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Identification of New Source for Resistance to Rust in Exotic Germplasm Lines of Soybean (*Glycine max* (L.) Merrill)

***P G SURESHA*[1]*, G T BASAVARAJA**[1]*, HARSHIY A BANU*[1]*, SHAMARAO JAHAGIRDAR*[1]*, GYANESH KUMAR SATPUTE*[2] *AND SANJAY GUPTA*[2]**

[1]*All India Co-ordinated Research Project on Soybean, Main Agricultural Research Station, University of Agricultural Sciences, Dharwad,*
[2]*ICAR-Indian Institute of Soybean Research, Indore 452 001, Madhya Pradesh*

**E-mail: basavarajagt@uasd.in*

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ABSTRACT

Soybean rust caused by Phakopsora pachyrhizi Syd. is one of the most important constraints to soybean production worldwide. So effective management practices need to be evolved for the management of this disease. Among them, the most effective method of managing rust disease is use of resistant cultivars. Screening of germplasm lines and utilization of resistant germplasm lines in breeding programme helps to develop the cultivars with resistance to Asian soybean rust. Hence, an attempt was made to identify the new sources by screening 144 exotic germplasm lines along with resistant and susceptible checks was conducted at Dharwad during kharif 2015. In the present study, results revealed that only one line EC 242104 (8.89%) recorded disease grade 1 and was found to be highly resistant. Nine lines recorded moderately resistant (grade 3), five lines registered moderately susceptible reaction (grade 5), 46 lines exhibited susceptible and 80 lines exhibited highly susceptible reaction (grade 7 and 9) respectively. Based on the resistance reaction, 22 lines which exhibited different range of resistant reaction were selected and further evaluated to confirm their resistance reaction along with checks under natural epiphytotic condition at two hotspots for rust viz., Ugarkhurd and Dharwad during kharif 2016. Among 22 exotic germplasm lines only one line EC 242104 recorded disease grade of 1 and found to be highly resistant, whereas 9 lines exhibited moderately resistant reaction, 9 lines registered moderately susceptible reaction, 3 lines exhibited susceptible and JS 335 exhibited highly susceptible reaction. In the present study EC 242104 which exhibited highly resistant reaction during different seasons, would be useful source of Soybean rust resistance genes for incorporation into high yielding and adapted cultivars in future breeding programmes for development of resistant genotypes as parents.

Key words : Rust, *Phakospora pachyrhizi*, PDI, Resistant source and Exotic germplasm.

Soybean ranks first as one of the oilseed crop both in area and production in India. In India it occupies an area of 11.25 million hectare with the production of 9.30 million tonnes and productivity of 830 kg/ha (Anon., 2020). In Karnataka, soybean is grown over an area of 3.31 lakh ha with a production of 2.69 lakh tonnes and productivity of about 816 kg/ha. The major constraint for cultivation of soybean in India are outbreak of diseases and insect pests. Among the diseases of soybean, soybean rust incited by pathogen *Phakopsora pachyrhizi,* is major disease and reported to cause an yield loss from 20-80 percent

(Bromfield, 1976). Soybean rust reduces yield through premature defoliation, decreasing the number of filled pods and by reducing the weight of seeds. It also lowers the quality of seed produced. The severity of loss and the particular components of yield affected depend primarily on the time of disease onset and the intensity of disease at particular growth stages of the crop (Bromfield, 1984). Apparently it is able to travel great distances via wind-borne spores. Also known as Asian rust, this fungal infection can defoliate soybean fields rapidly, often resulting in severe and sometimes total loss. The disease appeared suddenly in epiphytotic form during *Kharif* 1994-95 and caused substantial yield losses particularly in Northern parts of Karnataka, Maharashtra and Madhya Pradesh (Anahosur *et al*., 1995). Now, it has become a major constraint for the soybean production particularly in northern Karnataka and southern parts of Maharashtra. Currently, the primary form of control is based on the use of fungicides of different classes and action modes (Miles *et al.,* 2007). The continuous use of these chemical fungicides may pose problem of development of resistance to pathogen in addition to health hazards. Therefore, the development of high yielding rust resistant varieties is of prime importance. Chan (1977) opined that solely breeding cannot solve soybean rust problem until a highly resistant or immune cultivar is available.

Patil *et al.* (2004) identified two germplasm lines *viz.,* EC 241778 and EC 241780 of soybean as promising source of resistance to rust caused by *Phakopsora pachyrhizi* after rigorous screening of 982 germplasm lines. But these two germplasm lines are highly susceptible to bacterial pustule and soybean mosaic virus (SMV) with long maturity duration (110 days). In this regard, it was necessary to identify new sources for rust resistance. Hence, the study was conducted to screen exotic germplasm lines against *Phakospora pachyrhizi* resistance across different environments and seasons to identify potential sources of rust resistance.

MATERIAL AND METHODS

Experimental material and layout

A set of 144 exotic germplasm lines along with highly resistant checks *viz.,* DSb 21, EC 241780 and EC 241778 and highly susceptible check JS 335 collected from different geographical regions *viz.,* AVRDC (Taiwan), ICAR-IISR (Indore), ARI (Pune), NBPGR (New Delhi) and JNKVV (Jabalpur). The experiment was executed in Augmented block design (Federer, 1956). Each line was raised in one row of 5 m length with a spacing of 45 x 10 cm during *kharif* 2015 at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad. The experiment was conducted under rust prone condition (unprotected condition) without any fungicidal spray. Based on resistance reaction, Twenty two lines were selected and further evaluated to confirm their resistance along with checks under natural epiphytotic condition at two hotspots for rust *viz.,* Ugarkhurd and Dharwad. Each line was raised in one row of 5 m length with a spacing of 45 x 10 cm in two replications during *kharif* 2016.

Inoculum preparation

The leaves from rust infected fields were collected and soaked overnight. In the morning uredospores were oozed out and the uredospore suspension was sprayed on all the entries at 45 and 55 days after sowing. In addition to this leaf stapling technique also followed.

Rust severity assessment

Type of the lesions and count for the number of lesions

Type of lesions may be either reddish brown or tan colour. Reddish Brown lesions may produce few urediospores, whereas Tan lesions may produce numerous urediospores based on colour of lesions and these were scored either resistant or susceptible (Bromfield, 1984; Pham *et al.,* 2009, Sharadha and Jahagirdar 2015) respectively. The count of the number of lesions was taken per cm^2 of infected leaves from mid-vein and both sides of mid-vein. The lesion colour on the infected leaves was recorded in the form of Reddish Brown (resistant) and TAN (susceptible). The number of lesions per cm^2 square of infected leaves were recorded using a magnifying glass.

Severity of rust reaction and statistical analysis

The severity of rust was scored between 65-90 days after sowing based on percent leaf area infected by using 0-9 scale given by Mayee and Datar (1986) (Table 1). Per cent disease index (PDI) was calculated and the data was analyzed using standard statistical procedures.

Table 1. Disease rating scale

Disease grade	Description	Disease Reaction
0	<1% infection	Absolute Resistant
1	1-10% of leaf area infected	Highly resistant
3	11-25% of leaf area infected	Moderately resistant
5	26-50% of leaf area infected	Moderately susceptible
7	50-75% of leaf area infected	Susceptible
9	>75% of leaf area infected	Highly susceptible

$$\text{Per cent disease index (PDI)} = \frac{\text{Sum of numerical ratings}}{\text{Total number of leaves scored}} \times \frac{100}{\text{Maximum grade}}$$

Rate of development of disease (R)

The rate of development of disease (r) at different intervals was also calculated by following formula given by Vander plank (1963)

$$r = \frac{2.3}{t_2 - t_1}\left[\log \frac{X_2}{1-X_2} - \log \frac{X_1}{1-X_1}\right]$$

Where,

r = Apparent rate of infection or spread

X_1 = Per cent disease index at time t_1

X_2 = Per cent disease index at time t_2

$t_2 - t_1$ = Time interval in days between the two consecutive observations

Area under disease progress curve (AUDPC)

Area under disease progress curve is an important feature associated with disease resistance. It is the area of graph under the line that depicts the progress of epidemics and is calculated using the formulae by Wilcoxson (1975).

$$AUDPC = \sum_{i=1}^{n-1} \frac{y_i + y_{i+1}}{2} \times (t_{i+1} - t_i)$$

Y_i and Y_{i+1} are the disease scores done at t_i and t_{i+1} time intervals

RESULTS AND DISCUSSION

The results indicated that, Among 144 exotic germplasm lines including resistant and susceptible checks, only one line EC 242104 (8.89%) with resistant checks *viz.,* DSb 21 (8.89%), EC241780 (8.89%) and EC 241778 (8.89%) recorded disease grade 1 and was found to be highly resistant. Nine lines *viz.,* EC 391336 (20.00%), EC 385243, EC 333934, EC 308334, EC 287754, EC 100031, EC 14476 with 24.44%, EC 250578 and EC 15966 with 20.00% recorded disease grade 3 and were found to be moderately resistant (Table 2, Fig.1 and Fig.3) and they also showed same reaction screened under natural epiphytotic condition at two hotspots for rust *viz.,* Ugarkhurd and Dharwad during *kharif* 2016. These results are in conformity with earlier findings of Hartman *et al.* (2005) and Verma *et al.* (2004).

In general, the lines with a low initial per cent disease index invariably resulted with a low terminal disease index. PDI status at different intervals observed in lines as EC 242104 with resistance checks DSb 21 and EC 241780 recorded 6.67 % at 65 DAS and 8.89 % at 85 DAS and EC 241778 recorded 4.44 % at 65 DAS and 8.89 % at 85 DAS followed by EC 391336 and EC 15966 recorded 8.89 % at 65 DAS and 20.0 % at 85 DAS.

The apparent rate of infection was calculated and this has been widely used in identification of genotypes with low rate of disease development. The range of 'r' values among 144 germplasm lines ranged from 0.009 to 0.169 indicating the importance of infection rate in spreading the rust disease. The low average 'r' values indicate less rate of infection compared to higher values. Based on apparent rate of infection, germplasm lines EC 3251 (0.009) followed by EC 391346, EC 14426 (0.011), EC 685252 (0.017), EC 242104, DSb 21 and EC 241780 with (0.031) recorded lower 'r' values indicating the rate of infection in these lines is very slow. Whereas germplasm lines EC 33917 (0.169) followed by EC 37937 (0.151), EC 95291 (0.124) and EC 95815 (0.114) recorded higher 'r' values indicating fast spread of disease in these lines.

The check JS 335 (0.074) and germplasm lines *viz.,* EC 685250 (0.054), EC 39219 (0.054) and EC 242105 (0.054) having low apparent rate of infection actually recorded high disease infection at their early growth stage however infection rate was low. The germplasm lines EC 385243 (0.037), EC 391336 (0.047) and EC 308334 (0.060) having high apparent rate of infection registered very low level of disease infection at their early crop growth stage. However, once the infection started spread of the disease was fast. These results indicate the low apparent rate of infection which did not indicate the resistant level of the genotypes. The calculated 'r' values varied and at times they did not remain consistent for given genotype and also did not show a particular trend in general. These observations are in agreement with that of Wilcoxson *et al.* (1975) and Nargund (1989) who have pointed out that 'r' values are not useful criteria for selecting the genotype; 'r' values indicate the progressive development of diseases and help in categorizing as slow or fast rusters. However, it can be used in studying the disease development in different genetic background.

The Area Under Disease Progress Curve (AUDPC) revealed a wide variation among the different lines at different intervals. Among, the lines tested, the highest average AUDPC value was observed in the lines viz., JS 335 (944.44) followed by EC 685250 (855.55), EC 94625, EC 685255, EC 685252 (833.33). While, the least average AUDPC value was recorded in lines EC 241778 (66.67) followed by DSb 21, EC 242104, EC 241780 (83.33) and EC 15966, EC 391336 (150.00).

The exotic lines were screened in the field conditions for lesions count per cm^2 on mid-vein and both the sides of mid-vein of the infected leaves after 65 days of sowing. The line EC 242104 (5.0) followed by DSb 21 (6.87), EC 241780 (7.56), EC 241778 (8.73), EC 287754 (8.65) and EC 391336 (9.21) recorded least number of lesions while JS 335 (42.80) followed by EC 389178 (41.53), EC 917258 (38.20), EC 457406 (37.85) and EC 389400 (37.27) recorded highest lesion count. The lines EC 242104, DSb 21, EC 241780 and EC 241778 showed resistant reaction in the form of reddish brown reaction while dark tan colour appearance of lesions was shown by JS 335 signifying high susceptibility to rust. Similar results are in conformity with the findings of Miles *et al.* (2003) and Sharadha and Jahagirdar (2015) as the reddish brown lesion type is considered to be a resistant lesion type when compared to a fully susceptible tan lesion.

In the present study EC 242104 which exhibited highly resistant reaction during different seasons, can be utilized in future breeding programmes for development of resistant genotypes. In addition to rust resistance, the line EC 242104 as early in nature (matures in 90-95 days) when compared to earlier reported rust resistant lines *viz.,* EC 241780 and EC 241778 which matures in 100-110 days. The growth habit of this line is determinate as compared to those two lines which are semi determinate. These two lines are susceptible to bacterial pustule and soybean mosaic virus but EC 242104 not susceptible. These results are in conformity with the earlier reports of Patil *et al.* (2004), Hartman *et al.* (2005), Parameshwar (2006), Twizeyimana *et al.* (2007) and Shivakumar *et al.* (2011). The new source of resistance can be used in combination with already identified resistance genes. Till date, six independently inherited dominant genes *viz., Rpp1, Rpp2, Rpp3* (Hartwig and Bromfield, 1983), *Rpp4* (Hartwig, 1986), *Rpp5* (Garcia *et al.*, 2008) and *Rpp6* (Shuxian *et al.,* 2012) have been reported as resistant genes against soybean rust. These six genes alone or in various combinations confer resistance in various degrees. *i.e.,* from moderate resistant to highly resistant reaction. Even though single gene can offer good level of resistance. However, such resistance is broken down by the pathogen through evolution of new races or non compatible host pathogen reaction. Therefore, pyramiding of different resistant genes is required to overcome historical failure of monogenic resistance.

Reaction of germplasm lines during *kharif* 2016 at Dharwad and Ugarkhurd

Based on rust reaction, 22 lines were selected and these lines were further evaluated to confirm their resistance reaction along with susceptible check (JS 335) and resistant checks (DSb 21, EC 241780 and EC 241778) under natural epiphytotic condition at two hotspots for rust *viz.,* Ugarkhurd and Dharwad during *kharif* 2016. Scoring of the disease was done between 65 to 85 days after sowing based on percent leaf area infected by using 0-9 scale and yield components *viz.*, days to maturity, number of branches per plant, number of pods per plant, 100 seed weight and seed yield per plant were recorded on five randomly selected plants in each germplasm line.

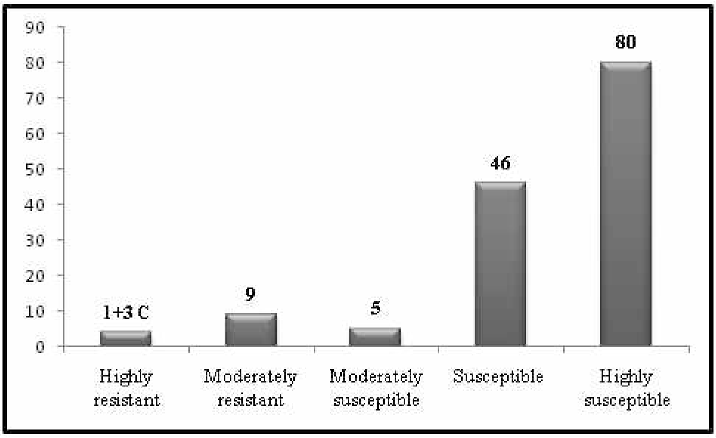


Fig. 1. Disease severity for rust in soybean 144 exotic germplasm lines during *kharif* 2015 at Dharwad

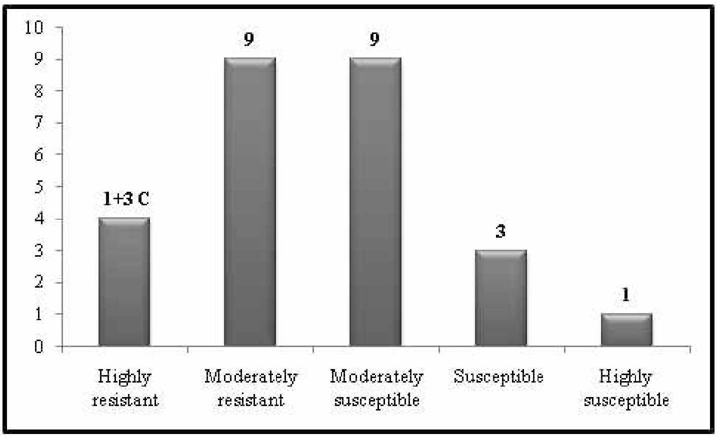


Fig. 2. Confirmation of 26 rust resistance reaction exotic germplasm lines at hotspots *viz.*, Dharwad and Ugarkhurd during *kharif* 2016

Table 2. Rust severity assessment through per cent disease index, number of lesions and type of lesion, AUDPC and rate of spread at 10 days interval in soybean exotic germplasm lines during *kharif* 2015 at Dharwad

Sl. No.	Germplasm Lines	PDI/ DAS			Grade (0-9 Scale)	Reaction	No. of lesions/ cm^2	Type of lesion	AUDPC/ DAS		Rate of spread 'r'/ DAS		Average 'r'
		65	75	85					65-75	75-85	65-75	75-85	
1	EC 1028	15.56	55.56	73.33	7	S	18.80	TAN	355.56	644.44	0.191	0.079	0.135
2	EC 10027	37.78	60.00	64.44	7	S	14.23	TAN	488.89	622.22	0.090	0.019	0.055
3	EC 100031	20.00	24.44	24.44	3	MR	9.23	RB	222.22	244.44	0.026	0.026	0.026
4	EC 100772	46.67	55.56	68.89	7	S	18.40	TAN	511.11	622.22	0.036	0.057	0.046
5	EC 104817	55.56	68.89	91.11	9	HS	21.13	TAN	622.22	800.00	0.057	0.153	0.105
6	EC 107416	51.11	68.89	82.22	9	HS	22.33	TAN	600.00	755.56	0.075	0.074	0.074
7	EC 114520	51.11	68.89	91.11	9	HS	21.27	TAN	600.00	800.00	0.075	0.153	0.114
8	EC 114573	37.78	60.00	91.11	9	HS	23.14	TAN	488.89	755.56	0.090	0.192	0.141
9	EC 116343	46.67	64.44	86.67	9	HS	27.40	TAN	555.56	755.56	0.073	0.128	0.100
10	EC 118420	28.89	42.22	46.67	5	MS	20.47	TAN	355.56	444.44	0.059	0.018	0.038
11	EC 118443	64.44	73.33	95.56	9	HS	21.27	TAN	688.89	844.44	0.042	0.205	0.124
12	EC 12570	51.11	64.44	82.22	9	HS	21.93	TAN	577.78	733.33	0.055	0.094	0.074
13	EC 14426	24.44	24.44	28.89	5	MS	19.27	TAN	244.44	266.67	0.000	0.023	0.011
14	EC 242091	46.67	60.00	73.33	7	S	23.80	TAN	533.33	666.67	0.054	0.061	0.057
15	EC 14476	15.56	24.44	24.44	3	MR	10.14	RB	200.00	244.44	0.056	0.056	0.056
16	EC 14573	37.78	68.89	77.78	9	HS	19.20	TAN	533.33	733.33	0.129	0.046	0.087
17	EC 149988	46.67	51.11	60.00	7	S	22.07	TAN	488.89	555.56	0.018	0.036	0.027
18	EC 15966	8.89	15.56	20.00	3	MR	10.25	RB	122.22	177.78	0.063	0.031	0.047
19	EC 16119	46.67	60.00	64.44	7	S	19.00	TAN	533.33	622.22	0.054	0.019	0.036
20	EC 16738	28.89	46.67	73.33	7	S	15.73	TAN	377.78	600.00	0.077	0.114	0.096
21	EC 172607	28.89	51.11	68.89	7	S	20.53	TAN	400.00	600.00	0.094	0.075	0.085
22	EC 175529	37.78	42.22	51.11	7	S	12.20	TAN	400.00	466.67	0.019	0.036	0.027
23	EC 177744	24.44	46.67	64.44	7	S	20.47	TAN	355.56	555.56	0.099	0.073	0.086
24	EC 187456	33.33	46.67	60.00	7	S	18.87	TAN	400.00	533.33	0.056	0.054	0.055
25	EC 184337	33.33	64.44	73.33	7	S	20.60	TAN	488.89	688.89	0.129	0.042	0.085
26	EC 19923	42.22	60.00	68.89	7	S	18.40	TAN	511.11	644.44	0.072	0.039	0.055
27	EC 225114	33.33	60.00	73.33	7	S	23.00	TAN	466.67	666.67	0.110	0.061	0.085
28	EC 221329	28.89	42.22	46.67	5	MS	19.33	TAN	355.56	444.44	0.059	0.018	0.038

Sl. No.	Germplasm Lines	PDI/ DAS			Grade (0-9 Scale)	Reaction	No. of lesions/ cm^2	Type of lesion	AUDPC/ DAS		Rate of spread 'r'/ DAS		Average 'r'
		65	75	85					65-75	75-85	65-75	75-85	
29	EC 2388	24.44	46.67	64.44	7	S	21.73	TAN	355.56	555.56	0.099	0.073	0.086
30	EC 232019	42.22	60.00	68.89	7	S	21.47	TAN	511.11	644.44	0.072	0.039	0.055
31	EC 241309	37.78	60.00	73.33	7	S	21.07	TAN	488.89	666.67	0.090	0.061	0.075
32	EC 241761	42.22	60.00	64.44	7	S	21.73	TAN	511.11	622.22	0.072	0.019	0.045
33	EC 241766	42.22	64.44	68.89	7	S	22.27	TAN	533.33	666.67	0.091	0.020	0.055
34	EC 242018	55.56	68.89	82.22	9	HS	23.53	TAN	622.22	755.56	0.057	0.074	0.065
35	EC 242038	46.67	60.00	68.89	7	S	20.40	TAN	533.33	644.44	0.054	0.039	0.046
36	**EC 242104**	**6.67**	**8.89**	**8.89**	**1**	**HR**	**5.00**	**RB**	**77.78**	**88.89**	**0.031**	**0.031**	**0.031**
37	EC 242105	77.78	82.22	91.11	9	HS	26.60	TAN	800.00	866.67	0.028	0.079	0.054
38	EC 245984	64.44	68.89	73.33	7	S	21.13	TAN	666.67	711.11	0.020	0.022	0.021
39	EC 245989	64.44	82.22	91.11	9	HS	24.47	TAN	733.33	866.67	0.094	0.079	0.087
40	EC 2581	68.89	77.78	86.67	9	HS	21.73	TAN	733.33	822.22	0.046	0.062	0.054
41	EC 25269	46.67	60.00	73.33	7	S	23.47	TAN	533.33	666.67	0.054	0.061	0.057
42	EC 250578	13.33	15.56	20.00	3	MR	9.82	RB	144.44	177.78	0.018	0.031	0.024
43	EC 250588	64.44	77.78	82.22	9	HS	20.53	TAN	711.11	800.00	0.066	0.028	0.047
44	EC 250607	60.00	68.89	73.33	7	S	25.13	TAN	644.44	711.11	0.039	0.022	0.030
45	EC 250608	46.67	64.44	73.33	7	S	21.27	TAN	555.56	688.89	0.073	0.042	0.057
46	EC 250619	46.67	64.44	73.33	7	S	26.07	TAN	555.56	688.89	0.073	0.042	0.057
47	EC 251329	46.67	55.56	64.44	7	S	23.73	TAN	511.11	600.00	0.036	0.037	0.036
48	EC 251334	42.22	55.56	68.89	7	S	22.33	TAN	488.89	622.22	0.054	0.057	0.055
49	EC 251341	46.67	60.00	68.89	7	S	20.60	TAN	533.33	644.44	0.054	0.039	0.046
50	EC 251358	24.44	55.56	60.00	7	S	22.07	TAN	400.00	577.78	0.135	0.018	0.077
51	EC 251401	28.89	46.67	51.11	7	S	20.87	TAN	377.78	488.89	0.077	0.018	0.047
52	EC 251409	73.33	77.78	86.67	9	HS	22.60	TAN	755.56	822.22	0.024	0.062	0.043
53	EC 251411	68.89	77.78	82.22	9	HS	25.40	TAN	733.33	800.00	0.046	0.028	0.037
54	EC 251 456	60.00	68.89	73.33	7	S	21.53	TAN	644.44	711.11	0.039	0.022	0.030
55	EC 251501	64.44	68.89	77.78	9	HS	21.67	TAN	666.67	733.33	0.020	0.046	0.033
56	EC 251516	64.44	73.33	82.22	9	HS	20.67	TAN	688.89	777.78	0.042	0.052	0.047
57	EC 251762	37.78	46.67	73.33	7	S	18.93	TAN	422.22	600.00	0.037	0.114	0.075
58	EC 274755	64.44	73.33	86.67	9	HS	17.47	TAN	688.89	800.00	0.042	0.086	0.064
59	EC 287754	13.33	24.44	24.44	3	MR	8.65	RB	188.89	244.44	0.074	0.074	0.074
60	EC 30832	51.11	64.44	86.67	9	HS	21.87	TAN	577.78	755.56	0.055	0.128	0.091

Sl. No.	Germplasm Lines	PDI/ DAS			Grade (0-9 Scale)	Reaction	No. of lesions/ cm^2	Type of lesion	AUDPC/ DAS		Rate of spread 'r'/ DAS		Average 'r'
		65	75	85					65-75	75-85	65-75	75-85	
61	EC 308334	8.89	20.00	24.44	3	MR	9.23	RB	144.44	222.22	0.094	0.026	0.060
62	EC 309512	73.33	77.78	86.67	9	HS	21.40	TAN	755.56	822.22	0.024	0.062	0.043
63	EC 309538	68.89	73.33	86.67	9	HS	23.56	TAN	711.11	800.00	0.022	0.086	0.054
64	EC 309545	64.44	73.33	82.22	9	HS	27.67	TAN	688.89	777.78	0.042	0.052	0.047
65	EC 315213	68.89	68.89	77.78	9	HS	23.20	TAN	688.89	733.33	0.000	0.046	0.023
66	EC 3251	42.22	42.22	46.67	5	MS	20.32	TAN	422.22	444.44	0.000	0.018	0.009
67	EC 325092	68.89	82.22	82.22	9	HS	21.40	TAN	755.56	822.22	0.074	0.074	0.074
68	EC 325099	64.44	68.89	82.22	9	HS	17.73	TAN	666.67	755.56	0.020	0.074	0.047
69	EC 325101	42.22	46.67	51.11	7	S	22.07	TAN	444.44	488.89	0.018	0.018	0.018
70	EC 325102	42.22	46.67	51.11	7	S	26.20	TAN	444.44	488.89	0.018	0.018	0.018
71	EC 329158	46.67	51.11	77.78	9	HS	20.13	TAN	488.89	644.44	0.018	0.121	0.069
72	EC 33875	64.44	73.33	82.22	9	HS	24.47	TAN	688.89	777.78	0.042	0.052	0.047
73	EC 33917	42.22	64.44	95.56	9	HS	31.00	TAN	533.33	800.00	0.091	0.247	0.169
74	EC 33922	24.44	42.22	46.67	5	MS	23.40	TAN	333.33	444.44	0.081	0.018	0.050
75	EC 33940	64.44	68.89	82.22	9	HS	24.20	TAN	666.67	755.56	0.020	0.074	0.047
76	EC 333868	55.56	68.89	73.33	7	S	19.53	TAN	622.22	711.11	0.057	0.022	0.039
77	EC 333875	68.89	73.33	82.22	9	HS	22.00	TAN	711.11	777.78	0.022	0.052	0.037
78	EC 333881	64.44	73.33	86.67	9	HS	21.60	TAN	688.89	800.00	0.042	0.086	0.064
79	EC 333886	51.11	64.44	77.78	9	HS	32.80	TAN	577.78	711.11	0.055	0.066	0.060
80	EC 333891	64.44	77.78	86.67	9	HS	28.53	TAN	711.11	822.22	0.066	0.062	0.064
81	EC 333904	37.78	60.00	68.89	7	S	26.13	TAN	488.89	644.44	0.090	0.039	0.065
82	EC 333909	42.22	55.56	64.44	7	S	21.13	TAN	488.89	600.00	0.054	0.037	0.045
83	EC 333920	46.67	60.00	77.78	9	HS	21.93	TAN	533.33	688.89	0.054	0.085	0.069
84	EC 333934	20.00	24.44	24.44	3	MR	9.45	RB	222.22	244.44	0.026	0.026	0.026
85	EC 338597	42.22	55.56	82.22	9	HS	23.87	TAN	488.89	688.89	0.054	0.131	0.092
86	EC 34057	64.44	73.33	82.22	9	HS	24.80	TAN	688.89	777.78	0.042	0.052	0.047
87	EC 34078	60.00	73.33	86.67	9	HS	21.40	TAN	666.67	800.00	0.061	0.086	0.073
88	EC 34079	60.00	68.89	86.67	9	HS	27.13	TAN	644.44	777.78	0.039	0.108	0.073
89	EC 34092	68.89	73.33	82.22	9	HS	32.25	TAN	711.11	777.78	0.022	0.052	0.037
90	EC 34500	73.33	82.22	86.67	9	HS	28.53	TAN	777.78	844.44	0.052	0.034	0.043
91	EC 340924	68.89	82.22	91.11	9	HS	25.80	TAN	755.56	866.67	0.074	0.079	0.077

Sl. No.	Germplasm Lines	PDI/ DAS			Grade (0-9 Scale)	Reaction	No. of lesions/ cm^2	Type of lesion	AUDPC/ DAS		Rate of spread 'r'/ DAS		Average 'r'
		65	75	85					65-75	75-85	65-75	75-85	
92	EC 36816	68.89	77.78	86.67	9	HS	30.73	TAN	733.33	822.22	0.046	0.062	0.054
93	EC 37937	51.11	73.33	95.56	9	HS	26.33	TAN	622.22	844.44	0.097	0.205	0.151
94	EC 376065	68.89	73.33	77.78	9	HS	25.20	TAN	711.11	755.56	0.022	0.024	0.023
95	EC 377552	60.00	73.33	91.11	9	HS	26.80	TAN	666.67	822.22	0.061	0.131	0.096
96	EC 380322	73.33	77.78	91.11	9	HS	25.47	TAN	755.56	844.44	0.024	0.107	0.066
97	EC 383165	60.00	77.78	91.11	9	HS	35.69	TAN	688.89	844.44	0.085	0.107	0.096
98	EC 385243	13.33	20.00	24.44	3	MR	9.89	RB	166.67	222.22	0.048	0.026	0.037
99	EC 389148	60.00	82.22	91.11	9	HS	32.07	TAN	711.11	866.67	0.112	0.079	0.096
100	EC 389151	73.33	82.22	86.67	9	HS	33.27	TAN	777.78	844.44	0.052	0.034	0.043
101	EC 389178	55.56	68.89	73.33	7	S	41.53	TAN	622.22	711.11	0.057	0.022	0.039
102	EC 389400	77.78	82.22	86.67	9	HS	37.27	TAN	800.00	844.44	0.028	0.034	0.031
103	EC 39219	77.78	82.22	91.11	9	HS	32.67	TAN	800.00	866.67	0.028	0.079	0.054
104	EC 39362	73.33	82.22	95.56	9	HS	32.33	TAN	777.78	888.89	0.052	0.153	0.103
105	EC 39491	73.33	82.22	86.67	9	HS	36.53	TAN	777.78	844.44	0.052	0.034	0.043
106	EC 39516	51.11	68.89	77.78	9	HS	29.93	TAN	600.00	733.33	0.075	0.046	0.060
107	EC 39536	64.44	73.33	77.78	9	HS	28.73	TAN	688.89	755.56	0.042	0.024	0.033
108	EC 390981	60.00	82.22	91.11	9	HS	23.40	TAN	711.11	866.67	0.112	0.079	0.096
109	EC 391158	42.22	46.67	51.11	7	S	22.67	TAN	444.44	488.89	0.018	0.018	0.018
110	EC 391336	8.89	15.56	20.00	3	MR	9.21	RB	122.22	177.78	0.063	0.031	0.047
111	EC 391346	68.89	68.89	73.33	7	S	22.20	TAN	688.89	711.11	0.000	0.022	0.011
112	EC 392532	60.00	73.33	77.78	9	HS	27.80	TAN	666.67	755.56	0.061	0.024	0.042
113	EC 392580	55.56	68.89	73.33	7	S	27.47	TAN	622.22	711.11	0.057	0.022	0.039
114	EC 394839	73.33	77.78	91.11	9	HS	24.13	TAN	755.56	844.44	0.024	0.107	0.066
115	EC 396052	60.00	73.33	73.33	7	S	23.27	TAN	666.67	733.33	0.061	0.061	0.061
116	EC 396053	55.56	68.89	73.33	7	S	32.87	TAN	622.22	711.11	0.057	0.022	0.039
117	EC 397158	55.56	73.33	91.11	9	HS	27.20	TAN	644.44	822.22	0.079	0.131	0.105
118	EC 4435	68.89	82.22	82.22	9	HS	24.93	TAN	755.56	822.22	0.074	0.074	0.074
119	EC 42081	64.44	68.89	73.33	7	S	28.87	TAN	666.67	711.11	0.020	0.022	0.021
120	EC 457161	64.44	73.33	82.22	9	HS	31.53	TAN	688.89	777.78	0.042	0.052	0.047
121	EC 457175	42.22	55.56	60.00	7	S	20.93	TAN	488.89	577.78	0.054	0.018	0.036
122	EC 457286	60.00	73.33	73.33	7	S	33.60	TAN	666.67	733.33	0.061	0.061	0.061

Sl. No.	Germplasm Lines	PDI/ DAS			Grade (0-9 Scale)	Reaction	No. of lesions/ cm^2	Type of lesion	AUDPC/ DAS		Rate of spread 'r'/ DAS		Average 'r'
		65	75	85					65-75	75-85	65-75	75-85	
123	EC 457406	73.33	82.22	86.67	9	HS	37.85	TAN	777.78	844.44	0.052	0.034	0.043
124	EC 457419	73.33	77.78	86.67	9	HS	27.13	TAN	755.56	822.22	0.024	0.062	0.043
125	EC 49393	77.78	82.22	91.11	9	HS	26.93	TAN	800.00	866.67	0.028	0.079	0.054
126	EC 65772	64.44	73.33	86.67	9	HS	35.27	TAN	688.89	800.00	0.042	0.086	0.064
127	EC 685246	68.89	82.22	86.67	9	HS	25.87	TAN	755.56	844.44	0.074	0.034	0.054
128	EC 685250	77.78	86.67	91.11	9	HS	30.07	TAN	822.22	888.89	0.062	0.045	0.054
129	EC 685251	73.33	82.22	91.11	9	HS	36.20	TAN	777.78	866.67	0.052	0.079	0.066
130	EC 685252	82.22	82.22	86.67	9	HS	34.60	TAN	822.22	844.44	0.000	0.034	0.017
131	EC 685255	73.33	82.22	95.56	9	HS	23.87	TAN	777.78	888.89	0.052	0.153	0.103
132	EC 685256	73.33	82.22	91.11	9	HS	32.00	TAN	777.78	866.67	0.052	0.079	0.066
133	EC 685258	64.44	77.78	86.67	9	HS	24.93	TAN	711.11	822.22	0.066	0.062	0.064
134	EC 7048	73.33	82.22	82.22	9	HS	23.93	TAN	777.78	822.22	0.052	0.052	0.052
135	EC 85705	68.89	82.22	91.11	9	HS	31.80	TAN	755.56	866.67	0.074	0.079	0.077
136	EC 917258	73.33	77.78	91.11	9	HS	38.20	TAN	755.56	844.44	0.024	0.107	0.066
137	EC 93413	55.56	82.22	91.11	9	HS	24.13	TAN	688.89	866.67	0.131	0.079	0.105
138	EC 94625	68.89	86.67	91.11	9	HS	32.53	TAN	777.78	888.89	0.108	0.045	0.077
139	EC 95291	64.44	82.22	95.56	9	HS	29.60	TAN	733.33	888.89	0.094	0.153	0.124
140	EC 95815	68.89	82.22	95.56	9	HS	36.33	TAN	755.56	888.89	0.074	0.153	0.114
141	EC 241778 (RC)	4.44	6.67	8.89	1	HR	8.73	RB	55.56	77.78	0.043	0.031	0.037
142	EC 241780 (RC)	6.67	8.89	8.89	1	HR	7.56	RB	77.78	88.89	0.031	0.031	0.031
143	DSb 21 (RC)	6.67	8.89	8.89	1	HR	6.87	RB	77.78	88.89	0.031	0.031	0.031
144	JS 335 (SC)	91.11	95.56	95.56	9	HS	42.80	TAN	933.33	955.56	0.074	0.074	0.074

*RC-Resistant check, SC- Susceptible check

Table 3. Disease severity for rust in soybean exotic germplasm lines with yield attributes during *kharif* 2016 at Dharwad and Ugarkhurd

Sl. No.	Genotypes	Disease scoring (0-9)				Yield attributing traits				
		Dharwad		Ugarkhurd						
		Grade	Reaction	Grade	Reaction	DM	NBP	NPP	100 SW	SYP
1	EC 14426	3	MR	3	MR	90	4.0	46.0	11.79	11.48
2	EC 15966	3	MR	3	MR	90	3.8	52.0	12.80	10.12
3	EC 16119	7	S	7	S	93	3.4	39.6	9.20	8.66
4	EC 33922	5	MS	5	MS	88	6.0	43.2	11.60	9.68
5	EC 100031	3	MR	3	MR	95	3.2	44.8	12.70	8.44
6	EC 118420	5	MS	5	MS	90	3.4	43.2	11.85	9.42
7	EC 149988	7	S	7	S	89	4.4	39.2	10.80	9.18
8	EC 175529	5	MS	5	MS	89	8.0	53.4	12.05	10.40
9	EC 221329	5	MS	5	MS	88	5.0	40.6	11.89	8.38
10	EC 242104	1	HR	1	HR	93	4.6	52.4	13.90	11.6
11	EC 250578	3	MR	3	MR	95	5.0	67.2	12.57	11.32
12	EC 251358	5	MS	5	MS	89	4.6	39.2	11.00	9.58
13	EC 251401	5	MS	5	MS	89	3.8	49.4	12.40	9.74
14	EC 257754	3	MR	3	MR	85	3.4	38.0	12.39	10.96
15	EC 308334	3	MR	3	MR	93	7.2	53.8	10.48	11.08
16	EC 325101	5	MS	5	MS	88	3.6	52.8	11.80	9.60
17	EC 325102	5	MS	5	MS	95	4.8	45.8	12.00	10.46
18	EC 333909	7	S	7	S	93	5.4	55.4	11.90	10.84
19	EC 333934	3	MR	3	MR	91	4.2	41.2	12.79	9.10
20	EC 385243	3	MR	3	MR	90	8.6	54.6	12.80	10.52
21	EC 391158	5	MS	5	MS	92	7.2	33.0	12.00	8.24
22	EC 391336	3	MR	3	MR	91	4.4	39.6	12.80	10.28
23	EC241778 (RC)	1	HR	1	HR	102	5.4	48.4	13.90	10.60
24	EC241780 (RC)	1	HR	1	HR	101	4.4	44.2	14.10	9.80
25	DSb 21 (RC)	1	HR	1	HR	92	4.4	54.8	14.00	15.72
26	JS 335 (SC)	9	HS	9	HS	84	3.4	43.4	8.10	9.30

*RC-Resistant check, SC- Susceptible check
DFF- Days to 50 % flowering; DM- Days to maturity; NB- Number of branches per plant;
NPP- Number of pods per plant; 100 SW- 100 Seed weight (g); SYP- Seed yield per plant (g).

Only one line EC 242104 and resistant checks *viz.*, DSb 21, EC 241780, EC 241778 recorded (grade 1) and found to be highly resistant; 9 lines recorded disease (grade 3) and found to be moderately resistant; 9 lines registered disease (grade 5) moderately susceptible reaction, 3 lines were found to be susceptible (grade 7) and JS 335 exhibited highly susceptible reaction. Reactions of these exotic germplasm lines for rust during *kharif* 2016 (Table 3, Fig. 2 and Fig. 4). EC 242104 recorded single plant yield of 11.6 g followed by EC 14426 (11.48 g), EC 250578 (11.32 g), EC 308334 (11.08 g). Highest 100 seed weight recorded in EC 242104 (13.90 g) followed by EC 15966, EC 385243 and EC 391336 (12.80 g).

Out of 144 exotic germplasm lines, EC 242104 exhibited highly resistant reaction (grade 1). In addition to rust resistance, yield attributes of EC 242104 are early maturity (90-95 days) with more number of branches per plant (4.6), number of pods per plant (52.4), 100 seed weight (13.90 g) and seed yield per plant (11.6 g) compared to EC 241778 (10.60 g) and EC 241780 (9.80 g). EC 242104 exhibited highly resistant reaction to rust compared to highly susceptible check JS 335 in large scale plot at Dharwad (Fig. 5). Hence, this line would be utilized in future breeding programmes for development of resistant genotypes.

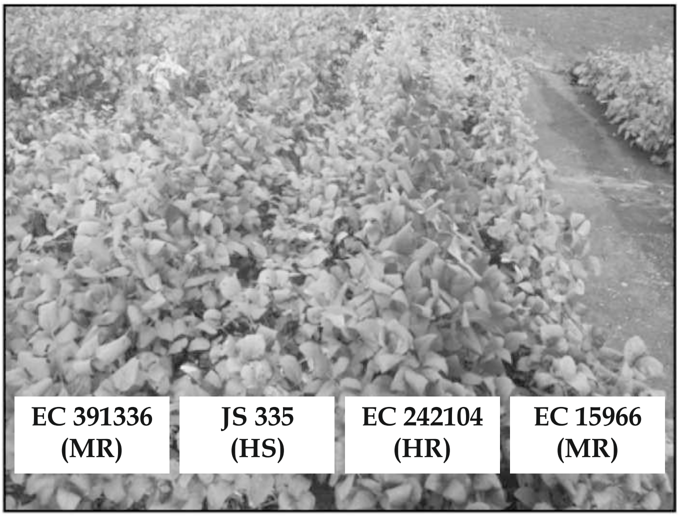
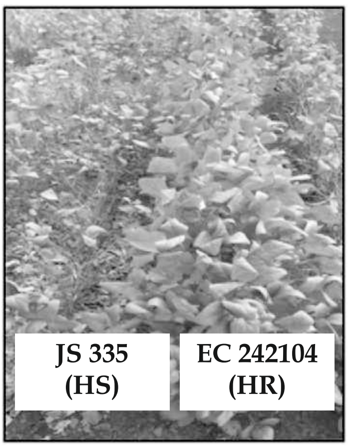


Fig. 3. Close up view of EC 242104 with highly susceptible check during *kharif* 2015 at Dharwad



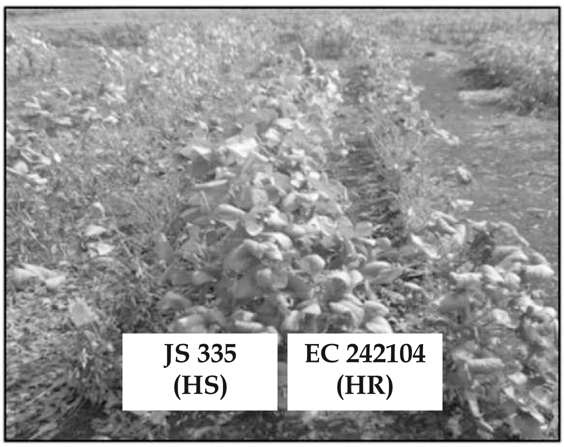


Fig. 4. Confirmation of rust resistance reaction of EC 242104 with highly susceptible check JS 335 during *kharif* 2016 at Dharwad & Ugarkhurd respectively

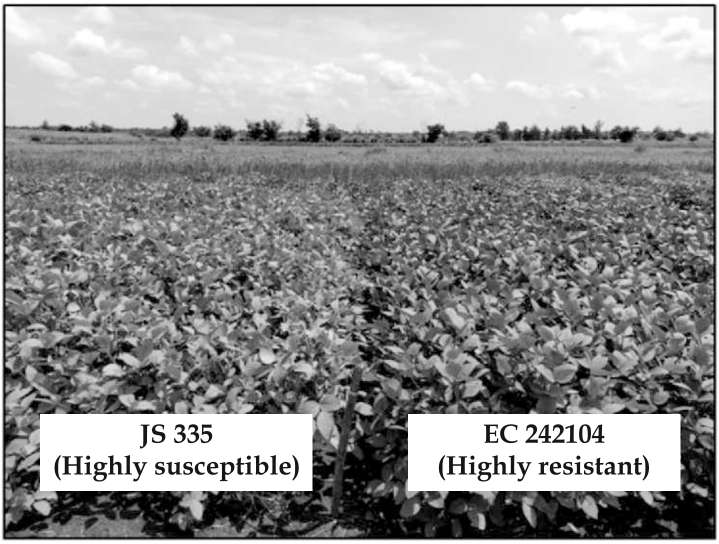


Fig. 5. Rust resistant reaction of EC 242104 with highly susceptible check JS 335 in Large scale plot after confirmation studies at Dharwad (*kharif* 2019)

REFERENCES

Anahosur K H, Rao V G and Patil P V. 1995. Soybean Rust Survey Report 1995, Univ. Agric. Sci., Dharwad, pp. 1-4.

Anonymous. 2020. Directors report and summery tables of experiments of AICRP on Soybean, Directorate of Soybean Research, Indore.

Bromfield K R. 1976. World soybean rust situation. In: World soybean research; Proceedings of ed. Hill, L D, Danville, I L, The Interstate Printers & Publishers, pp. 491-500.

Bromfield K R. 1984. Soybean rust. Monograph 11. APS Press, St. Paul, MN. Pp. 64.

Chan K L. 1977. Soybean rust in Taiwan. In : Rust of soybean. The problem and research needs: Report of ed. Ford R E and Sinclair J B, Urbana-Champaign, IL: University of Illinois, P.51.

Federer W. T. 1956. Augmented (or hoonuiaku) designs. Hawaii. *Plant Research*.**2**: 191–208.

Garcia A, Calvo E S, De Souza Kiihl R A, Harada A, Hiromoto D M and Vieira L G. 2008. Molecular mapping of soybean rust (*Phakopsora pachyrhizi*) resistance genes: Discovery of a novel locus and alleles. *Theory of Applied Genetics*. **117**: 545-553.

Hartman G L, Miles M R and Frederick R D. 2005. Breeding for resistance to soybean rust. *Plant Diseases*. **89**: 664-666.

Hartwig E E and Bromfield K R. 1983. Relationship among three genes conferring specific resistance to rust in soybean. *Crop Science*. **23**: 237-239.

Hartwig E E. 1986. Identification of 4th Major gene conferring resistance to soybean rust. *Crop Science*. **26**: 1735-1736.

Karnataka State Department of Agriculture, 2019-20.

Mayee C D and Datar V V. 1986. *Phytopathometry* Technical Bulletin-1 (special bulletin-3) Marthwada Agric. Univ., Parbhani, p. 95.

Miles M R, Frederick R D and Hartman G L. 2003. Soybean rust: Is the U.S. soybean crop at risk? http://www.aspent.org/online/feature/rust. Accesed 13/09/2004.

Miles M R, Levy C, Morel W, Mueller T, Steinlage T, Van N, Frederick R E and Hartman G L. 2007. International fungicide efficacy trials for the management of soybean rust. *Plant Diseases*. **91** (11): 1450-1458.

Nargund V B. 1989. Epidemiology and control of leaf rust of wheat caused by *Pucciniarecondit* af. sp. *tritici* Rob. Ex. Desm. *Ph.D. Thesis,* Univ. Agric. Sci., Dharwad, Karnataka, India. p. 337.

Parameshwar M. 2006. Genetic investigations in soybean (*Glycine max* (L.) Merrill). *M.Sc (Agri.) Thesis*, Univ. Agric. Sci., Dharwad.

Patil P V, Basavaraja G T, Husain S M. 2004. Two genotypes of soybean as promising source of resistant to rust caused by *Phakospora pachyrhizi* Syd. *Soybean Research*. **2**: 46-47.

Pham T A, Miles M R, Fedrick R D, Hill C B and Hartman G L. 2009. Differential response of Resistant soybean entries to isolate of *Phakospora pachyrizi. Journal of Plant Disease*. **93**:224- 228.

Sharadha H and Jahagirdar S. 2015. Identification of sources of resistance against Asian soybean rust caused by *Phakopsora pachyrhizi* Syd. *Journal Soils and Crops*, **25** (2) : 263- 265.

Shivakumar M, Basavaraja G T, Salimath P M, Patil P V and Akshay Talukdar. 2011. Identification of the rust resistance lines and their genetic variability and character association studies in soybean (*Glycine max* (L.) Merrill). *Indian Journal of Genetics*.**71** (3). 235-240.

Shuxian L, Smith J R, Ray J D and Frederick R D. 2012. Identification of a new soybean rust resistance gene in PI 567102B. *Theory of Applied Genetics*. 125:133–142.

Twizeyimana M, Ojambo, P S, Ikotun T and Paul C. 2007. Comparison of field greenhouse and detached leaf evaluations of soybean germplasm for resistance to *Phakposora pachyrhizi*. *Plant Diseases*. **9**: 1161-1169.

Vander Plank J E. 1963. Plant Disease Epidemics and Control. Academic Press, New York, p. 349.

Verma K P, Thakur M P, Agrawal K C and Khare N. 2004. Occurrence of soybean rust Some studies in Chattisgarh State. *Journal of Mycology and Plant Pathology*. **34** (1): 24-27.

Wilcoxson R D, Skovmand B and Atif A. 1975. Evaluation of wheat cultivars for ability to retard development of stem rust. *Annuals Applied Biology*. **80**: 275-281.

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Isolation and characterization of fungal endophytes and their effectiveness against major soil borne pathogens of soybean

BRUNDA K S, SHAMARAO JAHAGIRDAR*, NAGARAJU P AND KAMBREKAR D N

Department of Plant Pathology, University of Agricultural Sciences, Dharwad-580 005, Karnataka, India

**E-mail: shamaraoj@gmail.com*

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ABSTRACT

Thirty fungal endophytes were isolated from major soybean growing areas of northern Karnataka and Maharashtra. Out of which eight effective fungal endophytes were obtained by in vitro screening against major soilborne pathogens viz., Sclerotium rolfsii, Rhizoctonia bataticola and Fusarium oxysporum. The fungal endophytes RF-BV-3 (46.46%), SF-DM-8 (49.15%) were effective against S. rolfsii and the isolate SF-DM-8 (49.32%) was effective against R. bataticola. The effective fungal endophytes against F. oxysporum were RF-BV-3 (66.61%), SF-BV-3 (59.66%), SF-DM-8 (69.21%), SF-DS-10 (56.49%), LF-HH-5 (66.31%), LF-DM-10 (59.78%), LF-DD-13 (61.15%) and LF-KK-14 (59.78%). Based on molecular methods, the effective fungal endophytes were identified as Daldinia eschscholtzi (RF-BV-3), Fusarium solani (SF-BV-3 & LF-KK-14), Neofusicoccum parvum (SF-DM-8), Diaporthe phaseolorum (SF-DS-10 & LF-HH-5), Phomopsis sp. (LF-DM-10) and Colletotrichum aenigma (LF-DD-13).

Key words : Soybean, Fungal endophyte, *Sclerotium rolfsii*, *Rhizoctonia bataticola* and *Fusarium oxysporum*.

Endophytes are the microbes that live inside the plant tissues without causing any disease in plants. The term endophyte was coined by Heinrich Anton De Bary in 1866. Endophytes are ubiquitous in nature which colonise the plant systemically and reside latently in intercellular spaces, inside the vascular tissue or within cells (Khan and Doty, 2009). Endophytes benefit the plant in many ways by promoting plant growth, improving resistance to multiple stress including suppressing pathogens and insect pests. Endophytes protect the host plants from pathogens primarily by competition between the endophyte and the pathogen on the same resources, ability of the endophytes to enhance the host to produce phytoalexins or biocidal compounds and ability of the endophyte itself to produce fumigants and other antimicrobial agents (Mandyam and Jumpponen, 2005). Endophytes are also involved in improving host resistance against the pathogens by inducing host defense responses. In spite of the great importance of endophytic microorganisms in agricultural ecosystems, only a very small part of the microbial diversity relevant to agriculture is carefully described.

Soybean (*Glycine max* L. Merrill) is the world's most important seed legume & number one oil seed crop of India. The major constraints in soybean production are climate, rainfall, edaphic factors, biotic and abiotic stresses. Soil borne fungal pathogens are the majot stumbling block in successful cultivation of soybean in recent years in India. Over the years chemical management of the plant diseases has posed a greater threat to the Indian agriculture by the development of new races of the pathogens, pesticidal residues and environmental hazards. In this context, use of biological control is gaining importance to protect the environment and soil health. Endophytes have emerged as a new innovative and sustainable approach to manage the diseases, abiotic stresses and to promote plant growth. The benefits of native endophytes have been recognized over the past ten years from around the world and many interesting researches have been undertaken. In India, though there is research on fungal endopytes, the potentiality of endophytes in suppressing soil borne pathogens still remained as untapped resources. Hence, with a view of exploiting the native endophytes and their role in suppression of soil borne pathogens of soybean, the present investigation was undertaken.

MATERIAL AND METHODS

Isolation of fungal endophytes

Fungal endophytes were isolated from healthy soybean plants collected from major soybean growing areas of northern Karnataka *viz*., Belagavi, Bidar, Dharwad, Haveri and parts of Maharashtra *viz*., Kolhapur and Sangli. Roots, stems and leaves of healthy soybean plants collected during the survey were washed to remove dirt and cut into one cm^2 sections. Surface sterilization was done to ensure the absence of epiphytes. Sterilized sections were placed on petri plates containing potato dextrose agar (PDA) medium. Sterilized tissue segments were pressed onto the surface of PDA medium to check the efficacy of surface sterilization procedure and to confirm endophytic isolations only from internal tissues of the plant segments (Schulz *et al*., 1993).

In vitro evaluation of fungal endophytes

Soilborne fungal pathogens *viz*., *Sclerotium rolfsii Sacc, Rhizoctonia bataticola* (Taubenh) E J Butler, Bull Minist. and *Fusarium oxysporum* Schlecht. emend. Snyder & Hansen isolated from infected soybean plant samples were used for screening of the endophytes. Dual culture plate technique was employed for *in vitro* studies of the endophytes against the soilborne pathogens on PDA plates. Petriplate inoculated only with the pathogen served as control. Per cent mycelial inhibition over control was worked out according to the formula given by Vincent (1947).

$$I = \frac{C - T}{C} \times 100$$

Where,

I = Per cent inhibition

C = mycelial growth in control (mm)

T = mycelial growth in treatment (mm)

Molecular characterization of the effective endophytes

The total genomic DNA from pure culture of the different isolates of fungi were extracted by the CTAB (Cetyl Trimethyl Ammonium Bromide) method (Murray and Thompson, 1980) with some modifications. PCR amplification of rDNA sequences were conducted by using the universal primers (ITS1 and ITS4). Finally, the amplified products of the representative samples were sent for sequencing at Chromos Biotech Ltd., Bengaluru. The obtained sequence results were analyzed using Basic Local Alignment

Search Tool (BLAST) algorithm available at http://www.ncbi.nlm.nih.gov.

RESULTS AND DISCUSSION

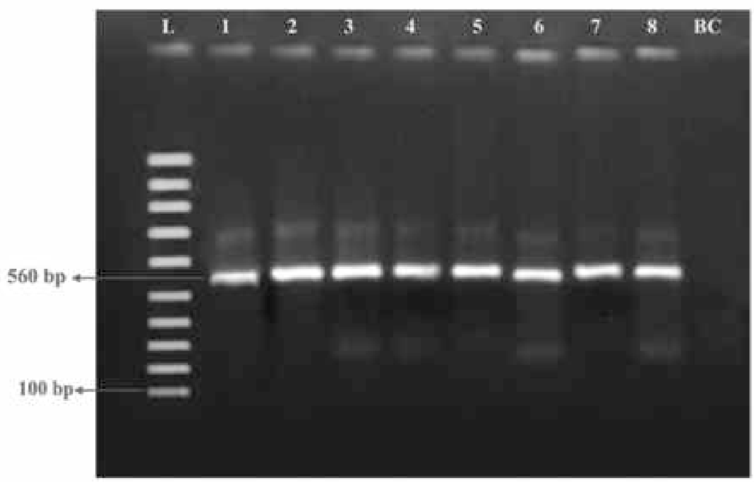
A total of 30 fungal endophytes (4 from root, 11 from stem and 15 from leaf) were obtained from 25 different locations of northern Karnataka and parts of Maharashtra. The endophytes were subjected for *in vitro* evaluation against *Sclerotium rolfsii, Rhizoctonia bataticola* and *Fusarium oxysporum*. The results are presented in the Table 1-3. Results clearly indicated that all the four root endophytes significantly inhibited the mycelial growth of the pathogens. Efficacy of root endophytes against three pathogens ranged from 4.96 to 66.61 per cent mycelial inhibition Table 1. Among the root isolates, RF-BV-3 was effective against both *S. rolfsii* (46.46 %) and *F. oxysporum* (66.61 %) but not against *R. bataticola*.

Among the 11 fungal endophytes evaluated, SF-DM-8 was effective against all the three pathogens with mycelial inhibition of 49.15 per cent against *S. rolfsii*, 49.32 per cent against *R. bataticola* and 69.21 per cent against *F. oxysporum*. The isolates SF-BV-3 (59.66 %) and SF-DS-10 (56.49 %) were also effective against *F. oxysporum* with clear inhibition zone. Efficacy of stem endophytes against three pathogens ranged from 1.47 to 69.21 per cent mycelial inhibition (Table 2).

A total of 15 fungal leaf endophytes were evaluated against the three pathogens by dual culture technique and results are presented in Table 3. Efficacy of leaf endophytes against three pathogens ranged from 0.22 to 66.31 per cent mycelial inhibition. The leaf isolate LF-HH-5 showed the maximum inhibition of 66.31 per cent followed by the isolate LF-DD-13 (61.15 %) and the isolates LF-DM-10 and LF-KK-14 with an inhibition of 59.78 per cent against *F. oxysporum*. So, based on dual culture method of screening, eight effective fungal isolates were obtained. The fungal endophytes RF-BV-3 (46.46 %), SF-DM-8 (49.15 %) were effective against *S. rolfsii* and the isolate SF-DM-8 (49.32 %) was effective against *R. bataticola*. The effective fungal endophytes against *F. oxysporum* were RF-BV-3 (66.61 %), SF-BV-3 (59.66 %), SF-DM-8 (69.21 %), SF-DS-10 (56.49 %), LF-HH-5 (66.31 %), LF-DM-10 (59.78 %), LF-DD-13 (61.15 %) and LF-KK-14 (59.78 %). The findings of the present study are in agreement with Zuhria *et al*. (2016) who evaluated 15 endophytic fungal species of soybean against *Sclerotium rolfsii* under *in vitro* conditions. Isolation of genomic DNA of eight effective fungal endophytes was made by CTAB method and confirmed by agarose gel electrophoresis. The PCR product was sequenced at Chromos Biotech Ltd., Bengaluru (Figure 1). The homology table was constructed using BLAST algorithm to identify the endophytic fungi. Eight effective endophytes of soybean were characterized and results revealed that the isolates RF-BV-3 was similar to *Daldinia eschscholtzi*, the isolates SF-BV-3 and LF-KK-14 were similar to *Fusarium solani*, the isolate SF-DM-8 showed similarity to *Neofusicoccum parvum*, the isolates SF-DS-10 and LF-HH-5 were similar to *Diaporthe phaseolorum*, the isolate LF-DM-10 showed similarity to Phomopsis sp. and the isolate LF-DD-13 was similar to *Colletotrichum aenigma*. The fungal endophytes were identified by the analysis of ITS region of the ribosomal DNA (rDNA) (Table 4). Similar endophyte identification procedure was followed by Akshatha (2016) who used nuclear ribosomal ITS1 and ITS4 sequence analysis and identified the tomato fungal endophytes as *Nigrospora sphaerica* and *Nigrospora oryzae*.

Endophytic *Colletotrichum* isolates have been already described in soybean by

Pimentel *et al*. (2006) and Fernandes *et al*. (2015). Impullitti and Malvick (2013) studied the diversity of fungal endophytes of soybean and reported that the genera *Diaporthe* constituted nine per cent of the total fungal endophyte diversity. Leite *et al*. (2013) identified the soybean fungal endophytes by analysis of ITS region of the ribosomal DNA (rDNA) and reported that fungal endophytes belonged to various genera *viz., Fusarium, Diaporthe, Colletotrichum, Phomopsis* and *Neofusicoccum. Daldinia concentrica* has been isolated as an endophyte from an olive tree in Israel and was known to inhibit *Meloidogyne javanica* (Liarzi *et al*., 2016) and *Daldinia eschscholtzi* was reported as an endophyte from orchid plants by Barnes *et al*. (2016). This is the first report of *Daldinia* and *Neofusicoccum* as fungal endophytes with antagonistic activity against soil-borne pathogens in soybean from India. Endophytes are considered as emerging potential tools for plant disease management. Among 30 fungal endophytes eight were found effective in inhibiting the soil borne pathogens under *in vitro* condition. These eight effective native fungal endophytes obtained from the study can be further evaluated under field condition for both disease management and plant growth promotion traits and used as potential biocontrol agents in future days.



a) PCR amplification of fungal endophytes by ITS primers

L - 100 bp ladder 1) RF-BV-3 2) SF-BV-3 3) SF-DM-8 4) SF-DS-10 5) LF-HH-5 6) LF-DM-10 7) LF-DD-13 8) LF-KK-14 BC) Buffer control

Fig. 1 : PCR Amplification of fungal endophytes by ITS primers

Table 1: ***In vitro*** **evaluation of soybean fungal root endophytes against** ***Sclerotium rolfsii, Rhizoctonia bataticola and Fusarium oxysporum***

Fungal	Per cent inhibition		
Endophyte	*S. rolfsii*	*R. bataticola*	*F. oxysporum*
RF-BC-1	20.78 (27.11)*	23.35 (28.88)*	51.56 (45.88)*
RF-BKh-2	13.92 (21.90)	4.96 (12.86)	41.31 (39.98)
RF-BV-3	46.46 (42.95)	38.44 (38.30)	66.61 (54.68)
RF-DK-4	35.68 (36.66)	16.56 (24.00)	57.69 (49.41)
S.Em. ±	0.30	0.34	0.29
C. D. @1 %	1.42	1.63	1.39

*Arc sine values

Table 2: ***In vitro*** **evaluation of soybean fungal stem endophytes against** ***Sclerotium rolfsii, Rhizoctonia bataticola and Fusarium oxysporum***

Fungal	Per cent inhibition		
Endophyte	*S. rolfsii*	*R. bataticola*	*F. oxysporum*
SF-BU-1	35.68 (36.67)*	28.80 (32.44)*	42.28 (40.54)*
SF-BK-2	32.08 (34.49)	38.84 (38.54)	47.80 (43.72)
SF-BV-3	2.22 (8.43)	41.08 (39.84)	59.66 (50.55)
SF-BV-4	19.82 (26.43)	28.43 (32.21)	48.29 (44.00)
SF-HS-5	3.84 (11.25)	18.35 (25.35)	38.78 (38.50)
SF-HB-6	31.91 (34.38)	34.43 (35.91)	41.15 (39.89)
SF-BiB-7	19.53 (26.21)	30.10 (33.26)	52.75 (46.56)
SF-DM-8	49.15 (44.50)	49.32 (44.59)	69.21 (56.28)
SF-DN-9	1.47 (6.90)	37.16 (37.53)	52.23 (46.26)
SF-DS-10	34.88 (36.18)	37.58 (37.79)	56.49 (48.71)
SF-SK-11	21.06 (27.31)	39.84 (39.12)	46.53 (42.99)
S.Em. ±	0.47	0.43	0.32
C. D. @1 %	1.88	1.71	1.34

*Arc sine values

Table 3: ***In vitro*** **evaluation of soybean fungal leaf endophytes against** ***Sclerotium rolfsii, Rhizoctonia bataticola and Fusarium oxysporum***

Fungal Endophyte	Per cent inhibition		
	S. rolfsii	*R. bataticola*	*F. oxysporum*
LF-BJ-1	27.05 (31.33)*	37.68 (37.85)	52.45 (46.38)
LF-BJ-2	17.45 (24.68)	40.43 (39.46)	53.68 (47.09)
LF-BS-3	20.70 (27.05)	0.37 (3.48)	51.23 (45.69)
LF-BV-4	38.49 (38.33)	1.31 (6.57)	48.31 (44.01)
LF-HH-5	37.97 (38.03)	34.56 (35.99)	66.31 (54.50)
LF-HY-6	33.85 (35.56)	0.22 (2.66)	50.18 (45.08)
LF-BiB-7	29.82 (33.09)	1.25 (6.41)	51.44 (45.81)
LF-BiI-8	40.79 (39.67)	33.46 (35.33)	50.80 (45.44)
LF-BiN-9	27.07 (31.34)	20.51 (26.91)	42.08 (40.43)
LF-DM-10	35.98 (36.84)	27.66 (31.72)	59.78 (50.62)
LF-DG-11	31.83 (34.33)	29.32 (32.77)	57.12 (49.08)
LF-DS-12	35.15 (36.35)	36.27 (37.02)	58.00 (49.58)
LF-DD-13	32.26 (34.59)	11.64 (19.93)	61.15 (51.42)
LF-KK-14	31.83 (34.33)	34.35 (35.86)	59.78 (50.62)
LF-SK-15	29.17 (32.68)	37.74 (37.89)	57.03 (49.02)
S.Em. ±	0.25	0.18	0.29
C. D. @1 %	0.96	0.71	1.14

*Arc sine values

Table 4: Comparative analysis of sequence similarity of association of native fungal endophytes

Source of isolation	Fungal endophyte	Comparison with already reported endophytes/ bioagents		
Root	RF-BV-3	Fungal endophyte isolate SNP378 (*Macaranga fallacina*, Papua New Guinea)	Fungal endophyte isolate 744 (*Parkinsonia microphylla*, stem USA)	*Daldinia eschscholzii* B6 (*Nothapodytes nimmoniana,* stem, India)
			(99 % similarity)	
Stem	SF-BV-3	*Fusarium solani* isolate Khf- Giza (*Mangifera indica* bark, Egypt)	*Fusarium solani* isolate CEF-325 (*Gossypium hirsutum,* stem, China)	*Fusarium solani* isolate 87 (*Phaseolus vulgaris,* Mexico)
			(100 % similarity)	
Leaf	LF-HH-5	Fungal endophyte strain STRI : ICBG-Panama: Tk1261 (*Acalypha macrostachya,* leaf, Panama)	Fungal endophyte strain STRI:ICBG-Panama: Tk1521 (*Callicarpa accuminata,* leaf, Panama)	*Diaporthe* sp. strain (*Merremia umbellata,* leaf, Panama)
			(99 % similarity)	
Stem	SF-DM-8	*Neofusicoccum parvum* isolate 167SS (*Syzygium samarangense,* flower, Malaysia)	*Neofusicoccum parvum* isolate H4461 (*Rhizophoraceae* sp., roots, China)	*Neofusicoccum* sp. SFC-2017c (*Eucalyptus grandis,* China)
			(99 % similarity)	
	SF-DS-10	Fungal endophyte strain 7124 (*Macaranga fallacina,* leaf, Papua New Guinea)	Fungal endophyte strain 6567 (*Psychotria micrococca,* Papua New Guinea)	*Diaporthe phaseolorum* strain TH2S14 (*Unicaria elliptica,* stem, Malaysia)
		(100 % similarity)	(99 % similarity)	

Source of isolation	Fungal endophyte	Comparison with already reported endophytes/ bioagents		
Leaf	LF-DM-10	Fungal endophyte culture collection STRI: ICBG-Panama-TK287 (*Saccharum* sp., leaf, Panama)	*Phomopsis* sp. strain UOC/ PTS/RDWW-14 (*Calamus thwaitesii*, stem, Srilanka)	*Phomopsis* sp. strain Ma194 (Mangrove plants, Thailand)
			(99 % similarity)	
	LF-DD-13	Fungal endophyte isolate 994 (*Ficus variegata*, leaf, Papua New Guinea)	Fungal endophyte isolate 7210 (*Psychotria micrococoa*, Papua New Guinea)	*Colletotrichum aenigma* strain Cg56 (*Fragaria* sp., Japan)
			(99 % similarity)	
Leaf	LF-KK-14	*Fusarium solani* strain Fso8 (*Olea europea*, Tunisia)	*Fusarium solani* strain ATLOY3 (Medicinal plant, bark, India)	*Fusarium solani* strain YJG3-2 (*Plunkenetia volubilis*, China)
		(100 % similarity)	(99 % similarity)	

REFERENCES

Akshatha S. 2016. Role of endophytes in suppression of plant nematode infecting vegetables. *M. Sc. (Agri.) Thesis*, Univ. Agric. Sci., Dharwad, Karnataka (India).

Barnes EC, Jumpathong J, Lumyong S, Voigt K, Hertweck C. 2016. Daldionin, an unprecedented binaphthyl derivative and diverse polyketide congeners from a fungal orchid endophyte. *Chemistry European Journal* 22: 4551-4555.

Fernandes EG, Pereira OL, Silva CC, Bento CBP, Queiroza MV. 2015. Diversity of endophytic fungi in *Glycine max*. *Microbiological Research* 181: 84-92.

Impullitti AE, Malvick DK. 2013. Fungal endophyte diversity in soybean. *Journal of Applied Microbiology* 114: 1500-1506.

Khan Z, Doty SL. 2009. Characterization of bacterial endophytes of sweet potato plants. *Plant Soil*. 322(1): 197-207.

Leite T, Cnossen-Fassoni A, Pereira OL, Mizubuti ES, Araujo EF, Queiroz MV. 2013. Novel and highly diverse fungal endophytes in soybean revealed by the consortium of two different techniques. *Journal of Microbiology* 51(1): 56-69.

Liarzi O, Bucki P, Miyara SB, Ezra D. 2016. Bioactive volatiles from an endophytic *Daldinia* cf. *concentrica* isolate affect the viability of the plant parasitic nematode *Meloidogyne javanica*. *PLoS ONE*. 11(12): e0168437.

Mandyam K, Jumpponen A. 2005. Seeking the elusive functions of the root-colonizing dark septate endophytic fungi. *Studies in Mycology* 53: 173-180.

Murray MG, Thompson WF. 1980. Rapid isolation of high molecular weight plant DNA. *Nucleic Acids Research* 8: 4321-4325.

Pimentel IC, Glienke-Blanco C, Gabardo J, Makowiecky R, Azevedo JL. 2006. Identification and colonization of endophytic fungi from soybean (*Glycine max* (L.) Merril) under different environmental conditions. *Brazilian Achieves of Biology Biotechology* 49(5): 705-711.

Schulz B, Wanke U, Draeger S. 1993. Endophytes from herbaceous and shrubs: effectiveness of surface sterilization methods. *Mycological Research* 97: 1447-1450.

Vincent, J. M., 1947, Distortion of fungal hyphae in the presence of certain inhibitors. *Nature*, 150: 850.

Zuhria SA, Djauhari S, Muhibuddin A. 2016. Exploration and antagonistic test of endophytic fungi from soybean (*Glycine max* (L.) Merr.) with different resistance to *Sclerotium rolfsii*. *Journal of Experimental Life Sciences*. 6(2): 101-105.

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Mitigating Water Stress in Soybean using Mulch and Anti-transpirant

S R MUNDHE[2], S A JAYBHAY*[1], R M PATIL[2], D H SALUNKHE[1], B D IDHOL[1] AND B N WAGHMARE[1]

[1]MACS- Agharkar Research Institute, G. G. Agarkar Road, Pune- 411 004, Maharashtra, [2]Savitribai Phule Pune University, Ganesh Khind, Pune-411 007, Maharashtra.

**E-mail: sajaybhay@aripune.org*

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ABSTRACT

A field experiment was conducted during kharif 2018 to study the response of soybean genotypes to water stress using mulch and anti-transpirant. The field experiment was laid out in factorial randomized block design with three replications comprising factor A as soil moisture conservation measures and factor B as soybean accessions. Results showed that the soil moisture conservation measures significantly affected the growth and developmental attributes of soybean. Combined application of wheat straw mulch along with anti-transpirant have produced significantly higher seed yield (3381 kg/ha) and recorded higher net returns (Rs. 60,341/ha) than other moisture conservation measures. Similarly, the grain production efficiency (34.59 kg/ha/day) and rainfall use efficiency (7.62 kg/ha/mm) was higher with the combined application of mulch and anti-transpirant. The moisture content of the soil was higher in the treatment of mulch and anti-transpirant than the treatment without mulch. Among the soybean genotypes, RSC 10-46 gave significantly high seed yield (3222 kg/ha), followed by TAMS 98-21 (3171 kg/ha) over rest of the two accessions. The maximum net returns (Rs. 57,564/ha) were obtained with RSC 10-46. The combination of soybean genotype RSC 10-46 along with mulch and anti-transpirant was found superior in terms of seed yield per hectare (3503 kg/ha) over the rest of the treatments.

Key words : Anti-transpirant, grain production efficiency, mulch, rainfall use efficiency, soil moisture conservation, soybean

Soybean [G*lycine max* (L.) Merrill] is a globally accepted essential crop commodity due its multipurpose uses as food, feed, and industrial by-produce, medicinal and pharmaceutical applications, etc. Soybean has gained the status of a nutrient rich food crop as its seed contains 38-40% proteins and 18-22% edible oil. In India, soybean has become a predominant rainy season oilseed crop grown under rainfed agro-ecosystem. Among oilseed crops, soybean has the largest area under cultivation (Singh, 2010). In India, 10.76 million ha area is under soybean cultivation with annual production of 9.30 million tons and 865 kg/ha productivity (Anonymous, 2019). Although a significant increase is achieved in the potential productivity of soybean through painstaking efforts by the breeders, the actual average productivity attained at the farmers' field is merely about 40% of the potential productivity (Venkateswarlu and Prasad, 2012). Constraints to optimum productivity of soybean include the limited availability of water due to rainfed area under cultivation coupled with the erratic behaviour of monsoon, heat, and moisture stress at critical growth stages, and biotic interferences to crop growth (Agarwal et al., 2013). Water-stress limits the yield of each crop which results in reduced productivity per hectare. Insufficient, erratic/irregular, and uneven rainfall during the soybean crop growth period hinders the yield due to the unavailability of soil moisture during critical growth stages. For mitigating the water deficit and making the optimum moisture availability to soybean crop for completion of its life cycle, the moisture conservation measures such as application of mulch to soil and anti-transpirant to the foliage is imperative. Application of straw mulch to the soil reduces the soil moisture evaporation and conserves it into soil. Straw mulch adds organic matter to soil, helps to improve water holding capacity of soil, regulates soil temperature, and also suppresses weed growth. Anti-transpirant helps to reduce the water loss from the crop plant by either reflecting the incident light energy or reducing the cuticular and stomatal transpiration. Soybean crop being cultivated in rainy season grows on the precipitation received and the available moisture in the soil thereafter. Long dry spells during the crop growth period hinder the growth and development of soybean crop, which results in lower seed yield. To encounter the water stress arising due to unavailability of sufficient soil moisture to soybean crop, agronomic measure such as use of mulch and anti-transpirant separately or the combination of both can be a better option to elevate soybean production and productivity. Many of the farmers in the country burn or dump the leftover crop residue or straw on the farm instead of using it as mulch. Similarly, the information on the use of anti-transpirant to check the loss of water from plant body is necessary to generate and disseminate among soybean growers. Considering this, the present investigation was undertaken to evaluate the elite soybean cultivars for their response under the straw mulch and anti-transpirant application in terms of growth, grain yield, yield attributes, and economics.

MATERIALS AND METHODS

Field experiment was conducted at the experimental farm of MACS-Agharkar Research Institute, Pune (M.S.), India (latitude $18^0 14'$ N, longitude $75^0 21'$ E and an altitude of 548.6 m above mean sea level) during *kharif* 2018. The experimental site was typically rainfed with 379 mm total rainfall received during crop growth period (June to October) of rainy season 2018. Average minimum and maximum temperature during 2018-19 growing season were 20.94 °C and 30.46 °C (Fig. 1). Soil of the experimental plot belongs to the order vertisol with slightly alkaline pH 7.3 and medium in organic carbon content (0.43%). Intermediate levels of N (294 kg/ha) and P_2O_5 (17.68 kg/ha) were available in the soil, whereas, amount of K_2O in the soil was on higher side (324 kg/ha). The experiment with three replication was laid out in factorial randomized block design (FRBD) comprising factor A: moisture conservation measures *viz*., mulch (wheat straw @ 5 t/ha), no mulch, anti-transpirant (Glycerol 5%), and mulch + anti transpirant; and factor B: soybean accessions *viz*., RSC 10-46, TAMS 98-21, AMS 1002 and VLS 75. The experiment was sown in a plot size of 2.25 m x 6 m, maintaining the row to row spacing of 45 cm and 5 cm between the plants. Experiment was sown on the first week of July and the crop was raised by following the all the recommended package of practices. Wheat straw mulch @ 5 t/ha and anti-transpirant (5% glycerol) application was done at 30 days after sowing (DAS) of the crop to the respective treatment. Soil moisture content in each treatment was recorded at 45 and 60 DAS following the gravimetric method given by Black (1965) as Soil moisture % = {[(Wt. of wet soil + tare) - (Wt. of dry soil + tare)]/ (Wt. of dry soil + tare) - (tare)} × 100. Similarly, the relative water content (RWC) of leaves was determined at 45 and 60 DAS using formula given by Turner (1981) as RWC = (FW – DW) / (SW – DW) × 100, where, FW is fresh leaf weight, SW is the turgid weight of leaves after soaking in water for four hour at room temperature (approx. 20 °C) and DW is dry weight of leaves after drying at 85 °C for three days. Half of the third (from the top) fully expanded leaf was used for the determination of the RWC. Data was recorded from five randomly selected plants on various morpho-agronomic traits *viz.*, number of branches per plant, dry matter per plant, height per plant, number of pods per plant and seed yield per plot. Crop growth rate (CGR) and relative growth rate (RGR) were calculated using formula, given by Watson (1947) and Williams (1946).

$$CGR = W_2 - W_1 / t_2 - t_1$$
$$RGR = (Log_{10} W_2 - Log_{10} W_1) / (t_2 - t_1)$$

Where, W_2 and W_1 are plant dry weight per plant at time period (t_2) and (t_1) respectively.

Soybean grain yield produced in kilogram per hectare per day was determined in terms of Grain production efficiency (GPE) using formula: GPE (kg/ha/day)= seed yield (kg/ha) / number of days required for maturity (Mukeshkumar, 2014). Rainfall use efficiency (EUE) was determined by dividing the seed yield (kg/ha) with rainfall (mm) received during crop growing period (Oweis, 1997). Economics of the treatment was calculated in terms of gross returns, net returns and benefit: cost ratio to find out the economic feasibility. The data were subjected to the analysis of variance using the techniques given by Gomez and Gomez (1994).

RESULTS AND DISCUSSION

Effect on growth and its attributes:

Agronomic measures to mitigate water-stress showed significant influence on the dry matter at 45 and 60 DAS (Table 1). Results revealed that the combination of anti-transpirant (5% glycerol) and mulching with wheat straw as well as anti-transpirant alone showed significantly ($P<0.05$) higher plant dry matter at 45 and 60 DAS than the no mulch treatment. Mulch treatment showed significant increase ($P<0.05$) in the dry matter at 60 DAS as compared to no mulch. An increase in dry matter content with the application of anti-transpirant and mulch might be due to high soil moisture content due to mulch over the ground and reduced stomatal closure; this opens the pathway for the exchange of water, carbon dioxide and oxygen, resulting in increase in photosynthetic rate and thereby increasing vegetative growth (Karkanis *et al.*, 2011). The moisture conservation measures had non-significant effect on plant height, number of branches, plant dry matter at 30 DAS (days after sowing), crop growth rate (CGR) and relative growth rate (RGR). Among the soybean accessions, significant difference was observed for plant dry matter at 60 DAS. Plant dry matter at 60 DAS was significantly higher in soybean entry RSC 10-46 (17.03 g/plant) over VLS 75 (16.38 g/plant) and was at par with the TAMS 98-21 and AMS 1002. An increase in dry matter content of the RSC 10-46 at 60 DAS may be attributed to better expression of vegetative parts *viz.*, leaves, twigs and more number of pod bearing as a result of availability of optimum soil moisture for certain metabolic processes in the plant cell. These results are in agreement with the findings by Zhang and Outlaw (2001). Interaction between the moisture conservation measures and soybean accessions was non-significant for plant growth and its attributes.

Effect on soil moisture content and relative water content of leaves

The soil moisture content might be varied due to fluctuation of rain, soil temperature and wind during crop growth period (Revathi et al., 2020). The soil moisture conservation measures significantly affected soil moisture content, except at 15-30 cm depth at 45 DAS (Table 2). The soil moisture content was significantly higher in the plots with straw mulch application than those having no mulch application. The treatment containing the combination of anti-transpirant and mulch recorded significantly higher soil moisture content (29.71%) at 0-15 cm depth at 45 DAS over no mulch (26.32%) and anti-transpirant (26.12%) application and closely followed by mulch application (28.86%). Similarly, at 60 DAS the soil moisture content was significantly higher with straw mulching over no mulch and anti-transpirant application and was closely followed by combination of mulch and anti-transpirant. Increase in soil moisture content with mulch application over the no mulch might be attributed due to the conservation of the soil moisture by organic straw mulch by reducing the soil temperature in the root zone of crop and exposure of soil to light (Sekhon *et al*., 2005; Dass and Bhattacharyya 2017; and Revathi *et al*., 2020). Soybean accessions did not show significant effect on the soil moisture content. Similarly, the interaction of the moisture conservation measures and soybean accessions was non-significant for soil moisture content.

The relative water content of the leaves at 45 and 60 days after sowing (Table 2) showed that the differences due to various moisture conservation practices were significant. The values of percent RWC of leaves at 45 and 60 DAS were significantly higher ($P<0.05$) under application of anti-transpirant as well as its combination with mulch than no mulch. The improvement in relative water content of leaves in the plots with combine mulch and anti-transpirant application might be due to the conservation of more soil moisture as a result of mulching on the soil surface as well as the reduction in transpiration of water from leaves. These results are in agreement with the findings by Dass and Bhattacharyya (2017). The values of RWC due to soybean accessions were almost similar hence; the differences for RWC of leaves due to various soybean accessions were non-significant.

Effect on seed yield and its attributes:

The moisture conservation measures showed significant effect on the seed yield (kg/ha) and its attributes (Table 3). Soybean seed yield was significantly higher under treatment combination of anti-transpirant and mulch application (3381 kg/ha) over rest of the three treatments of soil moisture conservation. Seed yield under mulching with wheat straw (3155 kg/ha) and application of anti-transpirant (3098 kg/ha) was significantly higher ($P<0.05$) than the seed yield observed under no mulch (2885 kg/ha). Combine application of anti-transpirant and mulch recorded a 14.67% yield increase over no mulch. The increase in yield might be attributed due to conservation of more soil moisture and its availability to the crop at important growth and developmental stages coinciding with the reduced transpiration losses from leaves due to anti transpirant application. These results are in conformity with the findings of Imliwati Jamir *et al*., 2016 and Brahma *et al*., 2007 who reported the seed yield differed significantly due to application of mulch and anti-transpirant. Similarly, other yield traits were significantly influenced by moisture conservation measures except for 100 seed weight (g) and straw yield (kg/ha). Harvest index is one of the yield attributes and was significantly higher (P<0.05) in the combined treatment of mulching and anti-transpirant (64.58%) than no mulch (60.39%). Similarly, harvest index was significantly higher in the treatment of mulch (63.76%) as well as anti-transpirant alone (62.56%) than the no mulch treatment.

Amongst the soybean accessions RSC 10-46 (3222 kg/ha) and TAMS 98-21 (3171 kg/ha) gave significantly higher seed yield (P<0.05) than VLS 75 (3016 kg/ha). Values for 100 seed weight were significantly higher in TAMS 98-21 (14.65 g) over rest of the accessions. RSC 10-46 (14.12 g) showed significantly higher 100 seed weight than VLS 75 (12.53 g) and AMS 1002 (12.00 g). Harvest index was significantly higher (P< 0.05) in TAMS 98-21 (63.67 %), AMS 1002 (63.61 %) and RSC 10-46 (63.22%) than VLS 75 (60.78 %). High seed yield of RSC 10-46 might be attributed due to genetic make and the improvement in growth and developmental traits due to availability of water as a result of moisture conservation measures. Interaction of moisture conservation measures and soybean accession was non-significant for seed yield (Table 4). The combination of Soybean accession RSC 10-46 and anti-transpirant with mulch gave the maximum seed yield (3503 kg/ha) over rest of the combinations. RSC 10-46 was the high yielding genotype whereas combination of anti-transpirant and mulch was the most promising among the moisture conservation measures (Table 4).

Grain production efficiency and Rainfall use efficiency:

Grain production efficiency (GPE) and rainfall use efficiency (RUE) was significantly influenced by moisture conservation measures (Table 3). Maximum value of GPE (34.59 kg/ha/day) was obtained with combine application of mulch and anti-transpirant compared to no mulch and separate application of mulch and anti-transpirant. This might be due to availability of more water required for completion of growth and development during reproductive stages and for metabolic processes of the soybean plant, which resulted into improved seed yield. The difference between GPE among soybean accessions was non-significant. Similarly, the interaction between the moisture conservation measures and soybean accessions was non-significant for GPE. Rainfall use efficiency was significantly higher under combine application of mulch and anti-transpirant (7.62 kg/ha-mm) than the rest of the treatments. Separate application of mulch or anti-transpirant also showed significantly higher RUE than the control treatment of no mulch. Improved RUE under mulch and anti-transpirant treatment may be attributed to the impartment of vigour of the crop and thereby reducing the crop-weed competition caused by smothering effect on weeds as well as holding the more soil moisture, and reduction in loss of water through transpiration losses (Boja, 2008; Sanbagavalli, 2017 and Kaur *et al*., 2019). Among the soybean accessions, RSC 10-46 (7.26 kg/ha-mm) recorded significantly higher rainfall use efficiency over VLS 75 (6.89 kg/ha-mm). The interaction between moisture conservation measures and soybean accessions was non-significant for the rainfall use efficiency.

Economics of the study:

Economic analysis of the moisture conservation measures presented in Table 5 showed that the combined application of mulch and anti-transpirant recorded significantly higher gross returns (Rs. 92,980/- /ha), net returns (Rs. 60,341/- /ha) and higher benefit-cost ratio (2.85:1) over rest of the three treatments. This may be due to efficient conservation of soil and plant moisture under combined application of mulch and anti-transpirant which leads to improvement in growth and yield attributes and enhanced economic returns in the above treatment. These findings are in conformity with Singh, 2018 and Kaur *et al.*, 2019. Among the soybean accessions, RSC 10-46 recorded significantly higher gross returns (Rs. 88,598/-), net returns (Rs. 57,564/-) and benefit-cost ratio (2.85:1) over VLS 75 and AMS 1002 and was closely followed by TAMS 98-21. An increase in seed yield of soybean accessions due to moisture availability during critical growth stages was witnessed, and the effect and utility of mulch and anti-transpirant application to the soybean was also demonstrated in the present study will be helpful to take optimum soybean yield under water stress situation.

CONCLUSION

Findings of the present study showed the practical deployment of the leftover crop residue, especially the wheat straw, which can be efficiently utilized as mulch for conserving the soil moisture and providing organic source of nutrient to raise the soybean crop. Also, the application of anti-transpirant to soybean crop reduces water loss through transpiration. This water can be utilized to complete the growth and developmental stages, ultimately converted into seed yield. The results of the present study showed the combine application of mulch and anti-transpirant to soybean crop have significantly increased net returns per hectare.

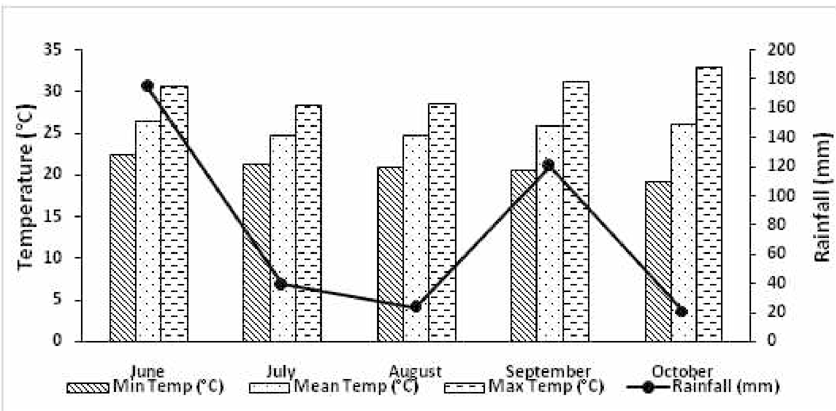

Fig. 1 Rainfall and temperature data during *kharif* 2018

Table 1. Effect of moisture conservation measures on growth parameters of soybean

Treatments	Plant height/ plant (cm)	No. of pods/ Plant	No. of bran-ches /Plant	Dry matter/ plant (gm)			CGR		RGR	
				30 DAS	45 DAS	60 DAS	30-45 DAS	45-60 DAS	30-45 DAS	45-60 DAS
Factor A: Moisture conservation measures										
Mulch	49.38	52	3.85	5.52	11.17	16.72	0.376	0.369	0.0206	0.0117
No mulch	47.73	47	3.87	5.28	10.61	16.05	0.355	0.362	0.0204	0.0120
Anti-transpirant	48.02	50	4.05	5.74	11.44	17.03	0.380	0.373	0.0200	0.0116
Anti-transpirant + Mulch	48.68	58	3.95	5.82	12.37	17.23	0.436	0.324	0.0219	0.0097
Sem	0.99	1.21	0.13	0.22	0.20	0.13	0.02	0.018	0.0013	0.0006
CD at 5%	NS	3.51	NS	NS	0.58	0.38	NS	NS	NS	NS
Factor B: Soybean accessions										
RSC 10-46	48.83	54	3.98	5.77	11.68	17.03	0.394	0.357	0.0206	0.0110
TAMS 98-21	47.30	53	3.95	5.55	11.44	16.92	0.392	0.365	0.0209	0.0114
VLS 75	48.85	48	3.88	5.63	11.20	16.38	0.371	0.346	0.0199	0.0111
AMS 1002	48.03	51	3.90	5.42	11.28	16.70	0.391	0.361	0.0215	0.0115
SEm	1.00	1.21	0.13	0.22	0.20	0.13	0.02	0.018	0.0013	0.0006
CD at 5%	NS	3.51	NS	NS	NS	0.38	NS	NS	NS	NS
A x B Int. SEm	1.98	2.43	0.27	0.43	0.40	0.26	0.04	0.036	0.0026	0.0013
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 2. Effect of moisture conservation measures on soil moisture content and relative water content of leaves

Treatments	Soil moisture content (%)				Relative water content of leaves (%)	
	0-15 cm depth (45 DAS)	15-30 cm depth (45 DAS)	0-15 cm depth (60 DAS)	15-30 cm depth (60 DAS)	45 DAS	60 DAS
Factor A: Moisture conservation measures						
Mulch	28.86	29.49	25.03	22.66	67.76	72.56
No mulch	26.32	28.93	22.42	20.72	65.86	66.60
Anti-transpirant	26.12	30.00	22.91	20.25	70.98	73.67
Anti-transpirant + Mulch	29.71	30.64	24.69	22.12	71.04	73.10
SEm	0.54	0.89	0.53	0.42	1.12	0.86
CD at 5%	1.57	NS	1.55	1.20	3.22	2.46
Factor B: Soybean accessions						
RSC 10-46	28.32	29.98	24.11	20.66	69.43	71.44
TAMS 98-21	27.87	28.97	23.89	22.20	69.19	72.75
VLS 75	27.84	30.55	22.96	21.52	68.62	70.69
AMS 1002	26.98	29.56	24.09	21.37	68.40	71.06
SEm	0.54	0.89	0.53	0.42	1.12	0.86
CD at 5%	NS	NS	NS	NS	NS	NS
A x B Int. SEm	1.09	1.77	1.08	0.12	2.24	1.71
CD at 5%	NS	NS	NS	NS	NS	NS

Table 3. Effect of moisture conservation measures in respect of yield parameters and yield of soybean

Treatments	100 seed weight (g)	Harvest index (%)	Straw yield (kg/ha)	Seed yield (kg/ha)	GPE (kg/ha/day)	RUE (kg/ha-mm)
Factor A: Moisture conservation measures						
Mulch	13.22	63.76	1795	3155	32.27	7.10
No mulch	13.35	60.39	1898	2885	29.52	6.50
Anti-transpirant	13.39	62.56	1854	3098	31.69	6.98
Anti-transpirant + Mulch	13.35	64.58	1853	3381	34.59	7.62
SEm	0.13	0.62	42.40	40.68	0.42	0.09
CD at 5%	NS	1.98	NS	130.00	1.33	0.29
Factor B: Soybean accessions						
RSC 10-46	14.12	63.22	1860	3222	32.22	7.26
TAMS 98-21	14.65	63.67	1805	3171	32.36	7.14
VLS 75	12.53	60.78	1948	3016	31.09	6.89
AMS 1002	12.00	63.61	1777	3109	32.39	7.00
SEm	0.13	0.62	42.40	40.68	0.42	0.09
CD at 5%	0.42	1.98	135.50	130.00	NS	0.29
A x B Int. SEm	0.27	1.24	84.80	81.36	0.83	0.18
CD at 5%	NS	NS	NS	NS	NS	NS

GPE: Grain production efficiency, RUE: Rainfall use efficiency

Table 4. Interaction effect of moisture conservation measures and soybean accessions on seed yield of soybean

Moisture conservation measures	Soybean accessions (Yield kg/ha)				
	RSC 10-46	TAMS 98-21	VLS 75	AMS 1002	Mean
Mulch	3236	3224	3049	3110	3155
No mulch	2894	2902	2852	2891	2885
Anti-transpirant	3254	3151	2909	3077	3098
Anti-transpirant + Mulch	3503	3407	3254	3360	3381
Mean	3222	3171	3016	3109	
SEm			81.36		
CD at 5%			NS		

Table 5. Economics of moisture conservation measures to mitigate water stress in soybean

Treatments	Seed yield (kg/ha)	Gross returns (Rs/ha)	Cost of cultivation (Rs/ha)	Net returns (Rs/ha)	Benefit: cost ratio
Factor A: Moisture conservation measures					
Mulch	3155	86752	31930	54822	2.72:1
No mulch	2885	79329	29430	49899	2.70:1
Anti-transpirant	3098	85192	30139	55053	2.83:1
Anti-transpirant + Mulch	3381	92980	32639	60341	2.85:1
SEm	40.68	1119	-	1119	0.035
CD at 5%	117.34	3227	-	3227	0.103
Factor B: Soybean accessions					
RSC 10-46	3222	88598	31034	57564	2.85
TAMS 98-21	3171	87205	31034	56170	2.81
VLS 75	3016	82941	31034	51907	2.67
AMS 1002	3109	85509	31034	54474	2.75
SEm	40.68	1119	-	1119	0.035
CD at 5%	117.34	3227	-	3227	0.103
A x B Int. SEm	81.36	2237	-	2237	0.071
CD at 5%	NS	NS	-	NS	NS

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REFERENCES

Agarwal D K, Billore S D, Sharma A N, Dupare BU and Srivastava S K. 2013. Soybean: Introduction, Improvement, and Utilization in India-Problems and Prospects. *Agricultural Research* 2 (4): 293-300.

Anonymous. 2019: Directors Report and Summary Tables of Experiments 2019-20, All India Co-ordinated Research Project on Soybean, ICAR-Indian Institute of Soybean Research, Indore. Pp.: ii-iii.

Black C A. 1965. "Methods of Soil Analysis: Part I Physical and mineralogical properties".

American Society of Agronomy, Madison, Wisconsin, USA.

Boja Mekonnen, 2008. Evaluation of straw and plastic mulch on water use efficiency of drip irrigated pepper (Capsicum annuum). M.Sc. Thesis, Haramaya University, Ethiopia.

Brahma R., Janawade A D and Palled Y B. 2007. Effect of irrigation schedules, mulch and anti-transpirants on growth, yield and economics of wheat (cv. DWD – 1006). *Karnataka Journal Agricultural Sciences* 20(1): 6-9.

Dass Anchal and Ranjan Bhattacharyya. 2017. Wheat residue mulch and anti-transpirants improve productivity and quality of rainfed soybean in semi-arid north-Indian plains. *Field Crops Research* 210: 9-19.

Gomez K A and Gomez A A. 1984. Statistical Procedures for Agricultural Research, 2nd ed. John Willey and Sons, New York

Imliwati Jamir, Singh A K S, Zulutemjen Jamir, Engrala A O and Pravin Prakash. 2016. Effect of straw mulch and anti-transpirants on yield and quality of soybean (*Glycine max* L. Merril). *The Bioscan* 11(1): 635-639.

Karkanis A, Bilalis D and Efthimiadou A. 2011. Architectural plasticity, photosynthesis and growth responses of velvetleaf (Abutilon theophrasti Medicus) plants to water stress in a semi-arid environment. *Australian Journal of Crop Science* 5(4): 369-374.

Kaur V K, Singh G, Aggarwal N and Poonam Sharma. 2019. Growth, nodulation and productivity of rainfed soybean (*Glycine max*) as influenced by mulching and anti-transpirants. *Indian Journal of Agronomy* 64(4): 506-510.

Mukeshkumar, Singh S R, Jha S K, Shamna A, Sonali P Mazumdar, Singh Amarpreet, Kandu D K and Mahapatra B S. 2014. System productivity, profitability and resource use efficiency of jute (*Corchorus olitorius*) based cropping systems in the eastern Indo-gangetic plain. *Indian Journal of Agricultural Sciences* 84 (2): 209-213.

Oweis T. 1997. Supplemental irrigation: a highly efficient water-use practice. ICARDA, Aleppo, Syria, Pp.: 16.

Revathi P, Arun M N, Sukumar K, Dhrua S and Bindu G S M. 2020. Enhancing the Water Stress Tolerance in Soybean

(*Glycine max* L.) through Anti-Transpirants and Mulch. *Legume Research* Pp.: 1-7, DOI: 10.18805/LR-4216

Sanbagavalli S, Vaiyapuri K and Marimuthu S. 2017. Impact of mulching and anti-transpirants on growth and yield of soybean (*Glycine max* L. Merril). *Advances in Environmental Biology* 11(1): 84-89.

Sekhon N K, Hira G S, Sidhu A S and Thind S S. 2005. Response of soybean to wheat straw mulching in different cropping seasons. *Soil Use Management* 21: 422–426.

Singh A K, Singh C S and Singh A K. 2018. Enhancing Productivity and Quality of Soybean through Mulching and Anti-Transpirants in Jharkhand, India. *International Journal of Current Microbiology and Applied Sciences* SI-7: 4268-4272.

Singh G. 2010. The Soybean, Botany, Production and Uses. Punjab Agricultural University, India, Oxford shire, UK: CABI Publishing. Pp. 512.

Turner N C. 1981. Techniques and experimental approaches for the measurement of plant water status. *Plant and Soil* 58 : 339-366.

Venkateswarlu B and Prasad J V N S. 2012. Carrying Capacity of Indian Agriculture: Issues Related to Rainfed Farming. *Current Science* 102: 882-888.

Watson D J. 1947. Comparative physiological studies on the growth of field crops I. Variation in NAR and LAR between species and varieties and within and between years. *Annals of Botany (London)* 11: 41-46.

Williams R F. 1946. The physiology of plant growth with special reference to the concept of net assimilation rate. *Annals of Botany* 10: 41-72.

Zhang S Q and Outlaw W H. 2001. Abscisic acid introduced into the transpiration stream accumulates in the guard cell apoplast and causes stomatal closure. *Plant, Cell and Environment* 24 (10): 1045–1054.

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Farmers' Perception on Climate Change and its Impact: A Case of Soybean Growers in Central India

B U DUPARE*[1], PURUSHOTTAM SHARMA[2], S D BILLORE[1] AND S K VERMA[1]

[1]ICAR-Indian Institute of Soybean Research, Khandwa Road, Indore-452001
[2]ICAR- National Institute of Agricultural Economics and Policy Research, New Delhi-12

**E-mail: soyextn@gmail.com*

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ABSTRACT

The study aims to understand the farmers' perception on different aspects of climate change and its impact on crops sector using primary data collected from randomly selected farmers of Madhya Pradesh state in Central India. The research results revealed that majority of farmers perceived change in arrival of monsoon, distribution of rainfall, decline in receipt of rainfall, increase in temperature and reduction in humidity. The multinomial logistic regression results indicated that age of household head, farm size, resource availability and extension contact significantly affected the perception of different aspects of climate change. The results indicated the importance of training and strengthening extension to educate farmers on climate change aspects.

Key words **:** Farmer's perception, climate change, multinomial logistic regression model, agriculture, Central India

The agricultural production systems worldwide as well as in India are facing the problem of uncertainties in production due to growing climate related challenges. It is a matter of great concern considering the ever-increasing population of the country more so in some of the Asian economies. The impact of climate change is more pronounced in agricultural economies than others. Studies also reported that the food systems contribute significantly to global warming and are responsible for 19-29% of global emissions (Vermeulen *et al*. 2012). Agricultural practices lead to emission of green-house gases (Edwards-Jones *et al*. 2009; Maraseni *et al*. 2009) which further compound the present volatile climate. The studies on impact of climate change in India revealed the changes with respect to increased seasonal temperature, occurrence of more events like severe and prolonged droughts, delayed onset of monsoon, uneven distribution and variation in seasonal rainfall, less rainy days of high intensity rainfall, heat waves, etc. (Mall 2006; Guhathakurta and Rajeevan 2008; Dash *et al*. 2009; Dash and Mamgain 2011; Attri and Rathore 2012; Jain and Kumar 2012; Birthal 2015; Oza and Kishtawal 2015, 2016; Mishra *et al*. 2016; Kumar *et al*. 2010).

The frequency of climatic adversities has increased coupled with yield losses due to adverse situations of drought or heavy rainfall spells during critical crop growth stages as well as climate change induced other biotic factors particularly insect-pest and diseases (Dash *et al*. 2007; Attri and Rathore 2012; Jain *et al*. 2013; Ramdas *et al*. 2016; Kumar *et al*. 2017; Dupare *et al*. 2017). The average temperature during the crop growth period also reported to be increased (Mishra and Shah 2016). The instances of heat wave, heavy rainfall and/ or drought have reported to be increasing since last decade (Birthal *et al*. 2015). Prevalence of these adverse climatic events makes the farmers more vulnerable. As far as soybean is concerned, frequent climatic variation has been noticed mainly during the current decade particularly the instances of delayed onset of monsoon, prolonged dry spells during the crop growth stages coupled with high intensity rains for short period, early cessation of monsoon and sometime damage to the crop produce during maturity period of soybean (Dupare *et al*. 2017). Ramteke *et al*. (2015) observed that there is a shift in the peak rainfall from July to August, and the total rainfall during the peak month was reduced. The rainfall during the field emergence and vegetative growth of the soybean crop has been reduced. Interestingly, Mohanty *et al*. (2017) in a study in Central India using simulation models found that increasing CO_2 concentrations alone resulted in increased soybean yield by around 20% under future climate scenarios, whereas reduction in rainfall amount indicated negative impact on it. Further, the rise in temperature would impact grain size and lower soybean productivity due to enhanced growth and reduced grain weight accumulation time (Seddigh and Joliff 1984; Baker *et al*. 1989; Adams *et al*. 1990; Sinclair and Rawlins 1993; Haskett *et al*. 1997; Lal *et al*. 1999; Billore *et al*. 2018).

Perceptions not only shape knowledge but knowledge also shapes perception. Farmers' perceptions about climate change, therefore, strongly affects how they deal with climate induced risks and uncertainties, and undertake specific measures by coping strategies to mitigate the adverse impact of climate change on agriculture. Understanding of the dimensions, causes and impacts of climate change is required to plan and undertake effective adaptation and mitigation strategies. Climate change mitigation behavior is greatly shaped by the knowledge and perception on climate change along with the personal experiences (Spence *et al*. 2011; Broomell *et al*. 2015). Studies on environmental behavior theories also established the relation between perception, knowledge of issue and behavior change (Stern *et al*. 1999). Consequently, the present study was undertaken to know the farmers' knowledge and perception on climate change, and its impact. This line of enquiry is required to plan for extension approaches and adaptation strategies in order to minimize the impact of climate change.

DATA AND METHODOLOGY

Location of the Study area: Soybean is mainly grown in Central India which contributes around 90 per cent of total soybean production in the country. Madhya Pradesh, located in the central India, accounts for more than 50 per cent of area and production of soybean in the country. It has sub-tropical climate with hot-dry summer (April-June) followed by the monsoon (June-September) season. Winter in Madhya Pradesh is cool and dry. Average annual rainfall in Madhya Pradesh is about 1300 mm (Mishra *et al*. 2016). Thus, the study is based on primary data collected from Madhya Pradesh state in Central India.

Data and collection method: The study was conducted in three districts of Madhya Pradesh covering *Malwa* plateau (Indore and Dewas Districts) and *Nimar* valley (Dhar district), major soybean growing area in the country. The data was collected from 280 farmers selected randomly from two villages of each district with the use of pre-tested structured interview schedule. The response of farmers on season-wise crops grown, pattern of arrival of monsoon & its distribution, receipt of total rainfall, prevailing temperature, humidity and sunlight/photoperiod along with perceived impact of climate change on insect/disease load, weed infestation, crop yields, etc. since the start of soybean cultivation were recorded along with some open ended questions related to the farmers' experience and their opinion about the prevailing climatic situation as well as its impact on crops. After the data collection, the entire interview schedules were coded with serial numbers and the response of farmers were computed. For some parameters, the qualitative data have been converted into quantifiable data. The quantitative data were tabulated and analyzed after applying statistical tools like percentage, mean, standard deviation etc. The data on weather parameters were also compared with that of actual secondary data available with meteorology department.

Modeling farmers' perception: The perception of farmers on different aspects of climate change was analyzed using multinomial logistic regression model (MNL) in which perceptions of farmers' were considered as dependent variable and socio-economic and demographic characters as explanatory variables. This model uses general logit transformation, the logarithm of odds of a particular outcome level comparative to the reference level (Stokes *et al*. 2000). The perception of 'no perceived change' is generally considered as the reference level of the dependent variable.

Since, the farmers' perception on different aspects of climate change such as change in arrival of monsoon, change in distribution of monsoon rainfall, change in receipt of precipitation, change in temperature and change in humidity, these perceptions were considered as dependent variable and modeled separately (Table 2). The explanatory variables considered for the analysis were; age of the household head in years, size of land holding in hectares, number of family members (continuous variables), level of family income (up to Rs. 2 Lakhs and above Rs. 2 Lakhs), education level (up to primary standard and above primary level), possession of farm resources and implements, and whether farmer is in contact with extension agencies (as categorical variables dummy coded with the largest value as reference) (Table 1). Five multinomial logistic regression models were estimated. The characteristics of sample farmers are presented in Table 1.

RESULTS AND DISCUSSION

The findings of the study are presented in different sub-heads covering farmers' perception about the changes in weather parameters as well as impact of climate change on cropping and crop yields. Wherever possible, the findings have been supported by the relevant studies conducted in the past.

Rainfall and temperature in selected districts

The annual rainfall, annual minimum and maximum temperature and per cent deviation from normal rainfall in selected districts were depicted in the figures 1a-c and 2. The normal annual rainfall in the selected districts is 886.24 mm in Dhar, 906.95 mm in Indore and 939.1 mm in Dewas. Most of the precipitation (around 94% of total annual rainfall) is received during the rainy/ monsoon season (June to September months). The rainfall trend indicates declining trend in Dewas and Dhar districts, whereas mostly no change in Indore district. The mean annual minimum and maximum temperature pattern indicates the marginal increase in Dewas district and in minimum temperature in Indore and Dhar districts also. The events of extreme rainfall have increased (Figure 2) in the selected districts.

Guhathakurta *et al*. (2020) analyzed the rainfall variability and changes for the period 1989-2018 in Madhya Pradesh and reported that rainfall in June month is decreasing but not significant in all three selected districts, while July rainfall is increasing but not significant. August and September rainfall reported to be decreasing and not significant in Dewas district, whereas it was increasing but not significant in Indore and Dhar districts. The monsoon season as well as annual rainfall was found to be increasing but not significant in western Madhya Pradesh. According to Bantilan *et al*. (2012) the long-term rainfall analysis of India indicates that rainfall has become more variable during the monsoons both in terms of timing as well as intensity within and between the main cropping seasons and farmers perceived that there have been significant variations in the quantum, distribution and onset of rainfall over the years.

Kundu *et al*. (2015) found that the variation for the period 1901-2011 followed decreasing trend. The probable break point in the series was 1978 and extreme negative event of rainfall became frequent in the years after the break point from 1979 to 2011. The annual decrease of −6.75 % of rainfall is observed from 1901 to 2011. In another study (Dash *et al*. 2007) also indicated a decreasing trend in monsoon rainfall in East Madhya Pradesh (1871–2002). Duhan and Pandey (2013) found that the most probable year of change was 1978 in annual precipitation. The percentage change in average rainfall of 1979-2002 over that of 1901–1978 average revealed the decrease in almost all the stations. The decrease in annual rainfall in Madhya Pradesh was − 2.59% during the period 1901-2002. However, there was higher increase in average rainfall in West MP as compared to East MP during the period of 1901–1978. While during the period 1979-2002, the decrease in rainfall was more in East MP as compared to West MP. Similarly, Mishra and Shah (2015) and Mishra *et al*. (2016) revealed that a majority of the state of MP experienced a significant decline in the monsoon season precipitation during the period of 1951-2013. Atmospheric temperature increased significantly in the post-monsoon (October-December) season. Results also indicated that the frequency of severe, extreme, and exceptional droughts has increased in Madhya Pradesh. Mean monsoon season precipitation declined significantly in the state of MP during the period of 1951-2013. Declines in the monsoon season precipitation were more concentrated in the eastern parts of Madhya Pradesh during the period of 1951-2013. Droughts have become more frequent and wide-spread during the recent decades in Madhya Pradesh. The number of hot days increased substantially after 1990 in Madhya Pradesh.

Farmers' perception on different parameters of climate changes in Central India

The perceptions of farmers on different aspects of climate change were recorded through primary survey in selected districts of *Malwa* plateau and *Nimar* valley in Central India, a major soybean growing region. The results of the analysis were presented on Table 2.

Farmers of the study area were asked about their experience of the arrival pattern of monsoon in their area. Most of them have clearly expressed their opinion through their perceived knowledge (Table 2). The results indicated that majority of farmers perceived that the arrival of monsoon has got delayed in the area. As per farmers' opinion, earlier the monsoon arrival period was first fortnight of June month, which has delayed by less than a fortnight (57% of farmers) or mainly arrives in second fortnight of June month. About 39 per cent of farmers perceive that the arrival of monsoon has delayed by more than a fortnight i.e. arrives during last week of June or first week of July month. The perception of the respondent farmers was found more in agreement with the statement that the onset of monsoon was getting delayed in recent years and they perceived a decreasing annual rainfall (Prasad *et al*. 2012; Singh *et al*. 2017; Rama Rao *et al*. 2018; Ramdas *et al*. 2018).

The farmers' perception about the overall distribution of monsoon rainfall in the study area indicated that a vast majority of respondents (81%) feel that the monsoon distribution pattern has mostly been erratic, with long dry spells either at initial growth stage as well as middle season as well as at maturity period affecting heavy yield losses of their *kharif* season crop. Similarly, the perception of another 13% of the respondents reflects the overall situation of monsoon distribution which is highly erratic. According to them, the number of rainy days has been drastically reduced with the increasing number of rains of high intensity within a short period. Even though the receipt of total rainfall considered being normal, its distribution throughout the season has affected drastically affecting the crop condition more prone to drought and/or water logging as well as increased pressure from biotic factors particularly weeds, insect-pest and diseases.

Regarding the amount of rainfall received, majority of farmers perceived that there was decline in the precipitation (71% of the farmers). However, the rainfall data presented on figures 1a to 1c also indicated marginal but no significant decline or no change in rainfall in the selected districts. Thus, majority of the farmers in-correctly perceived the decline in precipitation in the region. Nearly a quarter of the sample farmers perceive that there is no any change in the amount of rainfall received in the area. As mentioned above, the change in distribution of rainfall (erratic and uneven distribution) is a major concern.

Majority of farmers perceived that the onset of monsoon was getting delayed in recent years and they perceived a decreasing annual rainfall, decrease in the number of rainy days and an increase in the magnitude of the extreme rain events, unusually hot days, increased frequency of drought, no change in the frequency of flood, decreased frequency of rain with increased erratic pattern and less quantum of rainfall, increased sunshine hours and day/night temperature, and relative humidity (Prasad *et al*. 2012; Duhan *et al*. 2013; Dhanya and Ramachandran 2016; Mishra *et al*. 2016; Kawadia and Tiwari 2017; Mall *et al*. 2017; Singh *et al*. 2017; Rama Rao *et al*. 2018; Ramdas 2018). The frequency of severe, extreme, and exceptional droughts has increased in Madhya Pradesh. Droughts in the recent years were severe and wide-spread. The number of hot days has increased significantly in the state. The number of heat waves became more frequent during the recent years in Madhya Pradesh (Mishra *et al*. 2016). Study conducted by Mall *et al*. (2017) in Madhya Pradesh revealed that the trend is similar in *kharif* season. *Rabi* season did not show major change in rainfall except few districts. On the other hand, both minimum and maximum temperatures have been rising significantly in most part of the state in both the seasons. Shukla *et al* (2017) also reported that the temperature has significantly shifted upward in Madhya Pradesh and the change point year was observed to be 1963.

The studies also reveal agreement of the majority of the farmers for increased seasonal temperature in the area. The perception study conducted by Bantilan *et al*. (2012) found that the farmers also experience a rise in atmospheric temperature along with frequent occurrence of extreme events such as drought and high temperatures. Thus, the perceptions of farmers largely agree with the observed or recorded data. Dhanya and Ramachandran (2016) opined that the most of the farmers (89%) perceived that temperature is increasing and has become unbearable especially during the past two decades. According to a study by Rama Rao *et al* (2018), farmers perceive that climate is changing in terms of onset and withdrawal of monsoon, changes in the distribution of rainfall and rising temperatures.

Factors affecting farmers' perceptions on climate change

As mentioned above, farmers' perception on five different aspects of climate change were recorded, and accordingly five models were estimated using multinomial logistic regression, and the results are presented on Table 3. In Model 1 the dependent variable was farmers' perception on change in arrival of monsoon and the reference category was 'no change'. For the farmers perceiving arrival of monsoon delayed by more than a fortnight, the variables such as size of family and extension contact were positive and statistically significant, indicating that farmers in contact with extension agencies and with larger family size positively perceived delay in arrival of monsoon by more than a fortnight. For those who perceived delay in monsoon arrival by less than a fortnight the significant, however negative, variables were head of household and land holding, showing that large and older farmers were less likely to perceive the delay in monsoon by less than a fortnight. However, the perception of change in arrival of monsoon was not significantly affected by the variables such as family income, education of the respondent and possession of farm resources and implements.

Model 2 examined the farmers' perception of 'change in rainfall distribution' and the reference category was 'no change'. The other categories were 'high intensity rainfall in short duration' and 'erratic distribution of rainfall'. Age was found to be negative and significant variable affecting the perception of high intensity rainfall in short period of time. For the farmers perceiving erratic distribution of monsoon rainfall the variables like age of the respondent, land holding and farm resources and implements were turned out to be negative and significant, indicating that resource rich farmers with large size of farm holdings and old farmers were less likely to perceive the erratic rainfall. The resources available with them may have affected their opinion as they would be less likely to get affected with the distribution of rainfall.

The perception of change in receipt of precipitation was estimated using model 3, with reference category as 'no change' and the other categories of farmers' perception were 'increase' and 'decrease' in receipt of rainfall. The majority of the farmers in-correctly perceived the decrease in the receipt of average precipitation during monsoon season (As mentioned above). For the farmers perceiving increase in average monsoon rainfall, the coefficient of variables like age of the respondent, farm resources and extension contact was found to be significant. This indicated that resource rich farmers and farmers in contact with extension agencies were less likely to perceive the increase in average monsoon rainfall, whereas older farmers were more likely to perceive the rainfall increase. For the farmers perceived the decrease in average monsoon rainfall, the coefficient of variable farm resources and implements was positively significant, signifying thereby that the rich farmers more accurately perceived the rainfall trend. The coefficient for family income was negative and significant indicating that farmers with higher income were less likely to perceive the correct trend in rainfall.

Model 4 examined farmers' perception on change in average temperature and the reference category was 'no change'. The other categories of perceptions were 'considerably increased' and 'increased'. The age of respondent turned out to be only significant variable affecting the perception of considerable change in temperature with negative sign. For the farmers who perceived increase in temperature, the coefficient of extension contact was positively significant, indicating that farmers in contact with extension agencies correctly perceive the temperature trend.

Model 5 examined the farmers' perception of changes in humidity which is an important climate variable and the reference category was 'no change'. For the farmers who perceived the significant reduction in humidity, the coefficient of variables such as age of household head, land holding and farm resources turned out to be negative and significant, while, family income was significant with positive sign. This implied that resource rich, older and large farmers were less likely to perceive the significant change in the humidity. For the farmers who perceived the reduction in humidity, coefficient for extension contact was positively significant while farm resources variable was significant with negative sign.

Farmers' perception on impact of climate change

Patterson *et al*. (1999) cautioned that due to global greenhouse effect, the geographical distribution, vigor, virulence and agricultural impact of weeds, insects and plant pathogens would be impacted. This may be in specifically in terms of reduction in generation times, poleward migration along with physiological and biochemical changes induced in the host plants. Similarly, Wolfe *et al*. (2007) in their study also indicated that many crops would have yield losses associated with increased frequency of high temperature stress, inadequate water chill period for optimum fruiting in spring, increased pressure from marginally over-wintering and/or invasive weeds, insects or disease or other factors. An attempt in this study was made to understand the farmers' perception on the impact of climate change on their crops and cropping systems caused by different biotic factors (Table 4).

Perceived impact on insect pest infestation

An effort was made to know the experiences of farmers about the changes in insect load on *kharif* crops. As per the farmers' opinion, significant changes have been occurred with respect to insect load a major factor for yield reduction in their crops. The infestation of crop by various insects was not so serious issue in the past was suddenly increased to very high level in recent period. Majority of the farmers (65%) have perceived that their crop being attacked by insect to high levels but remaining respondents (31.43%) added that the insect attack in their *kharif* crop has increased to a very high level during the recent periods mainly because of changes in weather parameters.

Perceived impact on disease infestation

Over the period of last sixty years, the changes with respect to disease load on *kharif* crop also followed the same trend as that of insects (Table 4). Majority of the farmers perceived that the problem of concern for diseases started since 2000 but the severity of diseases reached to high levels in the present decade. The respondents (67.86) perceived that the incidences of infestation of soybean crop by number of fungal, bacterial and viral diseases have found increased along with high severity causing considerable yield losses. However, rest of the farmers (23.57) perceived that the severity of diseases infestation and its load has now a day's increasing to very high level compared to last few decades.

A study conducted by Dhaliwal *et al.* (2010) outlines changing trends of insect pest infestation and their shifting to new species or crops. In India, the crop losses have declined from 23.3 per cent in post-green revolution era to 17.5 per cent at present. An outbreak of *Spodoptera litura* in Rajasthan as well as its epidemic in Vidarbha Region of Maharashtra in the year 2008 experienced in the recent past leading to heavy losses (Dhaliwal and Koul 2010). Similarly, Kawadia and Tiwari (2017) reported that 73% of the farmers agreed for pest attack increase due to climate change. Punithavalli *et al.* (2014) stated that the climate change induced increase in insect-pest infestation in soybean is the major cause of reducing the realized yield.

Perceived impact on weed infestation

The problem of weed management is a serious concern in *kharif* grown crops. The yield losses due to weed has been reported to as high as 70% in soybean crop (Billore *et al.* 2007). Weed population will change with climate change and risk of invasiveness may increase. Effectiveness of current management practices may be affected (Billore 2018).

Surprisingly, the farmers believe that they didn't see weeds as a potential problem till 1990s. But subsequently, the problem of weed became major in the area. More than 39% farmers perceive that existence of weed and that too of different species started increasing in high levels since last 15-20 years. It is further being noted that the level of weed infestation has further been increased to very high levels during the period followed by 2010, the problem reported by more than 55% farmers. This could be attributed due to monoculture of soybean.

Farmers' perception of extent impact on yield due to climatic adversities

The farmers were also asked whether they feel any effect of changing climate for reduction in yield of *kharif* crop. The farmers feel that they have started experiencing severity in adverse climatic conditions leading to yield losses mainly during initial period of twenty first century. However, the yield losses were not considerable enough to worry about (<20%) which could be attributed to other biotic factors too. But it is astonishing to know that during last few years, 40% of the farmers felt that the climatic adversities have resulted in about 31-40% yield loss of soybean crop in their area. Further, another 37% farmers believed that the yield losses due to climatic adversities could be as high as 40-50% in spite of adoption of recommended production technologies during the last decade.

More precise impact of climate change on agricultural crop was recently studied by Ray *et al.* (2019) involving ten crops which included soybean and found that there is about ~1% average reduction (-3.5×10^{13} kcal/year) in consumable food calories in these ten crops. Kawadia and Tiwari (2017) while studying the perception of the farmers about the climate change in Madhya Pradesh found that 70% of the farmers identified significant decrease in crop yield due to climate change.

Farmers' perception of impact of climate change on soybean yield

In order to know the actual reflection of yield loss due to adverse climatic conditions prevailing in the area, farmers were asked to recollect and document the soybean yield achieved by them during last twenty years (Table 5). As has been perceived by the respondents, the average productivity of soybean during the last decade i.e. 2010 has declined for majority of the farmers Majority of the farmers (63.57%) were achieving the soybean productivity of about 21-30 q/ha during the period 2000-10 have reduced to only 22.86%. However, those farmers (32.86%) who used to achieve the soybean productivity of about 11-20 q/ha are found in increasing trend indicating decline in productivity levels across the levels. According to them, the reduction in productivity of soybean could be attributed to effect of adverse climatic conditions which the farmers have encountered during last 20 years particularly related to increase in atmospheric temperature, less and erratic monsoon distribution coupled with decrease in total rainfall etc.

The average productivity of soybean in India on the other hand is dwindling to nearly 10-13 q/ha since more than a decade though the productivity potential of more than 20-25 q/ha has successfully been demonstration under frontline demonstrations conducted across the location including Madhya Pradesh. Raghavendra and Suresh (2018) revealed that of the total farmers, almost 50 % large and small farmers perceived untimely rainfall as main risk factor in soybean cultivation with a mean score of 4.7. Also, 50% of both small and large farmers perceived drought condition as major source of risk, which was followed by late onset of monsoon agreed upon by 48 % of the farmers. Mohanty *et al*. (2015) conducted a simulation study on impact of rainfall pattern on soybean yield in Central India and reported a significant decrease of up to 96% yield loss in soybean when the rainfall reseeded during the initiation of flowering to maximum pod stage, and 56% when drought spell of two weeks during mid-vegetative stage. According to Haifeng *et al*. (2009) conducted a field experiment to analyze response of soybean yield to mean daily temperature during seed filling over the period 1987-2007 and found clear positive response with soybean yields with an increase of 6-10% for each 1°C increase in mean daily temperature during seed filling. Similarly, Rana *et al*. (2014) in his field experiment found that the elevated temperature of 1°C coupled with 50 ppm elevated level of carbon dioxide (420ppm) showed increase in yield up to 4.9 percent with shortened average growing period up to 2 days. The further rise of temperature to 2°C with 50 ppm elevated level of carbon dioxide caused increase in simulated yield up to 2.3 percent in simulations of 1989-2008 compared to control conditions. Similarly, 100 ppm elevated level of carbon dioxide with 10C rise in temperature caused increase in yield between 8.8 to 10.2 percent in all planting windows whereas it was 3.1 to 3.9 percent lesser in 2°C rise in temperature with 100 ppm elevated level of carbon dioxide with compared to 1°C rise in temperature. The climatic grid of 10 percent reduction in rainfall from recent decade 1998-2008 showed small decrease in yield but yield increase of 5.2 to 8.5 percent was observed when coupled with 50 ppm elevated carbon dioxide and 1°C rise in temperature. Hence, rise of temperature with elevated carbon dioxide in general increase the yield in region.

Table 1. Summary statistics of independent variables used in multinomial logistic regression

Variable	Description	Mean	Range	Standard deviation
Age of the household head	Continuous (years)	45.21	25-97	14.16
Land holding	Continuous (hectares)	5.83	0.63-50.00	6.90
Family income	Dummy, 0= up to Rs. 2.00 lakhs, 1= above Rs. 2.00 lakhs	0.30	0-1	0.46
Education	Dummy, 0= up to primary, 1= above primary	0.63	0-1	0.48
Family members	Continuous (number)	3.88	1-6	1.26
Farm resources and implements	Dummy, 1=resource rich, 0= otherwise	0.49	0-1	0.50
Extension contacts	Dummy, 1=Yes, 0= otherwise	0.73	0-1	0.45

Table 2. Farmers perception on climate change in Central India

Farmers perception on	**Frequency**	**Per cent**
Change in arrival of monsoon		
1. Delayed by more than fortnight	108	38.57
2. Delayed by less than fortnight	160	57.14
3. No change	12	4.29
Change in rainfall distribution		
1. High intensity in short period	36	12.86
2. Erratic	226	80.71
3. No change	18	6.43
Change in precipitation		
1. Increased	14	5.00
2. Decreased	200	71.43
3. No change	66	23.57
Change in temperature		
1. Considerably increased	162	57.86
2. Increased	104	37.14
3. No change	14	5.00
Change in humidity		
1. Significantly reduced	146	52.14
2. Reduced	114	40.71
3. No change	20	7.14

Table 3. Multinomial logistic regression results

Model 1: Farmers perception on change in monsoon arrival

Independent variables	Delayed more than fortnight v/s no change		Delayed less than fortnight v/s no change	
	Coeff.	*p*-value	Coeff.	*p*-value
Intercept	-1.139	0.529	4.673***	0.004
Age of the household head	-0.023	0.348	-0.067***	0.007
Land holding	-0.058	0.190	-0.111**	0.022
Family income	0.299	0.763	0.529	0.593
Education	-0.217	0.777	0.565	0.463
Farm resources and implements	-0.281	0.727	-1.159	0.144
Extension contacts	4.065***	< 0.001	0.566	0.489
Family members	0.468*	0.090	0.409	0.132
Reference category:		No change		
Overall model fit:				
Log-likelihood of constant-only model:		456.865		
Log-likelihood of full model:		323.271		
Chi-Square:		133.594		
d.f.:		14		
p-value:		< 0.001		
Pseudo-R^2 (Naglekerke's):		.470		

Note: *, **, *** denotes significance at 10, 5 and 1% level, respectively

Model 2: Farmers perception on change in rainfall distribution

Independent variables	High intensity v/s no change		Erratic v/s no change	
	Coeff.	*p*-value	Coeff.	*p*-value
Intercept	1.935	0.281	4.569***	0.003
Age of the household head	-0.053**	0.028	-0.034*	0.091
Land holding	-0.066	0.160	-0.078*	0.057
Family income	0.718	0.430	1.067	0.196
Education	-0.389	0.586	0.093	0.882
Farm resources and implements	-0.507	0.600	-2.469***	0.004
Extension contacts	0.946	0.351	0.062	0.943

Model 2: Farmers perception on change in rainfall distribution (continued)				
Independent variables	High intensity v/s no change		Erratic v/s no change	
	Coeff.	*p*-value	Coeff.	*p*-value
Family members	0.391	0.155	0.380	0.114
Reference category:	No change			
Overall model fit:				
Log-likelihood of constant-only model:	343.334			
Log-likelihood of full model:	290.187			
Chi-Square:	53.146			
d.f.:	14			
p-value:	< 0.001			
Pseudo-R^2 (Naglekerke's):	0.245			

Note: *, **, *** denotes significance at 10, 5 and 1% level, respectively

Model 3: Farmers perception on change in quantity of rainfall				
Independent variables	Increased v/s no change		Decreased v/s no change	
	Coeff.	*p*-value	Coeff.	*p*-value
Intercept	-3.182*	0.083	1.552*	0.058
Age of the household head	0.075***	0.007	0.012	0.353
Land holding	-0.165	0.228	0.004	0.863
Family income	-0.019	0.983	-1.024**	0.014
Education	1.174	0.145	0.210	0.574
Farm resources and implements	-1.557**	0.041	1.381***	< 0.001
Extension contacts	-1.693**	0.029	-0.061	0.888
Family members	0.006	0.981	0.028	0.836
Reference category:	No change			
Overall model fit:				
Log-likelihood of constant-only model:	409.227			
Log-likelihood of full model:	353.897			
Chi-Square:	55.331			
d.f.:	14			
p-value:	< 0.001			
Pseudo-R^2 (Naglekerke's):	0.233			

Note: *, **, *** denotes significance at 10, 5 and 1% level, respectively

Model 4: Farmers perception on change in temperature				
Independent variables	Considerably increased v/s no change		Increased v/s no change	
	Coeff.	*p*-value	Coeff.	*p*-value
Intercept	5.241***	0.002	0.940	0.610
Age of the household head	-0.039*	0.098	-0.018	0.443
Land holding	-0.090	0.103	-0.036	0.498
Family income	1.294	0.186	1.045	0.287
Education	0.580	0.405	-0.384	0.584
Farm resources and implements	-0.749	0.260	0.368	0.589
Extension contacts	-0.387	0.581	3.032***	0.002
Family members	-0.159	0.503	-0.222	0.365
Reference category:	No change			
Overall model fit:				
Log-likelihood of constant-only model:	463.591			
Log-likelihood of full model:	348.698			
Chi-Square:	114.893			
d.f.:	14			
p-value:	< 0.001			
Pseudo-R^2 (Naglekerke's):	0.415			

Note: *, **, *** denotes significance at 10, 5 and 1% level, respectively

Model 5: Farmers perception on change in humidity				
Independent variables	Significantly reduced v/s no change		Reduced v/s no change	
	Coeff.	*p*-value	Coeff.	*p*-value
Intercept	3.964***	0.005	-16.509***	< 0.001
Age of the household head	-0.043**	0.046	-0.005	0.794
Land holding	-0.120***	0.007	-0.063	0.110
Family income	1.518*	0.068	1.012	0.215
Education	0.360	0.564	0.023	0.970
Farm resources and implements	-2.008***	0.004	-1.358*	0.053
Extension contacts	0.188	0.767	19.427***	< 0.001

Model 5: Farmers perception on change in humidity (continued)				
Independent variables	Significantly reduced v/s no change		Reduced v/s no change	
	Coeff.	*p*-value	Coeff.	*p*-value
Family members	0.279	0.206	0.175	0.430
Reference category:	No change			
Overall model fit:				
Log-likelihood of constant-only model:	497.003			
Log-likelihood of full model:	352.989			
Chi-Square:	144.014			
d.f.:	14			
p-value:	< 0.001			
Pseudo-R^2 (Naglekerke's):	0.483			

Note: *, **, *** denotes significance at 10, 5 and 1% level, respectively

Table 4: Farmers perception on changes in biotic load and yield losses

Farmers perception on	Frequency (N=280)	Per cent
Insect load on kharif crop		
1. Increased to high levels	184	65.71
2. Increased to very high levels	88	31.43
3. No Change	8	2.85
Disease load on Kharif crop		
1. Medium	24	8.57
2. High	190	67.86
3. Very high	66	23.57
Weed load on kharif crop		
1. High	110	39.29
2. Very High	156	55.71
3. No change	14	5.00
Farmers perception on yield losses due to climate change		
Between 21-30%	8	2.86
Between 31-40%	114	40.71
>41-50%	104	37.14

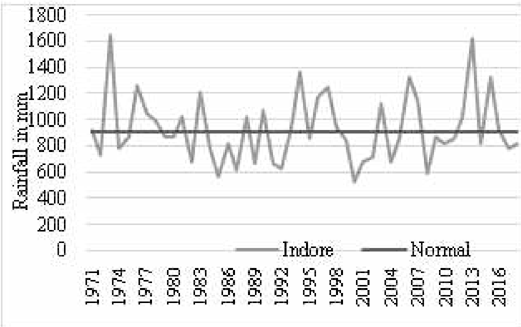

Fig1a. Actual and normal rainfall in Indore district

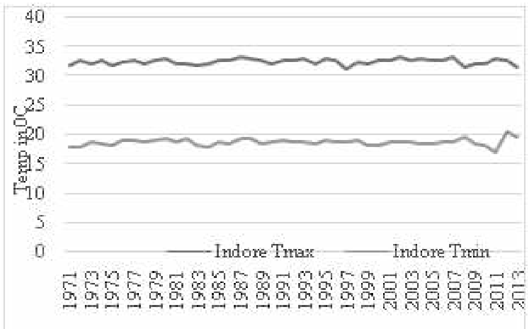

Fig 1d. Temperature changes in Indore district

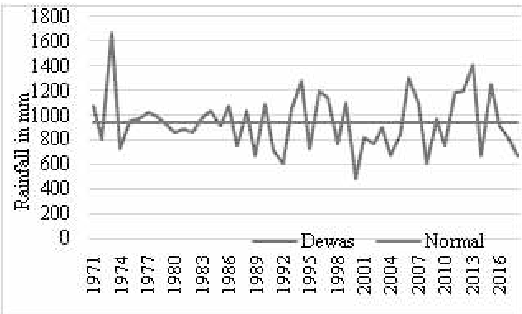

Fig 1b. Actual and normal rainfall in Dewas district

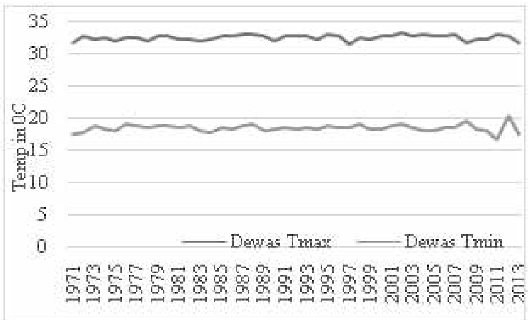

Fig 1e. Temperature changes in Dewas district

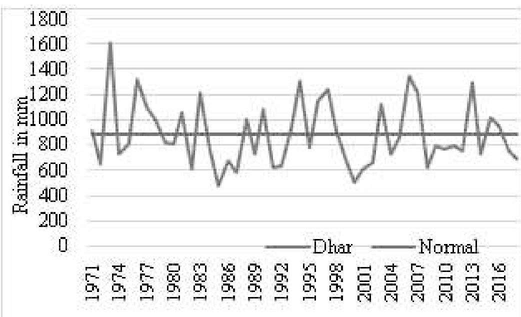

Fig 1c. Actual and normal rainfall in Dhar district

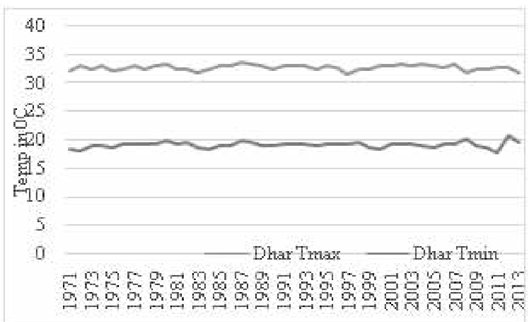

Fig 1f. Temperature changes in Indore district

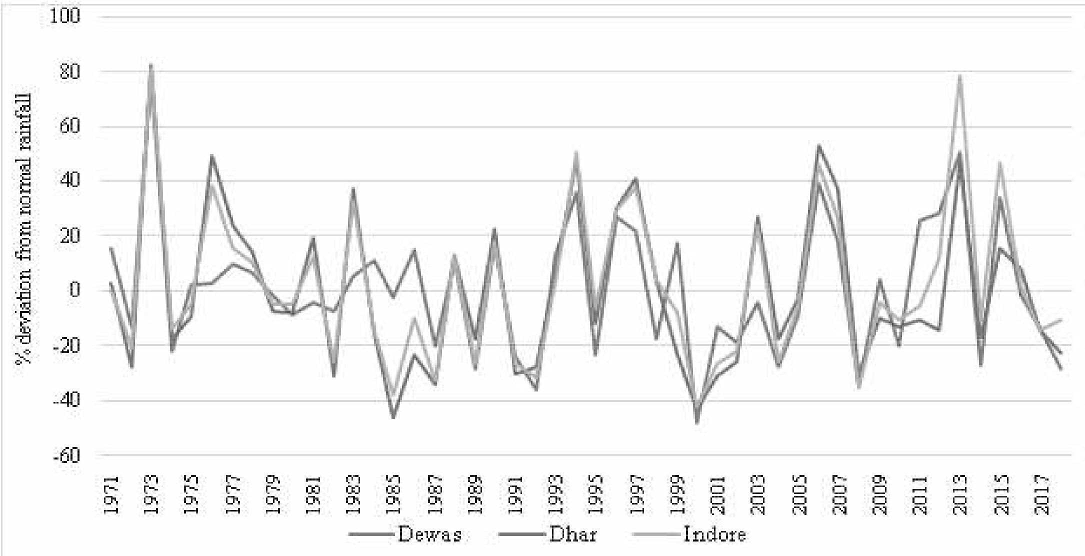

Figure 2. Deviation in rainfall from normal in selected districts

Table 5: Soybean yield over the period

Yield range	2000s	2010s
6-10 q	8 (2.86)	2 (0.71)
11-20 q	92 (32.86)	210 (75.00)
21-30 q	178 (63.57)	64 (22.86)
>30q	2 (0.71)	4 (1.43)

Note: Figures in parentheses represents percentage to total.

CONCLUSION

Climate change, affecting agriculture and livelihood of millions of farmers around the globe, continue to pose a greatest challenge for farmers to sustain productivity and profitability of farming enterprises and sustaining livelihood. Farmers' correct perception of climate change and its impact, largely affects their response to adopt measures in order to mitigate the consequences of climate change, is affected by many socio-economic and demographic factors. The study tries to address these issues using primary data collected from sample soybean growers from *Malwa* plateau and *Nimar* valley regions of Madhya Pradesh in Central India, a major soybean producing belt in the country. The results of the study indicated that majority of farmers perceived the delay in arrival of monsoon, uneven distribution of monsoon rainfall, decrease in precipitation, increase in temperature and reduction in humidity. Multinomial logistic regression model was employed to analyze the factors determining farmers' perception of different aspects of climate change. The analysis results indicated that age of household head, farm size, resource availability and extension contact significantly affected the perception of different aspects of climate change. Majority of the farmers perceived that there was increase in the incidence of insects and diseases and the higher yield losses due to climate change. The results indicated the importance of training and strengthening extension system to educate farmers on climate change aspects and on measures to minimize the impact so that they can sustain productivity, profitability and livelihood.

REFERENCES

Adams RM, Rosenzweig C, Peart RN, Ritchie JT, McCarl DA, Glyer JD, Jones JW, Boote KJ, Allen LH (1990) Global climate change and U.S. Agriculture. *Natu*, 345:219– 224.

Baker JT, Allen Jr LH, Boote KJ, Jones PH, Jones JW (1989) Response of soybean to air temperature and carbon dioxide concentration. *Crop Sci* 29: 98–105.

Bantilan Cynthia, Singh NP, Byjesh K, Padmaja R, Jayatilaka W (2012). Helping Communities Adapt: Climate Change Perceptions and Policy in Asia. Vulnerability to Climate Change: Adaptation Strategies and Layers of Resilience. Policy Brief No. 23. International Crop Research Institute for Semi-Arid Tropics, Hyderabad, India.

Billore SD, Dupare BU, Sharma P (2018). Addressing Climate Change Impact on Soybean through Resilient Technology. *Soy Res* 16(1&2): 01-24.

Billore SD, Vyas AK, Pandya N, Khan R (2007) Bio-efficacy of Flumioxazin in soybean (Glycine max). *Ind J Agric Sci* 77:5424.

Billore SD (2019). Regional Analysis of the Response of Soybean to Planting Date. *Soy Res* 17(1&2):83-88.

Birthal PS, Negi DS, Khan MT, Agarwal S (2015) Is Indian agriculture becoming resilient todroughts? Evidence from Rice system. *Food Pol* 56:1-12.

Broomell SB, Budescu DV, Por HH (2015) Personal experience with climate change predicts intentions to act. Glob Environ. Chng 32:67–73.

Dash SK, Mamgain A (2011) Changes in the frequency of different categories of temperature extremes in India. *Jn Appl Meteoro and Climato* 50:1842-1858.

Dash SK, Jenamani RK, Kalsi SR, Panda SK (2007) Some evidence of climate change in twentieth-century India. *Clim Chng* 85:299-321.

Dash SK, Kulkarni MA, Mohanty UC, Prasad K (2009) Changes in the characteristics of rain events in India. *Jn Geophy Res* 114: D10109.

Dhaliwal GS, Koul O (2010) Quest for Pest Management: From Green Revolution to Gene Revolution. Kalyani Publishers, New Delhi.

Dhaliwal GS, Jindal V, Dhawan AK (2010) Insect pest problems and crop losses: Changing trends. *Ind J Ecol* 74:1–7.

Dhanya P, Ramachandran A (2016) Farmers' perceptions of climate change and the proposed agriculture adaptation strategies in a semi arid region of south India. *Jn Integr Env Sci* 13(1): 1-18.

Duhan D, Pandey A (2013) Statistical analysis of long term spatial and temporal trends of precipitation during 1901–2002 at Madhya Pradesh, India. *Atmosp Res* 122:136–149.

Duhan D, Pandey A, Gahalaut KPS, Pandey RP (2013) Spatial and temporal variability in maximum, minimum and mean air temperatures at Madhya Pradesh in central India. *Comptes Rendus Geosci* 345(1):3-21, http://dx.doi.org/10.1016/j.crte.2012.10.016.

Dupare BU, Sharma P, Billore SD (2017) Strategy for Increasing the Soybean Productivity through Frontline Demonstrations and Its Role in Soybean Economy of India in Changed Climatic Scenario. *Intnl J. of Exten. Edu* 13:76-82.

Edwards-Jones G, Plassmann K, Harris IM (2009) Carbon foot-printing of lamb and beef production systems: insights from an empirical analysis of farms in Wales, UK. *The Jn Agril Sci* 147(6):707-719.

Guhathakurta P, Menon P, Prasad AK, Sable ST, Bhandari S, Shinde A, Kashyapi A (2020) Observed rainfall variability and changes over Madhya Pradesh State. Met. Monograph No. ESSO/IMD/HS/Rainfall Variability/15(2020)/39, Climate Research and Services, India Meteorological Department (Ministry of Earth Sciences), Pune.

Guhathakurta P, Rajeevan M (2008) Trends in the rainfall pattern over India. *Intnal Jn Clim* 28:1453-1469.

Haifeng Z, Chen L, Han X (2009) Response of Soybean Yield to Daytime Temperature Change during Seed Filling: A Long-Term Field Study in Northeast China. *Pl Prod Sci*. 12(4):526-532.

Haskett JD, Pachepsky YA, Acock B (1997) Increase of CO_2 and climate change effects on IOWA soybean yield simulated using GLYCIM. *Agron Jn* 89:167–176.

Attri SD, Rathore LS (2012) Climate Profile of India, India, Met Monograph, Environment Meteorology-01/2010, India Meteorological Department, New Delhi, 129.

Jain SK, Kumar V (2012) Trend analysis of rainfall and temperature data for India. *Cur Sci* 102 (1):37-49.

Jain SK, Kumar V, Saharia M (2013) Analysis of rainfall and temperature trends in northeast. *Intl Jn Clim* 33:968–978.

Kawadia G, Tiwari E (2017) Farmers' perception of climate change in Madhya Pradesh. *Jn Area Dev Pol* 2(2):192-207.

Kumar V, Jain SK, Singh Y (2010) Analysis of long-term rainfall trends in India, Hydrol Sci Jn 55(4):484-496, DOI: 10.1080/02626667.2010.481373

Kundu S, Khare D, Mondal A, Mishra P (2015) Analysis of spatial and temporal variation in rainfall trend of Madhya Pradesh, India (1901–2011). *Environ Earth Sci* 73(12):8197-8216.

Lal R, Follett RF, Kimble J, Cole CV (1999) Managing US cropland to sequester carbon in soil. *Jn Soil Water Conserv* 54: 374–381.

Mall RK, Gupta A, Sonkar G (2017) Effect of Climate Change on Agricultural Crops. In: Dubey SK, Pandey A, Sangwan RS (Eds) Current Developments in Biotechnology and Bioengineering: Crop Modification, Nutrition, and Food Production http://dx.doi.org/10.1016/B978-0-444-63661-4.00002-5 23 Elsevier BV: Pp: 23-46

Mall RK, Gupta A, Singh R, Singh RS, Rathore LS (2006) Water resources and climate change: An Indian perspective. *Curr Sci*. 90(12):1610–1626.

Maraseni TN, Mushtaq S, Maroulis J (2009) Greenhouse gas emissions from rice farming inputs: a cross-country assessment. *The Jn Agri Sci* 147(2):117-126.

Mishra V, Shah R (2015) Climate change in Madhya Pradesh: indicators, impact and adaptations. Indian Institute of Technology, Gandhinagar. Pp;96

Mishra V, Shah R, Garg A (2016) Climate Change in Madhya Pradesh: Indicators, Impacts and Adaptation. IIMA WP 2016-05-05, Indian Institute of Management, Ahmadabad.

Mohanty M, Sinha NK, Lenka S, Hati KM, Somasundaram J, Saha R, Rao AS (2015) Climate change impacts on rainfed soybean yield of central India: Management strategies through simulation modelling. *In* Singh A, Dagar J, Arunachalam A, Shelat K. (Eds.) Climate change modelling, planning and policy for agriculture. New Delhi: Springer.

Mohanty M, Sinha NK, Mcdermid SP, Chaudhary R, Reddy KS, Hati K, Somasundarm J, Lenka S, Patidar R, Mathyam P, Srinivas Rao Ch, Patra AK (2017) Climate change impacts vis-a-vis productivity of soybean in Vertisol of Madhya Pradesh. *Jn Agromet* 19(1):10-16.

Oza M, Kishtawal CM (2015) Spatio-temporal changes in temperature over India. *Cur Sci* 109(6):1154-1158.

Oza M, Kishtawal CM (2014) Spatial analysis of Indian summer monsoon rainfall. Jn Geom 8(1): 40-47.

Patterson DT, Westbrook JK, Joyce RJV, Lingren PD, Rogasik J (1999) Weeds, Insects, and Diseases. *Clim Chng* 43(4):711–727.

Prasad R, Pandey AK, Dhyani SK, Saroj NK, Tripathi VD (2012) Farmers' perception about climate change and its impact on agriculture in Panna district of Bundelkhand region (Madhya Pradesh), Central India. *Jn Soil and Water Cons* 11(4): 356-364.

Punithavalli M, Sharma AN, Rajkumar MB (2014) Seasonality of common cutworm *Spodoptera litura in a soybean ecosystem. Phytoparas*. 42:213-22.

Raghavendra KJ, Suresh A (2018) Risk management in rainfed agriculture: An analysis of strategies and adaptations followed by farmers in Madhya Pradesh. *Ind Jn Agr Sci* 88(6): 895–901.

Rama Rao CA, Raju BMK, Rao AVMS, Rao KV, Ramachandran K, Nagasree K, Samuel J, Ravi Shankar K, Srinivasa Rao M, Maheswari M, Kumar NR, Sudhakara Reddy P, Yella Reddy D, Rajeshwar M, Hegde S, Swapna N, Prabhakar M, Sammi Reddy K (2018) Climate Change Impacts, Adaptation and Policy Preferences: A Snapshot of Farmers' Perceptions in India. Policy Paper 01/2018. ICAR-Central Research Institute for Dryland Agriculture, Hyderabad, India.

Ramdas S, Ramasundaram P, Meena RP, Thimmappa K, Sharma I (2016) Tracking the yield sensitivity of rice-wheat system to weather anomalies. *Nat Acad Sci Letters* 39(6):401-405. DOI:10.1007/s40009-016-0485-6

Ramdas S, Kumar A, Singh S, Kumar S, Kumar A (2018) Perception, yield sensitivity and adaptation strategies to climate change: insights from wheat production in India. 30th International Conference of Agricultural Economists. July 28-August 2, 2018. Vancouver. IAAE.

Ramteke R, Murlidharan P, Shivakumar M, Gireesh C, Ramesh SV (2015) Morpho-agronomic characterization of Indian soybean for grouping and varietal protection. *Ind Jn Genet and Pl Breed* 75(3):382-385.

Rana RS, Chander N, Sharma R, Sood R, Sharma JD (2014) Modeling impacts and adaptations of climate change on soybean (Glycine max) production in Himachal Pradesh, India. *Ind Jn Agri Sci* 84(10): 1172–7.

Ray DK, West PC, Clark M, Gerber JS, Prishchepov AV, Chatterjee S (2019) Climate change has likely already affected global food production. *PLoS ONE* 14(5):0217148.

Seddigh M, Joliff GD (1984) Effects of night temperature on dry matter partitioning and seed growth of indeterminate field grown soybean. *Crop Sci* 24:704–710.

Shrivastava V, Khare NK, Pande AK (2018) Farmers' perception on climate vulnerability and responsive adaptation measures in district Jabalpur, Madhya Pradesh. *Jn Pharmaco and Phytochem* 7(4):1238-1243.

Shukla R, Khare D, Tiwari P, Mishra PK, Gupta S (2017) Analysis of Long Term Temperature Trend for Madhya Pradesh, India (1901-2005). *Curr World Environ* 12(1):68-79.

Sinclair TR, Rawlins SL (1993) Inter-seasonal variation in soybean and maize yields under global environmental change. *Agron Jn* **8**:406–409.

Singh NP, Arathy A, Pavithra S, Balaji SJ, Anand B, Khan MA (2017) Mainstreaming Climate Change Adaptation into Development Planning. *Policy Paper* 32. ICAR-National Institute of Agricultural Economics and Policy Research (NIAP), New Delhi.

Spence A, Poortinga W, Butler C, Pidgeon NF (2011) Perceptions of climate change and willingness to save energy related to flood experience. *Nat. Clim. Change* 1:46–49.

Stern PC, Dietz T, Abel T, Guagnano GA, Kalof L (1999) A value-belief-norm theory of support for social movements: the case of environmentalism. *Hum Ecol Rev* 6:81–97.

Stokes ME, Davis CS, Koch GG (2000) Categorical data analysis using the SAS system (2 ed) (Carry NC). SAS Institute.

Vermeulen SJ, Campbell BM, Ingram JSI (2012) Climate change and food systems. *Ann Rev Environ Res* 37:195.

Wolfe DW, Ziska L, Petzoldt C, Seaman A, Chase L, Hayhoe K (2007) Projected change in climate thresholds in the Northeastern US: implications for crops, pests, livestock, and farmers. Mitig. Adapt. Strateg. *Global Change* 13:555–575.

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Effect of *Aloe vera* on Keeping Quality of Soy Lassi

NEHA PANDEY AND RAJ KUMAR RAMTEKE*

ICAR-Indian Institute of Soybean Research, Indore, Madhya Pradesh- 452001

**E-mail: nehapandey.ft06@gmail.com*

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ABSTRACT

The study was carried out toharness health benefits of soybean and Aloe vera in easily consumable ready to serve (RTS) form and ascertain changes in its physicochemical, microbiological, and sensorial stability during 28 days of storage under refrigerated condition as compared to control. Concentration of Aloe vera juice was optimized on the basis of sensory evaluation done by panelists. A 10 % Aloe vera juice level gave desirable pH and higher titrable acidity and optimum overall acceptability. The storage study was conducted to evaluate the effect of Aloe vera enrichment on shelflife of soy lassi. The changes in titratable acidity and pH were less in optimized Aloe vera blended soy lassi as compared to soy lassi without Aloe vera taken as control. The data for sensory and microbiological studies revealed the same pattern. Addition of Aloe vera juice to soy lassi promoted growth of lactic acid bacteria and inhibited growth of yeast, molds and coliforms for up to 15 days of storage. The Aloe vera incorporated soy lassi was acceptable for longer period of time and also maintained total viable count of bacteria throughout the storage study. Therefore, Aloe vera incorporation enhanced shelf life of soy lassi as compared to control.

Key words : Soy lassi, Fermentation, RTS, Shelf life, Aloe vera, Soy milk, Physicochemical, sensory, Storage, Microbiological, soybean

The development of foods according to relationship between certain foods and health benefits is one of the key research priorities of food industry (Nath *et al*., 2015). Present dietary scenario demands exploring the possibility of incorporating novel ingredients in traditionally consumed foods rather than developing new food product (Zakir *et al*., 2012). Soy products offer a considerable appeal for a growing segment of consumers with certain dietary and health concerns. The dry soybean contains roughly 40% protein, 20% oil, 35% soluble and insoluble carbohydrate. Aqueous extract of soybean is an ideal product for people suffering from allergic, gastrointestinal diseases, cardiovascular diseases, osteoporosis, nervous system disorder, and anemia (Palagina *et al*. 2013). Epidemiological data have indicated that Asian populations consuming soybean as a dietary staple have a lower risk for cardiovascular diseases than those consuming a Western diet (Levi *et al*., 2002, Isagulyan *et al*., 2001). Cultured soya beverages fermented by lactic-acid bacteria beneficial to human health are high-technology products which can be easily used for the development of new types of products (Tiwari and Deen, 2015).

The plant of *Aloe vera* has stiff, fleshy, lance-shaped leaves containing clear gel in a central mucilaginous pulp. There is report of more than 200 active substances including vitamins, minerals, enzymes, sugars, anthoaquinones of phenol compounds, lignin, saponins, sterols, amino acids and salicylic acid in *Aloe vera. Aloe vera* comes under food related products (Singh *et al*., 2009) and recent trends show its use in theraputic foods like Yogurt (Malhotra *et al*., 2010) and various types of blended RTS like *Aloe vera* Aonla and ginger (Sangma *et al*., 2016), Bael-*Aloe vera* (Tiwari and Deen, 2015), *Aloe vera* Papaya (Baghoni *et al*., 2012) and *Aloe vera*-pineapple (Shasikumar and Vivek, 2015) and *Aloe vera* jackfruit (Hossain *et al*., 2017) juices are gaining importance.

Therefore, present study was taken to develop a therapeutic beverage by combining health benefits of soybean and *Aloe vera* and study the effect of *Aloe vera* enrichment on physicochemical, microbiological, sensorial quality of soy lassi under refrigerated storage conditions for 28 days.

MATERIAL AND METHODS

Lassi preparation

For soy-aloe lassi preparation soy milk was preparedusing method described in figure 1. Soy milk was blended with tonned milk at ratio of 60:40, inoculated with dahi culture @ 2% and incubated at 37℃ for 3.5 hours was refrigerated. Lassi was prepared using soy dahi with 16% TS, 0.19% acidity and 2.59% fat. The treatments used for preparation of soy-*aloe* lassi are S1 (Control)-soy dahi containing 100% soy dahi without *Aloe vera*, S2-95% soy dahi + 5% *Aloe vera* juice, S3-90% soy dahi + 10% *Aloe vera* juice, S4- 85% soy dahi + 15% *Aloe vera* juice, S5- 80% soy dahi + 20% *Aloe vera* juice, S6- 75% soy dahi + 25% *Aloe vera* juice, S7-70% soy dahi + 30% *Aloe vera* juice and. Best blended lassi was selected by organoleptic test which was conducted on 9 Point Hedonic Scale for appearance, colour, taste, flavour and overall acceptability by a semi trained sensory panel.

Aloe vera juice

Freshly harvested *Aloe vera* leaves were washed with tap water thoroughly to remove dirt and other extraneous matter on the leaves and kept for flash cooling to 5°C for gel stabilization. Leaves were kept to drain out water in a colander. Leaves were kept at low temperature for 2- 3 hours to make the gel solidified. After that each leaves were then carefully peeled off, starting from the both edges first and then the flat side of the leaves. Gel was thus separated from the leaves, washed once again and blended well in a blender to get sooth gel. The obtained juice was stored refrigerated temperature until further use.

Fig 1 Flow diagram for manufacture of soymilk

Soybeans

↓

Cleaning and Washing

↓

Soaking in water 1:3 w/w

↓

Washing

↓

Grinding with hot water 70°C (for 1 minutes Beans to water ratio 1:4 w/w)

↓

Slurry

↓

Residue ← Filtration

↓ (from Residue) ↑ (to Filtration)

4 times (Blending with hot water 70°C) for 1 minutes beans:water 1:1 w/w)

↓

Boiling till weight of soymilk is 6 times the weight of soybean

↓

Soymilk

Storage studies

Lassi with best blending ratio on the basis of organoleptic evaluation were packed in glass bottles and kept at refrigerated storage temperature along with control for comparison and changes were determined during storage in 4 days interval for 28 days. Physicochemical parameters were measured using standard protocols, pH (Digital pH meter), titratable acidity (AOAC, 2005) and overall acceptability was measured on 9 Point Hedonic Scale by 25 semi-trained panel members. The microbiological analysis was carried out according to the procedure given in APHA (1992).

RESULTS AND DISCUSSION

Organoleptic quality of blended Soy- Aloe lassi

Organoleptic quality characteristics of blended soy- *aloe* lassi were determined on 9 Point Hedonic Scale and presented in (Table 1). It could be observed from the table 1 that color score of soy lassi decreased significantly ($P \leq 0.01$)with increase in level of *Aloe vera* juice to 15 % in lassi. The similar effect of *Aloe vera* addition was reported by Baghoni *et al.*, (2012). The taste and flavor of soy lassi improved significantly ($P \leq 0.05$) with increase in concentration of *Aloe vera* juice up to the level of 10% while further increase in *Aloe vera* juice content reduced of taste due to lower consistency. The flavour score of sample, S3 was found to be superior to that of control sample, this may be due to improved mouth feel and acidity of product by *Aloe vera* juice while further increase resulted in decrease in flavour. It was observed that Overall acceptability of Sample S3 containing 10% *Aloe vera* juice was significantly ($P \leq 0.05$) higher than control and all other samples, thus S3 was taken as optimized product and analysed further for storage study.

Table 1: Effect of level of *Aloe vera* gel juice on sensory characteristics of soy-based buttermilk

Concentration of *Aloe vera* gel juice (%)	Mean Sensory Scores[1]				
	Colour	Taste	Flavour	Consistency	Overall acceptability
0 (S1)	8.03	7.765	7.84	7.21	7.7
5 (S2)	7.95	8.35*	8.15*	7.55*	8.01*
10 (S3)	7.85	8.45*	8.35*	7.45*	8.15*
15 (S4)	7.02**	7.12*	7.06*	7.1	7.15*
20 (S5)	6.08**	6**	5.69**	5.6**	6.15**
25 (S6)	5.75**	5.37**	5.14**	5.03**	5.25**
30 (S7)	5.34**	5.01**	4.81**	5**	5.15**
CD at 1 % level	1.025	1.025	1.025	1.025	1.025
CD at 5 % level	0.202	0.202	0.202	0.202	0.202

[1]average score of 10 panelists, ** significant at ($P \leq 0.01$)

Changes during Storage

The data on changes in chemical properties and overall acceptability of *soy-aloe* lassi during 28 days of storage is presented in Table 2. The data pertaining to titratable acidity showed that there was significant increase in titratable acidity of the *Aloe vera* incorporated soy lassi with storage time. Similar increase in acidity during storage has been reported byTiwari and Deen (2015). Singh *et al*., (2014) reported influence of ingredients on acidity of product. Rapid conversion of proteins to amino acids in *Aloe vera* RTS are also the reasons for increase in the titratable acidity of the *Soy- aloe* lassi. The incorporation of *Aloe vera* gel juice resulted in lowering of pH of lassi as compared to control. Panesar and Shinde, (2012), Baghoni *et al*., (2012) and Sangma *et al*., (2016) also reported similar trends in *Aloe vera* fortified products.

The soluble nitrogen content was initially higher in *Soy- aloe* lassi as compared to control (Table 2) but the change in total soluble nitrogen with storage time was less in *Soy- aloe* lassi. The similar findings had also been reported by Amiri (2001). The content of free fatty acid increased during storage for both the samples but the release of free fatty acid was significantly less in *Aloe vera* blended soy lassi as compared to control (Table 2). This increase in free fatty acid content value may be due to lipid breakdown by enzyme lipase present in microorganisms and its conversion to free fatty acid during storage. The soluble nitrogen and free fatty acid contents increased with addition of *Aloe vera* juice in *Aloe vera* lassi (Singh *et al*., 2012).

Table 2: Effect of *Aloe vera* incorporation on physico-chemical and sensory characteristics of lassi during storage

Index time	Titratable acidity %		pH		Soluble nitrogen %		Free fatty acid (meq/ml)		Overall acceptability	
	S1	S3	S1	S3	S1	S3	S1	S3	S1	S3
Day 0	0.91	1.02	4.6	4.2	0.065	0.075	7.14	7.35	7.7	8.15
Day 4	1.08	1.24	4.01	4.1	0.069	0.07	7.96	7.38	7.20	7.70
Day 8	1.24	1.44	3.52	3.83	0.075	0.073	8.64	7.98	7.00	7.60
Day 12	1.8	2.09	3.43	3.69	0.08	0.077	8.78	8.09	6.55	7.35
Day 16	2.34	2.43	3.11	3.54	0.084	0.08	9.36	8.16	5.55	7.05
Day 20	2.34	2.51	3.01	3.31	0.09	0.083	9.79	8.55	4.65	6.95
Day 24	2.3	2.58	3.01	3.24	0.10	0.086	10.12	8.92	4.00	5.85
Day 28	2.3	2.56	3.00	3.23	0.15	0.091	11.65	8.95	3.90	5.5

The values above are average of 3 determinations, S1-lassi prepared from tonned milk-soymilk blend, S3- lassi prepared from tonned milk-soymilk blend with *Aloe vera*.

The organoleptic acceptability of any novel food product is a prime factor to consider the marketability of product. During storage, it was observed that overall sensorial quality profile of *soy- aloe* lassi slightly decreased during storage of 28 days yet remained under acceptable range for up to 20 days. However, after 20 days the overall acceptability decreased to non acceptable range. On the other hand the sensory quality of soy lassi (control) decreased rapidly within 15 days of storage (Table 2). The overall acceptability of soy lassi sample prepared with the addition of *Aloe vera* gel juice was higher at the end of storage period as compared to those prepared without *Aloe vera* gel juice indicating better keeping quality of *Aloe ver*a blended soy lassi. The similar results were also found by Malhotra *et al*., (2006) in yoghurt sample. Wijesundara and Adikari, (2017) found that *Aloe vera* incorporation in drinking yoghurt can produce an organoleptically acceptable product for up to 15 days under refrigerated conditions.

Microbiological changes during storage

Standard plate count

The standard plate count (SPC) of soy lassi samples was higher for *Aloe vera* incorporated samples. The incorporation of *Aloe vera* maintained the SPC for longer period of time. Nagpal *et al*., (2012) also observed that *Aloe vera* juice was effective in promoting the growth of lactic acid bacteria like *L. acidophilus, L. plantarum* and *L. casei*. SPC increased initially and then decreased slightly as the samples were kept for 28 days under refrigerated conditions (Figure 2).

Yeast and mold

Yeast and mold counts could not be detected upto 8 days in soy lassi samples and for 16 days in *Aloe vera* blended soy lassi (Figure 3). Results show that the samples with *Aloe vera* gel juice could inhibit growth of yeast and mold for longer period of time. Shrikanth *et al*., (2017) found similar antifungal properties in *Aloe vera* incorporated peda. Jain *et al*., (2017) found antifungal effect of *Aloe vera* gel against Candiada albicans. In fermented drinks, several metabolic products produced by these lactobacilli have antimicrobial properties including organic acids, fatty acids and hydrogen peroxide (Wijesundara and Adikari, 2017). Increasing the yeast and mold count after 15 days of storage may be due to increment of acidity (Table 2) and reduction of oxygen during fermentation process which offers proper conditions for growth of yeasts and molds.

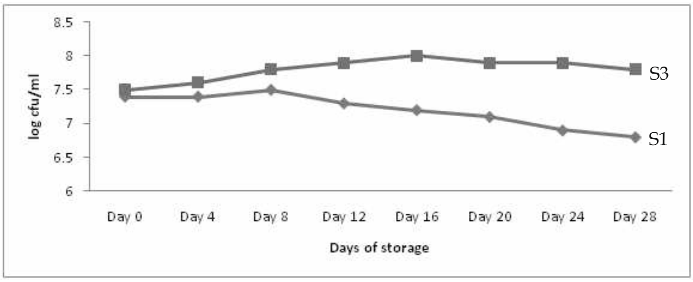

Figure 2: Change in SPC (log cfu/ml) during storage

S1- lassi prepared from tonned milk-soymilk blend, S3- lassi prepared fromtonned milk - soymilk blend + *Aloe vera* gel juice

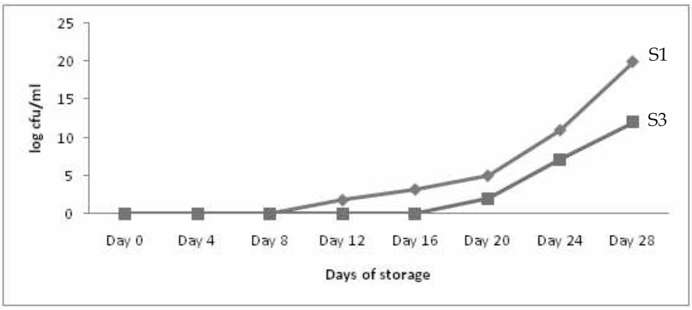

Figure 3: Change in Yeast and Mold count log cfu/ml) during storage

S1- lassi prepared from tonned milk-soymilk blend, S3- lassi prepared from tonned milk - soymilk blend + *Aloe vera* gel juice

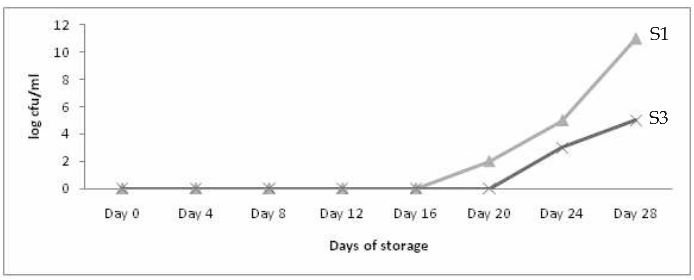

Figure 4: Change in Coliform count log cfu/ml) during storage

S1- lassi prepared from tonned milk-soymilk blend, S3- lassi prepared from tonned milk - soymilk blend + *Aloe vera* gel juice

Coliform count

The coliform count of the samples of lassi during 28 days of storage is represented in Figure 4 which showed less coliform count at end of storage period for *Aloe vera* blended soy lassi. Total coliform counts were zero for all treatments during storage period of 20 days (Table 2), probably due to good hygienic practices adapted during manufacturing process. Atibhan *et al*. (2012) also found antimicrobial activity of *Aloe vera* gel against common contaminants like *E. coli, E. faecalis* and *Staph. Aureus*. Kargaran *et al*. (2016) also reported similar findings for *Aloe vera* gel against *E. coli.*

CONCLUSION

In present investigation, efforts were made to develop blended *Aloe* - soy lassi incorporating health benefits of soybean and *Aloe vera*. Sensory evaluation revealed that *Aloe vera* gel could be successfully incorporated in development of Blended *Aloe* - soy lassi with improved sensorial quality profile up to the level of 10%. The storage studies revealed that blended soy-*Aloe* lassi could be successfully stored for the period of 20 days without significant effect on chemical, microbial and organo-leptic qualities. Therefore, it can be concluded that *Aloe vera* may be incorporated to increase shelf life of soy lassi besides harnessing health benefits of *Aloe vera* and soybean in healthy RTS form.

REFERENCES

A O AC. 1984. Official methods of analysis. 14th edition. Association of Official Analytical Chemists, Washington D.C.

APHA. 1992. Vanderzant, C. and Splits-Toesser, E.D. Compendium of methods for microbiological examination of foods. Washington. American Public Health Association. pp. 919-927.

Amiri Z R. 2001. Optimization of parameters for low fat prebiotic quality yoghurt using RSM and to study the effect of probiotic cultures during its storage. Thesis, Doctor of Philosophy, G.B. Pant University of Agriculture and Technology, Pantnagar.

Athiban PP, Borthakur B J, Ganesan S and Swathika B. 2012. Evaluation of antimicrobial efficacy of *Aloe vera* and its effectiveness in decontaminating gutta percha cones. *J Conserv Dent*; 15(3): 246–248.

Boghani A H, Raheem A and Hashmi S I. 2012. Development and Storage Studies of Blended Papaya-*Aloe vera* Ready to Serve (RTS) Beverage. *J Food Process Technol*. 3:10: 1-4.

Hossain M M, Ram L, Ngupani PS and Bepary R H. 2017. Development of Jackfruit-Aloe Vera Blended Ready to Serve (RTS) Functional Beverage at Refrigerated Condition. *International Journal of Agriculture Innovations and Research*, 6 (2): 227-230.

Isagulyan EA, Sagun GV, Efimov AN. 2001. Formulation of juice-containing beverages on the basis of soya milk. *Proceedings of higher educat Institut Food processing* 4: 55-56.

Jain S, Mujoo S, Daga M, Kalra S, Nagi R, Laheji A. 2017. Comparison of antifungal effect of *Aloe vera* gel and Triphala: An in vitro study. *J Indian Acad Oral Med Radiol* 29: 90-94.

Kargaran, M, Moradabadi, A R, Arjomandzadegan, M, Hosseini, H, Habibi, G. 2017. Effects of the Aqueous

Extract of *Aloe vera* on the Morphological and Physiological Properties of *E. coli.Iran Red Crescent Med J*.19(2): e23896. doi: 10.5812/ircmj.23896.

Levi F, Lucchini F, Negri E, Vecchia CL. 2002. Trends in mortality from cardiovascular and cerebrovascular diseases in Europe and other areas of the world. *Heart* 88 : 119-124.

Malhotra R, Tyagi, S M and Saini, P. 2010. Studies on *Aloe vera*- A component of functional foods. *Bev. and Fd World*. 37 (7): 36-39.

Nagpal R, Kaur V, Kumar M, MarottaF. 2012. Effect of *Aloe vera* juice on growth and activities of Lactobacilli in-vitro. *Acta Biomed*. 83 (3):183-8.

Nath A H, Ukkuru M P and Kumari M KS. 2015. “Development of a probiotic honey beverage” *International Journal of Applied and Pure Science and Agriculture* 1(9): 1-9.

Palagina M V, Plekhova N G, Fishchenko E S, Cherevach E I and Tekutyeva L A. 2013. The New Combined Soy Beverage for Elderly People: the Technology Process and the Use. *J Food Process Technol*. 4 (6): 1-8

Panesar PS and Shinde C. 2012. Effect of Storage on Syneresis, pH, *Lactobacillus acidophilus* Count, *Bifidobacterium bifidum* Count of *Aloe vera* Fortified Probiotic Yoghurt. *Current Research in Dairy Sciences* 4 : 17-23.

Sangma D C M, Sarkar S and Mishra L K. 2016. Preparation and Evaluation of Ready-to-Serve Drink Made from Blend of *Aloe vera*, Sweet Lime, Amla and Ginger. Intl. *J. Food. Ferment. Technol*. 6 (2): 457-465.

Sashikumar R. and Vivek K. 2015 Process Development of Theraputic RTS Beverage from Blend of *Aloe vera* and Pine apple. *J. Agric. Technol*., 2 (1&2): 7-12

Singh R, Farhaan B and Divya S. 2014. Development and Quality Evaluation and Shelf Life Studies of Whey Guava Beverage. International Journal of Current Engineering and Technology. 4(3): 2171-2175.

Singh S, Kumar A and Shalini R. 2009. Studies on effect of preservation techniques and storage condition on TSS and pH of flavoured *Aloe vera* juice. *Bev. and Fd World*. 36 (12): 15-19.

Srikanth K, Kartikeyan Sand Kalla A M. 2017. Effect of *Aloe vera* incorporation on chemical and microbial characteristics of fresh Peda. *Res. J. Animal Hus. & Dairy Sci*.8(1): 20-25.

Tiwari D K and Deen B. 2015. Prepration and Storage of Blended Ready-To-Serve Beverage from Bael and *Aloe vera*. *The Bioscan* 10 (1): 113-116

Wijesundara WMAS and Adikari AMJB. 2017. Development of *Aloe vera (Aloe barbadensismiller)* incorporated drinking yoghurt. *International Journal of Scientific and Research Publications*, 7 (11).

Zakir AMD, Genitha TR and Syed IH. 2012. Effects of Defatted soy flour incorporation on physical sensorial and nutritional properties of biscuits *J. Food Processing Technol*., 3: 1-4.

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Identification of Source of Resistance Against Pod Blight Disease of Soybean Caused by *Colletotrichum truncatum* (Schwein) Andrus and W. D. Moore

KAVANASHREE K[1], SHAMARAO JAHAGIRDAR[1], BASAVARAJ G T[2], SANJAY GUPTA[3] AND KAMBREKAR D N[4]*

[1]Department of Plant Pathology, [2]AICRP on Soybean, [4]Department of Agricultural Entomology University of Agricultural Sciences, Dharwad- 580005, Karnataka, India
[3]ICAR-Indian Institute of Soybean Research, Indore,

**E-mail: kavanashreesa@gmail.com*

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ABSTRACT

The study was undertaken to identify the source of disease resistance during kharif 2018 & 2019 under epiphytotic condition by infector row method. A total of 155 germplasm and advanced breeding lines along with released varieties were evaluated under natural epiphytotic conditions. The disease severity of pod blight was recorded at weekly interval. During kharif 2018 among 155 genotypes, 6 genotypes were Absolutely Resistant (AR), 37 showed Resistant (R) Reaction, 104 were Moderately Resistant (MR) and 8 showed Moderately Susceptible (MS) reaction. During kharif 2019 absolute resistant, resistant, moderately resistant and moderately susceptible reaction were expressed by 2, 35, 89, 27 and 2 genotypes respectively. AGS 31 and EC 125738 germplasm lines were found to be promising source of pod blight resistance as they showed absolute reaction in 2018 and 2019.These can be use in contemporary resistance breeding programme.

Key words **:** Soybean, screening, genotypes, *Colletotrichum truncatum*

Soybean [*Glycine max* (L.) Merrill] is an economically important oilseed crop yielding 20 percent oil and 40 percent protein. It has multiple names such as Golden bean, Miracle bean, Manchurian bean, Chinese bean due to its various properties and characters. *Colletotrichum truncatum* (Schwein) Andrus and W. D. Moore causing pod blight/ anthracnose disease in soybean is an emerging threat in northern Karnataka. The disease spread was noticed in all soybean growing regions. The pathogen affects almost all parts of the crop. Primary inoculum is seed and the lesion starts on cotyledon itself. Further, symptoms also observed in stem, leaves and pods. Major damage is during reproductive stage, where pods gets twisted and unfilled (Hartman *et al.*, 1999). Survey in various districts of northern Karnataka revealed a gradual increase in severity (37.6 PDI) in the infection of *Colletotrichum truncatum* (Mamatha *et al.*, 2019). Common management method of the diseases chemical, which is health hazardous and non-ecofriendly. Other eco-friendly management options such as use of botanicals and biocontrol agents are quite effective, but require repeated applications. In order to prevent the spread of disease, host plant resistance is a long term sustainable approach. In this regard, an attempt was made to identify resistant source for *Colletotrichum truncatum* by screening germplasms.

MATERIAL AND METHODS

Germplasm and advanced breeding lines along with the released varieties of soybean were used for field screening to assess the natural epiphyotic infections of *Colletotrichum truncatum*. Around 155 lines including eighty four breeding lines collected from ICAR-Indian Institute of Soybean Research (IISR), Indore and other germplasm lines along with rust differentials and released varieties collected from AICRP on Soybean, MARS, Dharwad were tested for severity.

Field screening was conducted at the MARS, Dharwad during *kharif* 2018 and 2019 by infector row method. The trial was conducted by following augmented design with two rows of 3 meters length for each entry. One row of susceptible check, JS 335 was grown after every 5 entries. Disease severity was scored at weekly interval using 0-9 scale given by Mayee and Datar (1986).

Rating	Reactions	Description
0	Absolute Resistant (AR)	No of lesions/ discolouration
1	Resistant (R)	1 % area covered with lesions/ spots/ discolouration
3	Moderately Resistant (MR)	1.1-10 % area covered with lesions / spots/ discolouration
5	Moderately Susceptible (MS)	10.1-25 % area covered with lesions/ spots/ discolouration
7	Susceptible (S)	25.1-50 % area covered with lesions/ spots/ discolouration
9	Highly Susceptible (HS)	>50 % area covered with lesions/ spots/ discolouration

RESULT AND DISCUSSION

The result of screening of 155 germplasm against pod blight disease of soybean during *kharif* 2018 and 2019 in MARS, Dharwad are represented in table 1 to 3. The results of screening revealed that among, 155 entries screened, six and two entries were found absolute resistant during *kharif* 2018 and 2019 respectively. The number of entries showing resistant, moderately resistant and moderately susceptible during *kharif* 2018 was 37, 104 and 8 respectively. During *kharif* 2019, 35, 89, 27 and 2 entries showed resistant, moderately resistant, moderately susceptible and susceptible reaction respectively. The pooled reaction over two years revealed that 2, 24, 75 and 5 entries exhibiting absolute resistant, resistant, moderate resistant and moderate susceptible reaction respectively.

Absolute resistant reaction was expressed by entries *viz*., AGS 31, EC 107416, EC 125738, SQL 106, YP 1 and YP 2 during *kharif* 2018 wherein AGS 31 and EC 125738 during *kharif* 2019. Among these, AGS 31 and EC 125738 entries were found to be best as

Table 1: Reaction of different soybean genotypes during screening against pod blight in *kharif* 2018

Grade	Reaction	No. of entries	Entries
0	AR	6	AGS 31, EC 107416, EC 125738, SQL 106, YP 1 and YP 2
1	R	37	AGS 12, AMS 108, AMS 19B, CAT 142/AK SS62, CAT 1843B, CAT 1957, CAT 2059,CAT 796/ EC 333892, CAT 886/ EC 39177, EC 107407, EC 14626, EC 172577, EC 241656, EC 251383, EC 308287, EC 313976, NRC 127, SKY/AK 403, SL 599, 6A-47, NRC 128, NRC 129, VCI 22, CAT 1328, CAT 1477, CAT 488, PS 1347, DSb 28, PI 459024B, PI 459025F, EC 241778, EC 241780, PI 230970, PI 200492, TK-5, Wyne and PI 463212
3	MR	104	AGS 38, AMS 110, AMS 148, AMS 26A, AMS 38-24, AMS 56, AMS 59, CAT 1085/IC 219, CAT 127, CAT 1487/RICUM, CAT 1526, CAT 2061/EC 87019-4-1B-4, CAT 356/ EC 230143, CAT 642, CAT 649/EC 289099, CAT 6A/AGS 102, CAT 703/ EC 309537, CAT 808, DCB 199, DS 74-20-02, EC 103332, EC 14476, EC 242038, EC 251470, EC 274747, EC 291399, EC 383165, EC 39177, Harder, JS 20-80, JS 2055, M 204, MACS 58, P 239, PCPGR BHATT 5464, SQL 31, SQL 34, SQL 37, SQL 8, SQL 88, SQL 89, TGX 852-3D, 6A-22-1, 6A-58, 7A-85, JS 20-69, JS 20-98, MP 10, NRC 37, NRC 86, YP 3, CAT 1483, CAT 1539, CAT 1847, CAT 1857, CAT 1878, CAT 1927, CAT 1935B, CAT 1995, CAT 2026, CAT 2034B, CAT 2071, CAT 2082, CAT 2083A, CAT 2090, CAT 2091, CAT 2144A, CAT 233, CAT 248, CAT 292, CAT 313A, CAT 349, CAT 377, CAT 400, CAT 407, CAT 408, CAT 410, CAT 411A, CAT 411B, CAT 418, CAT 460B, CAT 473B, CAT 483, CAT 606, CAT 992, DSb 1, JS 20-37, JS 20-42, KB 17, MAUS 176, NRC 67, NRC 71, NRC 78, NRC 84, SQL 89, VP 1165, CAT 326, DSb 19, DSb 23, JS 93-05, EC 391160, PI 230971, PI 459025 and PI 200490
5	MS	8	CAT 2082/VP 1143, EC 280149, JSM 258, 6A-34, DSb 21 PI 459025B and EC 462312
7	S	1	JS 335
9	HS	0	-

Table 2: Reaction of different soybean genotypes during screening against pod blight in *kharif* 2019

Grade	Reaction	No. of entries	Entries
0	AR	2	AGS 31 and EC 125738
1	R	35	CAT 142/AK SS62, CAT 1843B, CAT 886/ EC 39177, EC 107416, EC 14626, EC 172577, EC 241656, EC 251383, EC 313976, SKY/AK 403, SL 599, SQL 106, NRC 128, NRC 129, NRC 86, VCI 22, YP 1, YP 2, CAT 1328, CAT 1477, CAT 1483, CAT 460B, CAT 488, PS 1347, JS 93-05, PI 459024B, PI 459025F, EC 241778, EC 241780, EC 391160, PI 200492, PI 230971, TK-5, PI 463212 and PI 200490
3	MR	89	AGS 12, AGS 38, AMS 108, AMS 148, AMS 19B, AMS 26A, AMS 38-24, AMS 56, AMS 59, CAT 127, CAT 1487/RICUM, CAT 1526, CAT 1957, CAT 2059, CAT 356/ EC 230143, CAT 642, CAT 649/ EC 289099, CAT 6A/ AGS 102, CAT 703/ EC 309537, CAT 796/ EC 333892, CAT 808, DCB 199, DS 74-20-02, EC 103332, EC 1074NR07, EC 14476, EC 242038, EC 251470, EC 274747, EC 308287, EC 383165, EC 39177, JS 20-80, JS 2055, MACS 58, NRC 127, P 239, PCPGR BHATT 5464, SQL 34, SQL 37, SQL 8, SQL 88, SQL 89, TGX 852-3D, 6A-22-1, 6A-58, 7A-85, JS 20-69, JS 20-98, Mp10, NRC 37, CAT 1539, CAT 1847, CAT 1857, CAT 1878, CAT 1935B, CAT 2026, CAT 2071, CAT 2082, CAT 2083A, CAT 2144A, CAT 233, CAT 248, CAT 292, CAT 313A, CAT 377, CAT 400, CAT 407, CAT 408, CAT 411A, CAT 411B, CAT 418, CAT 473B, CAT 483, CAT 606, CAT 992, JS 20-37, JS 20-42, KB 17, MAUS 176, NRC 78, SQL 89, CAT 326, DSb 23, DSb 28, PI 230970, EC 462312, Wyne and PI 459025
5	MS	27	AMS 110, CAT 1085/ IC 219, CAT 2061/EC 87019-4-1B-4, CAT 2082/VP 1143, Ec291399, Harder, JSM 258, M 204, SQL 31, 6A-34, 6A-47, YP 3, CAT 1927, CAT 1995, CAT 2034B, CAT 2090, CAT 2091, CAT 349, CAT 410, DSb 1, NRC 67, NRC 71, NRC 84, VP 1165, DSb 19, DSb 21 and PI 459025B
7	S	2	EC 280149 and JS 335
9	HS	0	-

Table 3: List of genotypes showing same reaction against pod blight in *kharif* 2018 and 2019

Grade	Reaction	No. of entries	Entries
0	AR	2	AGS 31 and EC 125738
1	R	24	CAT 142/ AKSS 62, CAT 1843B, CAT 886/ EC 39177, EC 14626, EC 17257, EC 241656, EC 251383, EC 313976, SKY/ AK 403, SL 599, JS 128, NRC 129, VCI 22, CAT 1328, CAT 1477, CAT 488, PS 1347, PI 459024B, PI 459025F, EC 241778, EC 241780, PI 200492, TK-5 and Pi463212
3	MR	75	AGS 38, AMS 148, AMS 26A, AMS 38-24, AMS 56, AMS 59, CAT 127, CAT 1487/ RICUM, CAT 1526, CAT 356/ EC 230143, CAT 642, CAT 649/EC 289099, CAT 6A/AGS 102, CAT 703/ EC 309537, CAT 808, DCB 199, DS 74-20-02, EC 103332, EC 14476, EC 242038, EC 251470, EC 274747, EC 383165, EC 39177, JS 20-80, JS 2055, MACS 58, P 239, PCPGR BHATT 5464, SQL 34, SQL 37, SQL 8, SQL 88, SQL 89, TGX 852-3D, 6A-22-1, 6A-58, 7A-85, JS 20-69, JS 20-98, MP 10, NRC 37, CAT 1539, CAT 1847, CAT 1857, CAT 1878, CAT 1935B, CAT 2026, CAT 2071, CAT 2082, CAT 2083A, CAT 2144A, CAT 233, CAT 248, CAT 292, CAT 313A, CAT 377, CAT 400, CAT 407, CAT 408, CAT 411A, CAT 411B, CAT 418, CAT 473B, CAT 483, CAT 606, CAT 992, JS 20-37, JS 20-42, KB 17, MAUS 176, NRC 78, SQL 89, CAT 326 and DSb 23
5	MS	5	CAT 2082/VP 1143, JSM 258, 6A-34, DSb 21 and PI 459025B
7	S	1	JS 335
9	HS	0	-

they showed absolute resistant reaction during screening of both the years and can be further used for resistance breeding. None of the entries were susceptible or highly susceptible during *kharif* 2018 except JS 335, whereas during *kharif* 2019 two entries EC 280149 and JS 335 were found susceptible to *Colletotrichum truncatum*. Ruling variety of north Karnataka, JS 335 expressed susceptible during *kharif* 2018 and 2019. DSb 21 was moderately susceptible to pod blight in both years of screening.

The present study was in agreement with the screening results of Mamatha *et al*. (2018) who found EC 107407 and 14476 to be moderately resistant and JS 335 as highly susceptible. The research findings are in partial similarity with the results of Sunilkumar *et al*. (2018) where EC 241778 showed resistant, NRC 127 moderately susceptible and JS 335 showed susceptible reaction. The results are in partial accordance with the results of Nagaraj *et al*. (2014) who identified that JS 335 was highly susceptible, DSb 21 and DSb 19 was moderately resistant against *Colletotrichum truncatum* during *kharif* 2016. Similar results were also observed by Chavan *et al*. (2018). Screening outcome conducted during *kharif* 2011 by Sajeesh *et al*. (2014) was also in similarity with present study as DSb 21 was moderately susceptible.

Screening of 155 germplasm against *Colletotrichum truncatum* revealed that cultivated varieties showed moderately susceptible to susceptible reaction. Among 155, only two germplasms (AGS 31 and EC 125738) were absolutely resistant. These two entries can be further effectively used in contemporary breeding programme to develop a resistant soybean variety against *Colletotrichum truncatum*.

REFERENCE:

Chavan SS, Shinde DA, Kadam AM. 2018. Screening of soybean genotypes against *Colletotrichum truncatum*. *Journal of Pharmacognosy and Phytochemistry* SP1: 2972-2974.

Hartman GL, West ED, Herman TK. 2011. Crops that feed the World 2. Soybean-worldwide production, use, and constraints caused by pathogens and pests. Food Security, London 3: 5-17.

Mamatha, Jahagirdar S, Kulkarni S, Basavaraja GT. 2018. Identification of source of resistance against major hemibiotrophic foliar fungal pathogens of soybean. *Journal of Plant Disease Sciences* 13(1): 41-47.

Mamatha, Jahagirdar S. 2019. Severity of major hemibiotropic foliar fungal diseases of soybean in parts of northern Karnataka. *Journal of Farm Sciences* 32(3): 300-303.

Mayee CD, Datar VV. 1986. Phytopathometry, Marathwada Agricultural University, Parbhani (India) p. 146.

Nagaraj BT, Jahagirdar S, Basavaraja T. 2014. Identification of resistant sources in glass house and field evaluation of soybean genotypes to anthracnose caused by *Colletotrichum truncatum* (Schw.) Andrus and Moore. *The Bioscan* 9(3): 1333-1336.

Sajeesh PK, Rao MSL, Jahagirdar S. 2014. Screening of soybean [*Glycine max* (L.) Merill] genotypes against purple seed stain and anthracnose disease. *Environment & Ecology* 32: 1092-1095.

Sunilkumar DS, Rao MSL, Shamarao J, Basavaraj GT. 2018. Screening of available genotypes against pod blight complex of soybean *Glycine max* (L.) Merill. *International Journal of Current Microbiology and Applied Sciences* 7(1): 2006-2010.

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Bio-Efficacy And Phytotoxicity Of Newer Combination Picoxystrobin 7.05%+Propiconazole 11.71% W/W SC Against Alternaria Leaf Spot And Myrothecium Leaf Spot In Soybean

D L YADAV*, CHIRAG GAUTAM AND PRATAP SINGH
AGRICULTURE UNIVERSITY, KOTA, RAJASTHAN (INDIA)

E-mail: dlaau21@gmail.com

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ABSTRACT

Bio-efficacy of newer fungicides Picoxystrobin 7.05%+Propiconazole 11.71% w/w SC has been evaluated against alternaria and myrothecium leaf spots in Soybean at Agricultural Research Station, AU, Kota over two growing seasons Kharif 2018 and 2019. Pooled results revealed that two foliar sprays of Picoxystrobin 7.05%+Propiconazole 11.71% w/w SC @ 1000ml/ha resulted in least disease severity (6.0 and 6.8%) as well as maximum (76.0 and 69.6%) disease management and recorded highest (23.18q/ha) seed yield with 35% increase in seed yield. However, it was found to be significantly at par with the same fungicide applied @ 1125 ml/ha, resulting in PDI 5.3 and 6.0, and percent disease management 79.00 and 73.3 respectively and recorded 23.23q/ha seed yield. Moreover, during investigation, the chemical was found to be safe as no phytotoxic effect was noticed on soybean even at the double dose (2000ml/ha).

***Key word*: *Alternaria,* Myrothecium, phytotoxicity, Picoxystrobin, Propiconazole fungicide and Soybean.**

Soybean (*Glycin max* (L.) Merril) is a worldwide economic crop and the most important cultivated legume with hundreds of food, feed and industrial uses. Soybean ranks first among oilseed crop both in India and world. The wide spread cultivation of the crop has dramatically changed the socioeconomic status of the farmers of Rajasthan. It is a primary source of vegetable oil and protein concentrates. Soybean is an excellent source of major nutrients with about 40 per cent of dry matter being protein and 20% being fat. All parts of soybean crop plant are susceptible to phyto-pathogens. More than 135 phyto-pathogens are known to affect soybean, of which 35 are of economic significantly (Sinclair and Backman, 1989 and Hartman 2015). A number of pathogens infecting leaf and pods have been identified viz., *Alternaria alternata, Cercospora sojina, Septoria glycines, Myrothecium roridum, and Anthracnose Corynespora cassicola*. These have been reported in India (Shrivastva and Gupta, 2001). Members of genus *Alternaria* are cosmopolitan in nature and significant fungal pathogen which mostly cause diseases on aerial parts of many plants worldwide. The members of this genus like *A. alternata, A. solani, A. porri, A. helianthi, A. duaci, A. carthami, A. tenuissima* and *A. macrospora* causes different diseases in their respective hosts (Rostem, 1994). The disease incidence of *Alternaria alternata* causing leaf spot disease on Soybean was recorded up to 30 per cent and infected plants displayed necrotic, circular to oval, and dark brown spots on the upper surfaces of the lower leaves in Antalya Province of Turkey (Rustem *et al.* 2019). Zade *et al.,* (2018) reported 41.66 % in Walgoan village of Amravti, 40.19 per cent in Mozari and 12.50 per cent in village Tuljapur Taluka Seloo district Wardha of Alternaria leaf spot of soybean. Myrothecium leaf spot of soybean is occurring in almost all the major soybean growing areas of India casusing about 30 percent yield loss (Shrivastava and Khan, 1994). The disease severity of myrothecium leaf spot in soybean was in the range of 35 to 45 per cent and disease incidence of myrothecium leaf spot soybean was in the range of 30 to 55 percent (Singh and Shrivastava, 1994).

Diseased lesions are round or restricted by a major vein or merge with another lesion. Some have brown concentric rings with a well-defined border. The lesions expand and may combine to result in larger dead areas on the leaves. Infected leaves eventually dry out and fall Beside the conventional groups of fungicides, a number of new molecules have been tested. With the advent of time new generation molecule combination has been introduced for effective management. Looking to this prospective, present investigation can be considered worthwhile in respect of management measures for leaf spot diseases of soybean.

MATERIALS AND METHODS

The experiment was conducted at Agricultural Research Station, Agriculture University, Kota during *kharif* 2018 and 2019 to evaluate the efficacy of various Strobilurin and triazole group fungicides against leaf spot disease of soybean. The experiment was laid out in a Randomized Block Design (RBD) with three replications and eight treatments. Cultivar RKS 45 was sown in 20 m^2 plot at 45 cm row to row distance. Crop was raised as per the recommended package of practices as per zone and protective irrigation was given as and when required. Fungicides were sprayed twice using a hand operated knapsack sprayer fitted with hollow cone nozzle and water volume of 500 lit/ha was maintained. First spraying was given just after the appearance of the disease and second was given 14 days after the first spray. Observations related to diseases were recorded 15 days after first application (at 15 days) and second 15 days after second application (at 30 days). It was recorded from randomly selected 10 plants in each treatment (plot). Each selected plants were approximately divided into three positions as bottom, middle and top. From each position two to four leaves were graded as per the following disease assessment key of Mayee and Datar (1986) which was mainly based on the per cent leaf area infected (0-9 scales) Phytotoxicity of Picoxystrobin 7.05%+Propiconazole 11.71% w/w SC was evaluated on soybean variety RKS. One spray was given and visual observations were recorded at 1, 3, 5, 7 and 10 days after spray of test products. Matured and dried plants were harvested at maturity of the crop. Grain yield was recorded in all the treatments and was computed on hectare basis. Ten plants per plot were randomly selected and phytotoxicity symptoms *viz;* leaf chlorosis, tip burning, necrosis, epinasty, hyponasty, vein clearing and wilting were recorded as per CIB guidelines using a rating scale of 0 – 10 (Bijender Kumar, 2019) where,

0= no phytotoxicity,
1= 1-10% phytotoxicity,
2= 11-20% phytotoxicity,
3= 21-30% phytotoxicity,
4= 31-40% phytotoxicity,
5= 41-50% phytotoxicity,
6= 51-60% phytotoxicity,
7= 61-70% phytotoxicity,
8= 71-80% phytotoxicity,
9= 81-90% phytotoxicity,
10= 91-100% phytotoxicity.

Disease rating scale: Every infected leaf has been assigned 0-9 ratings/ grades which are given below based on the percent leaf area infected.

Calculation of Per cent Disease index (PDI)

These grades are then utilized for the calculation of PDI by using the following formula of Wheeler.

Yield assessment: The soybean seeds were harvested and weighed plot wise; the average seed yield per treatment was recorded and converted into quintals per ha and statistically analyzed

RESULTS AND DISCUSSION

In present experiment, all applied fungicides were found significantly superior in reducing the disease severity as compared to check against alternaria leaf spot and myrothecium leaf spot of soybean during *Kharif* 2018 and 2019 and both the year similar treatment trend was observed. Pooled result revealed that among the different treatments, foliar spraying of Picoxystrobin 7.05% +Propiconazole 11.71% w/w SC at the rate of 1000 ml/ha provided minimum disease severity (6.0%) and maximum (76.0%) disease management along with highest (23.18q/ha) seed yield with increase in seed yield (35.00%) which was at par with the same fungicide applied @ 1125 ml/ha, provided (PDI 5.3), 79.00 per cent management of the disease and recorded 23.23 q/ha seed yield when compared to untreated (PDI 25.0) and seed yield (17.18q/ha). Whereas, Propiconazole 25 % w/w EC @ 500ml/ha (PDI 6.9 and PDC 72.3), Picoxystrobin 22.52% w/w SC @ 400ml/ha (PDI 7.6 & PDC 69.7), Pyraclostrobin 20%w/w WG @ 500ml/ha (PDI 8.2 and PDC 67.3) and Hexaconazole 5% EC @ 500 (PDI 8.8 and PDC 64.7) (Table 1).

Pooled result revealed that combination of Picoxystrobin 7.05% +Propiconazole 11.71% w/w SC @ 1000 ml/ha provided the minimum disease severity (6.8%) and disease management (69.6%) against myrothecium leaf spot disease of soybean which was at par with its higher dose of Picoxystrobin 7.05% +Propiconazole 11.71% w/w SC @ 1125 (PDI 6.0) and 73.3% disease management. However, single Propiconazole 25 % w/w EC @ 500ml/ha (PDI 8.3), Picoxystrobin 22.52% w/w SC @ 400ml/ha (PDI 8.7), Pyraclostrobin 20%w/w WG @ 500ml/ha (PDI 9.7) and Hexaconazole 5% EC @ 500 (PDI 10.7), when compared to check (PDI 24.3) (Table 2).

All the treatments provided significantly higher yield as compared to control (Table 3). Evaluation of Phytotoxicity of Picoxystrobin 7.05% +Propiconazole 11.71% w/w SC on soybean was evaluated at 3 doses i.e. 875, 1000 and 2000 ml/ha and observed at 1, 3, 5, 7 and 10 days after application for phytotoxicity symptoms. The plants were observed for symptoms of phytotoxicity viz., chlorosis, necrosis, wilting, scorching, hyponasty and epinasty. None was no phytotoxic effect on plants even at the double tested dose of 2000 ml/ha of Picoxystrobin 7.05% +Propiconazole 11.71% w/w SC during *Kharif* 2018 and 2019 (Table 4).

Present findings are in accordance with Miles *et al*., (2007) which reported that the applications of triazole in single and triazole + strobilurin combination fungicides resulted in lower severity and higher yields compared with other fungicides in soybean. The strobilurin fungicides interfere with spore germination and germ tube development,

$$\text{Per cent Disease Index (PDI)} = \frac{\text{Sum of individual rating}}{\text{No. of leaves examined}} \times \frac{100}{\text{Max. Disease rating}}$$

Table 1. Study of efficacy of various fungicides on Alternaria leaf spot disease of soybean

SN	Treatments	g ai/ha	Dose g or ml/ha	PDI on Alternaria leaf spot				Pooled data after second spray	PDC
				1st Spray		2nd Spray			
				2018	2019	2018	2019		
1	Picoxystrobin 7.05% + Propiconazole 11.71% w/w SC	175	875	10.0 (18.42)	8.2 (16.59)	8.0 (16.41)	9.0 (17.44)	8.5 (16.95)	66.0
2	Picoxystrobin 7.05% + Propiconazole11.71% w/w SC	200	1000	5.2 (13.09)	5.3 (13.31)	6.0 (14.15)	6.0 (14.15)	6.0 (14.15)	76.0
3	Picoxystrobin 7.05% + Propiconazole 11.71% w/w SC	225	1125	4.7 (12.46)	4.7 (12.45)	5.0 (12.88)	5.5 (13.55)	5.3 (13.23)	79.0
4	Picoxystrobin 22.52% w/w SC	100	400	8.3 (16.74)	6.2 (14.34)	8.3 (16.77)	6.8 (15.13)	7.6 (15.98)	69.7
5	Propiconazole 25 % w/w EC	125	500	7.0 (15.32)	5.8 (13.87)	7.7 (16.07)	6.2 (14.33)	6.9 (15.24)	72.3
6	Pyraclostrobin20%w/w WG	100	500	9.3 (17.75)	7.3 (15.69)	8.5 (16.95)	7.8 (16.24)	8.2 (16.60)	67.3
7	Hexaconazole 5% EC	25	500	9.7 (18.08)	8.0 (16.41)	9.0 (17.44)	8.7 (17.10)	8.8 (17.27)	64.7
8	Untreated control	-	-	20.3 (26.79)	17.8 (24.97)	26.7 (31.08)	23.3 (28.88)	25.0 (29.99)	–
	S. Em. ±			0.62 (0.50)	0.91 (0.74)	0.72 (0.49)	0.87 (0.63)	0.67 (0.45)	–
	C.D. at 5 %			2.24 (2.28)	1.95 (2.25)	1.54 (1.51)	1.87 (1.93)	1.43 (1.38)	–

Values are means of three replications; PDI = Per cent disease index; PDC= Per cent disease control
Figures in parentheses are arc sine transformed values

Table 2. Study of efficacy of various fungicides on Myrothecium leaf spot disease of soybean

SN	Treatments	g ai/ha	Dose g or ml/ha	PDI on Alternaria leaf spot				Pooled data after second spray	PDC
				1st Spray		2nd Spray			
				2018	2019	2018	2019		
1	Picoxystrobin 7.05% + Propiconazole 11.71% w/w SC	175	875	9.1 (17.54)	10.2 (18.58)	10.5 (18.90)	9.8 (18.27)	10.2 (18.59)	54.8
2	Picoxystrobin 7.05% + Propiconazole11.71% w/w SC	200	1000	4.8 (12.67)	6.3 (14.57)	7.0 (15.32)	6.7 (14.95)	6.8 (15.14)	69.6
3	Picoxystrobin 7.05% + Propiconazole 11.71% w/w SC	225	1125	4.1 (11.60)	5.3 (13.34)	6.3 (14.57)	5.7 (13.76)	6.0 (14.17)	73.3
4	Picoxystrobin 22.52% w/w SC	100	400	7.3 (15.62)	8.0 (16.41)	9.0 (17.44)	8.3 (16.77)	8.7 (17.12)	61.5
5	Propiconazole 25 % w/w EC	125	500	6.4 (14.67)	7.3 (15.70)	8.7 (17.12)	8.0 (16.41)	8.3 (16.77)	63.0
6	Pyraclostrobin20%w/w WG	100	500	8.3 (16.77)	8.6 (17.03)	10.0 (18.42)	9.3 (17.78)	9.7 (18.11)	57.0
7	Hexaconazole 5% EC	25	500	8.8 (17.27)	9.7 (18.08)	11.0 (19.36)	10.3 (18.72)	10.7 (19.04)	52.6
8	Untreated control	-	-	19.1 (25.90)	16.3 (23.82)	24.3 (29.55)	20.7 (27.03)	22.5 (28.31)	–
	S. Em. ±			0.65 (0.51)	0.82 (0.54)	0.66 (0.44)	0.85 (0.55)	0.64 (0.44)	–
	C.D. at 5 %			1.38 (1.56)	1.75 (1.65)	1.41 (1.33)	1.82 (1.69)	1.37 (1.33)	

Values are means of three replications; PDI = Per cent disease index; PDC= Per cent disease control
Figures in parentheses are arc sine transformed values

Table 3. Study of efficacy of various fungicides on yield of soybean seeds

SN	Treatments	g ai/ha	Dose g or ml/ha	Seed Yield (q/ha)			
				2018 Kharif	2019 Kharif	Pooled	% Increase over control
1	Picoxystrobin 7.05% + Propiconazole 11.71% w/w SC	175	875	20.4	21.5	20.92	22
2	Picoxystrobin 7.05% +Propiconazole11.71% w/w SC	200	1000	22.9	23.4	23.18	35
3	Picoxystrobin 7.05% +Propiconazole 11.71% w/w SC	225	1125	23.0	23.5	23.23	35
4	Picoxystrobin 22.52% w/w SC	100	400	20.8	21.7	21.25	24
5	Propiconazole 25 % w/w EC	125	500	20.9	21.8	21.32	24
6	Pyraclostrobin20%w/w WG	100	500	20.1	21.4	20.73	21
7	Hexaconazole 5% EC	25	500	19.5	20.2	19.89	16
8	Untreated control	-	-	17.1	17.3	17.18	--
	S. Em. ±				0.85	0.61	0.63--
	C.D. at 5 %				1.84	1.31	1.36

Values are means of three replications

Table 4. Evaluation of Phytotoxicity of Picoxystrobin 7.05% + Propiconazole 11.71% w/w SC in soybean (*Kharif* 2018 & 2019)

Treatments	g a.i./ha	Formulation g or ml/ha	Days of observation after spray	Phytotoxicity symptoms						
				Chlorosis	Necrosis	Wilting	Scorching	Vain clearing	Hyponasty	Epinasty
Picoxystrobin 7.05% + Propiconazole 11.71% w/w SC	175	875	1st day	0	0	0	0	0	0	0
			3rd day	0	0	0	0	0	0	0
			5th day	0	0	0	0	0	0	0
			7th day	0	0	0	0	0	0	0
			10th day	0	0	0	0	0	0	0
Picoxystrobin 7.05% + Propiconazole 11.71% w/w SC	200	1000	1st day	0	0	0	0	0	0	0
			3rd day	0	0	0	0	0	0	0
			5th day	0	0	0	0	0	0	0
			7th day	0	0	0	0	0	0	0
			10th day	0	0	0	0	0	0	0
Picoxystrobin 7.05% + Propiconazole 11.71% w/w SC	225	1125	1st day	0	0	0	0	0	0	0
			3rd day	0	0	0	0	0	0	0
			5th day	0	0	0	0	0	0	0
			7th day	0	0	0	0	0	0	0
			10th day	0	0	0	0	0	0	0
Picoxystrobin 7.05% + Propiconazole 11.71% w/w SC	400	2000	1st day	0	0	0	0	0	0	0
			3rd day	0	0	0	0	0	0	0
			5th day	0	0	0	0	0	0	0
			7th day	0	0	0	0	0	0	0
			10th day	0	0	0	0	0	0	0
Untreated Control (Water spray)	--	–	1st day	0	0	0	0	0	0	0
			3rd day	0	0	0	0	0	0	0
			5th day	0	0	0	0	0	0	0
			7th day	0	0	0	0	0	0	0
			10th day	0	0	0	0	0	0	0

absorbed into the leaf tissue and move in a translaminar manner (Sauter *et. al*. 1999). However, the triazole fungicides are sterol inhibitors that interfere with sterol biosynthesis in fungal membranes and are absorbed into the leaf tissue (Tsuda *et al*. 2004). Present result of strobilurin + triazole (Picoxystrobin 7.05% +Propiconazole 11.71% w/w SC) at the rate of 1000 ml/ha provided minimum disease severity and maximum disease management and recorded highest (23.18q/ha) seed yield without any phytotoxicity effect on soybean and this finding corroborate with finding of Bijender Kumar (2019) reported that combination of trifloxistrobin 25% + tebuconazole 50% @ 350g/ha provided (78.06%) best disease control and recorded highest grain yield (1059.26 kg/ha) against anthracnose leaf spot and pod blight disease of soybean without any phytotoxicity effect on soybean plant.

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REFERENCES

Bijender Kumar. 2019. Bio-efficacy of newer fungicide Trifloxystrobin 25% plus tebuconazole 50% WG (Nativo 75 WG) against Anthracnose leaf spot and pod blight of soybean. *The Bioscan*, 14(1): 001-007.

Hartman GL. 2015. Worldwide importance of soybean pathogens and pests. The *American Phytopathology* USA.

Mayee, C. D. and Datar, V. V. 1986. Phytopathometry: A Technical Bulletin-I, Marathawad Agricultural University, Parbhani, India. p.146.

Miles, M. R., Levy, C., Morel, W., Mueller, T., Steinlage, T., van Rij, N., Frederick, R. D., and Hartman, G. L. 2007. International fungicide efficacy trials for the management of soybean rust. *Plant disease*. 91:1450-1458.

Rostem, J. 1994. The Genus Alternaria: Biology, Epidemiology and Pathogenicity. The American Phytopath. Society, St. Paul, Minnesota. 326.

Rustem Ustun, Ahmet Cat, Bulent Uzun, and Mursel Catal 2019. First Report of Alternaria alternata Causing Leaf Spot Disease on Soybean (*Glycine max*) in Antalya Province of Turkey. *Plant disease,* 103 (12).

Sauter, H., Steglich, W., and Anke, T. 1999. Strobilurins: evolution of a new class of active substances. *Angew. Chem. Int. Ed. Engl*. 38:1328-1349.

Shrivastava, S.K. and Khan, S.U. (1994). Impact of host age at infection time on the severity of myrothecium leaf spot disease of soybean. *Indian Phytopathology*, 47 (2): 190-191.

Sinclair, J. B., and Backman, P. A., 1989. Compendium of Soybean Diseases, 3rd ed., American Phytopathological Society, St. Paul.

Singh, S.M. and Shrivastava, S.K. 1994. Screening of soybean varieties against leaf spot disease caused by myrothecium roridum. *Indian Journal of Mycology and Plant Pathology*, 24 (3): 222.

Tsuda, M., Itoh, H., and Kato, S. 2004. Evaluation of the systemic activity of simeconazole in comparison with that of other DMI fungicides. *Pest Manage. Sci*. 60:875-880.

Zade S. B., Ingle Y. V., Mane S. S. and Gathe A. G. 2018. Survey of alternaria leaf spot of soybean in central vidarbha. *Journal of Plant Disease Sciences*. Volume 13 (2), pp-107-110.

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Reproductive Stage Water-logging Tolerance: A Critical Assessment of Traits in Soybean

SUBHASH CHANDRA*[1], G K SATPUTE[1], SHIVANI NAGAR[2], MAHARAJ SINGH[1], G KUMAWAT[1], V RAJESH[1], V NATARAJ[1], MAMTA ARYA[3], SHIVAKUMAR M[1], M B RATNAPARKHE[1], SANJAY PANDEY[1] AND SANJAY GUPTA[1]

[1]ICAR-Indian Institute of Soybean Research, Indore; [2] ICAR-Indian Agricultural Research Institute, New Delhi; [3]ICAR-NBPGR, Regional station, Bhowali, India

**E-mail: chandraasubhash@gmail.com*

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ABSTRACT

Soybean (Glycine max L. Merrill) is an important oilseed crop for food, feed and industrial applications. Soybean is sensitive to flooding stress; loss due to this abiotic stress varies with intensity of water logging and plant's growth stages. The water logging at reproductive stages is more deleterious to yield than any other crop stage. In order to identify the potential donors and trait associated with water logging tolerance, 28 diverse soybean genotypes including checks were evaluated at R1 stage under natural flooded fields for 15 days. In water logging conditions, an array of variability was recorded for reduction in seed yield.plant-1(3.16 - 71.94%), reduction in 100 seed weight(1.69 - 45.11%), increase in plant height (-34.78 -56.81%), reduction in no. of pods.plant-1 (0.48 - 54.46%), reduction in total chlorophyll content (8.49 - 54.42%) in relation to non-stressed control field. Genotypes viz., JS 20-38, Hardee, JS 71-05, C-2797 and NRC 128 were identified as prominent genotypes for water logging tolerance. Correlation analysis among the traits revealed that percentage reduction in seed yield.plant-1was positively associated with percentage reduction in number of pods.plant^{-1}(r2=0.61), seed size (r2=0.43), SPAD readings (r2=0.67), chlorophyll content (r2=0.83) and specific leaf weight (r2=0.77) in relation to water logging tolerance. Identified traits and potential tolerant genotypes will strengthen in soybean breeding programs for developing climate smart soybean varieties.

Key words **:** Soybean, water logging stress, flooding, tolerance, physiological trait

Flooding is a major abiotic stress, adversely affecting the food crop productions globally. Flooding is mainly caused by extended periods of rain, storms, rainfall just after irrigation, excessive irrigation, overflow of rivers and impermeable soils. Globally, various economically important crops were affected with flooding or water logging stress in past; the annual yield losses in rice, wheat and maize were reported nearly about 18%, 40% and 25% respectively in different regions of world (Mohanty and Khush, 1985; Rathore and Warsi, 1998; Collaku and Harrison, 2002). It was estimated that flooding causes about 16% annual loss in soybean productivity world-wide (Ahmed *et al*., 2013; Boyer, 1982). In India, excessive soil moisture or water logging caused slaughter in grain yield nearby 18%, mainly in the central India (SOPA, 2019). In the wake of global climate change, weather simulation models showed an expected increase in loss of crop production due to flooding in the future (Rosenzweig *et al*., 2002).Based on current scenarios, soybean growing regions of central India (States of Madhya Pradesh, Rajasthan and Maharashtra) receive more than 70% rainfall in July-August months when soybean crop having late vegetative stages or early reproductive stages in farmer fields (Rajendran and Lal, 2020).The climate change projection scenario for years 2021 to 2050 also indicated about increase of 11.6 % annual rainfall with irregular extreme events in central India (Goswami *et al*. 2006) which may affect the total soybean production negatively in India.

Soybean [*Glycine max* (L.) Merrill] is *numero uno* oilseed crop in the world and India in terms of production. It contributes around 18-19 per cent and 40-45 per cent to the edible oil pool and total oilseeds production, respectively, of the Indian subcontinent. In addition to sizeable share in edible oil, the crop earns more than 70 thousand million rupees annually, through the export of de-oiled cake (Shrivastava *et al*., 2014). Besides protein (38-45%), this 'miracle bean' contains oil (18- 22%), carbohydrate, ash, nutritional elements and antioxidants largely beneficial for human being. Therefore, it is gaining boundless popularity in the food, health, pharmaceutical and cosmetic industries worldwide (Kumar *et al*., 2019). In India, Soybean cultivation has substantially elevated the social and economic status of farmers as well as generated employment in based industries.

Soybean genotypes are sensitive to water logging stress, resulting in significant yield reduction ranging from 17% to 46% at the vegetative stage stress and 50% to 56% at the reproductive stage stress (Oosterhuis *et al.*,1990; Van Toai *et al*., 2010). Water logging, for periods enduring as short as 2 days, reduces yields by as much as 27% (Linkemer *et al*., 1998). Yield losses due to water logging are mainly because of damages in the roots, insufficient water and nutrient uptake, reduction in nodule formation, chlorosis due to impaired photosynthesis and carbon assimilation, and plant death due to diseases (Oosterhuis *et al.,* 1990; Sakazono *et al.,* 2014; Ye *et al.,* 2018). Nguyen *et al.* (2012) reported about loss of 40% - 57% in yield due to flooding stress during the reproductive stage of soybean. Flooding stress at R1 and R5 growth stage brought loss of 45.9% -76.6% (Wu *et al*., 2017a) and 20% - 39% (Rhine *et al*., 2010) in soybean grain yield respectively. Very few studies are available on the evaluation of soybean genotypes for water logging tolerance at reproductive stages stress in India. Arya *et al*. (2014) screened fifty genotypes at R_1 stage in small pots, during their investigation genotypes i.e. JS 95-60, JS 97-52, Bhatt, Cat 3299 and JS 93-05 were found relatively better on the basis of per cent increase in plant height and per cent reduction in dry weight of plants. Shrivastava *et al*. (2014) evaluated 25 soybean genotypes for water logging tolerance and genotypes viz., JS 95-60, JS 20-87, JS 20-69 and RVS 2007-1 reported as tolerant for excessive moisture conditions. Furthermore, Shrivastava *et al*. (2014) also suggested the preponderance of additive gene action for seed yield plant^{-1} and yield attributes in water logged environment. So, the available genotypic variation in Indian germplasm may be exploited in developing soybean cultivars with water logging tolerance at reproductive stages to combat this abiotic stress. Appropriate fieldbased screening technique, morpho-physiological traits associated with tolerance and identification of prominent genotypes is the primary need for development of waterlogging tolerant soybean. The present study intended to understand the genetic variations for morpho-physiological traits associated with water logging tolerance andto identify tolerant genotypes at reproductive stages.

MATERIALS AND METHODS

A total of 28 soybean genotypes diverse in nature (Table 3) were evaluated for water logging stress in the fields of ICAR-Indian Institute of Soybean Research, Indore during the *Kharif* season of 2018. Because of their different maturity duration (90-110days), these lines were grown in three different blocks of control and water logging stress plots to manage the stress period. A set of eight genotypes having almost equal days to flowering raised in each block with four checks (JS 97-52, JS 90-41, JS 335 and PK 472), so 24 soybean genotypes (Table 3) were grown in three blocks with 4 checks including water logging tolerant check (JS 97-52) and susceptible check (JS 90-41) in each block in augmented design. Each line was planted in one 3 meter row and crop was raised with recommended package and practices of ICAR-IISR, Indore (Dupare and Billore, 2021).

Soybean genotypes were exposed to flooding stress when 80% lines attained R1 stages (first flower at any node) (Wu *et al.* 2017b). Water logging stress was imposed by maintaining the 12-15 cm of water above the soil surface for 15 days, and flooding treatment was terminated by draining off the water subsequently. Genotypes in control plot were maintained under normal irrigated conditions. Three days after termination of water logging stress chlorophyll content was estimated in 0.05 g (w) leaf (third trifoliate) samples by non-maceration method (Hiscox and Israelstam, 1979). Leaves were incubated in 10 ml of DMSO dimethyl sulfoxide (aceton:DMSO) in the dark for 4 hrs at 65^{o}C. Absorbance was recorded at 645 (A645) and 665 (A665) nm then total chlorophyll was calculated using the formula of Arnon (1949). It is calculated as: total chlorophyll = (20.2 x A645 + 8.02 x A663) x V x w / 1000.

Seed yield per plant and other yield attributing traits i.e. pod per plant, plant height and 100 seed weight were recorded for 28 genotypes grown in control and stress plots. Among the 28 genotypes, seven genotypes (JS 20-38, JS 20-98, PK 472, NRC 37, RVS 2001-18, Bragg and tolerant check JS 97-52) were used to understand the inter-relationship among morpho-physiological traits associated to water logging tolerance, for this purpose the number of root nodules per plant, dry weight of root nodules per plant, SCMR (SPAD chlorophyll meter reading) and specific leaf weight was also recorded from control and stress plots as methodology suggested by Jumrani *et al*., (2017) and Lopez *et al*., (2018).

Analysis of variance (ANOVA) for seed yield per plant, pod per plant, plant height, 100 seed weight and chlorophyll content in both plots (control and stress) was conducted using the R package 'augmented RCBD' (Aravind *et al*., 2018). Adjusted means was also calculated for 24 soybean genotypes for these five traits. Various descriptive statistical parameters viz. mean, range, variances, heritability and genetic advance etc. were analyzed using adjusted means after testing homogeneity of variance. Correlation analysis was performed by using the R function cor() and linear regression analysis was performed using the R function lm(). A dependent variable - per cent reduction from water logging treatment to the control treatment was calculated according to the formula:

Parameter = (control – water logging)/control * 100 for each morpho-physiological trait.

RESULTS AND DISCUSSION :

Effect on Yield attributes

Excessive moisture stress and flooding stress severely affects soybean crop at every growth stage, but susceptibility varies stage to stage i.e. germination / vegetative / reproductive stage (Wu *et al.*, 2017a; Rajendran *et al.*, 2019). However, yield and yield attributes gets negatively affected more during water logging stress at reproductive stage than vegetative stage (Rhine *et al.*, 2010; Nguyen *et al.*, 2012). In present investigation, flooding stress was imposed through partial submergence which occurs frequently during soybean cultivation with different intensities. The analysis of variance demonstrated the existence of notable amount of genetic variability among the soybean germplasm accessions for yield and yield related parameters evaluated in control and stress plots (Table 1). ANOVA for augmented randomized block design revealed that mean squares of all four yield traits were significant for different source of variations except mean squares due to blocks ignoring the treatments in control plot for the trait of seed size. The mean, range, variance, coefficient of variance, heritability and genetic advance for all the four yield traits are presented in Table 2. Among the traits, grain yield plant^{-1}found to be having maximum and seed index having least variations but all the traits showed good variations with high heritability and high genetic advance in general (Table 2). Influence of water logging stress on yield traits is represented in terms of percentage reduction in yield plant^{-1}, seed index, no of pods and percentage increase in plant height (Table 3). Among the yield attributes, yield plant^{-1}, seed index, no of pods get reduced after water logging stress in comparison to control treatment while plant height found to be increased in general (Table 3) but in contrast, in some genotypes *viz.*, JS 71-05, JS 95-60, Hardee, NRC 37, CAT 1043 plant height got decreased in stress plot in comparison to control plot (Table 3). This type of bi-directional variations (-ve & +ve) were also recorded by Arya *et al.*, (2014) in case of plant height in soybean. It means that most of these genotypes under water logged conditions are capable of maintaining the plant height in compared to controlled conditions. Reduced plant height due to waterlogging was also observed in tomato (Ezin *et al.*, 2010) and soybean (VanTotai *et al.*, 2010). According to Cox *et al.,* (2003), plant height can be enlarged due to promotion of shoot extension, that is one of the developmental effect of water logging and it supplements the aerenchyma system where it recover access to dissolved oxygen to generate photosynthetes. The percentage reduction in yield per plant was ranging from 3.16% (JS 71-05) to 71.94% (JS 20-50) with mean of 24.41%, and genotypes i.e. JS 71-05, JS 20-38, NRC 128, Hardee and Cat 2797 performed better for yield per plant than tolerant check JS 97-52 (Table 3). The percentage reduction in seed size in terms of 100 seed weight ranged from 1.69% (NRC 128) to 45.11% (JS 95-60) with mean of 11.21%. Similarly, the percentage reduction in number of pods per plant ranged from 0.48% (YP 1) to 54.46% (JS 20-50) with mean of 23.20%. Similar trends were also recorded by Van Toai *et al.*, (2010), Nigam *et al.*,(2012) and Shrivastava *et al.*, (2014) for yield and its related traits in soybean. In totality, in this investigation, some genotypes *viz.*, JS 20-38, JS 71-05, Hardee and NRC 128 performed better for almost all yield attributing traits in water logging stress condition in comparison to tolerant check JS 97-52. When percentage reduction in yield is correlated with other yield attributes, correlation matrix (Table 4) showed significant positive correlation of % reduction in grain yield with % reduction in 100 seed weight (0.43) and % reduction in pods per plant (0.61), however percentage increase in plant height found to be almost non-correlated (0.025) in this study (Table 4). Simple linear regression analysis was performed for % reduction in grain yield versus other yield traits showed that % reduction in pods per plant had more direct effect ($R^2 \sim 0.35$) than % reduction in 100 seed weight ($R^2 \sim 0.16$). In general, plant height enhancement as a water logging trait in water logging plot over control plot in this study, couldn't associated well with percentage reduction in seed yield in this study.

Effect on morpho-physiological traits

The ANOVA revealed remarkable amount of genetic variability among the 28 soybean genotypes for total chlorophyll content estimated in control and stress plots (Table 1). The total chlorophyll content exhibited good variations with high heritability and high genetic advance in set of 28 genotypes (Table 2). Total chlorophyll content was found to be significantly decreased in water logging plot with mean value of 9.73 mg/gFW in compared to control plot (13.56 mg/gFW). Percentage reduction for total chlorophyll content was ranged from 8.49 % (NRC 137) to 54.42 % (SG 3) with mean of 28.10%. Based on the percent reduction in total chlorophyll content, some genotypes viz., JS 20-98, YP 3, DS 9712, RVS 2001-4, NRC 137, JS 20-98 etc. performed better than water logging tolerant check JS 97-52.

In this investigation, influence of flooding on some other morpho-physiological traits was also studied using seven selective genotypes (Table 5). The SPAD value found to be significantly decreased in stress plot with 12.83 % in comparison to control plot (Table 5). Similar trend was also observed by Mutava *et al.*, (2015) and Wu *et al.*, (2017a) in soybean. The percent reduction in SPAD chlorophyll meter readings (SCMR) was significantly correlated (0.85) with percent reduction in total chlorophyll content estimated through acetone/DMSO method explaining the importance of SPAD measurement for chlorophyll content in soybean. The percent reduction in yield per plant was significantly correlated with % reduction in SPAD chlorophyll meter readings (0.67) and % reduction in total chlorophyll content (0.83) (Table 6). With this fact, SPAD reading (SCMR) may be useful to measure the leaf chlorophyll content to identifying the water logging tolerant soybean genotypes.

Specific leaf weight (SLW) calculated as the ratio of leaf dry weight to leaf area is also an important component for phenotyping of traits related to abiotic stress i.e. drought and water logging. In general, it is directly correlated to water use efficiency of plant (Bhatia *et al.*, 2014). Present investigation showed that water logging reduced SLW up to 15 % over the control. (Table 5). Correlation studies showed significant relationship (0.77) between percent reduction in specific leaf weight and seed yield per plant; percent reduction in SLW also showed significant correlation (0.68) with percent reduction in SCMR (Table 6). These finding revealed that specific leaf weight may be used as important trait to phenotype water logging tolerance in soybeans. In present investigation, water logging treatment showed 34.14 % and 25.69% reduction in number of root nodules and dry weight of root nodules over the control (Table 5). Reduction in root nodule number and dry weight of root nodules was also observed by Youn *et al.,* (2008). The percent reduction in number of root nodules and dry weight of root nodules has no significant relationship with percent reduction in seed yield (Table 6). This kind of non-significant association may be due to less active root nodule numbers and decreased biological nitrogen fixation at initial reproductive phase (R3/R4), that may be possible cause for this disconnection (Pitumpe Arachchige *et al*., 2020).

Simple linear regression analysis performed for % reduction in grain yield versus physiological traits showed that % reduction in total chlorophyll content had more direct effect ($R^2 \sim 0.63$) than % reduction in SPAD meter reading ($R^2 \sim 0.34$) and % reduction in specific leaf weight also had effect with $R^2 \sim 0.50$ on yield reduction. Over all, in this investigation, chlorophyll content of leaf or SPAD reading and specific leaf weight recognized as good trait to identify water logging tolerant genotypes.

Identification of water logging tolerant genotype and associated trait

Breeding for any trait specific/high yielding cultivar relies on variability in genetic resources available for particular trait or trait complex. Like other abiotic stress such as drought and high temperature, water logging is also recalcitrant to breeding. The use of physiological traits associated to with abiotic stress tolerance in a breeding programme, either by direct selection or through a surrogate such as molecular markers, depends on their relative genetic correlation with yield, extent of genetic variation, heritability and genetic advance (Bhatia *et al*., 2014). In presented study, yield attributes and associated morpho-physiological traits showed abundant variability. On the basis of yield and morpho-physiological traits, genotypes viz., JS 20-38, JS 71-05, NRC 128 and Hardee identified as water logging tolerant genotypes. Among the genotypes, JS 20-38 suggested as water logging tolerant genotype in across the studies conducted in ICAR-IISR, Indore.JS 20-38 and PK 472 identified as tolerant genotypes based on seed yield under water logging treatment at R1 stage(Anonymous, 2014).Based on plant survival rate and adventitious root emergence, JS 20-38 ranked first along with JS 97-52 as water logging tolerant genotype during screening at germination stage water logging stress (Anonymous, 2015), furthermore it was also confirmed with root anatomical and root porosity studies (Anonymous, 2015). This genotype (JS 20-38) also performed better under water logging stress at vegetative stage (V_2-V_3) in *Kharif* 2019 in ICAR-IISR, Indore and ICAR-RCNEH, Umiam (Anonymous, 2019; Anonymous, 2020). This potential genetic resource (JS 20-38) is being used as parental genotype for genetic studies related to water logging tolerance in ICAR-IISR, Indore.

Here we report that SPAD meter readings and specific leaf weight besides of yield traits *viz*., seed yield per plant, number of pods and 100 seed weight may be used as potential trait for phenotyping of water logging tolerance. The traits and tolerant genetic resources identified in this research will be effective for developing flooding-tolerant soybean lines for the benefit of soybean growing farmers.

Table 1: Analysis of variance for chlorophyll content and yield attributing traits under control and stress plots

Source	Df	Grain yield per plant (g)	100 seed weight (g)	Nos. of pods per plant	Plant height (cm)	Chlorophyll content (mg/gFW)
Block (ignoring Treatments) C	2	30.71***	2.06 ns	99.53**	65.46**	19.47***
Block (ignoring Treatments) W	2	4.95***	3.53***	41.1**	306.1***	1.82 ns
Treatment (eliminating Blocks) C	27	534.80***	185.12***	7981.08***	325.63***	107.22***
Treatment (eliminating Blocks) W	27	16.86***	7.13***	243.26***	424.06***	4.14**
Treatment: Check C	3	79.26***	53.24***	2007.11***	1188.07***	19.96***
Treatment: Check W	3	23.7***	25.04***	767.45***	718.47***	5.29**
Treatment: Test and Test vs. Check C	24	455.54***	131.88***	5973.98***	217.82***	87.26***
Treatment: Test and Test vs. Check W	24	16.01***	4.89***	177.74***	387.26***	3.99**
Residuals C	6	0.86	1.48	32.52	6.73	1.42
Residuals W	6	0.12	0.04	3.42	1.54	0.43

C: Control plot; W: water logging plot; ns P > 0.05; * P <= 0.05; ** P <= 0.01; *** P <= 0.001

Table 2: Statistical parameters for traits related to water logging tolerance under control and stress plots

Trait		Mean +SE	Variance (P)	Variance (G)	Range	PCV (%)	GCV (%)	Heritability	Genetic advance as % of mean
Chlorophyll content	C	13.59±0.38	4.62	4.39	8.94 -19.24	15.82	15.41	94.87	30.97
(mg/gFW)	W	9.73±0.38	3.98	3.56	4.43 – 13.01	20.5	19.37	89.28	37.76
Plant height (cm)	C	60.42±2.93	228.18	221.45	36.08 - 95.14	25.00	24.63	97.05	50.06
	W	71.33±3.78	416.14	414.60	23.57 – 122.6	28.60	28.55	99.63	58.78
No of pods plant^{-1}	C	58.19±2.99	250.81	245.39	24.77 - 82.77	27.22	26.92	97.84	54.93
	W	44.42±2.61	188.51	185.10	17.4 – 71.44	30.91	30.63	98.19	62.61
100 seed weight (g)	C	10.67±0.44	5.33	5.08	6.68 -15.58	21.64	21.13	95.37	42.58
	W	9.46±0.43	5.05	5.01	5.44 – 14.95	23.77	23.67	99.17	48.63
Grain yield plant^{-1}(g)	C	10.38±0.81	19.92	19.78	4.59 - 23.42	42.99	42.84	99.28	88.05
Grain yield plant^{-1} (g)	W	7.78±0.74	16.69	16.57	3.27 - 21.34	52.51	52.32	99.27	107.55

C: Control plot; W: water logging plot

Table 3: Changes (%) in chlorophyll content and yield attributing traits after water logging stress

S. No	Genotype	Per cent reduction in Yield	Per cent reduction in 100 seed weight	Per cent reduction in No of pods	Per cent increase in Plant height	Per cent reduction in Total Chlorophyll Content
1	DS 9712	19.26	10.57	27.50	12.45	14.32
2	RVS 2001-18	12.46	1.78	26.24	10.86	18.28
3	CAT 2065	28.09	6.02	21.13	30.57	36.85
4	JS 71-05	3.16	2.49	10.57	-0.85	25.10
5	NRC 86	50.08	25.18	44.39	6.41	22.93
6	JS 20-50	71.94	18.39	54.46	20.09	13.18
7	EC 546882	11.55	15.81	23.08	5.82	36.16
8	NRC 128	8.88	1.69	30.29	6.50	26.93
9	JS 95-60	46.58	45.11	42.54	-34.78	28.85
10	Hardee	6.99	4.67	12.11	-8.97	28.24
11	NRC 37	48.41	20.49	44.38	-18.15	43.15
12	CAT 2797	8.91	9.24	14.20	1.93	30.44
13	CAT 1043	13.94	14.30	37.71	-5.16	22.04
14	JS 20-98	20.92	8.08	27.24	55.17	8.85
15	SG 3	38.43	2.03	31.33	31.02	54.42
16	JS 20-38	6.65	18.46	9.14	9.75	20.21
17	SG 2	54.79	10.49	16.33	40.36	17.47
18	SG 1	14.54	3.58	16.10	49.25	31.14
19	EC 572109	16.31	8.96	31.77	40.69	21.63
20	YP 1	30.28	4.04	0.48	29.79	53.42
21	YP 2	16.27	6.39	4.20	35.30	50.45
22	YP 3	9.49	10.85	20.86	52.15	9.95
23	Bragg	15.33	12.25	3.75	56.81	27.48

S. No	Genotype	Per cent reduction in Yield	Per cent reduction in 100 seed weight	Per cent reduction in No of pods	Per cent increase in Plant height	Per cent reduction in Total Chlorophyll Content
24	NRC 137	36.11	2.99	26.23	36.98	8.49
Check	JS 335	33.04	3.36	15.18	32.21	47.77
Check	JS 9041	36.99	23.70	31.95	3.67	46.41
Check	JS 9752	9.00	12.27	11.29	11.79	22.99
Check	PK 472	15.22	10.77	15.02	27.35	19.82
Mean		24.41	11.21	23.20	19.25	28.10

Table 4 Correlation coefficients of percentage reduction in yield per plant after water logging stress with percentage reduction in other yield traits

Traits	% reduction in yield plant^{-1}	% reduction in 100 seed weight	% reduction in no of Pods	% increase in Plant height
% reduction in yield plant-1	1.00	0.43*	0.61***	0.025
% reduction in 100 seed weight		1.00	0.51**	-0.37
% reduction in no of Pods			1.00	-0.31
% increase in Plant height				1.00

*** P <= 0.05; ** P <= 0.01; *** P <= 0.001**

Table 5: Changes (%) in different morpho-physiological traits after water logging stress in selective genotypes

Genotype	% reduction in SCMR	% reduction in TCC	% reduction in SLW	% reduction in no of root nodules	% reduction in root nodule weight
PK 472	18.37	51.94	12.20	42.11	26.52
JS 20-98	7.65	32.54	20.15	21.57	13.59
JS 20-38	0.68	28.98	6.79	26.79	29.87
NRC 37	27.58	69.93	26.07	44.84	36.94
RVS 2001-18	0.13	37.82	13.54	61.96	26.03
Bragg	22.78	49.19	20.62	29.20	19.48
JS 9752 **(Check)**	12.63	32.12	5.66	12.50	27.43
Mean	12.83	43.22	15.01	34.14	25.69

Table 6: Correlation coefficients of percentage reduction in yield per plant after water logging stress with percentage reduction in different agro-morphological traits

Traits	% reduction in yield $plant^{-1}$	% reduction in SCMR	% reduction in TCC	% reduction in SLW	% reduction in no of nodules	% reduction in nodule weight
% reduction in yield $plant^{-1}$	1.00	0.67*	0.83*	0.77*	0.29	0.41
% reduction in SCMR		1.00	0.85*	0.68*	-0.039	0.24
% reduction in TCC			1.00	0.67	0.45	0.49
% reduction in SLW				1.00	0.024	-0.067
% reduction in no of nodules					1.00	0.34
% reduction in nodule weight						1.00

*** P <= 0.05; ** P <= 0.01; *** P <= 0.001**

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REFERENCES :

Ahmed F, Rafii MY, Ismail MR, Juraimi AS, Rahim H A, Asfaliza R and Latif MA. 2013. Waterlogging tolerance of crops: breeding, mechanism of tolerance, molecular approaches, and future prospects. *BioMed Research International*: 1–10.

Anonymous. 2014. Annual Report 2013-2014, Directorate of Soybean Research, Indore

Anonymous.2015. Annual Report 2014-2015, Directorate of Soybean Research, Indore

Anonymous.2019. Annual Report 2018-2019, ICAR-Indian Institute of Soybean Research, Indore

Anonymous.2020. Annual Report 2019, ICAR-Indian Institute of Soybean Research, Indore

Aravind J, Sankar MS, Dhammaprakash P W and Kaur V. 2018.AugmentedRCBD: Analysis of Augmented Randomised Complete Block Designs. R package version 0.1.0, https://aravind-j.github.io/augmentedRCBD/.

Arnon D I.1949. Copper enzymes in intact chloroplast, polyphenoxide in Beta vulgaris. *Plant Physiology* 24: 1-15.

Arya M, Bhatia V S, Ansari M M, Husain S M. 2014. Soybean (Glycine max L.) Genotypes for Water Logging Tolerance. *Soybean Research* (Special Issue I). 15-21.

Bhatia VS, Jumrani K, Pandey GP. 2014. Developing drought tolerance in soybean using physiological approaches. *Soybean Research* 12(1): 1-19.

Boyer J S.1982. Plant productivity and environment. *Science* 218:443-448.

Collaku A and Harrison S A. 2002. Losses in wheat due to waterlogging. *Crop Science* 42: 444-450.

Cox M C H, Millenaar F F, de Jong van Berkel Y E M, Peeters A J M and Voesenek L A C J. 2003.Plant Movement. Submergence- Induced Petiole Elongation in *Rumex palustris* depends on Hyponastic Growth. *Plant Physiology* 132: 282–91.

Dupare B U and Billore S D. 2021. Soybean production: Package of practices and technical recommendations. Extension Bulletin No. 16. ICAR-Indian Institute of Soybean Research Publications.Pp:50

Ezin V, Robert De La Pena and Ahanchede A. 2010. Flooding tolerance of tomato genotypes during vegetative and reproductive stages. Brazilian Journal of *Plant Physiology* 22(1): 131-42.

Goswami B N, Venugopal V, Sengupta D, Madhusoodanan M S, Xavier P K. 2006. Increasing trend of extreme rain events over India in a warming environment. *Science* 314: 1442-1445.

Hiscox, J D and Israelstam G F. 1979. A method for the extraction of chlorophyll from leaf tissue without maceration. *Canadian Journal of Botany* 57: 1332-1334.

Jumrani K, Bhatia V S and Pandey G P. 2017.Impact of elevated temperatures on specific leaf weight, stomatal density, photosynthesis and chlorophyll fluorescence in soybean. *Photosynthesis Research* 131:333–350.

Kumar A, Chandra S, Talukdar A, Yadav R R, Saini M, Poonia S, Lal S K. 2019. Genetic studies on seed coat permeability and viability in RILs derived from an inter-specific cross of soybean [*Glycine max* (L.) Merrill]. *Indian Journal of Genetics and Plant Breeding* 79(1): 48-55.

Linkemer G, Beard J E and Musgrave M E. 1998. Waterlogging effects on growth and yield components in late-planted soybean. *Crop Science* 38, 1576-1584.

López S M, Sánchez M D, Pastorino G N, Franco M E, García N T, Balatti P A. 2018. Nodulation and delayed nodule senescence: strategies of two Bradyrhizobium japonicum isolates with high capacity to fix nitrogen. *Current microbiology* 75(8):997-1005.

Mohanty H K and Khush G S. 1985.Diallel analysis of submergence tolerance in rice, *Oryza sativa* L. *Theoretical and Applied Genetics* 70: 467–473.

Mutava R N, Prince S J, Syed N H, Song L, Valliyodan B, Chen W, Nguyen H T. 2015. Understanding abiotic stress tolerance mechanisms in soybean: a comparative evaluation of soybean response to drought and flooding stress. *Plant Physiology and Biochemistry* 86:109-120.

Nguyen VT, Vuong TD, VanToai T, Lee JD, Wu X, Mian MR, Dorrance AE, Shannon JG, Nguyen HT. 2012. Mapping of quantitative trait loci associated with resistance to Phytophthora sojae and flooding tolerance in soybean. *Crop Science* 52(6):2481-93.

Nigam D, Khare D and Shrivastava A N. 2012.Excess moisture tolerance in soybean. *Soybean Research* 10: 1-10.

Oosterhuis D M, Scott H D, Hampton R E and Wullschleter S D. 1990. Physiological response of two soybean [*Glycine max* (L.) Merr.] cultivars to short-term flooding. *Environmental and Experimental Botany* 30: 85–92.

Pitumpe Arachchige P S, Rosso L H, Hansel F D, Ramundo B, Torres A R, Asebedo R, Ciampitti I A, Jagadish S K. 2020.Temporal biological nitrogen fixation pattern in soybean inoculated with Bradyrhizobium. *Agrosystems, Geosciences & Environment*, 3(1): e20079.

Rajendran A and Lal S K. 2020. Assessing the Need of Pre-germination Anaerobic Stress-Tolerant Varieties in Indian Soybean (*Glycine max* (L.) Merrill).National Academy Science Letter: 1-5.https://doi.org/10.1007/s40009-020-00937-9

Rajendran A, Lal SK, Jain SK and Dhandapani R. 2019. Screening of soybean genotypes for pre-germination anaerobic stress tolerance to waterlogging. *Journal of Pharmacognosy and Phytochemistry Special Issue* 2: 01-03.

Rathore T R and Warsi M Z K. 1998. Production of maize under excess soil moisture (waterlogging) conditions (p. 23). *In* Proceedings of the 2nd Asian Regional Maize Workshop PACARD, Laos Banos, Philippines.

Rhine M D, Stevens G, Shannon G, Wrather A and Sleper D. 2010. Yield and nutritional responses to waterlogging of soybean cultivars. *Irrigation Science* 28(2):135-42.

Rosenzweig C, Tubiello F N, Goldberg R, Mills E and Bloomfield J. 2002. Increased crop damage in the US from excess precipitation under climate change. *Global Environmental Change* 12(3):197-202.

Sakazono S, Nagata T, Matsuo R, Kajihara S, Watanabe M, Ishimoto M, Shimamura S, Harada K, Takahashi R, Mochizuki T. 2014. Variation in root development response to flooding among 92 soybean lines during early growth stages. *Plant Production Science*17: 228–236.

Shrivastava A N, PandeyS K and Kobayashi S. 2014. Infleunce of excessive moisture stress on Genetic Parameters in Soybean. *Soybean Research* (Special Issue 2). 33-43.

Soybean Processors Association of India. (SOPA). 2019. https://www.thehindubusinessline.com/economy/agri-business/excess-rains-trim-soyabean-output-by-18-per-cent-to-899-lakh-tonnes-says-sopa/article29657049.ece

Striker G G. 2012. Flooding Stress on Plants: Anatomical, Morphological and Physiological Responses. In: Botany, J.K. Mworia (Ed.). InTech, Rijeka, Croatia, ISBN: 978-953-51-0355-4, pp: 3–28.

VanToai T T, Hoa T T, Hue N T, Nguyen H T, Shannon J G, Rahman M A. 2010. Flooding tolerance of soybean [Glycine max (L.)Merr.]germplasm from Southeast Asia under field and screen-house environments. *The Open Agriculture Journal* 4: 38–46.

Wu C, Zeng A, Chen P, Florez-Palacios L, HummerW, Mokua J, Klepadlo M, Yan L, Ma Q and Cheng Y. 2017a. An effective field screening method for flood tolerance in soybean. *Plant Breeding*136(5):710–719.

Wu C, Zeng A, Chen P, Hummer W, Mokua J, Shannon J G and Nguyen H T. 2017b. Evaluation and development of flood.tolerant soybean cultivars. *Plant Breeding* 136(6):913-23.

Ye H, Song L, Chen H, Valliyodan B, Cheng P, Ali L, Vuong T, Wu C, Orlowski J, Buckley B, Chen P. 2018. A major natural genetic variation associated with root system architecture and plasticity improves waterlogging tolerance and yield in soybean. *Plant, cell & environment* 41:2169-2182. https://doi.org/10.1111/pce.13190

Youn JT, Van K, Lee JE, Kim WH, Yun HT, Kwon YU, Ryu Y H and Lee S H. 2008. Waterlogging effects on nitrogen accumulation and N2 fixation of supernodulating soybean mutants. *Journal of Crop Science and Biotechnology*11:111–118

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Yield Determining Traits, Genetic Variability and Character Association in Exotic Lines of Soybean [*Glycine max* (L.) Merrill]

PIYUSH UPADHYAY, M K SHRIVASTAVA, PAWAN K AMRATE AND R B YADAV*

Department of Plant breeding and Genetics, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur- 482 004, Madhya Pradesh

**E-mail: shrivastava.manoj03@gmail.com*

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ABSTRACT

An experiment was carried out to assess the yield attributing traits in fifty genotypes (48- exotic and 02- Indigenous as checks) of soybean at J.N.K.V.V., Jabalpur during Kharif, 2019. All the genotypes were planted in randomized block design and five random competitive plants were selected from each of three replications to analyze genotypic & phenotypic variability, heritability, genetic advance, correlation and path coefficient analysis for eleven yield associated traits. All the characters had showed significant amount of genetic variability. The highest per cent of phenotypic (30.76) and genotypic (29.84) coefficient of variations were estimated for seed yield per plant. Whereas, highest heritability (98.42 %) and genetic advance as percent of mean (59.62) were recorded for number of seeds per plant and seed yield per plant, respectively. Highly significant positive correlation was obtained between seed yield per plant and number of pods per plant, number of seeds per plant, 100 seed weight and biological yield per plant. Path coefficient analysis was also revealed direct positive effects of biological yield per plant (0.5048) followed by harvest index (0.4097) and number of seeds per plant (0.2427) on seed yield per plant. Hence, all these character could be selected from these exotic collections and can be incorporated through hybridization for divergence and further yield improvement in the development of new improved varieties.

Key words : Correlation and Path analysis, Genetic advance, Genetic variability, Heritability, Soybean

Soybean [*Glycine max* (L.) Merrill] also known as 'golden bean' or "Miracle bean" is a prominent oil seed crop of India. Soybean is one of the richest sources of vegetable protein. The seed of soybean contains 39.4– 44.4 % protein and 14.0–18.7 % edible oil (Sharma *et al*., 2014) and could be considered as an ideal food for the people belongs to poor and developing nations. Soybean ranks first in the world and third after groundnut and rapeseed-mustard in India among the major oilseed crops (Anonymous, 2008). USA, Brazil and Argentina are major soybean producing countries in the world. India also occupies fifth position, as per 2018-19, in area under cultivation (10.83 million ha) and production (10.93 million ton) of soybean (SOPA, 2020). Madhya Pradesh had been a key state as far as soybean cultivation in India, and is still accounting more than fifty percent of total area and production. Hence, MP is called as "Soya State".

Genetic parameters like genotypic (GCV) and phenotypic (PCV) coefficient of variation, heritability and high genetic advance are very useful biometrical tools for measuring the variability as well as facilitating the selection of traits for further crop improvement in soybean (Johnson *et al.*, 1955; Shukla *et al.*, 1998; Ganesamurthy and Seshadri, 2004). The genetic parameters and associated characters for yield were also estimated by many researches and traits like number of pods/plant, number of branches/plant, seed yield per plant, 100-seed weight, biological yield /plant were found to be significant in determining the yield level of genotypes (Muhammad *et al.*, 2007; Bhat and Basavaraja, 2011; Mehra *et al.*, 2020).

The area coverage, production and productivity of soybean in India have always been fluctuating. Most of the soybean varieties in India posses narrow genetic base in present scenario. Therefore, there is urgent need to incorporate the genetic makeup of geographically distance genotypes in high yielding indigenous one for making the cultivation of soybean profitable and sustainable. Hence, an investigation was undertaken with the objective of estimating the extent of genetic variability and association of different yield contributing traits in diverse exotic genotypes of soybean.

MATERIAL AND METHODS

The present experiment was carried out with forty eighty exotic soybean genotypes plus two checks JS 20-98 and JS 20-34 at All India Coordinated Research Project (AICRP) on Soybean, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur during *Kharif*, 2019. The genotypes comprise i.e. EC 393228, EC 456610, EC 113778, EC 241708, EC 468597, EC 114572, EC 107407, EC 333929, EC 350664, EC 393224, HARDER, EC 528675, EC 34117, EC 389153, EC 335721, EC 389748, EC 257352, EC 250619, EC 110778, EC 456615, EC 377883, EC 393222, EC 389170, EC 280129, YOUNG, EC 39220, EC 391181, EC 38828, EC 200149, EC 547464, EC 250608, EC 251358, EC 393228, EC 393981A, EC 23001B, AGS 32, AGS 12, AGS 59, AGS 2, AGS 16, AGS 76, AGS 31, AGS 205, AGS 48, AGS 125, EC 250348, EC 34396 and EC 396055 were collected from AICRP on Soybean, Jabalpur.

Each of these genotypes was sown in three rows of 3m length with 40 cm row to row and 7 cm plant to plant spacing in Randomized Block Design with three replications. All the recommended packages and practices were followed to raise the crop. All the genotypes were critically observed for eleven important characters *viz.*, days to flower initiation, days to maturity, plant height (cm), number of primary branches, number of pods/plant, number of nodes per plant, number of seeds/plant, biological yield/plant (g), 100-seed weight (g), harvest index (%) and seed yield/plant (g). Phenological observations were taken on plot basis. The observations were recorded from five random competitively selected plants. Analysis of variance for different characters was carried out as per the standard procedure of Fisher (1963). Genotypic and phenotypic coefficients of variation were estimated according to Burton and De Vane (1953). Heritability in broad sense and genetic advance were worked out as per Hanson *et al.* (1956) and Johnson *et al.* (1955), respectively. Phenotypic and genotypic correlation and path coefficients analysis were computed based on the method given by Dewey and Lu (1959).

RESULTS AND DISCUSSION

The analysis of variance revealed that the mean squares were significant for yield and its associated traits. The phenotypic and genotypic coefficients of variation were varied from 4.94 to 30.76 and 4.84 to 29.84%

for all the characters that indicated the presence of large amount of variability for different traits (Table 1). The closer values of PCV and GCV also indicated that there were very less effect of environment in the expression of traits. The highest PCV (30.76%) and GCV (29.84%) were recorded for seed yield per plant followed by number of seeds per plant (25.91% and 25.70%), pods per plant (25.81% and 25.32%), biological yield per plant (21.63% and 20.35%), primary branches per plant (21.23% and 20.08%) and harvest index (20.51% and 19.82%). Hence, these traits had ample scope and could be important in varietal improvement programme. Whereas, moderate PCV and GCV recorded for 100 seed weight (16.41% and 15.57%), plant height (14.12% and 13.45%), days to flower initiation (12.06% and 11.95%) and nodes per plant (11.85% and 9.09%). Days to maturity were recorded lowest PCV and GCV (4.94% and 4.84%). Similar finding were also recorded by Aditya *et al.* (2011); Karnwal and Singh (2009); Jain *et al.* (2015); Mehra *et al.* (2020) in respect of high PCV and GCV while evaluating different set of soybean genotypes.

High heritability coupled with high genetic advance as percentage of mean was observed for number of seeds per plant, days to flower initiation, number of pods per plant, seed yield per plant, harvest index, plant height, 100 seed weight and biological yield per plant (table 1). This suggested the preponderance of additive gene action with low environmental influence for the determination of these characters and could be effective in phenotypic selection. Heritability estimates along with genetic advance are usually more helpful in predicting the genetic gain than heritability estimates alone (Johnson *et al.*, 1955). Similar results were also obtained by Badkul *et al.*, (2014) for number of pods per plant, Chandel *et al.* (2017) for biological yield per plant and for pods per plant, Jain *et al.* (2018) for number of pods per plant, Neelima *et al.* (2018) for plant height, number of pods per plant and seed yield per plant and Mehra *et al.*, (2020) pods per plant.

Correlations coefficients revealed degree and direction of association between two or more variables and thereby helps breeder in crop improvement programmes. In this study (table 2), Days to flower initiation was non-significant and significant positive association with yield per plant and days to maturity, respectively. Plant height and days to maturity also had significant positive (0.2586** and 0.1879) correlation with yield per plant. Number of primary branches and nodes were negatively and positively correlated with yield per plant. Number of pods per plant showed highly significant positive association with seed per plant (0.7056), yield per plant (0.4082), harvest index (0.3628), biological yield per plant (0.2216) and highly significant negative association with 100 seed weight (-0.2337). Number of seeds per plant was found to be highly significant positive association with yield per plant (0.8079), biological yield per plant (0.5225) and with harvest index (0.5929). 100 seed weight showed highest significant positive association with yield per plant (0.5808). Biological yield per plant (0.7000) and harvest Index (0.6538) were established highly significant positive association with yield per plant. Significant positive association between seed yield per plant with number of seeds per plant, pods per plant, biological yield per plant and harvest index were also reported by Akram *et al.* (2011) and Badkul *et al.*, (2014).

Path coefficient analysis (table 3) revealed that higher positive direct effect were recorded for biological yield per plant (0.5048), harvest index (0.4097), number of seeds per plant (0.2427) and 100 seed weight

Table 1: Estimates of variability (PCV & GCV), heritability [h2 b (%)] and genetic advance (GA) for different traits in soybean during Kharif 2019

S.No	Character	Mean	Range		PCV (%)	GCV (%)	h^2 b (%)	GA as of mean (5%)
			Min.	Max.				
1	Days to flower initiation	44.12	30.66	59.33	12.06	11.95	98.07	24.38
2	Days to maturity	103.18	94.00	114.33	4.94	4.84	96.00	9.78
3	Plant height(cm)	73.05	52.86	96.91	14.12	13.45	90.69	26.39
4	No. of primary branches	2.92	1.63	3.90	21.23	20.08	32.94	14.40
5	No. of nodes/plant	17.15	14.24	22.66	11.85	9.09	58.81	14.36
6	No. of pods/plant	46.74	25.63	93.19	25.81	25.32	96.25	51.17
7	No. of seeds/plant	89.76	54.73	161.67	25.91	25.70	98.42	52.53
8	100 seed weight(g)	11.17	7.13	14.56	16.41	15.57	90.09	30.45
9	Biological yield/plan(g)t	23.41	13.24	33.21	21.63	20.35	85.90	38.28
10	Harvest index (%)	43.02	15.90	56.98	20.51	19.82	93.38	39.46
11	Seed yield/plant(g)	10.04	3.93	17.22	30.76	29.84	94.08	59.62

Table 2: Estimates of Genotypic (g) and phenotypic (p) correlation coefficients between different traits of soybean

Characters		Days to flower Initiation	Days to maturity	Plant height (cm)	No. of primary branches	No. of nodes/ plant	No. of pods/ plant	No. of seeds/ plant	100 seed weight	Biological yield /plant	Harvest Index (%)	Seed yield/ plant(g)
Days to flower initiation	G	1.0000	0.3937	0.1401	-0.3696	0.4575	0.2503	0.1847	-0.0133	-0.0107	0.1887	0.0945
	p	1.0000	0.4037***	0.1331	-0.2035*	0.3640***	0.2478**	0.1838*	-0.0156	-0.0080	0.1811*	0.0930
Days to maturity	G		1.0000	0.3404	-0.1410	0.1715	0.2345	0.2140	0.1234	0.1836	0.1591	0.1961
	p			0.3255***	-0.0699	0.1466	0.2305**	0.2097**	0.1119	0.1672*	0.1507	0.1879*
Plant height(cm)	G			1.0000	0.0663	-0.1104	0.1538	0.1471	0.2596	0.2486	0.1603	0.2747
	p				0.0984	-0.0698	0.1474	0.1425	0.2457***	0.2161**	0.1548	0.2586**
No. of primary branches	G				1.0000	0.0693	-0.1072	-0.1458	0.2660	-0.1448	0.1743	-0.0002
	p					0.0373	-0.0705	-0.0891	0.1662*	-0.1009	0.0181	-0.0019
No. of nodes/plant	G					1.0000	-0.0814	0.0499	0.2067	-0.1709	0.3523	0.1130
	p						0.0212	0.0864	0.2288**	0.0121	0.2489**	0.1656*
No. of pods/plant	G						1.0000	0.7035	-0.2808	0.1858	0.3926	0.3941
	p							0.7056***	-0.2337**	0.2216**	0.3628***	0.4082***
No. of seeds/plant	G							1.0000	0.0033	0.5261	0.6257	0.8132
	p								0.0255	0.5225**	0.5949***	0.8079***
100 seed weight (g)	G								1.0000	0.3825	0.3700	0.5597
	p									0.4085	0.3608***	0.5808***
Biological yield/plan(g)t	G									1.0000	-0.0243	0.7000
	p										-0.0652	0.7000***
Harvest index (%)	G										1.0000	0.6871
	p											0.6538***
Seed yield/plant(g)	G											1.0000
	p											1.0000

Table 3: Estimates of Path coefficient (direct and indirect effect) of seed yield per plant with its component traits in soybean Genotypic (g) and phenotypic (p) correlation coefficients between different traits of soybean

Characters	Days to flower initiation	Days to maturity	Plant height	No of primary branches/plant	No of nodes/plant	No of pods/plant	No. of seeds/plant	100 seed weight.	Bio yield /plant	Harvest index
Days to flower initiation	**-0.0390**	-0.0153	-0.0055	0.0144	-0.0178	-0.0098	-0.0072	0.0005	0.0004	-0.0073
Days to maturity	-0.0190	**-0.0482**	-0.0164	0.0068	-0.0083	-0.0113	-0.0103	-0.0060	-0.0089	-0.0077
Plant height	0.0009	0.0021	**0.0062**	0.0004	-0.0007	0.0010	0.0009	0.0016	0.0015	0.0010
No. of primary branches/plant	0.0185	0.0071	-0.0033	**-0.0502**	-0.0035	0.0054	0.0073	-0.0134	0.0075	-0.0087
No. of nodes/plant	0.0015	0.0006	-0.0004	0.0002	**0.0032**	-0.0003	0.0002	0.0007	-0.0006	0.0011
No. of pods/ plant	0.0022	0.0021	0.0014	-0.0010	-0.0007	**0.0089**	0.0063	-0.0025	0.0017	0.0035
No. of seeds/plant	0.0448	0.0520	0.0357	-0.0354	0.0121	0.1708	**0.2427**	0.0008	0.1277	0.1519
100 seed weight	-0.0027	0.0251	0.0528	0.0541	0.0420	-0.0571	0.0007	**0.2033**	0.0778	0.0752
Biological yield/plant	-0.0054	0.0927	0.1255	-0.0751	-0.0863	0.0938	0.2656	0.1931	**0.5048**	-0.0123
Harvest index	0.0926	0.0781	0.0786	0.0855	0.1729	0.1927	0.3071	0.1816	-0.0119	**0.4907**
Seed yield/ plant	0.0945	0.1961	0.2747	-0.0002	0.1130	0.3941	0.8132	0.5597	0.7000	0.6874

seeds per plant (0.2427) and 100 seed weight (0.2033). Whereas, negligible amount of positive direct effect on seed yield per plant were found for pods per plant (0.0089), plant height (0.0062) and nodes per plant (0.0032). Negligible amount of negative direct effect on seed yield per plant were found to be with number of primary branches per plant (-0.0502), days to maturity (-0.0482) and days to flower initiation (-0.0390). Higher positive direct effect were also reported by Mishra *et al.*, (2015) for number of seeds per plant, 100 seed weight and number of pods per plant, Chandel *et al.* (2017) for biological yield per plant, harvest index, branches per plant, Dessia and Gemechu (2018) for pods per plant, biological yield per plant and 100 seed weight.

CONCLUSION

The study concluded that substantial amount of genetic variability was present for yield and its component traits in most of the investigated exotic lines of soybean. Therefore, these genotypes governing with important traits should be considered for selecting superior and desirable plants for further yield improvement in existing soybean varieties. These lines may be utilized as donor for incorporation of desired genes in existing as well as new genotypes of soybean through hybrization.

REFERENCES

Aditya J P, Bhartiya0 P and Bhartiya A. 2011. Genetic variability, heritability and character association for yield and component characters in soybean [*G. max* (L.) Merrill]. *Journal of Central European Agriculture* 12: 27-34.

Akram R M, Fares W M, Fateh H S A and Rizk A M A. 2011. Genetic variability, correlation and path analysis in soybean. *Egyptian Journal of Plant Breeding* 15(1): 89 – 102.

Anonymous. 2018. Directors Report, Indian Institute of Soybean Research, Indore, pp. 327.

Badkul A, Shrivastava A N, Bisen R and Mishra S. 2014. Study of principal components analyses for yield contributing traits in fixed advanced generations of soybean [*Glycine max* (L.) Merrill]. *Soybean Research* 12 (Spcl issue 2): 44-50

Bhat S and Basavaraja G T. 2011. Genetic variability and correlation studies in segregating generations of soybean [*Glycine max* (L.) Merrill]. *Crop Improvement* 38: 77-87.

Burton, G.W. and De Vane E.H. (1953). Estimating heritability in tall fescue (Festuca arundinacea) from replicated clonal material. *Agronomy Journal* 45: 478-481.

Chandel K K, Patel N B, Sharma L K and Gali S. 2017. Genetic variability, correlation coefficient and path analysis for yield and yield attributing characters in soybean (*Glycine max* L. Merrill). *Green Farming* 8(3): 547-551

Desissa D H, Gemechu H L. 2018. Correlation and Path analysis studies among yield and yield related traits in Soybean (*Glycine max* (L.) Merrill) varieties. *International Journal of Plant Breeding and Crop Science* 5(1): 352-360.

Dewey J R and Lu K H. 1959. A correlation and path co-efficient analysis of components of crested wheat seed production. Agronomy Journal 51: 515-518.

Fisher R A and Yates F 1963. Statistical tables for biological, agricultural and medical research. Oliver and Boyd, London.

Ganesamurthy K. and Seshadri P. 2004. Genetic variability, character association and path coefficient analysis in soybean. Madras *Agriculture Journal* 91: 61-65.

Hanson W D, Robinson H F and Comstock R E. 1956. Biometrical studies of yield segregating population Korean lespandeza. *Agronomy Journal* 48:268-272.

Jain R K, Joshi A, Chaudhary H R, Dashora A and Khatik C L 2018. Study on genetic variability, heritability and genetic advance in Soybean [*Glycine max* (L.) Merrill]. *Legume Research* 41(4):532-536.

Jain S, Srivastava S C, Singh S K, Indapurkar Y M and Singh B K. 2015. Studies on genetic variability, character association and path analysis for yield and its contributing traits in soybean [*Glycine max* (L.) Merrill]. *Legume Research* 38 (2): 182-184.

Johnson H W, Robinson H F and Comstock R E (1955). Estimate of genetic and environmental variability in soybean. *Agronomy Journal* 47: 314-318.

Karnwal M K and Singh K. 2009. Studies on genetic variability, character association and path coefficient for seed yield and its contributing traits in soybean [*Glycine max* (L.) Merrill]. *Legume Research* 32: 70-73.

Mehra Shrishti, Shrivastava M K, Amrate Pawan K and Yadav R B (2020) Studies on variability, correlation coefficient and path analysis for yield associated traits in soybean [*Glycine max* (L.) Merrill]. *Journal of Oilseeds Research* 37(1): 56-59.

Mishra S, Shrivastava A N, Jha A, Tantaway S 2015. Correlation and Path Coefficient Analysis of Advance Breeding Lines of Soybean. *Annals of Plant and Soil Research* 17(Special Issue): 34-37.

Muhammad F A M Ashraf M, Qureshi A S and Ghafoor A. 2007. Asesement of genetic variability, correlation and path analyes for yield and its components in soybean. *Pakistan Journal of Botany* 39 (2): 405-413.

Neelima G, Mehtre S P and Narkhede G W. 2018. Genetic Variability, Heritability and Genetic Advance in Soybean. *International Journal of Pure Applied Bioscience* 6 (2): 1011-1017.

Sharma S, Kaur M, Goyal R, and Gill B S. 2014. Physical characteristics and nutritional composition of some new soybean (*Glycine max* (L.) Merrill) genotypes, *Journal of Food Science and Technology* 51 (3): 551-557.

Shukla S, Singh K and Pushpendra. 1998. Correlation and path coefficient analysis of yield and its components in soybean (*Glycine max* (L.) Merrill). *Soybean Genetics Newsletter* 25: 67-70.

SOPA. 2020. The Soybean Processors Association of India (SOPA) report http://www.sopa.org/statistics/world-soybean-production/

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MACS 1407: A High Yielding Soybean Variety for North-Eastern States

S A JAYBHAY, PHILIPS VARGHESE, S P TAWARE, B D IDHOL, B N WAGHMARE, D H SALUNKHE AND J S SARODE*

MACS Agharkar Research Institute, G.G. Agarkar Road, Pune (M.S.): 411 004

**E-mail: sajaybhay@aripune.org*

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ABSTRACT

Soybean [Glycine max (L.) Merrill], popularly known as golden bean, is the premier oilseed crop of India and the World. Although, the crop has shown unparallel growth in area and production in past five decades, the productivity still hovers around 1 t per ha. Soybean crop yield is mainly influenced by climatic conditions throughout the growing season, especially under rainfed conditions. This yield gap arising can be reduced through better agronomic management, disease and pest management, use of seeds of improved and high yielding recommended varieties etc. Among this easy availability of seeds of high yielding soybean varieties suitable to agro-climatic conditions for sowing is one of the important obstacles in getting the better soybean yield. Keeping in mind the development of high yielding soybean varieties suitable for agro-climatic conditions of North-Eastern states efforts has been made at MACS Agharkar Research Institute, Pune (M.S.).

***Key words*:** Good germinability, high yielding, MACS 1407, non-pod shattering, Soybean variety

The Central Sub-Committee on Crop Standards, Notification and Release of Varieties of Agricultural Crops (CVRC) vide notification No. S.O. 500 (E) dated 29.01.2021 has notified new soybean variety MACS 1407 for cultivation in the North- Eastern Zone of India, comprising the states of Jharkhand, Chhattisgarh, West Bengal, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Tripura and Sikkim. It is suitable for rainfed condition with medium to high rainfall condition and medium to heavy soils of North-Eastern zone. MACS 1407 (IC No. 618719) developed through the Pedigree method of breeding from the cross of MAUS 144 / MACS 450. Where, MAUS 144 was the female parent, is a germplasm line maintained at V.N.M.K.V. Parbhani (M.S.) from cross of JS 80-21 / IC 13050-1 while, MACS 450 (S.O. No. 425 (E)) was the male parent, is a variety developed at MACS Agharkar Research Institute, Pune (M.S.) from the cross of Bragg / MACS 111.

MACS 1407 has showed high and stable yield in three years of all India coordinated trials. MACS 1407 gave superior yield (2101 kg/ha) over the highest yielding check variety RKS 18 (1801 kg/ha), JS 97-52 (1786 kg/ha) and national check variety Bragg (1589 kg/ha); and the increase was by 17%, 18% and 32%, respectively. It ranked first in yield in combined three years data of the zone and was superior in yield over qualifying varieties JS 20-71 by 4%, RKS 113 by 5%, NRC 93 and KDS 705 by 7% each. Morphologically, MACS 1407 has determinate type of growth habit, absence of anthocyanin pigment on hypocotyl, thick stem, non-lodging plant type with 4-5 branches, medium height (58 cm average) and normal leaf surface with green colour, it has white colored flowers and its initiation from 37th (average) day after sowing and takes an average 43 days for 50% flowering after sowing, pubescence is present on pod, each plant bear 43 (average) pods, brown pod and stem color at maturity, it is resistant to pod shattering habit, it has round and medium size seed with yellow colour and brown colored hilum, it has average three seeded pods with 100 seed weight of average 10.27 g. The seed of MACS 1407 has better seed germinability. It fall under mid late type of maturity group and takes an average 104 days for maturity after sowing. It is stable high yielding and having high yield potential of 3900 kg per hectare under optimum conditions.

The variety has shown the field resistance to Girdle beetle, Leaf miner, Leaf roller, Stem fly, Defoliators, Aphids and White fly in the zone. Seeds of the MACS 1407 contain 19.81% Oil and 41% Protein.

In Agronomic studies, MACS 1407 showed to have wide range of sowing time adaptability and is suited for sowing from 20th June to 5th July with mean yield of 3279 kg/ha. Whereas, at 0.45 million per hectare plant population it gave significantly higher yield (2883 kg/ha) over checks RKS 18, JS 335 and Bragg by 25%, 28% and 42%, respectively. Due to presence of thick stem, lodging character and higher pod insertion (7cm) from ground MACS 1407 is suitable for mechanical harvesting. Hence, with the above mentioned yield and quality characters, morphological features, agronomic suitability and insect-pest resistance, this new soybean variety MACS 1407 would be a commercially viable option to be adopted by the famers of North- Eastern Zone of India.

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Dr. Ramgopal Devadas, Principal Scientist (Plant Breeding), ICAR-National Research Center for Orchids

Dr. A.N. Sharma, Ex. Principal Scientist (Entomology), ICAR-Indian Institute of soybean Research, Indore 452001, Madhya Pradesh

Dr. M. Ansari, Ex. Principal Scientist (Plant Pathology), ICAR-Indian Institute of soybean Research, Indore 452001, Madhya Pradesh

Dr. Rahul Phukey, Scientist, ICAR-Indian Agricultural Research Institute- Regional Station, Indore

Dr. M. Shivkumar, Senior Scientist (Genetics and Plant Breeding), ICAR-Indian Institute of soybean Research, Indore 452001, Madhya Pradesh

Dr. Rajesh Vangala, Scientist (Genetics and Plant Breeding), ICAR-Indian Institute of soybean Research, Indore 452001, Madhya Pradesh

Ms. Namrata Giri, Scientist (Food technology), ICAR-National Research Center of Pomegranate, Solapur, Maharashtra 413255

Dr. S. D. Billore, Principal Scientist (Agronomy), ICAR-Indian Institute of soybean Research, Indore 452001, Madhya Pradesh

Dr. R. Ramteke, Principal Scientist (Genetics and Plant Breeding), ICAR-Indian Institute of soybean Research, Indore 452001, Madhya Pradesh

Dr. Laxman Singh Rajput, Scientist (Plant Pathology), ICAR-Indian Institute of soybean Research, Indore 452001, Madhya Pradesh

Dr. Rajendar Reddy Musku, Assistant Professor (Plant Breeding), Professor Jayashankar Telangana State Agricultural University, Hyderabad, India

Dr. Subhash Chandra, Scientist, (Plant Breeding) ICAR-Indian Institute of soybean Research, Indore 452001, Madhya Pradesh

Dr. V. Nataraj, Scientist (Genetics and Plant Breeding), ICAR-Indian Institute of soybean Research, Indore 452001, Madhya Pradesh

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Abstract: This should not exceed 150 words and should indicate main findings of the paper, without presenting experimental details.

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Results and Discussion: Data should be presented in text, tables or figures. Repetition of data in two or three forms should be avoided. All quantitative data should be in standard/metric units. Each table, figure or illustration must have a self-contained legend. Use prefixes to avoid citing units as decimals or as large numbers, thus, 14 mg, not 0.014 g or 14000 µg. The following abbreviations should be used: yr, wk, h, min, sec., RH, g, ml, g/l, temp., kg/ha, a.i., 2:1(v/v), 1:2 (w/w), 0:20: 10 (N:P:K), mm, cm, nm, cv. (cvs., for plural), % etc.

References: References should be cited by authors and year: Ansari (2000) or Ansari and Sharma (2000) in the text. References should be arranged in alphabetical order and listed at the end of the paper as follows:

Ansari M M and Sharma A N. 2000. Compatibility of Bacillus thuringiensis with chemical insecticides used for insect control in soybean (*Glycine max*). *Indian Journal of Agricultural Sciences* **70:** 48-9. (**Journal**)

Joshi O P, Billore S D, Ramesh A and Bhardwaj Ch . 2002. Soybean-A remunerative crop for rainfed forming. In: Agro technology for dry land forming, pp 543-68. Dhopte AM (Eds.). Scientific Publishers (India), Jodhpur. (**Book chapter**)

Ansari M M and Gupta G K. 1999. Epidemiological studies of foliar diseases of soybean in Malwa plateau of India. Proceedings, World Soybean Research Conference VI, Aug 4-7, 1999, Chicago, Illinois, USA, 611p. (**Symposium/ Conf./Workshop**)

Pansae V G and Sukhatme P V. 1978. *Statistical Methods for Agricultural Workers*. Indian Council of Agricultural Research, New Delhi. pp.186. (**Book**)

Table: Each table should be typed on separate page and numbered sequentially. Tables should have descriptive heading. Authors are advised to avoid large table with complex columns. Data are restricted to only one or two decimal figures only. Transformed values should be included if these are discussed in the text.

Illustrations: Number all illustrations consecutively in the text. Line drawing should be made in undiluted black ink on smooth white card or tracing paper. Original and two Photostat copies should be drawn approximately twice the size of reproduction. Original should not be labeled and should also not be numbered. Line diagrams of plants, fungi etc. should indicate the scale.

Photographs: Photographs should be on glossy paper and have good contrast. Trim unnecessary areas. Three copies of the photographs should be provided. On the back of the photographs write names of authors, figures numbers and indicate top of the photographs with an arrow using a soft pencil. Show magnification with a bar scale. **Coloured photographs can be printed on payment of full printing cost by the authors**. Legends for figures should be typed separately and numbered consequently.

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They should not exceed more than 1300 words (total 5 typed pages, which deal with (i) research results that are complete but do not warrant comprehensive treatment, (ii) description of new material or improved techniques or equipment, with supporting data and (iii) a part of thesis or study. Such notes require no heading of sections. It should include key words. Figures and tables should be kept to a minimum.

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Authors with in-depth knowledge of the subject are welcome to submit review articles. It is expected that such articles should consist of a critical synthesis of work done in a field of research both in India and/or abroad, and should not merely be a compilation.

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