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EVALUATION OF F_3 PROGENIES FOR YIELD CONTRIBUTING AND DROUGHT TOLERANCE RELATED TRAITS IN SOYBEAN

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ABSTRACT

The present investigation of the segregants derived from JS 2098 (Early maturity and High adaptable) and NRC 142 (Quality trait) were field evaluated under drought tolerance. Total of thirty F_3 lines were evaluated for five drought tolerances associated physiological and eight yield contributing characters under restricted irrigation conditions during summer season. As per the analysis the thirty segregating lines found to be significantly variable for all 13 characters. Among thirty lines, four were found to be promising for yield contributing traits under drought stress. The mean performance analysis shows slightly significant difference among parents and segregating lines. The analysis of mean values of all the lines for drought tolerance related and yield contributing traits gives out some better promising lines which can be utilized properly in future breeding programme or in research lane to developed enhanced soybean genotypes. The traits like primary branches per plant, wilting score, cluster per plant and seed yield per plant represent high heritability with high genetic advance as percent of the mean. The traits like days to 50% flowering, primary branches, cluster per plant, pods per plant, chlorophyll content and seed index shows positive and significant correlation with seed yield. Only the chlorophyll content shows high positive direct effect on seed yield; however, the primary branches, cluster per plant, pods per plant and seed index showed highly significant indirect effect on the seed yield.

Key words : Hybrid, Yield, Advancement, Drought tolerance, Correlation, Breeding.

Introduction

Originating in North-Eastern China, soybean [*Glycine max* (L.) Merrill], 2n=40, is a member of the leguminoceae family, dubbed the "King of American Agriculture" (Kuehn, 1972) and a global miracle crop (Leppik, 1971). Commercial soybeans typically include 20% outstanding oil and 40% premium protein. The fact that soybeans are widely used as a base for margarine and other consumer goods, as well as a source of cooking oil, contributes significantly to the demand for them throughout the world, including in India. Due to its remarkable adaptability, this plant also acts as a natural soil fertilizer by fixing atmospheric nitrogen.

The total soybean production of world is 396.725 MT during 2022-23, with India holding the fifth position and contributing to about 3% of total world production (FAS, 2023). In India, 120.90 lakh hectares were planted to soybeans in 2022–2023 compared to 120.86 lakh hectares in 2021–2022. Madhya Pradesh topped the list of states with 50.18 lakh ha, followed by Maharashtra (49.10 lakh ha. These main soybean producing states were found to be in the zone of rainfed situation. The Government of India's second advance projections for 2022–2023 indicate that soybean production will amount to 139.75 lakh tonnes, up from 129.87 lakh tonnes in 2021–2022 (Soybean Outlook March, 2023).

Additionally, Wilson *et al*. (2004) state that it is a good source of vitamins, minerals, folic acid and iso-flavones, which are thought to inhibit the development of some disorders. Out of all the crops that are grown

worldwide, this one has the highest protein content and the biggest gross output of vegetable oil. The development of emulsified and soluble soybean goods, including meat, milk, flour, quick and fast-frozen meals, candies, and beverages, has also been aided by the alteration in the structure of processed soybean products. Extracting high-value added soybean biochemical has been realized in commercial production; these products are sold as functional health foods (Singh, 2010).

India's soybean farming is too reliant on the unpredictable and uneven seasonal monsoon rainfall, which leads to the termination of growth from germination to seed filling (Joshi and Bhatia, 2003). Drought is known to impact all phases of plant growth and development, including seed filling, development, and quality, from germination to blooming (Siddique *et al*., 2001; Manavalan *et al*., 2009). This has an impact on soybean output. Drought at the terminal growth stage, particularly during seed filling to seed maturity stage, would cause severe yield loss that could not be recovered by any means. However, drought stress that occurs during the vegetative stage can be compensated for with rains during the later part of crop growth (Sionit and Kramer, 1977; Hirasawa *et al*., 1994; Saitoh *et al*., 1999). Drought frequently results in 40% reductions in soybean output (Specht *et al*., 1999) and these losses are amplified when moisture stress strikes during both the vegetative and reproductive stages of the plant. Soybean leaves that are stressed by drought during the vegetative stage start to curl or drop, which reduces plant growth and results in significant leaf loss and production decline. During the reproductive phases, soybeans are particularly vulnerable to the effects of drought. Early reproductive stages of soybeans under drought stress exhibit higher flower and pod abortion; later reproductive stages, sustained drought causes tiny pods with more shriveled, smaller, and fewer seeds than usual (Boyer, 1983).

The first obvious sign of soil water deficiencies brought on by drought is canopy wilting. The slow-wilting soybeans not only wilted much more slowly under conditions of water deficit but also maintained a lower amount of solute potential, with higher-pressure potential and relative water content (Shin *et al*., 2015). Therefore, one of the main goals for plant breeders is to generate crops with increased drought resistance features, although this is a difficult task.

Soybean contains the anti-nutritional factor Kunitz trypsin inhibitor (*KTI*) which reduces the digestibility when consumed by humans and soybean also having lipoxygenase-2 (Lox2) which gives beany smells to the soybean even if slight damage during storage. Hence soybean varieties genetically free from Kunitz trypsin inhibitor (*KTI*) (Roychaudhuri *et al*., 2003) and lipoxygenase-2 (Lox2) (Shivkumar *et al*., 2014) are ideal to boost human consumption because the latter is the main cause of off-flavor and the former is an anti-nutritional component that impairs protein digestion.

The aim of manuscript is to develop soybean genotypes which fit to moisture deficit or rainfed conditions with quality trait to overcome the upcoming climate change challenges and to fulfill the food demand and protein consumption through the soybean and soy product.

Materials and Methods

The present investigation was conducted at Post Graduate Institute Farm, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar, Maharashtra during four consecutive seasons namely *Kharif*-2021, summer-2022, *Kharif*-2022 and Summer-2023. The experimental material consisted of two parental genotypes, sixty F_2 lines and thirty F_3 lines derived by crossing between JS 2098 and NRC 142 parents. JS 2098 having ability to tolerate abiotic stresses with broader adoptability and early maturing habit, while NRC 14 is free from *kti* and *lox2* which are harmful for human consumption and storability of seed. The parental material provided by the Agriculture Research Station, Kasbe Digraj, Sangli, Maharashtra (Table 1).

The experiment was laid out under Randomized Block Design (RBD) with two replications. Crossings were affected in first season *kharif*-2021 between two parents by planting each parent in 5 m row separately in two replications by dibbling. In summer-2022 the obtained F_1 seed were planted in 10 m row it gives F_2 seed by selfing. The obtained F_2 seed were line sown in next season *kharif*-2022 which gives segregating population and F_3

Table 1 : Experimental material.

S. no.	Parent/Lines	Characteristics
1	JS 2098	Early maturity, tolerant to abiotic stresses
2	NRC 142	Null or free from *kti* and *lox2*
Material generated from cross		
3.	F_1 (18 = 13 True hybrid)	Advanced
4.	F_2 (60)	Advanced
5.	F_3 (30)	Field evaluated during this investigation

seed were harvested.

The harvested F_3 seed were line sown in summer-2023 to carry out evaluation of segregating population. The trial was conducted under restricted irrigation conditions during summer season. The evaluation for drought associated character as well as some yield contributing character was laid out. The observations were recorded on five randomly selected plants in each replication for all the thirteen characters with proper scale, tools and instruments at precise stage of crop (Table 2). Among thirty characters eight are the yield contributing *viz.*, days to 50% flowering, Days to physiological maturity, Plant height (cm), Primary branches/plant, Cluster/plant, Pods/plant, Seed Index (gm), Seed yield/ plant (gm), while five are the drought tolerance associated characters *viz.*, Canopy Temperature Depression (CTD) (ºC), Chlorophyll content (mg/gm), Wilting score, Relative water Content (%).

The canopy temperature was measures using CT Gun (Canopy Temperature Gun) or Infrared Thermometer then by subtracting canopy temperature from air temperature the CTD was estimated. The chlorophyll content measured by using SPAD Meter. The canopy temperature and chlorophyll content measured during 11.00 to 15.00 hr in day time and ensured that there was bright sunshine during recording observation. Wilting score (range 1 to 5) were scored during 12.00 to 15.00 hr during day time, with the score 1 indicating no wilting, 2 indicates few top leaves showed wilting, 3 indicates half of the leaves get wilted, 4 indicates the severe wilting that is 75% leaves get wilted out and 5 indicates the severe wilting more than 90% (Heng *et al*., 2020). The RWC is measured by taking Fresh weight (FW), Saturated weight (SW) and Dry weight (DW) of leaves in gram and by using formula given below the RWC in percent was estimated. All observations of drought were recorded at pod filling stage. All recorded observation is analyze using statistical techniques *viz.*, ANOVA, Coefficient of variation, heritability, Genetic advance, correlation and Path analysis as per Panse and Sukhatme (1955).

All necessary cultural practices and fertilizer dose was incorporated and applied at the time of sowing as well as top dress during irrigation.

$$\text{Relative Water Content (RWC) \%} = \frac{\text{FW} - \text{DW}}{\text{SW} - \text{DW}} \times 100$$

Results and Discussion

At first season *Kharif*-2021 the crosses between two parents (JS 2098 × NRC 142) were affected. Those crosses gave rise to the total eighteen (18) F_1 hybrids. These F_1 were checked for presence of the phenotypic characters inherited from male parent during summer-2022, out of eighteen the thirteen (13) were found to be true. These F_1s were confirmed on the basis of guidelines for DUS characteristics of soybean provided by PPV and FR, 2009. The F_2 seed obtained from true hybrids were planted in next season *Kharif*-2022 and among this sixty (60) promising F_2 segregating lines were selected and their seed harvested separately as F_3 lines. The thirty (30) promising segregating F_3 lines planted in summer-2023. The observations recorded were analyzed statistically and following results and conclusion was depicted.

Analysis of variance depicted in Table 2 were revealed that the all the lines showed significant variation for thirteen characters studied. The error mean sum of square also resulted as lower which is good estimate.

The mean performance of every F_3 line was estimated simultaneously along with parents as represented in Table 3. The mean performance analysis shows slightly significant difference among parents and segregating lines. The mean value for days to 50% flowering was 33.23 days, therefore Line 5 presents the 31.50 days for flowering which is confirmed as earliest line to be flower. The Line 6 and 7 calculated as 34.50 days to flower, so this are classified as late flowering lines. The mean days to physiological maturity was found to be 94.42 days. The Line 2 depicted the 93.75 days to maturity which was earliest, while the Line 6 and 19 matured in 94.80 days. The estimates of plant height revealed the 60.94 cm as mean height. The Line 12 and 30 represented significantly higher height 70.12 cm, 67.35 respectively than the mean hence which termed to be tall lines, in contrast the Line 26 recorded significantly lower height 52.90 cm which referred to be short lines. The mean for primary branches per plant was 6.10, hence the Line 25 having significantly higher branches *i.e.*; 7.90, so these line regarded to be good branching capacity line. In contrast Line 17 shows lowest branches 4.50. But the Line 7, 13, 23, 28, 29 and 30 having primary branches 7.65, 7.15, 6.90, 6.70, 7.30 and 6.90, respectively which are also higher than mean so these also promising for branching. Cluster in terms of pod is the group of pods that are attached to single pedicel. The mean value for the cluster per plant was 9.91 among all lines. The Line 23 and 4 showed highest clusters *i.e.*; 12.30 and 12.15 respectively, while Line 19 gave 7.50 clusters which were significantly lower. Also most of all other lines show lesser cluster than the mean. The pods per plant amongst the F_3s studied was found to be 22.04 pods as a mean of all lines , among these lines the Line 2 and 28 having highest significant pods 24.35 pods each and the Line 29

Table 2 : Analysis of variance for thirteen characters of thirty lines and two parent genotypes.

S. no.	Characters	Mean Sum of Square		
		Replication	Genotypes	Error
	DF	*1*	*31*	*31*
1	Days to 50 % flowering	1.13*	2.35**	0.48
2	Days to physiological maturity	0.03*	0.40**	0.15
3	Plant height (cm)	6.06*	18.96**	3.75
4	Primary branches/plant	0.12*	1.38**	0.04
5	Cluster/plant	0.90*	3.29**	0.76
6	Pods/plant	2.38*	4.54**	1.06
7	Canopy Temperature Depression (CTD) (ºC)	0.01*	0.42**	0.13
8	Chlorophyll content (mg/gm)	1.11*	2.21**	0.46
9	Wilting score	0.06*	0.41**	0.22
10	Relative water Content (%)	0.20*	18.87**	0.43
11	Leaf area (mm^2)	3829.75*	173058.01*	35521.81
12	Seed Index (gm)	2.21*	1.19**	0.43
13	Seed yield/plant (gm)	3.61*	8.77**	0.95

*, ** Significant at 5% and 1% levels, respectively.

having 24.15 pods was also higher. While the Line 1 have 19.15 pods which was lower than all other ones.

The seed index refers to weight of 100 seed estimated as good parameters of yield improvement. The mean number for the seed index were estimated as 11.29, the Line 28 gives out seed index 13.60 which more than mean so it is good yield contributor line and also Line 11 and 15 having on par seed index 12.30 than mean. In disparity the Line 4 having lowest seed index 9.75 which was poor contributor of yield. Directly in terms of seed yield the mean performance as a average is 20.55gm. Out of all lines the Line 29 having significantly higher yield 23.75gm than mean and Line 1 significantly poor 14.80gm in terms of seed yield. The Line 2, 28 and 30 shows 23.10 gm, 23.30 gm and 22.50 gm seed yield respectively which were also greater than mean yield.

Therefore, from the mean performance analysis the Line 2, Line 28, Line 29 and Line 30 were found to be promising line in yield contributing character, so these lines need to be utilized in further advancement and in breeding program to improve the yield of soybean crop.

The analysis of drought tolerant associated character is discussed as follows. Canopy Temperature Depression (CTD) is the one of the parameters that will useful to study the moisture stress. The mean value for CTD in 30 F_3 lines evaluated was 2.44ºC, the Line 16 gives out the 1.46ºC CTD values, it means the lines less likely be able to thrive under moisture stress. In comparison with that the Line 1 with 3.45 ºC CTD, which is higher than means hence such line are good to thrive under same stress. The chlorophyll content in the 30 F_3 lines evaluated had the mean value of 33.85 mg/gm. The Line 5 and Line 12 shows highest significant chlorophyll content 35.96 mg/gm and 35.28 mg/gm than other line while Line 4 having 31.90 mg/gm content which is significantly lower. Also some other lines including Line 13, 15, 21, 25, 26 and 29 also on par than the mean.

Wilting score (1 to 5) for each line indicate how much plant gets wilted as passing the time. Lower wilting score of 1 indicates no wilting, while 5 score indicates the severe wilting more than 90% (Heng *et al*., 2020). The mean score for wilting of canopy in the F_3 lines evaluated was 1.54. The Line 8 having lowest score 1.05 which represent the lowering time for wilting due to stress. Also some other lines 2, 4, 7, 9, 24 and 30 having score lower than mean and critical difference subtraction value so this all are line are good thriving capacity under rain fed condition or low moisture condition. The Line 10 shows 2.90 wilting score which was not fit under such stress condition. The graphical representation of wilting in individual F_3 line is as depicted in Fig. 1. Comparable findings for wilting score also reported by Rober *et al*. (1984), Andy King *et al*. (2009), Karl and Barend (2020) and Heng *et al*. (2020).

Relative water content (RWC) is the water which is maintained by the plant in its leaf cell. High RWC is a good indicator to the plant to sustain in moisture deficit condition. The analysis of 32 lines shows 82.09% mean RWC, among that Line 2 having 74.96% RWC, which was significantly lower than mean hence this line not fit the criteria. The Line 8 shows 88.61% RWC, which is higher than mean value means it fit the criteria. Similarly, Lines 5, 6, 7, 9, 10 and 18 having RWC more than mean so they also healthier in competition to fulfill the criteria. The leaf area estimated to be mean value 5305.72 mm^2, the Line 12 having highest 6032.85 mm^2 leaf area and Line 2 having lowest 4520.22 mm^2 leaf area. Higher the leaf area under abiotic stress, is better for the plant's photosynthetic and transpiration activity.

The analysis of mean values of all the lines for drought

Table 3 : Mean performance of thirteen characters of thirty lines and two parent genotypes for yield contributing characters and drought tolerance related character in soybean.

S. no.	Days to 50 % flowering	Days to physiolog-ical maturity	Plant height (cm)	Primary branches/ plant	Cluster/ plant	Pods/ plant	Canopy temperature Depression (ºC)	Chlorophyll content (mg/gm)	Wilting score	Relative water content (%)	Leaf area (mm^2)	Seed Index (gm)	Seed yield / plant (gm)
Line -1	32.50	94.20	63.20	5.30	8.65	**19.15**	**3.54**	32.82	1.50	75.83	5086.98	10.00	**14.80**
Line -2	32.00	**93.75**	58.70	6.50	11.20	**24.35**	3.08	32.43	1.10	**74.96**	**4520.22**	11.20	23.10
Line -3	33.50	94.00	60.60	6.00	10.80	22.95	3.48	33.73	1.45	77.85	4959.44	11.25	21.55
Line -4	33.50	94.60	59.65	6.00	12.15	21.20	3.15	**31.90**	1.15	81.92	4964.31	**9.75**	18.70
Line -5	**31.50**	94.10	61.40	5.65	9.95	21.80	2.44	**35.96**	1.40	84.10	5402.64	11.70	21.25
Line -6	**34.50**	**94.80**	57.55	6.10	10.20	22.85	2.97	32.80	1.10	84.96	5485.82	10.60	19.30
Line -7	**34.50**	94.40	64.15	7.65	11.20	22.15	2.72	34.63	1.25	87.89	5502.74	11.55	21.30
Line -8	34.00	94.50	60.25	5.55	8.30	19.75	2.22	33.51	**1.05**	**88.61**	5432.11	11.40	16.90
Line -9	34.00	94.10	62.30	6.30	10.30	22.45	2.71	33.01	1.25	87.15	4991.54	11.80	19.90
Line -10	32.50	94.40	60.20	6.35	10.05	22.15	2.14	32.05	**2.90**	88.00	5173.35	11.00	19.50
Line -11	33.50	93.90	60.85	5.60	10.10	21.80	2.38	34.69	2.30	82.35	5585.77	12.30	18.30
Line -12	32.50	94.60	**70.60**	6.05	11.10	23.75	2.28	35.28	2.10	83.13	**6032.85**	10.80	22.00
Line -13	32.50	94.60	59.50	7.15	9.10	20.55	1.93	34.89	1.50	82.16	5839.12	11.60	18.50
Line -14	32.50	94.30	56.30	5.05	8.05	21.05	2.38	33.64	2.25	79.85	5257.38	11.10	19.80
Line -15	32.50	94.20	58.90	5.00	10.00	20.77	2.09	34.36	2.35	81.61	5397.71	12.30	20.00
Line -16	32.50	94.45	58.70	6.45	10.75	20.75	**1.46**	33.95	1.50	83.16	5500.07	10.70	19.80
Line -17	32.50	94.20	60.40	**4.50**	8.70	20.80	2.39	32.47	1.90	83.16	5502.70	10.30	18.60
Line -18	32.50	93.90	60.60	6.00	10.40	21.25	2.10	33.68	1.65	83.83	5267.86	10.90	19.75
Line -19	33.50	**94.80**	60.85	4.70	**7.50**	19.80	2.42	33.14	1.70	81.90	5253.18	10.70	18.85
Line -20	33.25	94.30	61.65	6.65	10.40	23.05	2.02	35.08	1.30	82.14	5300.28	12.00	22.20
Line -21	33.50	94.10	61.30	5.45	8.30	20.75	2.00	34.87	2.10	81.05	5229.88	11.50	19.40
Line -22	33.50	94.50	62.50	4.70	10.85	21.15	1.93	33.78	1.35	80.02	5255.12	10.60	22.00
Line -23	32.50	94.40	61.95	6.90	**12.30**	22.35	2.18	32.64	1.45	82.34	5438.95	11.10	22.00
Line -24	32.50	94.30	64.20	6.50	9.60	23.00	2.25	32.67	1.10	82.00	5564.44	11.10	22.10
Line -25	32.50	94.00	62.80	**7.90**	11.30	22.95	2.58	34.55	1.30	80.34	5048.68	11.80	22.05
Line -26	32.50	94.60	**52.90**	5.90	7.90	20.30	1.92	33.93	1.90	82.33	4887.90	11.80	19.20
Line -27	33.50	94.20	60.60	6.05	9.25	22.00	2.40	33.74	1.30	81.02	5337.02	11.40	20.80

Table 3 continued...

Table 3 continued...

Line -28	33.50	94.50	60.30	6.70	10.60	**24.35**	2.64	32.05	1.45	80.30	5428.95	**13.60**	23.30
Line -29	33.50	94.50	61.30	7.30	10.60	24.15	2.38	34.46	1.30	80.95	5309.73	12.15	**23.75**
Line -30	33.00	94.50	67.35	6.90	11.00	23.65	2.74	33.72	1.25	82.08	5348.49	11.00	22.50
JS-2098	**34.50**	**95.85**	**58.65**	**5.95**	**8.50**	**22.85**	**2.27**	**34.96**	**1.10**	**80.72**	**4903.98**	**10.35**	**21.65**
NRC-142	**37.50**	**95.75**	**60.05**	**6.30**	**8.00**	**25.35**	**2.70**	**35.56**	**1.15**	**79.33**	**5573.90**	**12.00**	**24.65**
Mean	**33.23**	**94.42**	**60.94**	**6.10**	**9.91**	**22.04**	**2.44**	**33.85**	**1.54**	**82.09**	**5305.72**	**11.29**	**20.55**
C.V.	2.0933	0.4031	3.1799	3.3813	8.7821	4.6840	14.7463	2.0132	8.6085	0.8042	3.5522	6.0924	4.7517
S.E.	0.4918	0.2691	1.3704	0.1458	0.6154	0.7299	0.2538	0.4818	0.0941	0.4668	133..27	0.4865	0.6904
C.D. 5%	1.4185	0.7761	3.9526	0.4205	1.7749	2.1053	0.7321	1.3897	0.2713	1.3465	384.39	1.4031	1.9912

Table 4 : Estimates of variability parameters for yield contributing characters and drought tolerance related character in soybean.

S. no.	Character	Mean	Range	GCV (%)	PCV (%)	ECV (%)	Heritability h^2 (broad sense) (%)	Genetic advance at 5%	Genetic advance as % of mean at 5%
1	Days to 50% flowering	33.23	31.50 – 34.50	2.90	3.58	2.09	65.90	1.61	4.86
2	Days to physiological maturity	94.42	93.75 - 94.80	0.38	0.55	0.40	46.50	0.50	0.53
3	Plant height (cm)	60.94	52.90 - 70.60	4.52	5.53	3.18	66.90	4.65	7.62
4	Primary branches/plant	6.10	4.50 - 7.90	13.42	13.84	3.38	94.00	1.63	26.81
5	Cluster/plant	9.91	7.50 - 12.30	11.36	14.36	8.78	62.60	1.84	18.53
6	Pods/plant	22.04	19.15 – 24.35	5.98	7.59	4.68	62.00	2.14	9.69
7	Canopy Temperature Depression (CTD) (ºC)	2.44	1.46 – 3.54	15.72	21.56	14.75	53.20	0.57	23.63
8	Chlorophyll content (mg/gm)	33.85	31.90 – 35.96	2.76	3.42	2.01	65.30	1.55	4.59
9	Wilting score	1.54	1.05 – 2.90	28.76	30.02	8.61	91.80	0.88	56.75
10	Relative water Content (%)	82.09	74.96 – 88.61	3.70	3.78	0.80	95.50	6.11	7.44
11	Leaf area (mm^2)	5305.72	4520.00-6032.85	4.94	6.09	3.55	65.90	438.66	8.27
12	Seed Index (gm)	11.29	9.75 – 13.60	5.32	8.09	6.09	43.30	0.81	7.21
13	Seed yield/plant (gm)	20.55	14.80 – 23.75	9.62	10.73	4.75	80.40	3.65	17.77

Table 5 : Estimates of genotypic (above diagonal) and phenotypic correlation coefficients (below diagonal) of yield contributing characters and drought tolerance related character in soybean.

Characters	Days to 50 % flowering	Days to physiolo-gical maturity	Plant height (cm)	Primary branches /plant	Cluster /plant	Pods/ plant	Canopy Temp. depression (ºC)	Chloro-phyll content (mg/gm)	Wilting score	Relative water content (%)	Leaf area (mm^2)	Seed Index (gm)	Seed yield/ plant (gm)
Days to 50 % flowering	**1.000**	0.888**	-0.046	0.088	-0.303*	0.522**	0.389**	0.321*	-0.400**	0.105	0.206	0.143	0.314*
Days to physiological maturity	0.543**	**1.000**	-0.278*	-0.010	-0.531**	0.139	-0.142	0.258*	-0.301*	0.044	0.251*	-0.180	0.226
Plant height (cm)	0.007	-0.027	**1.000**	0.209	0.435**	0.229*	0.161	0.154	-0.110	0.107	0.504**	-0.251*	0.217
Primary branches/plant	0.085	0.017	0.254*	**1.000**	0.554	0.580**	0.076	0.190	-0.391**	0.117	0.053	0.361**	0.478**
Cluster/plant	-0.159	-0.243	0.378*	0.502**	**1.000**	0.365**	0.237	-0.175	-0.266*	0.055	-0.022	-0.164	0.336**
Pods/plant	0.265*	0.253*	0.324*	0.540**	0.434*	**1.000**	0.292*	0.188	-0.358**	-0.205	0.010	0.375**	0.889**
Canopy Temp. depression (CTD) (ºC)	0.107	-0.064	0.137	0.047	0.139	0.218	**1.000**	-0.419**	-0.463**	-0.448**	-0.548**	-0.138	-0.049
Chlorophyll content	0.152	0.228	0.157	0.159	-0.147	0.241	-0.237	**1.000**	0.004	-0.029	0.445**	0.660**	0.371**
Wilting score	-0.326*	-0.218	-0.096	-0.362**	-0.157	-0.270*	-0.239	-0.015	**1.000**	0.137	0.219	0.116	-0.118
Relative water Content (%)	0.060	0.034	0.079	0.108	0.028	-0.172	-0.314*	-0.029	0.139	**1.000**	0.404**	0.035	-0.231
Leaf area (mm^2)	0.018	0.108	00367**	0.044	-0.024	0.031	-0.270	0.333**	0.131	0.334**	**1.000**	0.203	0.029
Seed Index (gm)	0.114	-0.128	-0.010	0.338**	0.101	0.385**	-0.189	0.401**	0.077	0.048	0.138	**1.000**	0.398**
Seed yield/ plant(gm)	0.219	0.214	0.244	0.480	0.411	0.864	-0.024	0.321	-0.277	-0.217	-0.003	0.419	**1.000**

*, ** significant at 5 % and 1 % levels, respectively.

Table 6 : Estimates genotypic direct (diagonal) and indirect effects (above and below diagonal) of component characters on seed yield /plant (gm) in 30 lines and 2 genotypes of soybean.

Characters	Days to 50 % flowering	Days to physiolo-gical maturity	Plant height (cm)	Primary branches /plant	Cluster /plant	Pods/ plant	Canopy Temp. depression (ºC)	Chloro-phyll content (mg/gm)	Wilting score	Relative water content (%)	Leaf area (mm^2)	Seed Index (gm)	Seed yield/ plant (gm)
Days to 50 % flowering	**-0.004**	-0.004	0.002	-0.004	0.001	-0.002	-0.002	-0.001	0.002	-0.005	-0.009	-0.006	0.314**
Days to physiological maturity	-0.339**	**-0.382****	0.106	0.004	0.203	-0.053	0.054	-0.098	0.115	-0.017	-0.096	0.069	0.226
Plant height (cm)	0.009	0.053	**-0.193**	-0.040	-0.084	-0.044	-0.031	-0.028	0.021	-0.021	-0.097	0.048	0.217
Primary branches/plant	-0.006	0.001	-0.015	**-0.072**	-0.039	-0.041	-0.005	-0.014	0.028	-0.008	-0.004	-0.026	0.478**
Cluster/plant	0.046	0.081	-0.067	-0.084	**-0.152**	-0.056	-0.036	0.027	0.040	-0.008	0.003	0.025	0.336**
Pods/plant	0.633**	0.169	0.279*	0.704**	0.442**	**0.213**	0.355**	0.229	-0.434**	-0.249*	0.012	0.455**	0.889**
Canopy Temperature Depression (CTD) (ºC)	-0.172	0.062	-0.071	-0.033	-0.104	-0.129	**-0.440****	0.185	0.203	0.197	0.241	0.061	-0.049
Chlorophyll content (mg/gm)	0.124	0.099	0.059	0.073	-0.068	0.073	-0.162	**0.387****	0.001	-0.011	0.172	0.255*	0.371**
Wilting score	0.099	0.075	0.027	0.097	0.066	0.089	0.115	-0.001	**-0.249***	-0.034	-0.055	-0.028	-0.338**
Relative water content (%)	-0.005	-0.002	-0.005	-0.006	-0.002	0.010	0.022	0.001	-0.007	**-0.049**	-0.020	-0.002	-0.231
Leaf area (mm^2)	-0.007	-0.009	-0.017	-0.001	0.007	-0.003	0.019	-0.015	-0.008	-0.014	**-0.035**	-0.007	0.029
Seed Index (gm)	-0.064	0.081	0.113	-0.163	0.074	-0.017	0.062	-0.298	-0.052	-0.016	-0.092	**-0.451**	0.398**
Residual effect (R) = 0.236													

*, ** significant at 5 % and 1 % levels, respectively.

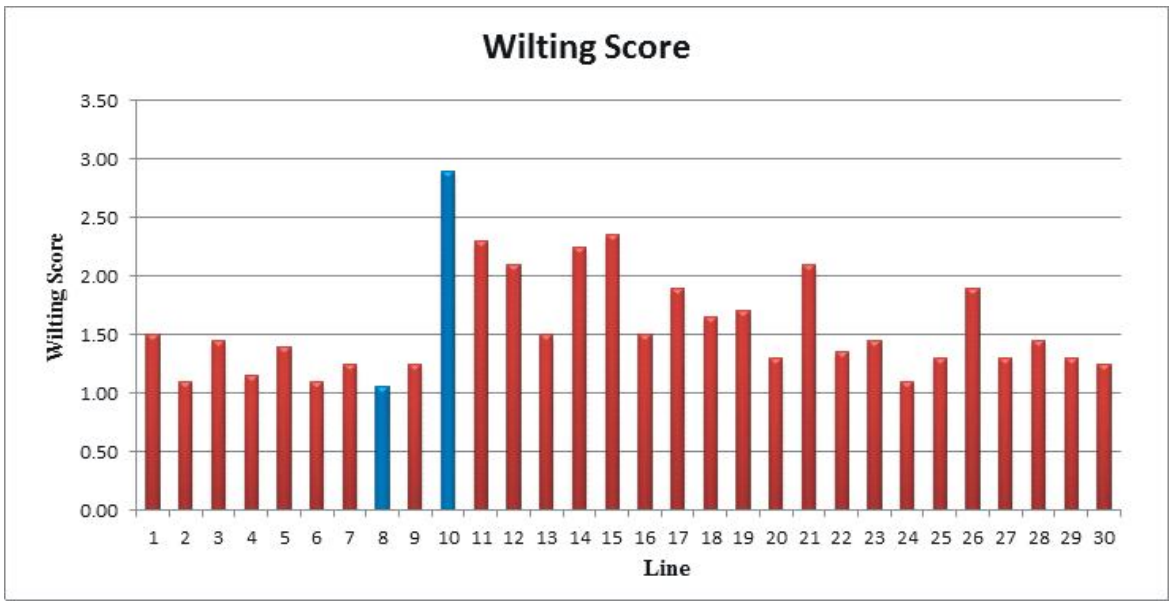

Fig. 1 : Wilting score.

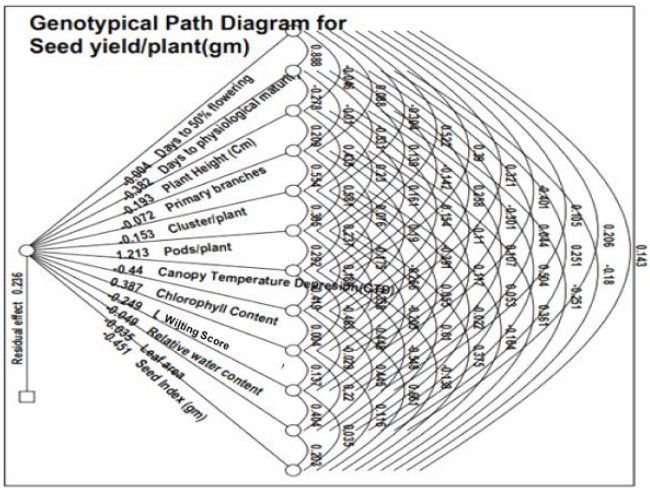

Fig. 2 : Genotypic path diagram.

tolerance associated traits gives out some better promising lines *viz*. Line 2, Line 5, Line 6, Line 7, Line 9 and Line 12.

Line 2 was found to be best line in both yield contributing and drought tolerance related character, therefore can be utilized properly in future breeding programme or research lane to develop stress resilient soybean genotypes.

The variability among the individual is an indicator of differences among the individual of same species and is estimated by coefficient of variation. In terms of plants the phenotype and genotype were affected by environmental factor hence usefulness of genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) is remarkable and their estimates for present investigation indicated in Table 4. The character wilting shows the high GCV (28.76) and PCV (30.02%) reflect variability for that character in the lines. Four characters viz. Primary branches per plant, Cluster per plant, CTD and seed yield show the moderate variation among all lines. In contrast to that the remaining character like days to 50% flowering, days to physiological maturity, Plant height, RWC, leaf area and seed index shows low variability. The highly variable traits are profound for improvement than the low variable trait. The result obtained were found to be similar with the previous findings like by Sharma *et al*. (2007), Patil *et al*. (2011), Ramteke *et al*. (2010), Sirohi *et al*. (2007).

The heritability is nothing but the degree of transmission of character from parent to offspring. For making effective improvement in the trait for which selection is practiced, heritability has been adopted by large number of workers as a reliable indicator. In couple with heritability the estimates of genetic advance useful as a selection of character for breeding programme. According to Table 3 the traits like primary branches per plant, delay leaf senescence cluster per plant and seed yield per plant represent high heritability with high genetic advance as percent of mean. It shows that these characters are reliable for selection soybean genotypes as breeding material as they govern by additive gene action. While the character days to physiological maturity and seed index have low heritability and low genetic advance hence they are less promising for selection as they govern by non-additive gene action. The remaining plant height, pods per plant, chlorophyll content and leaf area having high heritability but low genetic advance hence are not rewarding for selection. The character CTD shows medium heritability with high genetic advance also

useful for selection. The above findings find to be in accordance with previous literature (Sulistyo *et al*., 2018; Aditya *et al*., 2011; Hakim and Suyamto, 2012; Barmawi *et al*., 2013).

The correlation shows the association between two or more characters. It reflects the how particular characters were responsible for influencing the other character. Six traits like days to 50% flowering (0.314*), primary branches (0.478**), cluster per plant (0.336**), pods per plant (0.889**), chlorophyll content (0.371**) and seed index (0.398**) shows positive and significant correlation with seed yield as shown by Table 5, that means selection of these traits definitely helps in improving the yield of soybean. Negative and non-significant correlation shows by the wilting score (-0.118) and relative water content (-0.231). Aditya *et al.* (2011), Balla and Ibrahim (2017), Li *et al*. (2013) also reported the significant correlation among various characters for soybean.

Path coefficient analysis on the other hand is an efficient statistical technique specially designed to partition the correlation coefficient into direct and indirect effect, provides the information on actual contribution of a trait on the yield s presented in Table 6. Only chlorophyll content shows high positive direct effect on seed yield; however other traits like primary branches, cluster per plant, pods per plant and seed index shows high significant indirect effect on the seed yield. These characters indicate the truly contribution for improving yield through direct and indirect manner. The Fig. 2 indicate the effect of various character on yield which indicated by top on the row from -0.004 to -0.451. The values in front of the rounds indicate the respective correlation coefficient between the characters and yield which values varies from 0.888 to 0.143. The residual effect was found to be 0.236 which is good as it is below 0.4 and indicating the effect due to other character which not included in the study is less. Comparable results were reported by Machikowa and Laosuwan (2011) and Balla and Ibrahim (2017). The residual effect is 0.236 which indicates the 77% of variability was due to the characters which were considered for the studies.

Conclusion

The current investigation on evaluation of 30 F_3 and 2 parental lines comes with following conclusion as - the Line 2, Line 28, Line 29 and Line 30 were found to be promising line in yield contributing character; while for drought tolerance related characters gives out some better promising lines says Line 2, Line 5, Line 6, Line 7, Line 9 and Line 12. Among all 30 $F_{3,}$ Line 2 was found to be best line in both yield contributing and drought tolerance related characters studied.

The character chlorophyll content, primary branches, cluster per plant, pods per plant and seed index showed high significant correlation with direct as well as direct effect on the seed yield. Therefore, utilizing such prominent lines and selection of these characters for improving yield in breeding programme is rewarding for future.

Conflict of interest : All authors declared that there is no conflict of interest.

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