and packed in clean sterilized glass bottles, upturned and sealed. The juice was then analyzed for physiochemical parameters (TSS, acidity, pH and ascorbic acid) and antioxidant (betacyanin, total phenolic, total flavonoid) contents and total antioxidant activity. The data obtained in the present investigation were analyzed as suggested by Panse and Sukhatme (1995).

Results and Discussion

Data presented in Table 1 revealed that the effect of enzyme assisted prosessing on juice yield of dragon fruit. There was a significant increased in juice yield to 79.36% and 82.79% was observed with EAP. Significantly higher juice yield (86.05%) was found in treatment T_3 - 0.15% pectinase. Enhanced juice yield is a result of the enzyme catalyzed degradation of the pectin in the plant cell wall matrix and in the middle lamella that not only acts as putty between the cells but also binds water. The pectinase enzyme at all concentration was thus effective in catalyzing the desired degradation of pectin to release juice from dragon fruit pulp. Similar results reported by Truong *et al*., (2016) found significant increase in juice yield by using hydrolytic enzyme assisted processing.

The data regarding pH and titrable acidity in dragon fruit juice are presented in Table 2. The lowest pH (3.01) and maximum titrable acidty (0.41) was found in tratment T_3 - 0.15% pectinase, while highest pH (4.78) and minimum acidity (0.29) was observed in T_4 - control. The increased concentration of pectinase showed increased in acidity of Dragon fruit juice. The juice treated with enzyme became more acidic, which might be due to the formation of galacturonic acid by the enzymatic

Table 2. Effect of enzyme assisted processing on pH and titrable acidity of dragon fruit

Treatment	pH			Acidity (%)		
	2018-19	**2019-20**	**Pooled mean**	**2018-19**	**2019-20**	**Pooled mean**
T_1 - Pectinase 0.05%	4.37	4.40	4.52	0.35	0.34	0.35
T_2 - Pectinase 0.1%	3.87	4.10	4.66	0.37	0.36	0.37
T_3 - Pectinase 0.15%	4.14	4.60	3.01	0.41	0.41	0.41
T_4 - Control	4.44	4.66	4.78	0.29	0.28	0.29
C.D	0.26	0.063	NS	0.015	0.019	0.020
S.E(m) ±	0.08	0.019	0.753	0.005	0006	0.006

Table 3. Effect of enzyme assisted processing on TSS and Ascorbic acid of dragon fruit juice

Treatment	TSS (%)			Ascorbic acid (mg 100 g^{-1})		
	2018-19	2019-20	Pooled mean	2018-19	2019-20	Pooled mean
T_1 - Pectinase 0.05%	11.47	11.45	11.42	32.19	32.19	32.19
T_2 - Pectinase 0.1%	13.20	13.15	11.87	32.25	32.25	32.25
T_3 - Pectinase 0.15%	11.60	11.65	12.57	32.28	32.27	32.28
T_4 - Control	12.17	12.20	11.05	29.64	29.63	29.64
C.D	0.69	0.31	0.42	0.035	0.011	0.022
S.E(m) ±	0.21	0.09	0.13	0.010	0.003	0.007

breakdown of pectin. Similar findings reported by Acar *et al.*,(1999).

Data presented in Table 3 revealed that the increased trend of TSS and ascorbic acid content was found with increasing pectinase concentration. The maximum TSS (12.57%) and ascorbic acid content (32.28 mg 100 g^{-1}) was found in treatment T_3 - 0.15% pectinase. Similar results reported by Schobinger *et al.* (1981), the rise in TSS could be partially due to the increment of soluble sugars, which may result from the conversion of insoluble pectin by pectinolytic enzymes and the action of cellulose on cellulose to produce soluble sugars. The combination of Pectinex ultra SP-L and Viscozyme L resulted in degrading the glycocel bonds of pectin, cellulose and hemicellulose in the cell wall of fruit tissues, led to release out more cell components such as Vitamin c (Mutlu *et al.*, 1999).

The data regarding betacyanin content in dragon fruit juice are presented in Table 4 revealed that the substantial increases in the level of betacyanins was found with increasing pectinase concentration The highest betacyanin content (71.19 mg 100 g^{-1}) was recorded in treatment T_3 - 0.15% pectinase. While lowest betacyanin content (59.17 mg 100 g^{-1}) was recorded in control treatment.

Data presented in Table 5 regarding effect of enzyme assisted processing on total phenol and total flavonoids content of dragon fruit juice revealed that the total phenol and total flavonoid content was positively affected by pectinase treatment. The phenol and flavonoid content value was increased with increase in pectinase concentration. The highest total phenol (1888.09 GAE mg 100 g^{-1}) and total flavonoid (837.03 CE mg 100 ml^{-1}) content was found in treatment T_3 - 0.15% pectinase. Similar results also reported by Choo and Yong, (2011) and Nurliyana *et al.* (2010).

The effect of enzyme assisted processing on antioxidant activity by FRAP and CUPRAC assay of dragon fruit juice are presented in Table 6 showed that the concentration pectinase enzyme increased the corresponding values for total AOX also increased. The maximum FRAP assay (4.58 µmol Trolox ml^{-1}) and CUPRAC assay (10.42 µmol Trolox ml^{-1}) was recorded in treatment T_3 - 0.15% pectinase.

Table 4. Betacyanin content of dragon fruit juice as affected by enzyme assisted Processing

Treatment	Betacyanin (mg 100 g^{-1})		
	2018-2019	2019-2020	Pooled mean
T_1 - Pectinase 0.05%	67.62	62.61	65.11
T_2 - Pectinase 0.1%	60.71	61.96	61.34
T_3 - Pectinase 0.15%	73.24	69.15	71.19
T_4 - Control	62.76	55.58	59.17
C.D	9.11	4.92	4.74
S.E(m) ±	2.75	1.49	1.43

Table 5. Total phenolic and Total flavonoid content of dragon fruit juice as affected by enzyme assisted Processing

Treatment	Total phenol (mg GAE 100 g^{-1})			Total flavonoid (mg quercetin 100 g^{-1})		
	2018-19	2019-20	Pooled mean	2018-19	2019-20	Pooled mean
T_1 - Pectinase 0.05%	1769.04	1632.14	1596.42	788.88	707.40	748.14
T_2 - Pectinase 0.1%	1446.42	1277.38	1479.76	576.85	579.63	578.24
T_3 - Pectinase 0.15%	1891.66	1853.57	1888.09	837.03	837.03	837.03
T_4 - Control	1197.62	1216.66	1377.38	510.18	487.03	498.61
C.D	431.98	270.87	98.90	137.96	124.79	22.09
S.E(m) ±	130.43	81.79	29.86	41.65	37.68	6.67

Table 6. Antioxidant activity of dragon fruit juice as affected by enzyme assisted Processing

Treatment	CUPRAC (µmol Trolox g^{-1})			FRAP (µmol Trolox g^{-1})		
	2018-19	2019-20	Pooled mean	2018-19	2019-20	Pooled mean
T_1 - Pectinase 0.05%	8.59	8.82	8.71	4.05	3.79	3.92
T_2 - Pectinase 0.1%	9.27	9.57	9.41	4.34	4.35	4.35
T_3 - Pectinase 0.15%	9.85	10.98	10.42	4.65	4.52	4.58
T_4 - Control	8.54	8.76	8.65	3.95	3.53	3.74
C.D	0.50	0.59	0.10	0.20	0.74	0.31
S.E(m) ±	0.15	0.18	0.03	0.07	0.22	0.09

Enzyme assisted preparation prior to pressing remarkably improved the functional quality of dragon fruit juice resulting in enhanced juice yield, level of phenol, flavonoid, betacyanin and antioxidant activity.

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Design of Pressure Relief Valve for Control Valve Assembly of Tractor Mounted Hydraulic Boom Sprayer

Er. Pranav Pawase[1], S. S. Meena[2], G. B. Bhanage[3] and S. M. Nalawade[4]
Department of Farm Machinery and Power Engineering, Dr. ASCAET,
Mahatma Phule Krishi Vidyapeeth, Rahuri - 413 722 (India)
Email : pawasepranav@gmail.com

Abstract

The most common method of applying pesticides to the field crops in the more developed and relatively wealthy agricultural regions of the world is with hydraulic boom sprayers. The working principal of the tractor mounted boom sprayer is to move the spray liquid to the individual nozzle along the boom. Control valve assembly of tractor mounted boom sprayer was design and developed considering the various deficiencies in the existing control valve assembly of boom sprayer. In order to developed control valve assembly of boom sprayer, initially the performance of the existing control valve assembly of boom sprayer was evaluated. The pressure relief valve was developed for control valve assembly of boom sprayer. The developed control valve assembly of boom sprayer was tested in a laboratory in terms variables viz., of droplet size, droplet density, uniformity coefficient, nozzle pressure and nozzle discharge for four level of operating pressure (278, 413, 551 and 689 kPa) and number of active openings of on-off valves (all valves open, one valve closed, two valves closed, three valves closed and four valves closed). Droplet size, droplet density and uniformity coefficient was constant while closing the number of on-off valves of modified control valve assembly of boom sprayer. The pressure and discharge of nozzle was also remains constant while closing the number of on-off valves. The developed control valve assembly of the boom sprayer reduces the wastage of liquid. In developed five outlets control valve assembly of boom sprayer while closing one, two, three and four on-off valves of sprayer the liquid was saved 5.88, 11.88, 27.7 and 33.47 per cent respectively.

Key words : Boom sprayer, Pressure relief valve, Nozzle pressure, Nozzle discharge.

The world's population is continuously increasing, especially in most of the developing countries. To satisfy the demand, food crop yields need to be increased. Continuous growing of world population and an increased pressure on the available land to produce more crop, demands for more intensive agriculture. The challenge for Indian agriculture is to achieve the higher productivity in a sustainable manner which despite constraints on availability of land, irrigation and labour. To achieve all these, farmers need to be empowered with new farming technologies like irrigation systems, high yielding seeds, advanced crop protection technologies etc.

Plant protection strategies have significant role in the overall crop production programmes for sustainable agriculture and keeping aim to minimizing crop losses due to ravages of insect pests, diseases, weeds, nematodes, rodents, etc. Total field losses in India due to insects, diseases and weeds were ranged from 10 to 30 per cent (Anonymous, 2016).

In the present status of agricultural mechanization, the plant protection equipment such as sprayer plays a vital role to protect crops from pests, diseases and crop destructive micro-organisms. Wastage of pesticides and poor pest control give rise to loss of yield in field crops.

1 Ph.D. Student, 2. Assistant Professor, Dept. of Farm Machinery & Power Engineering, Dept. of Farm Machinery & Power Engineering, College of Technology & Engineering, MPUAT, Udaipur-313001, Rajasthan, 3. Research Associate, CAAST-CSAWM, MPKV, Rahuri and 4. Professor.

When number of nozzles are spaced on the boom, the individual nozzle spray pattern must overlap to obtain uniform distribution over the entire boom length.

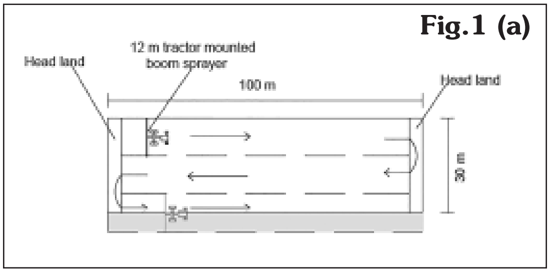


Fig.1 (a)

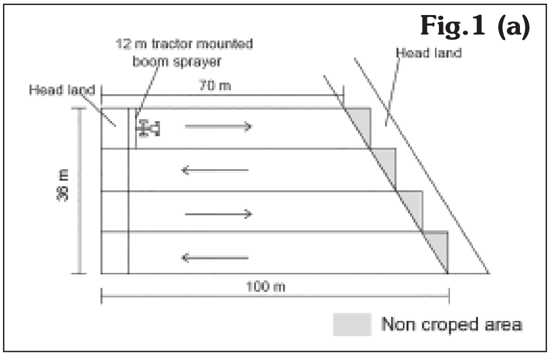


Fig.1 (a)

Fig. 1 (a) shows the field condition where rectangular field having 100 m length and 30 m width. Suppose the boom sprayer having width of operation is 12 m then in order to completely cover the 30 m width the operator has to cover two complete round and in third round if boom length is completely used then it will result in liquid loss to avoid these liquid loss the some on-off valves of the boom sprayer need to close.

Similarly, in Fig. 1 (b) field condition where field having irregular length for example 70 m on one side and 100 m on other side in these kind of situation the operator to make sure that no liquid loss and overlapping takes place while working in a non cropped area, which has shown in above figure.

The problem in existing boom sprayer (Fig. 2) is that when one or more on-off valves are closed then pressure increases in remaining open sections. The lack of balance occurs due to an increase in the liquid flow, thus increasing the pressure and flow in the nozzles. This results in increasing the spray dose in that area. To overcome this problem, modification in the control valve assembly is necessary. The entire modification includes the design of pressure relief valve, which consists of a spring loaded component which can set at a particular pressure to control the flow of liquid from pump to nozzle.

Fig. 2. Existing tractor mounted boom sprayer

Material and Methods

Design of Pressure relief valve : The pressure relief valve was designed based on the result obtained from the laboratory evaluation of the existing control valve assembly of tractor mounted boom sprayer and developed in ASPEE workshop (Mumbai). The Specification of developed pressure relief valve is shown in Table 1. The developed pressure relief valve is shown in Fig. 3

Design parameters of pressure relief valve

a) Valve body

Body is the outermost part of the valve. The material of the valve body is brass. The inside diameter of the pipe depends upon the quantity of fluid to be delivered.

Quantity of fluid flowing (Q) was calculated by using equation 1

$$Q = A \times V \quad ...(1)$$

Where, Q=Quantity of flowing fluid, $m^3 s^{-1}$, A = Area of pipe, m^2 and V = Velocity of flowing fluid, $m s^{-1}$

Thickness of valve body (t) was calculated by using equation 2

$$t = \frac{pD}{2\sigma_t} + C \quad \text{(Khurmi, 1988)} \quad ...(2)$$

Where, p = Pressure, $N mm^{-2}$, D = Inside diameter, mm, σ_t = Tensile strength, $N mm^{-2}$ (469 $N mm^{-2}$), C = Constant (3) and t = Thickness of valve body, mm.

b) Spring

Force acting on the spring (F) was calculated by using equation 3

$$F = \frac{\pi}{4} \times d^2 \times p \quad ...(3)$$

Where, d = Diameter of valve body (mm) and p = Maximum operating pressure, N mm-2.

i) Mean diameter of the spring coil

Using the equations 4, 5, 6 and 7 the diameter of the spring wire and mean diameter of the spring coil was calculated,

$$T = W1 \times \frac{D}{2} \quad ...(4)$$

$$T = \frac{\pi}{16} \times \tau \times d^3 \quad ...(5)$$

$$K = \frac{4C-1}{4C-4} + \frac{0.615}{C} \quad ...(6)$$

$$C = D/d \quad \text{(Thakar et al., 2015)} \quad ...(7)$$

Outer diameter (Do) and inner diameter (Di) of the spring coil was calculated by using equations 8 and 9 respectively,

$$D_o = D + d \quad ...(8)$$

$$D_i = D - d \quad ...(9)$$

ii) Number of turns of the spring coil (n)

Number of turns of the spring coil (n) was calculated by using equation 10

$$\delta = \frac{8 \times W \times C^3 \times n}{G \times d} \quad ...(10)$$

Where, δ = deflection of the spring, mm, W = Load range, N, G = Modulus of Rigidity, (84 $kN mm^{-2}$), n = Number of active turns

For squared and ground ends, the total number of turns,

$$n' = n + 2 \quad ...(11)$$

iii) Free length of the spring (L_f)

Free length of the spring was calculated by using equation 12 and 13

$$L_f = n'd + \delta max + 0.15\delta max \quad ...(12)$$

$$\delta_{max} = \frac{\delta}{W} \times W_1 \quad ...(13)$$

Where, δ_{max} = maximum deflection of the spring, mm, L_f = Free length of the spring, mm, n' = Total number of turns and d= wire diameter, mm

iv) Pitch of the coil (p)

Pitch of the coil was calculated by using equation 14

$$p = \frac{Lf}{n' - 1} \quad \text{(Thakar et al., 2015)} \quad ...(14)$$

The Specification of developed pressure relief valve is shown in Table 1.

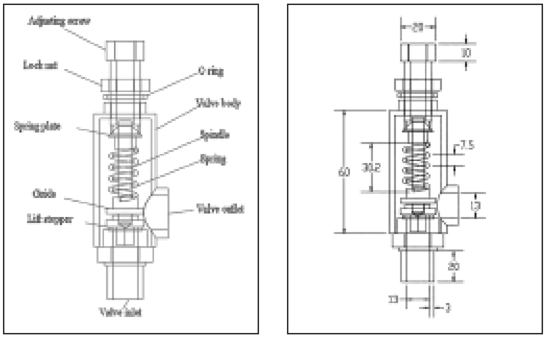


Fig. 3. Pressure relief valve

Table 1. Specification of Pressure relief valve

Material	**Brass**
Inlet diameter	13 mm
Outlet diameter	13 mm
Thickness	3 mm
Spring specification-	
Material	Carbon steel
Style of end	Plain and ground
Outer diameter	24.2 mm
Inner diameter	18.8 mm
Wire diameter	2.64 mm
Pitch	7.5 mm
Total coils	5
Number of active coils	3
Solid height	13.45 mm
Free length	30.2 mm

Pressure Relief Valve Testing Set-up : The developed pressure relief valve was tested in the ASPEE laboratory. The pressure relief valve was fitted to the outlet of pump. Outlet of the pressure relief valve was given to tank. The pump pressure was adjusted using the control valve and check the opening of the pressure relief valve. The pump pressure set for the pressure of 278 to 689 kPa and check the opening of pressure relief valve. The tension of the spring was adjusted using the adjusting bolt. The setup for pressure relief valve is shown in Fig. 4. The Developed pressure relief valve fitted with control valve assembly of boom sprayer is shown in Fig. 5.

Fig. 4. Pressre relief valve testing set-up

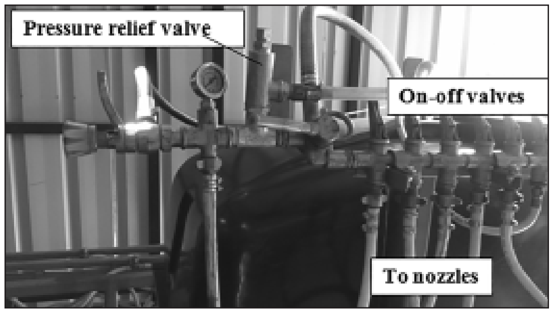


Fig. 5. Developed pressure relief valve fitted with control valve assembly of boom sprayer

Performance evaluation of developed control valve assembly of tractor mounted hydraulic boom sprayer under laboratory condition

For nozzle pressure, nozzle discharge and spray deposition independent variables were operating pressure 278, 413, 551 and 689 kPa (Gholap, 2012), respectively, while the number of active openings of on-off valves were all valves open, one valve closed, two valves closed, three valves closed and four valves valves closed. The experiment was replicated three times under laboratory condition on brinjal crop.

The performance evaluation of the boom sprayer included pressure and discharge measurement of nozzles and droplet deposition on the plant leaves. These are discussed below.

a) Pressure and discharge measurement of nozzles

The pressure and discharge was measured from left to right of the boom for each individual nozzle. The pressure was measured by pressure gauge, the discharge was measured with the help of graduated cylinder and a stop watch.

b) Measurement of droplet deposition

Laboratory experiments were conducted to study the effect of different experimental variables on spray deposition at different location of leaves and their position. The operating speed was kept constant.

c) Plant position

The boom sprayer has mostly used for spraying pesticide on vegetable, pulses, etc. For measurement of the droplets deposition the brinjal plant was selected for the study. To facilitate the evaluation of spray penetration into the canopy of brinjal plant, the plant was divided into six different sections depending upon the location where the effect of independent variables on spray deposition was to be observed. The sections are shown in Table 2.

Table 2. Six different positions of plant leafs where glossy paper attached

Leaf position	Position
Top position of the plant and upper leaf surface (TU)	Position 1
Top position of the plant and lower l eaf surface (TL)	Position 1
Middle position of the plant and upper leaf surface (MU)	Position 1
Middle position of the plant and lower leaf surface (ML)	Position 1
Bottom position of the plant and upper leaf surface (BU)	Position 1
Bottom position of the plant and lower leaf surface (BL)	Position 1

The arrangement of the glossy paper on brinjal plant is shown in Fig. 7.

Fig. 7. Set-up for pressure and discharge measurement of nozzles

For determination of droplets size, droplet density and uniformity coefficient of sprayer, a blue colored dye was mixed with water and the impression of droplets was taken on glossy paper. Three glossy papers were stapled on each position to observe the deposition of the droplets. After making all adjustments, set-up of the equipment was run for 30 minutes before actually starting the experiment. The sample cards of size 62 mm x 44 mm were used to collect the sample. Royal blue indigo dye was mixed with water to prepare a colored spray solution. The colored spray was allowed to fall onto the sample glossy photographic paper.

After the experiment, the sample cards were carefully removed and then taken for further analysis in the laboratory. Digital image analyzer was used to determine droplet size, droplet density and uniformity coefficient which analyze these samples after 24 hours of application to ensure that droplets had stop spreading.

d) Instrument used to analyze the droplet spectrum

'Image pro plus' electronic imaging program was used for analysis of glossy paper. The advanced image processing features of the program was provided through the Microsoft Windows. This consisted of microscope, connected to computer software through Graphical interface card, which enable to directly visualize the image on computer screen. These images were then processed in a computer which directly gave droplet size and droplet density is shown in Fig. 9.

e) Data analysis

The image-pro program was used to calculate the VMD and Mean diameter of the droplet spectrum collected on the sample card at a specific location. The data obtained in various experiments were analyzed on computer using factorial CRD statistical software packages.

Fig. 8. Brinjal plant with glossy paper

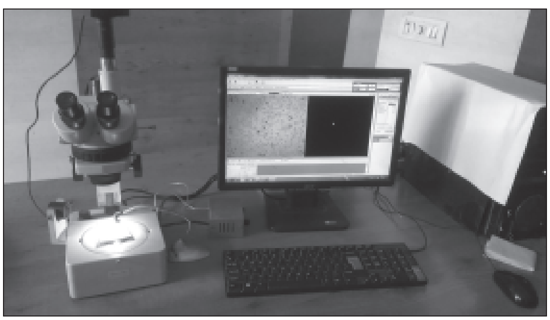


Fig. 9. Electronic imaging instrument for analysis of droplet deposition

Results and Discussion

Different experiments were conducted in the laboratory to evaluate the performance of the developed control valve assembly of boom sprayer.

Discharge and pressure measurements of nozzles

a) Effect of operating pressure and number of active openings of on-off valves on nozzle pressure

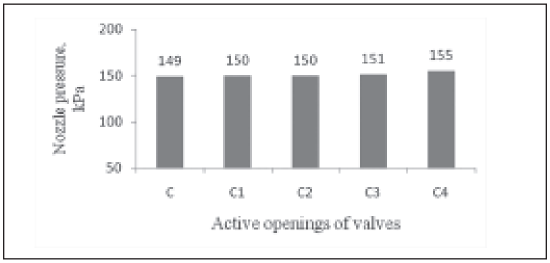
The nozzle pressure increases with increasing operating pressure. Numbers of active openings of on-off valves had less effect on nozzle pressure. These happened because of excess amount of pressure and discharge release through the pressure relief valve.

The maximum nozzle pressure of 510 kPa was observed with 689 kPa operating pressure when four valves are in closed condition whereas minimum nozzle pressure of 149 kPa was observed with 278 kPa operating pressure when all valves are in open condition (Fig. 10).

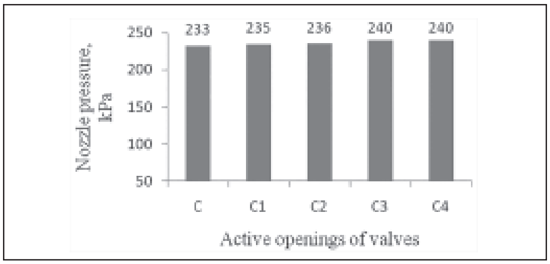
b) Effect of operating pressure and number of active openings of on-off valves on nozzle discharge

The nozzle discharge increases with increasing operating pressure. Numbers of active openings of on-off valves had less effect on nozzle discharge. These happen because of excess amount of pressure and discharge release through the pressure relief valve.

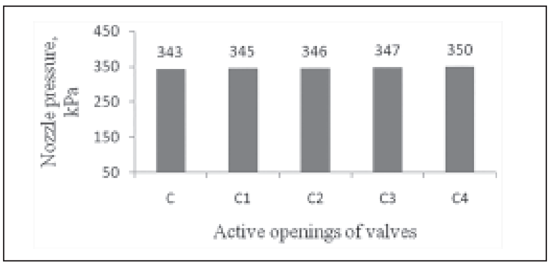
The maximum nozzle discharge of 0.9 l/min was observed with 689 kPa operating pressure when four valves are in closed condition whereas minimum nozzle discharge of 0.49 l/min was observed with 278 kPa operating pressure when all valves are in open condition (Fig. 11).



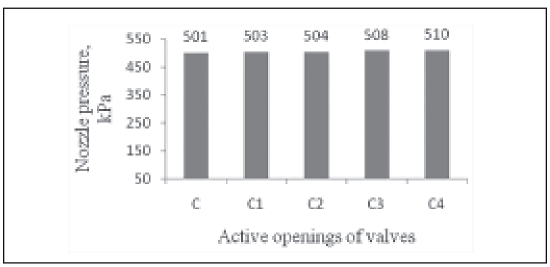
(a) Operating pressure 278 kPa



(b) Operating pressure 413 kPa

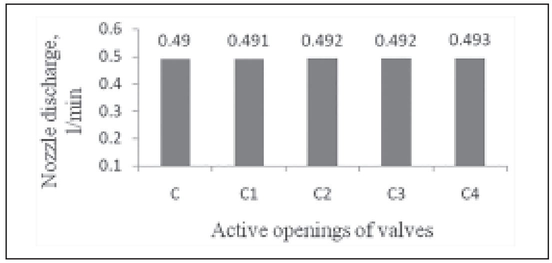


(c) Operating pressure 551 kPa

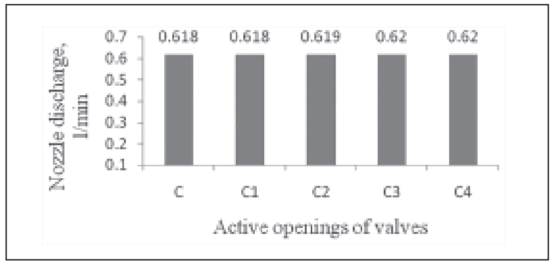


(d) Operating pressure 689 kPa

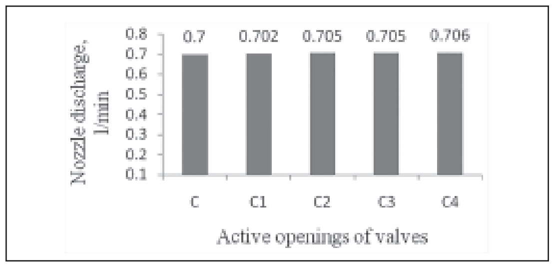
Fig. 10. Effect of operating pressure and number of active opening on nozzle pressure for developed control valve assembly of boom sprayer (C- All valves open, C1- One valve closed, C2- Two valves closed, C3- Three valves closed and C4- Four valves closed)



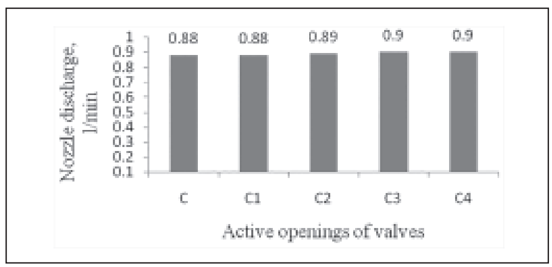
(a) Operating pressure 278 kPa



(b) Operating pressure 413 kPa



(c) Operating pressure 551 kPa



(d) Operating pressure 689 kPa

Fig. 11. Effect of operating pressure and number of active opening on nozzle discharge for developed control valve assembly of boom sprayer (C- All valves open, C1- One valve closed, C2- Two valves closed, C3- Three valves closed and C4- Four valves closed)

Effect of operating pressure and number of active opening on droplet size (VMD), droplet density (DD) and uniformity co-efficient for developed control valve assembly of boom sprayer

a) Effect on droplet size (VMD)

At all selected plant positions, droplet size decreased with increase in operating pressure. The lighter effect of closing the on-off valves on droplet size was observed. Higher values of droplet size were observed on upper leaf surface as compared to lower leaf surface and droplet size values observed at top plant position were marginally higher than the values observed at other plant positions. Maximum droplet size of 232 µm was observed on upper leaf surface at top plant position with operating pressure of 278 kPa when all valves are in open condition whereas minimum droplet size of 126 µm was observed at bottom plant position and on lower leaf surface with combination of operating pressure of 689 kPa when four valves are in condition (Fig. 12 and 13).

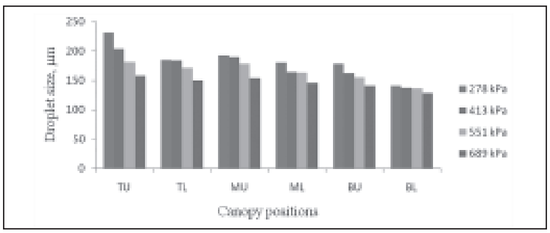


Fig. 12. Effect of operating pressure on droplet size for developed control valve assembly of boom sprayer

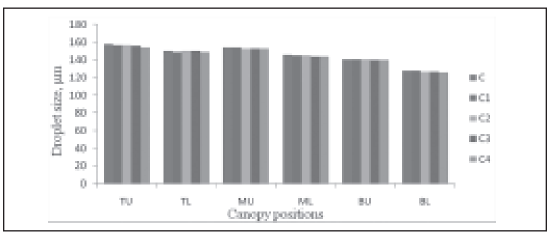


Fig. 13. Effect of number of active openings on droplet size for developed control valve assembly of boom sprayer at 689 kPa operating pressure

b) Effect on droplet density (DD)

Droplet density increased with increase in operating pressure from 278 to 689 kPa whereas number of active opening of on-off valves had non-significant effect on droplet density at all selected plant positions. Higher droplet density was observed at top plant position on upper leaf surface as compared to other plant positions. The maximum droplet density of 31 nos/cm2 was observed at top plant position and on upper leaf surface with combination of operating pressure of 689 kPa when four valves are in closed condition and minimum droplet density of 16 nos cm^{-2} was observed at bottom plant position and on lower leaf surface with combination of operating pressure of 278 kPa when all valves are in open condition (Fig. 14 and 15).

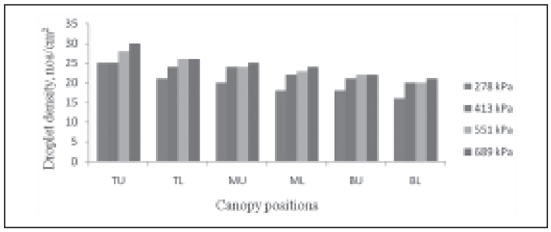


Fig. 14. Effect of operating pressure on droplet density for developed control valve assembly of boom sprayer

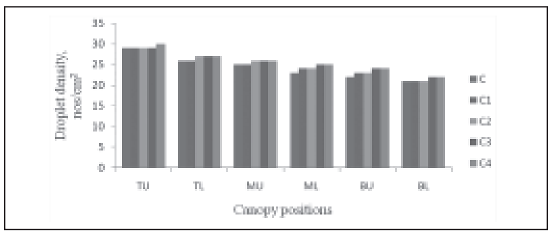


Fig. 15. Effect of number of active openings on droplet density for developed control valve assembly of boom sprayer at 689 kPa operating pressure

c) Effect on uniformity coefficient (UC)

Uniformity coefficient decreases with increase in operating pressure from 278 to 689 kPa whereas number of active opening of on-off valves had non-significant effect on uniformity coefficient at all selected plant positions. Higher uniformity coefficient was observed at top plant position on upper leaf surface as compared to other plant positions. The maximum uniformity coefficient of 1.42 was observed at top plant position and on upper leaf surface with combination of operating pressure of 689 kPa when all valves are in open condition and minimum uniformity coefficient of 0.96 was observed at bottom plant position and on lower leaf surface with combination of operating pressure of 278 kPa when four valves are in closed condition (Fig. 16 and 17).

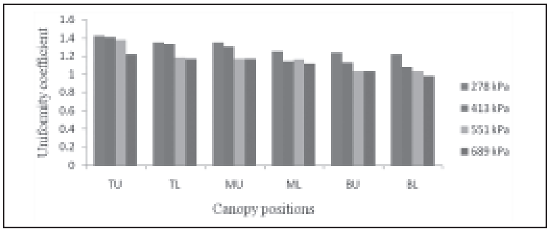


Fig. 16. Effect of operating pressure on uniformity coefficient for developed control valve assembly of boom sprayer

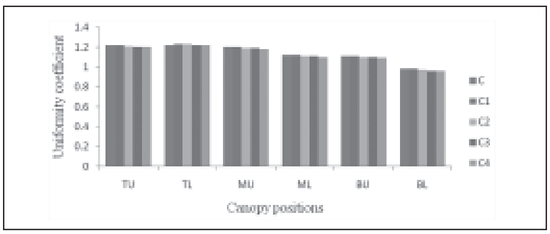


Fig. 17. Effect of number of active openings on uniformity coefficient for developed control valve assembly of boom sprayer at 689 kPa operating pressure

Conclusions

Boom sprayers are hydraulic equipment used for pesticide application in field row crops. Uniform distribution and deposition of chemical from top to bottom of plant canopy and on the undersides of leaves is of utmost importance for effective pest control. Wastage of pesticides and poor pest control give rise to loss of yield in field crops. The problem in commercially available 12 m boom sprayer is that when one or more on-off valves are closed then pressure increases in remaining open sections. The lack of balance occurs due to an increase in the liquid flow, thus increasing the pressure and flow in the nozzles. This results in increasing the spray dose in that area. To overcome this problem, modification in the control valve assembly is necessary. The entire modification includes the design of pressure relief valve, which consists of a spring loaded component which can set at a particular pressure to maintain system pressure by diverting excess amount of flow to tank.

In the developed control valve assembly of boom sprayer, it was found that while closing the on-off valves, droplet size, droplet density and uniformity coefficient remains constant because of nozzle pressure and discharge were not varied.

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