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RESEARCH ARTICLE

Evaluation of growth parameters and physiological basis of yield in summer soybean genotypes

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SUMMARY

Pod and seed number are the most important yield components of soybean. Leaf area index (LAI), leaf area duration (LAD) during the reproductive period strongly influence yield components. The study was undertaken with objectives to investigate the significant differences in yield components, physiological traits and growth parameters among genotypes and to examine the dynamics of LAI and LAD during the reproductive period for the high-yielding genotypes. Significant variations were found for LAI, LAD, leaf area, number of branches, plant height and physiological traits. Photosynthetic rate was closely related to stomatal conductance, transpiration and PAR.The rate of photosynthesis is an important physiological parameter which governs the dry matter production and consequently the yield.The genotype KDS-347 (63.60 µmol $m^{-2}s^{-1}$) showed higher photosynthesis rate reflected in high grain yield (2708.33 kg/ha) in these genotypes during summer season. The efficiency of converting biological yield in to economic yield and explained the cause of high grain yield in KDS-347 due to a higher harvest index (46.78%). The high yielding genotypes possessed higher rate of photosynthesis indicating the importance of the parameter in determining the productivity.

Key Words : Soybean, Yield, LAI, LAD, Photosynthesis

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In recent years, soybean [*Glycine max* (L.) Merill] has assumed important position in India, as it is one of the most stable crops yielding cost effective production in varied agro-climatic conditions unlike otherpulses and oilseeds of our country. Soybean is an excellent source of protein and has the potential to supply adequate and nutritious food and feed used by ever increasing world population. It has become a major oilseed crop in India next to groundnut and mustard. Soybean cultivar contains approximately 36 to 43 per cent proteins and 18 to 21 per cent oil in seed. Beside oil and proteins, it fixes atmospheric nitrogen in the soil @ 65-100 kg/ha, with the help of *Rhizobium japonicum* bacteria on the global scale.

Soybean is C_3 plant. Photosynthesis is carbon assimilation process. The rate of photosynthesis varies with light intensity, genotype and LAI. Whigham (1983) and Evans (1980) reported that, with high light intensity maximum CO_2 assimilation occurs at 5-6 LAI but with low light intensity the assimilation rate reaches maximum when the LAI is 3-4. Leaf photosynthesis rate decreases due to moisture stress or

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reduction in LAI. Soybean thrives well in subtropical climate with good rainfall and warm sun and is sensitive to photoperiod (Satwe, 1992). A temperature of 26.5 to 30°C appears to be the optimum for most of the varieties. Soil temperature of 15.5°C or above favours rapid germination and vigorous seedling growth. The minimum temperature for effective growth is about 10°C. Day length is the key factor in most of the soybean varieties as they are short day plant and are sensitive to photoperiod. Most of the varieties will flower and mature quickly if grown under condition where the day length is less than 14 hours provided that temperatures are also favourable.

The study was undertaken with objectives to investigate the significant differences in yield components, physiological traits and growth parameters among genotypes and to examine the dynamics of LAI and LAD during the reproductive period for the high-yielding genotypes.The light and temperature are two principle environmental factors which decide the season boundness of the genotypes which are referred to as photo-thermo-sensitive. However, for commercial exploitation, the barrier of 'season-specific-genotypes' need to be broken either genetically or through physiological screening for the photo-thermo-insensitive genotypes so as to exploit them in summer season and to avoid the huge capital investments during season specific seed production and storage programmes.

MATERIAL AND METHODS

Field experiment was conducted during the summer season of 2011 at Research Farm, Mahatma Phule Krishi Vidyapeeth, Rahuri ($19^0 47^1$ N, $74^0 81^1$ E, 657M above MSL). The experiment was laid out in Randomized Block Design with three replications including eight soybean genotypes *i.e.* MACS-57, MACS-450, MAUS-71, KDS-321, KDS-343, KDS-347, KDS-378, KDS-345. The recommended dose of fertilizers was applied. The growth observations were recorded after sowing of crop at 30 days interval up to harvest.The observations were recorded on plant height, total number of branches and functional leaf area of each sampled plant by using automatic leaf area meter. LAI and LAD were calculated according to the formula given by Watson (1947). Physiological traits such as rate of photosynthesis, rate of transpiration, stomatal conductance, photo synthetically active radiation were determined from fully expanded leaf by using portable IRGA (Infra red gas analyzer, model LI 6400, USA). Statistical analysis was carried out by method suggested by Panse and Sukhatme (1985).

RESULTS AND DISCUSSION

The present investigation was conducted during the summer season of the year 2011 at research farm, MPKV, Rahuri. The results obtained are discussed below.

Growth studies :

Growth is an effect of metabolic activities of the plant, when anabolic processes are more than catabolic processes, there is synthesis and accumulation of various organic substances which result in growth. In case of soybean, the major traits for this are plant height, number of branches, leaf area, leaf area index and leaf area duration.The data on the plant height recorded are presented in Table 1. The soybean genotypes differed significantly for plant height at 30, 60, 90 DAS and at harvest. Growth in terms of plant height increased progressively and rapidly up to 90 DAS in soybean genotypes. At 90 DAS and at harvest, the mean plant height ranged from 51.66 to 71.44 with a mean (59.31 cm). The genotype KDS-347 recorded significantly the highest mean plant height (71.44 cm). The plant height is influenced by the interaction between

Table 1 : Periodical mean plant height (cm) of soybean genotypes during summer, 2011

Sr. No.	Genotypes	Mean plant height (cm)			
		Crop age (DAS)			
		30 DAS	60 DAS	90 DAS	At harvest
1.	MACS-57	12.70	47.78	57.21	57.21
2.	MACS-450	16.00	42.27	51.66	51.66
3.	MAUS-71	13.06	44.33	53.70	53.70
4.	KDS-321	12.40	45.49	53.77	53.77
5.	KDS-343	12.50	47.16	56.83	56.83
6.	KDS-347	13.13	61.83	71.44	71.44
7.	KDS-378	15.96	58.55	68.16	68.16
8.	KDS-345	11.76	50.83	61.72	61.72
	Range	11.76 – 16.00	42.27 - 61.83	51.66 - 71.44	51.66 – 71.44
	Mean	13.44	49.78	59.31	59.31
	S.E.±	0.39	1.98	1.43	1.43
	C.D. (P=0.05)	1.21	6.02	4.36	4.36

the environmental condition and genetic constitution of plant. The growth in terms of plant height followed an increasing trend with age of the crop up to 90 DAS in all the soybean genotypes during summer season. This result is in confirmatory with conclusion by Pushpa Kumari *et al.* (1993). The soybean genotypes differed significantly in plant height at different stages of the growth during summer season. These findings are confirmatory with result of Kolak *et al.* (1994). The higher plant height was observed in these genotypes due to differential growth potential. From present investigation it is observed that, higher seed yield was positively correlated with plant height of soybean. These results are in agreement with Sarma and Sarma (1993).

The data regarding mean number of branches per plant revealed that, the differences among varieties were significant at 30, 60, 90 DAS and at harvest of crop during summer season (Table 2). These results are confirmatory with conclusion of PushpaKumari *et.al* (1993). At 90 DAS and at harvest, the genotype KDS-321 recorded the highest mean number of branches per plant (5.88) than other genotypes. The differences may be due to photoperiod effect, environmental variation during summer season. The results are confirmatory with Board and Settimmi (1986).

The leaves are the primary organ for light interception and photosynthesis. Leaf area is the basis of growth and yield. In the present studies, there were significant differences due to leaf area at periodically *i.e.* 30, 60, 90 DAS and at harvest during summer season (Table 3). These results are in agreement with Mehetre *et al*. (1997 b). At 60 DAS, the genotype KDS-347 recorded significantly highest mean leaf area per plant (28.74 dm^2). Higher leaf area during 60 DAS might have intercepted more light enhancing their photosynthetic rate

Table 2 : Periodical mean number of branches per plant of soybean genotypes during summer, 2011

Sr. No.	Genotypes	Mean number of branches/plant — Crop age (DAS)			
		30 DAS	60 DAS	90 DAS	At harvest
1.	MACS-57	3.33	4.44	5.66	5.66
2.	MACS-450	3.91	4.66	5.66	5.66
3.	MAUS-71	3.10	4.10	5.33	5.33
4.	KDS-321	3.77	4.88	5.88	5.88
5.	KDS-343	2.99	3.99	4.99	4.99
6.	KDS-347	3.55	4.66	5.77	5.77
7.	KDS-378	3.21	4.33	5.44	5.44
8.	KDS-345	2.77	3.77	4.88	4.88
	Range	2.77 - 3.91	3.77 – 4.88	4.88 – 5.88	4.88 – 5.88
	Mean	3.33	4.35	5.45	5.45
	S.E.±	0.23	0.22	0.17	0.17
	C.D. (P=0.05)	0.71	0.68	0.52	0.52

Table 3 : Periodical mean leaf area (dm^2) per plant of soybean genotypes during summer, 2011

Sr. No.	Genotypes	Mean leaf area (dm^2) per plant — Crop age (DAS)			
		30 DAS	60 DAS	90 DAS	At harvest
1.	MACS-57	3.03	22.57	12.23	4.96
2.	MACS-450	2.80	18.37	10.02	3.98
3.	MAUS-71	3.17	23.38	12.98	5.14
4.	KDS-321	2.94	19.39	10.53	4.66
5.	KDS-343	3.37	24.06	13.29	5.75
6.	KDS-347	3.51	28.74	16.60	6.48
7.	KDS-378	3.46	26.24	15.48	6.05
8.	KDS-345	3.44	24.64	14.45	6.05
	Range	2.80–3.51	18.37-28.74	10.02-16.60	3.98–6.48
	Mean	3.21	23.42	13.20	5.38
	S.E.±	0.11	0.34	0.24	0.15
	C.D. (P=0.05)	0.36	1.06	0.73	0.48

which ultimately resulted in higher dry matter. The high assimilatory surface of the genotype KDS-347 during reproductive phase might had intercepted more solar energy enhancing their photosynthetic rate (63.60 µmol $m^{-2}s^{-1}$) which resulted into high grain yield (2708.33 kg/ha) during summer season. This indicating a leaf area during summer season could be super optimal levels resulting in reduced net photosynthesis because of respiration of lower shaded leaves might have exceed their photosynthesis, such older leaves on plant have low respiration rates and soon die if they exceed their photosynthesis rate, with a result that net photosynthesis tends to plateau at high leaf area in summer season. This season variation in leaf area was mainly due to wide range of environmental conditions. Sinclair (1984) reported that, soybean leaf area was critical for light interception and leads in decrease in yield. This may be the reason for lowest yield of some genotypes. Rolim *et al.* (1986) reported that, leaf area was minimum at photoperiod of 8-10 hrs and it increased further. Photoperiod plays a vital role in increase of leaf area which ultimately concerned with seed yield.

The data regarding mean leaf area index revealed that, the values for this trait was highest at 60 DAS in all genotypes which declined afterwards during summer season (Table 4). At 60 DAS, the genotype KDS-347 recorded significantly highest mean LAI (9.58), while the genotype MACS-450 recorded significantly the lowest LAI (6.12) among all genotypes. According to Pawar (1978) LAI was less at seedling stage and increased continuously up to 60DAS and thereafter declined. These findings are similar with the observations obtained in present investigation. Also Jain *et al*. (1996) obtained similar findings regarding LAI.

The data regarding mean LAD indicated that, there were

Table 4 : Mean leaf area index (LAI) of soybean genotypes during summer, 2011

Sr. No.	Genotypes	Mean leaf area index (LAI) Crop age (DAS)			
		30 DAS	60 DAS	90 DAS	At harvest
1.	MACS-57	1.01	7.52	4.07	1.65
2.	MACS-450	0.93	6.12	3.34	1.32
3.	MAUS-71	1.05	7.79	4.32	1.71
4.	KDS-321	0.98	6.46	3.51	1.55
5.	KDS-343	1.12	8.02	4.43	1.91
6.	KDS-347	1.17	9.58	5.53	2.16
7.	KDS-378	1.15	8.74	5.16	2.01
8.	KDS-345	1.14	8.21	4.81	2.01
	Range	0.93 – 1.17	6.12 – 9.58	3.34 – 5.53	1.32 – 2.16
	Mean	1.07	7.80	4.40	1.79
	S.E.±	0.03	0.11	0.08	0.05
	C.D. (P=0.05)	0.12	0.35	0.24	0.16

Table 5 : Mean leaf area duration (LAD)(Days) of soybean genotypes during summer, 2011

Sr. No.	Genotypes	Mean leaf area duration (Days) Crop age (DAS)		
		30-60	60-90	90-At harvest
1.	MACS-57	128.04	174.04	27.71
2.	MACS-450	105.89	141.99	32.70
3.	MAUS-71	132.77	181.82	31.24
4.	KDS-321	111.67	149.64	19.41
5.	KDS-343	137.14	186.78	33.83
6.	KDS-347	161.29	226.74	62.81
7.	KDS-378	148.54	208.66	52.63
8.	KDS-345	140.42	195.45	48.97
	Range	105.89-161.29	141.99-226.74	19.41-62.81
	Mean	133.22	183.14	36.66
	S.E.±	2.16	2.23	1.72
	C.D. (P=0.05)	6.56	6.78	5.23

significant differences among all varieties at 30-60, 60-90 and 90 DAS-at harvest of crop during summer season (Table 5). This finding is in conformity with the result of Xiaobing Liu *et al*. (2005). The genotype KDS-347 recorded highest LAD at all growth stages of crop during summer season. Also they show positive correlation with seed yield. This finding is in conformity with the result of Martin *et al*. (1995) and Tandale and Ubale (2007).

Physiological studies :

The data regarding physiological study revealed that, all genotypes differed significantly during summer season (Table 6). All factors influencing growth and development of crop plant must be integrated at an optimum level, if the maximum production potential has to be obtained. Since the photosynthesis is the corner stone of crop production, it is important to be aware of the energy available to drive photosynthesis process. The rate of photosynthesis is an important physiological parameter which governs the dry matter production and consequently the yield. The rate of photosynthesis differed significantly among genotypes. The genotype KDS-347 (63.60 µmol $m^{-2}s^{-1}$) showed higher photosynthesis rate reflected in high grain yield (2708.33 kg/ha) in this genotype during summer season. The efficiency of converting biological yield in to economic yield and explained the cause of high grain yield in KDS-347 due to a higher harvest index (46.78%). The high yielding genotypes possessed higher rate of photosynthesis indicating the importance the parameter in determining the productivity. These results are in similar line with those obtained by Cho Jin Wong *et al*. (2003).

Lee kangSae *et al*. (2003) reported that photosynthetic

Table 6 : Physiological traits at 50% flowering stage of soybean genotypes during summer, 2011

Sr. No.	Genotypes	Physiological traits at 50% flowering stage			
		Photosynthetic rate (µmol $m^{-2}s^{-1}$)	Transpiration rate (mmol $m^{-2}s^{-1}$)	Stomatal conductance (mol m^{-2} s^{-1})	PAR (µ mol m^{-2} s^{-1})
1.	MACS-57	58.05	0.54	0.02	1052.67
2.	MACS-450	54.15	0.33	0.01	951.00
3.	MAUS-71	58.83	0.33	0.05	1056.67
4.	KDS-321	57.90	0.46	0.01	1027.00
5.	KDS-343	59.00	0.06	0.02	1064.67
6.	KDS-347	63.60	0.82	0.01	1120.67
7.	KDS-378	61.50	0.16	0.02	1092.67
8.	KDS-345	61.11	0.50	0.01	1068.00
	Range	54.15-63.60	0.06-0.82	0.01-0.05	951.00-1120.67
	Mean	59.26	0.40	0.019	1054.17
	S.E.±	1.71	0.04	0.002	12.97
	C.D. (P=0.05)	5.19	0.12	0.006	39.35

Table 7 : Yield and yield contributing characters of soybean genotypes during summer, 2011

Sr. No.	Genotypes	Yield contributing traits		Grain yield		Harvest index (%)
		No. of pods per plant	No. of seed per pod	kg/plot	kg/ha	
1.	MACS-57	34.31	2.77	0.410	1220.10	33.65
2.	MACS-450	36.49	2.44	0.335	997.02	29.93
3.	MAUS-71	28.63	2.83	0.428	1273.80	34.04
4.	KDS-321	31.58	2.55	0.399	1187.50	32.11
5.	KDS-343	54.14	2.91	0.573	1705.35	35.00
6.	KDS-347	46.53	3.11	0.910	2708.33	46.78
7.	KDS-378	33.03	3.00	0.752	2238.09	38.73
8.	KDS-345	46.99	2.77	0.670	1994.04	37.97
	Range	28.63-54.14	2.44-3.11	0.335-0.910	997.02-2708.33	29.93-46.78
	Mean	38.96	2.80	0.560	1665.53	36.02
	S.E.±	2.27	0.13	0.047	141.72	2.16
	C.D. (P=0.05)	6.90	0.40	0.144	429.89	6.56

rate was closely related to stomatal conductance, transpiration and water use efficiency. The data on transpiration rate indicated that, there were significant differences among all genotypes during summer season. The genotype KDS-347 (0.82 mmol $m^{-2}s^{-1}$) showed higher transpiration rate among all genotypes during summer season. The data on stomatal conductance revealed that, the differences were significant among all genotypes during summer season. The stomatal conductance was higher in the genotype MAUS-71 (0.05 mol m^{-2} s^{-1}) during summer season. This is due to some environmental factors like temperature, photoperiod and rainfall which influences the rate of stomatal conductance and transpiration rate by lowering down soil moisture content in soybean field. As soil moisture plays important role in growth and development of crop. These results are in conformity with Lee *et al.* (1994). When plants having continuous light that gives a surplus source, although total photosynthetic capacity and total biomass production are likely to increase, the efficiency of plant photosynthetic matter production is likely to decrease because of lowered leaf stomatal conductance and had lowered activation state of rubisco. This is in conformity with the conclusion of Minobu Kasai (2008).

The data on photosynthetically active radiation (PAR) indicated that, there were significant differences among all genotypes during summer season. The genotype KDS-347 recorded significantly highest photosynthetic active radiation among all genotypes during summer season.The result indicates that summer soybean population of relatively uniform distribution could improve population structure and increase PAR interception.These results are in conformity with the results of Zhou *et al.* (2011). Praharaj and Dhingra (2002) shows significant positive correlation between solar radiation interception and LAI, dry matter and seed yield.

Yield traits :

A crop yield is an end product of various closely interlinked metabolic processes of the plants. Understanding of various physiological traits imperative for efficient development of crop plant. The yield of soybean is dependent upon number of components like number of pods per plant, number of seed per pod etc. Significant differences were observed among soybean genotypes for yield and yield traits during summer season (Table 7), as reported earlier by Amarnath *et al*. (1990). The data regarding number of pods per plant revealed that, there were significant differences among all genotypes during summer season. The genotype KDS-343 (54.14) shows significantly highest number of pods per plant during summer season. As Board and Harville (1994) observed that, pod number of soybean are determined during R_3 to R_5. The pod number decreased with light interception. The data regarding number of seed per pod revealed that, there were significant differences among all genotypes during summer season. The genotype KDS-347 (3.11) showed significantly highest number of pods per plant during summer season. However Rolim *et al.* (1986) reported that, the soybean seeds per plant were less at photoperiod of 8-10 hrs per day and increased as photoperiod was increased. Also Kantolic and Slafer (2001) concluded that, the possibility of using sensitivity to photoperiod after flowering as a criteria for increasing yields through increasing seed number and pod number, which corroborate with results obtained in the present investigation.

Harvest index (HI) reflects the physiological capacity of crop varieties to mobilize or translocate photosynthates to plant part having economic value. HI is good measure of the efficiency of genotype converting the biological yield into economic yield. Differences among the soybean genotypes were significant for HI in summer season. This finding is in conformity with the result of Mehetre *et al.* (1997 a). The more efficient translocation of assimilates from leaf to stem (source) to organ having economic value as evidenced from HI.The genotype KDS-347 (46.78 %) showed significantly highest harvest index during summer season. Harvest index was larger contributor to the progress of soybean yield improvements. The finding is in accordance with result of Ui and U (2005) and Nirmalakumari and Balsubramanian (1991).

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10th Year
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