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Morpho-physiological markers and plant architecture of Soybean (*Glycine max* L. Merrill) genotypes for higher yield

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Abstract
The morpho-physiological divergence was assessed in 44 Soybean (*Glycine max* L. Merrill) genotypes were studied in three groups. The objectives of the research work to evaluate the diversity of soybean genotypes at morpho-physiological traits and plant architecture linked to higher yield and their correlation among the traits. Negative and significant correlations were observed between HI and CGR, RGR, NAR, and biological yield in early duration group. However CGR of medium duration and long duration group was positively correlated with RGR, NAR, and biological yield and negatively correlation with test weight in (Medium group). HI was positively correlated with seed yield and test weight in long duration genotypes. The correlation of morpho-physiological traits showed positive correlation of plant height with HI and test weight. In yield traits negative and significant correlation was observed between chlorophyll (SPAD) value and biological yield. Genotype KDS 775 (Early) RSC10-30 (Early) NRC123 (Medium) and PS1570 (Long) have higher HI amongst their group. Genotype RVS 2010-1 (Early), KDS-975 (Early),RSC10-04 (Medium), NRC 117 (Medium), JS 20-94 (Medium) and JS 97-52 (c)(long) and RSC 10-29 (Long) have shown significantly higher seed yield amongst their respective groups. These genotypes having efficient partitioning of photo assimilates during the period of sink development.

Keywords: Crop growth rate, relative growth rate, net assimilation rate, harvest index

Introduction

Soybean (*Glycine max* L. Merrill) is an important pulse as well as oil seed crop designated as Golden bean and considered as Wonder crop of 20th century being an excellent source of both proteins (40-44%) and oil (18-20%). It also contains a good amount of minerals (4.5%).

Soybean is originated in the temperate northern plains of china and domesticated in about 1100BC. It spread to Europe, USA and other countries of South America and South East Asia and has undergone expression in cultivation from temperate to tropical and sub-tropical region. In India major soybean producing state and Madhya Pradesh, Maharashtra, Rajasthan, Uttaranchal. Madhya Pradesh account for about 75% of total soybean production in India. While Chhattisgarh stand with 156590 hectare area and production 1070 kg h^{-1}. The average productivity of Soybean in India is very poor (1008 kg h^{-1}) in comparison to world productivity (2148 kg h^{-1}).

Due to the certain constraints of productivity like lower sink demand is inviting the wild group in critical yield status, resulting in stagnant genetic yield potential. In view of the fast shrinkage of agricultural resources, it is gently needed to identify the possible key and morpho-physiological markers and plant architecture associated with the seed yield. Therefore, the experimentation was undertaken to identify the suitable genotypes and their associated traits for high yield for Raipur region of Chhattisgarh plain. One of major constraints in soybean production is lack of suitable location specific genotypes to particular region. Major physiological constraints limiting its production are flower drop and fruit drop. The crop is very sensitive to temperature extreme pollen formation in highly sensitive to higher and lower temperature. Efficiency of conversion of incident radiation plays an important role in photo assimilate production and its efficient partitioning depends on photo thermal sensitivity. This manipulation of photo thermal sensitivity offer most powerful tool for improving HI. To understand the physiological basis of yield difference among the genotypes, it is essential to identify the morpho-physiological markers and growth parameters associate with high yield, which will be useful for crop improvement. A better understanding of efficient partitioning of assimilates into sink (seed) would help to expedite yield improvement of soybean. Little work done has been done in this region. Therefore the detailed analysis of morpho-physiological markers and plant architecture 44 genotypes of soybean was undertaken for study.

Materials and Methods

The study was conducted to assess the morphogenetic divergence among forty four soybean genotypes. The experiment was carried out during June, 2015 to Oct, 2015 at the instructional farm of IGKV, Raipur. The experimental material consisting forty four genotype were sown in randomized block design with three replications, each plot considered of a single row of three meter long with row to row distance of 45 cm maintaining 40 plants m^2. Sowing was done with the help of hand drill. Three random plants were used to take data on days to first flower, days to 50% flowering, days to maturity and growth analysis LAI (Watson, 1947), LAR (Whitehead and Myerscough, 1962) [23], CGR (Potter and Jones, 1977), NAR (Gregory, 1917), RGR (Williams, 1946) and HI (Synder and Carlson, 1984) [21]. The morphological and yield parameters *i.e.,* Plant height, number of branches per plant, number of pods per plant, pod length, number of seeds per pod, seed per plant, hundred seed weight and seed yield per plant from each plot of each replications. All intercultural operations were carried out following standard procedure as described Mondal and Wahhab (2001) [18]. The data were analyzed statistically use in LSD least significant test at 0.05% probability level to compare the difference among the genotypes.

Results and Discussion

Leaf Area

The leaf area per plant indicated significant differences between early, medium and late maturing genotypes at all the stages *i.e.* 60 and 90 days after sowing. It differed significantly with all the genotypes, In early maturing genotype RVS 2010-1 have significantly maximum leaf area (625.72) followed by NRC 120 (563.91). The minimum leaf area exhibited in PS 1569 (168.41) and followed by VLS 90 (271.82) at both the stage of growth. In medium duration group RSC 10-04 have significantly higher LA (803.35) followed by MACS 1491 (553.43). The minimum leaf area was observedin NRC 117 (265.94) followed by AMS 1001 (284.09) (fig -1). In long duration cultivars DSb 29 having maximum (652.80) leaf area followed by SL 1074 (521.96). Whereas, minimum LA was obtained by NRC 121(175.78) followed by JS 97-52 (c) (213.56). Khargakharate, *et al*. (1992) also reported the suitable equation for estimating leaf area in soybean from linear measurement was calculated to be leaf area = maximum length x maximum width x 0.68.(fig-1)

Leaf Area Index

The data on leaf area index per plant indicated significant differences between the early, medium and late maturing genotypes at all the stages. There was a linear increase in leaf area index up to flowering stage and declined thereafter in all the genotypes. Among the early maturing genotype RVS 2010-1 (2.78) having significantly higher LAI followed by NRC 120 (2.51) Whereas, PS 1569 exhibited significantly minimum (0.75) LAI followed by KDS 975 (1.15). In medium duration cultivars RSC 10-04 having maximum LAI (3.58) followed by MACS 1491 (2.46) and minimum LAI observed in NRC 117 (1.18) followed by RVS 2010-2 (1.21). In long duration cultivars maximum LAI (2.90) was observed in DSb 29 followed by SL 1074 (2.32) while minimum was observed in NRC 121 (0.78) followed by JS 97-52 (c) (0.95) in long group of cultivars. (fig-2). Pawar (1978) also observed the increased LAI up to 60 days and decreased thereafter in soybean. (fig-2).

Plant Height (cm)

The data on plant height (Table1) indicated significant differences among the genotypes of early, medium and late maturing groups. In early maturity group, the genotype *i.e.* MACS 1491, MACS 1488 were having more plant height and RSC 10-04 and KDS 754 were having less plant height. However, there were non significant association between plant height and number of leaves. Early group of genotypes *i.e.,* PS 1569 having significantly more foliage (number of leaves). Whereas, medium duration genotypes *i.e.,* AMS 100-1 having maximum leaves. Pawar (1978) [15] also observed the increased LAI up to 60 days and decreased thereafter in soybean. (fig-3)

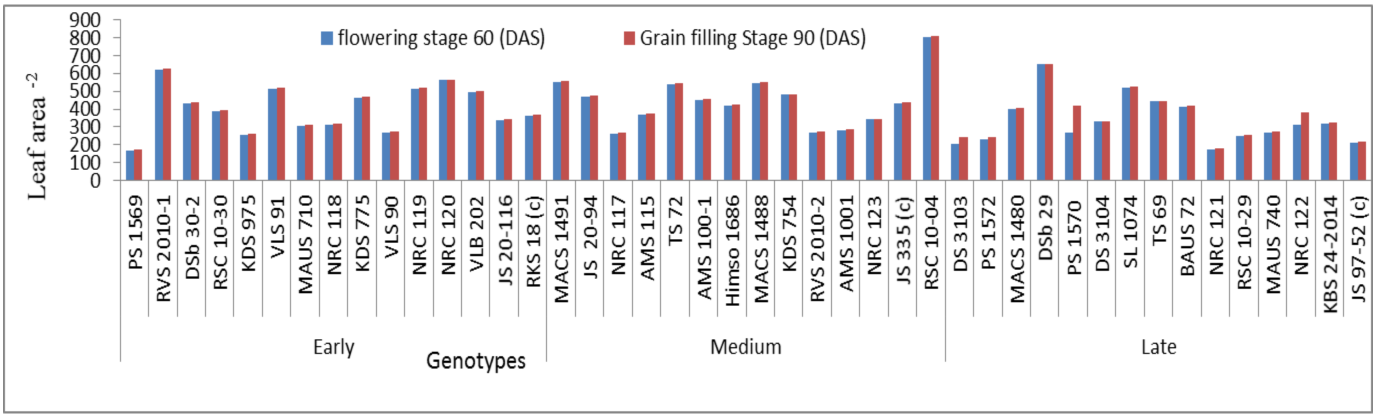

Fig 1: Variation in leaf area cm^{-2} in soybean cultivars at various growth phases.

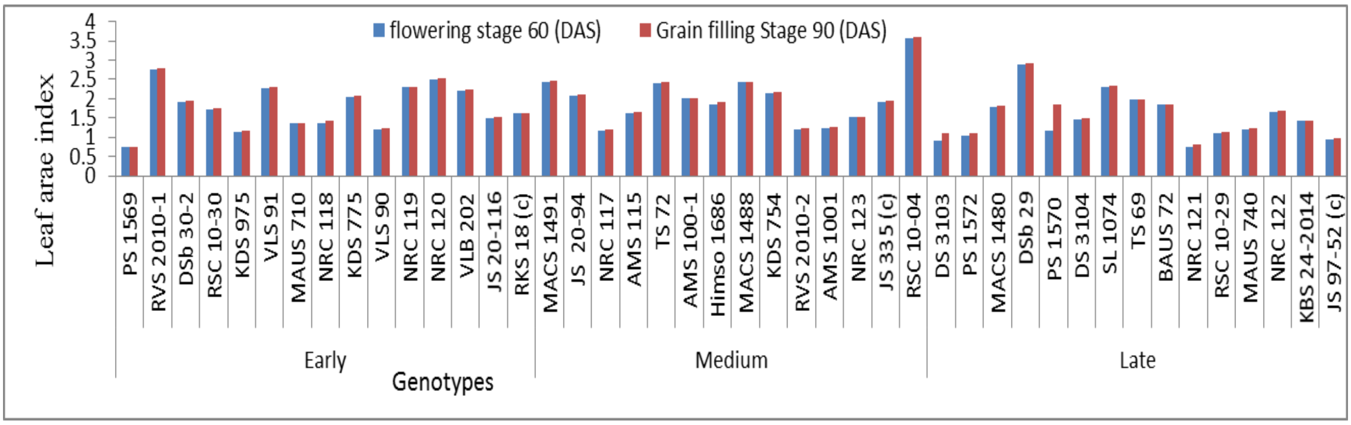

Fig 2: Variation in leaf area index plant^{-1} in soybean cultivars at various growth phases.

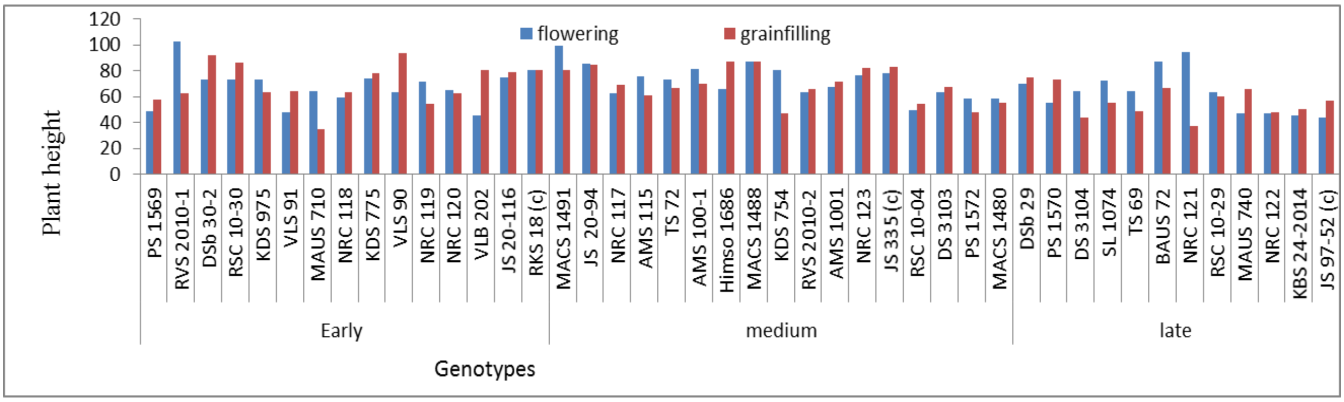

Fig 3: Variation in Plant height (cm) in soybean cultivars at various growth phases.

Number of pods plant^{-1}

The number of pod is an important factor to be considered during selection of desirable genotypes. The variations in number of pods in present investigations were found to be highly significant due to divergent genotypes. The number of pods ranged from 53.42, 46.18 to 43.89 per plant. Among early maturing genotypes RVS 2010-1 having highest (100.66) pod per plant followed by RKS 18 (c) (69.00) whereas minimum was observed in MAUS 710 (16.33) followed by NRC 120 (27.66) at grain filling stage. In medium duration cultivars RSC 10-4 having maximum (88.66) number of pod per plant followed by Himso 1686 (80.66). However, MACS 1488 havingminimum pod per plant (21.00) followed by KDS 754 (22.33).In long duration cultivars PS 1570 having highest (83.00) number of pod per plant followed by MAUS 740 (62.33), the minimum number of pod per plant was obtained in MACS 1480 (23.66) followed by DS 3103 (24.00) at grain filling stage. At harvest stage early cultivars the maximum number of pods was observed in RVS 2010-1 (71.66) followed by RSC 1030 (58.93), while minimum was observed in VLS 90 (12.33) followed by VLS 91 (12.60). In medium cultivars RSC 10-4 having highest (60.53) number of pods per plant at harvest stage followed by NRC 117 (47.93). Whereas, the minimum pods was observed in MACS 1488 (27.86) followed by AMS 1001 (31.00). In long cultivars the numbers of pods were high in JS 97-52 (c) (60.86) followed by RSC 10-29 (41.33). However, the minimum number of pods in DSb 29 (4.66) followed by TS 69 (7.40) at harvest stage. (fig-4). Pramila Rani and Ramaiah (1999) also suggested that plant height number of pod plant^{-1}, 100 seed weight, day to harvest and grain yield decreased in with delay in sowing. (fig-4)

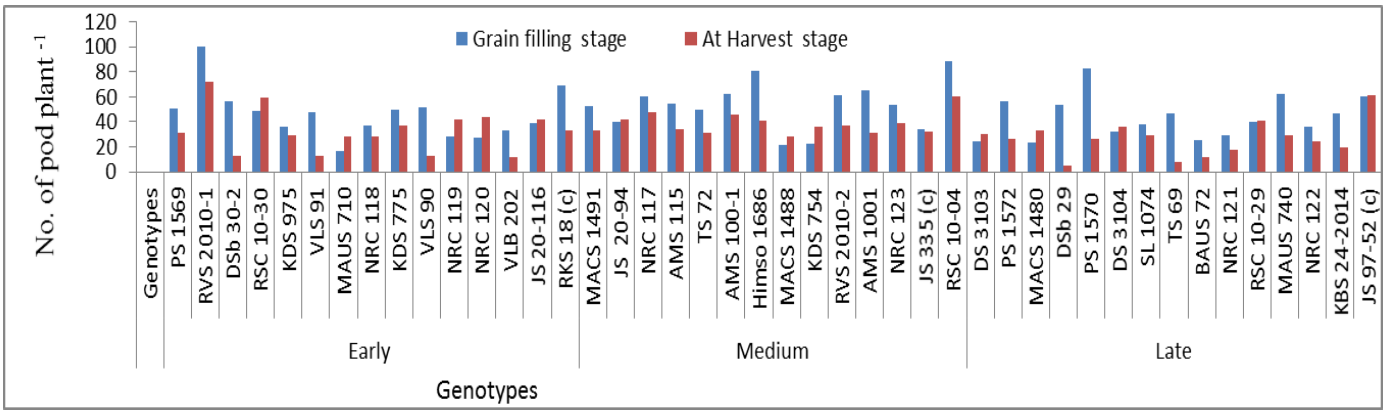

Fig 4: Variation in Number of pod plant^{-1} in soybean cultivars at various growth phases.

Pod bearing node plant^{-1}
Pod bearing node was calculated at flower initiation. The non significantly higher Pod bearing nod per plant was observed in medium duration cultivars at flowering stage 60 DAS in followed by late and then early duration cultivars. However, the pod bearing node per plant was maximum in grain filing stage 90 DAS in medium duration cultivars followed by long and then early duration cultivars. The average maximum pod bearing node per plant was achieved by VLB 202 (3.83) followed by RKS 18 (c) (3.72). The non significant lowest pod bearing node per plant was observed in VLS 91 (2.17) and NRC 118 (2.17) followed by KDS 775 (2.39). In medium duration cultivars TS 72 having non significantly maximum pod bearing node (4.50) followed by MACS 1491 (4.44). The minimum pod bearing node per plant was observed in JS 20-94 (2.22) followed by AMS 100-1 (2.28). In long duration cultivars BAUS 72 have higher pod bearing node per plant (4.66) followed by SL 1074 (3.55). The non significantly minimum pod bearingnode per plant was observed in cultivars NRC 121 (2.50) followed by DS 3103(2.66). (fig-5).

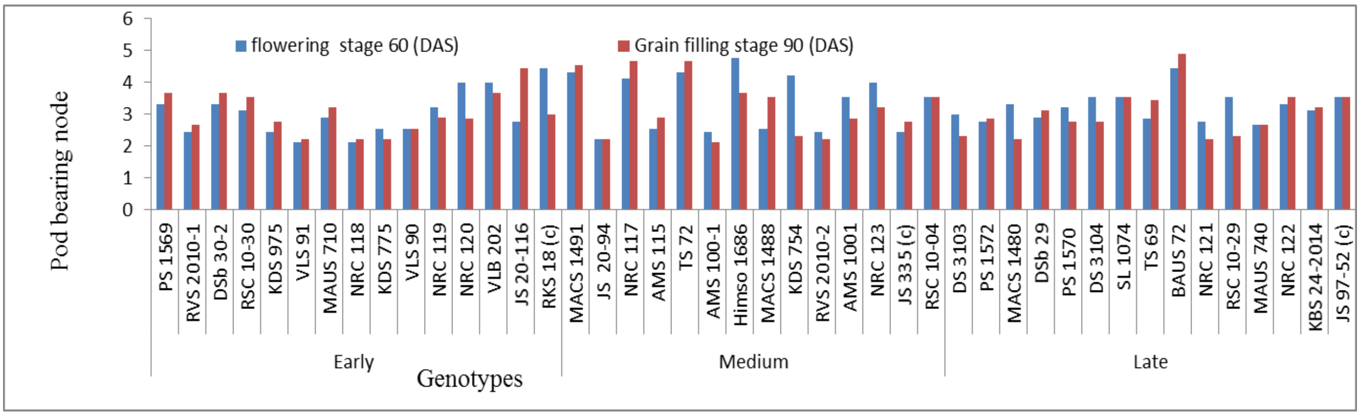

Fig 5: First Pod bearing nodes plant^{-1} in soybean cultivars at growth phases.

Seed Weight (g)
Seed weight is an important yield parameter and vary from genotype to genotype. The average 100 seed weight of long duration cultivars of soybean was recorded 10.60 g. followed by medium then late. In early duration cultivars KDS 775 having non significantly maximum test weight was (16.15) followed by NRC 119 (15.98). Whereas, lowest yield was obtained in PS1569 (7.26) followed by MAUS 710 (7.51). In medium duration cultivars RVS 2010-2 having non significantly maximum test weight was (13.90) observed followed by KDS 754 (12.43). Whereas lowest yield was obtained in PS 1569 (7.26) followed by MAUS 710 (7.51). In long duration cultivars NRC 121 having non significantly maximum test weight obtained in (19.08) followed by KDS 2014 (12.87). While, lowest yield was observed in SL 1074 (7.76). Taware *et al*. (1994), also reported the mean square verities and seasons were highly significant for days to flowering, days to maturity, plant height, pods per plant, 100 seed weight, oil content and seed yield.

Harvest Index
Harvest index reveals the efficiency of translocation of assimilates towards economic parts and therefore, harvest index and seed yield are closely related. Among early maturing genotypes, the genotype KDS 775 exhibited significantly maximum HI (44.82) followed by RSC 10-30 (43.96). The minimum HI was obtained in RVS 10-1(29.49) followed by VLB 202 (26.91). In medium group NRC 123 having significantly higher HI (51.32) and TS 72 have significantly minimum HI (32.88). However, in long duration cultivars PS 1570 have highest HI (38.14) followed by JS 97-52 (c) (37.46). Whereas, minimum HI was observed in MACS1480 (29.17) followed by DS 3103 (32.35). NirmalaKumari and Balasubramanian (1991) [20], mentioned that harvest indexhas high significant positive correlation with seed yield plant^{-1} followed by numberof primary branches plant^{-1}. The results indicated that harvest index influenced by sink capacity. It might be possible to isolate the cultivars with high dry matter production and harvest index for further improvement in grain yield. (fig-6).

Seed Yield (g/m^2)
Seed yield was measured at physical maturity in all the three duration cultivars. Early cultivars have taken 90 days and medium duration cultivars have taken 90-100 days for maturity and long duration cultivars have taken 101-115 days for maturity. The average yield was highest in medium duration cultivars (149.32) followed by early (133.33) and long duration (90.67) In early cultivars RVS 2010-1 having high yield (358.02) followed by KDS 975 (242.80). Whereas, VLS 90 having lowest yield 28.81 followed by VLB 202 (41.15), VLS 91 (45.27). Medium duration cultivars RSC 10-04 (378.60) having significantly higher yield followed by NRC 117 (255.14) and JS 20-94 (205.76). While MACS 1491 having significantly lowest yield (57.61) and TS 72 (57.61) followed by AMS 100-1 (76.13) and Himso1686 (78.17). In long duration cultivars JS 97-52 (c) having significantly higher seed yield (189.30) followed by RSC 10-29 (162.55) and MACS 1480 (162.14).Whereas, significantly lowest yield was obtained in BAUS 72 (32.92) followed by PS 1570 (37.04), NRC 121 (41.15), KBS 24-2014 (61.73) (fig-7). Saxena and Pandey (1970) reported that seed yield of soybean in highly association with number of pod plant^{-1}, 100 seed weight (test weight) and days taken from planting to maturity (duration of variety in soybean). (fig-7)

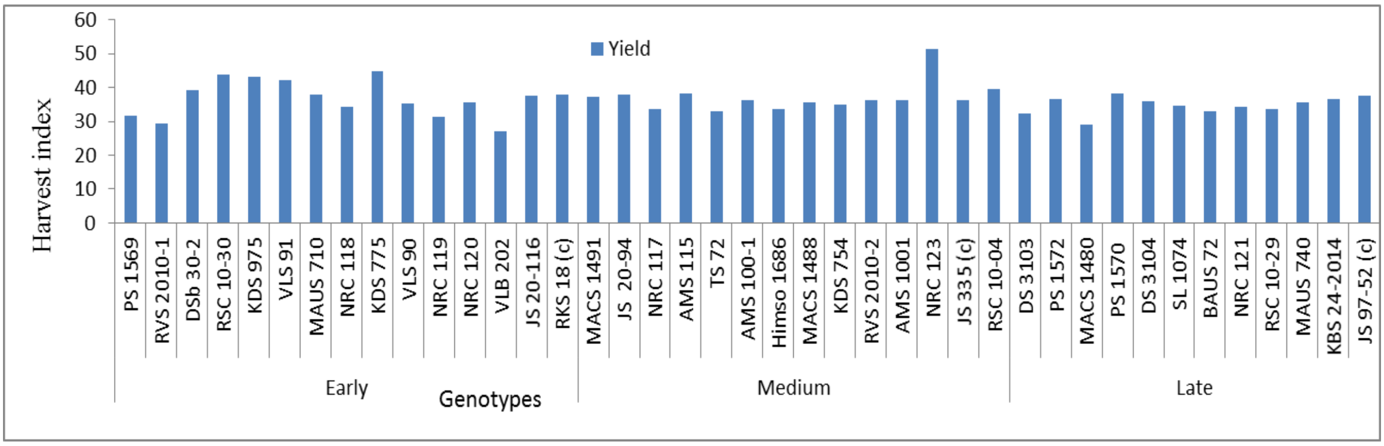

Fig 6: Harvest index (%) in soybean cultivars at maturity stage.

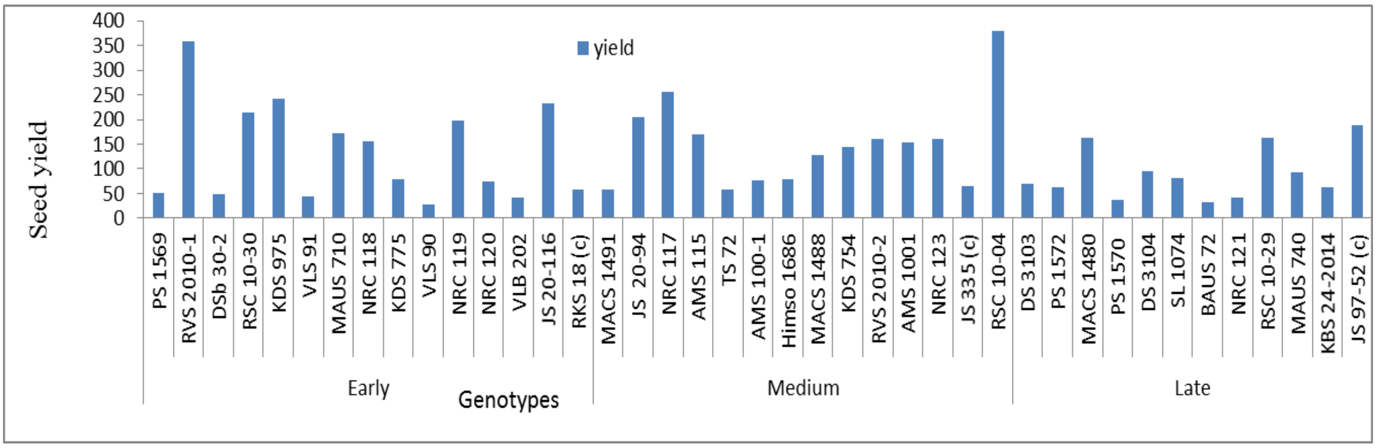

Fig 7: Seed yield g/m^2 in soybean cultivars at maturity stage

Correlation Study

The correlation studies indicated that the HI was highly and positively correlated with test weight, seed yield and plant height. Seed yield was also positively correlated with test weight, no. of pods plant^{-1}, no. of seed plant^{-1}. However, BY (biological yield) was highly negatively correlated with physiological maturity, chlorophyll SPAD value. The no. of seeds pod^{-1} was highly negatively associated with days to flower initiation. No. of seed plant^{-1}, was positively correlated with no. of leaves plant^{-1}, no. of branches plant^{-1} and no. of pod plant^{-1}.

The LAI was highly significant and positively correlated with LA, CGR of early group cultivars was highly significant and positively correlated with RGR (0.736), NAR (0.722), Biological yield (0.957) and negatively correlated with Harvest index (-0.633). However, Harvest index was negatively correlated with CGR, RGR, NAR and Biological yield. Biologicalyield was positively associated with CGR, RGR and NAR.

The LAI was highly significant and positively correlated with LA (0.999), CGR of medium group cultivars was highly significant and positively correlated with RGR (0.897), NAR (0.897) Biological yield (0.975) and negatively correlated with Test weight (-0.595). However, Biological yield was highly significant and positively correlated with CGR (0.975), RGR (0.781) and NAR (0.781). Test weight was negatively correlated with CGR, RGR, NAR and Biological yield.

Table 1: Correlation of growth parameters from (40-60 DAS) with yield parameters (early group of soybean cultivars).

	LA	LAI	CGR	RGR	NAR	BY	SY	TW	HI
LA	1								
LAI	0.999999**	1							
CGR	0.132202	0.132676	1						
RGR	-0.2015	-0.20104	0.736069**	1					
NAR	-0.20518	-0.20471	0.722411**	0.999194**	1				
BY	0.246511	0.246903	0.957103**	0.522212*	0.503317*	1			
SY	0.166985	0.167094	0.124764	-0.27887	-0.30352	0.310752	1		
TW	0.474636*	0.475006*	0.129311	-0.23222	-0.21868	0.203525	0.076165	1	
HI	-0.18549	-0.18567	-0.63388**	-0.61493**	-0.59721**	-0.59365**	-0.04028	0.192415	1

Early :- *= Significant at 5% df 0.441 **= Significant at 1% df 0.592

LA = Leaf area, LAI = Leaf area index, CGR = Crop growth rate, RGR = Relative growth rate, NAR = Net assimilation rate, BY = Biological yield, SY = Seed yield, TW = Test weight, HI = Harvest index

Table 2: Correlation of growth parameters from (40-60 DAS) with yield parameters (medium group of soybean cultivars).

	LA	LAI	CGR	RGR	NAR	BY	SY	TW	HI
LA	1								
LAI	0.999999**	1							
CGR	0.231218	0.23174	1						
RGR	0.071236	0.071823	0.897321**	1					
NAR	0.071236	0.071823	0.897321**	1	1				
BY	0.294877	0.295367	0.975099**	0.781862**	0.781862**	1			
SY	0.244937	0.245351	-0.29029	-0.3747	-0.3747	-0.20962	1		
TW	-0.34294	-0.34328	-0.59514**	-0.56362*	-0.56362*	-0.56413*	0.2034	1	
HI	-0.03138	-0.03094	-0.28504	-0.15554	-0.15554	-0.28651	0.240376	-0.0975	1

Medium :- *= Significant at 5% df 0.441 **= Significant at 1% df 0.592

LA = Leaf area, LAI = Leaf area index, CGR = Crop growth rate, RGR = Relative growth rate, NAR = Net assimilation rate, BY = Biological yield, SY = Seed yield, TW = Test weight, HI = Harvest index

The Leaf area was highly significant and positively correlated with leaf area (0.998), CGR of long group cultivars was significant and positively correlated with RGR (0.511), NAR (0.496) highly significant and positively correlated with Biological yield (0.959) and NAR was significant and positively correlated with CGR (0.496) RGR (0.990) and Test weight was correlated with Seed yield (0.488). However, Harvest index was found highly significant and positively correlated with Seed yield (0.591) and Test weight (0.816).

Table 3: Correlation of growth parameters from (40-60 DAS) with yield parameters (long group of soybean cultivars)

	LA	LAI	CGR	RGR	NAR	BY	SY	TW	HI
LA	1								
LAI	0.99817**	1							
CGR	-0.21964	-0.21992	1						
RGR	-0.28195	-0.29481	0.511296*	1					
NAR	-0.25469	-0.26938	0.496408*	0.990089**	1				
BY	-0.18103	-0.1746	0.959918**	0.271062	0.246164	1			
SY	-0.06981	-0.08937	0.359263	0.257305	0.290841	0.262716	1		
TW	0.133123	0.105549	-0.08567	-0.06188	-0.02261	-0.12568	0.488933*	1	
HI	0.195991	0.163434	-0.12224	0.104919	0.161725	-0.23054	0.591529*	0.816651**	1

Long :- *= Significant at 5% df 0.441 **= Significant at 1% df 0.592

LA = Leaf area, LAI = Leaf area index, CGR = Crop growth rate, RGR = Relative growth rate, NAR = Net assimilation rate, BY = Biological yield, SY = Seed yield, TW = Test weight, HI = Harvest index.

Therefore the cultivars KDS 775 (early), RSC 10-30 (early) NRC 123 (medium) and PS 1570 (long) have higher HI amongst their group KDS 775 also have high test weight. The cultivars RVS 2010-1 (early), KDS 975 (early), RSC 10-04 (medium), NRC 117 (medium), JS 20-94 (medium) and JS 97-52(c) (long) and RSC 10-29 (long) have significantly higher seed yield amongst their group. These cultivars have less flower drop, more sink realization and efficient photo assimilate partitioning towards economic sink.

Table 4: Correlation study of soybean cultivars of morpho-physiological & growth parameter with yield parameters

	PH	NL	NB	LA	DFI	DTF	PM	CHL	NPP^{-1}	$NSPL^{-1}$	Nspod-^{1}	PBN	TDW	SY	BY	TW	HI
PH	1																
NL	-0.223	1															
NB	-0.078	-0.035	1														
LA	0.282	-0.280	0.144	1													
DFI	-0.188	0.088	0.086	-0.008	1												
DTF	0.142	0.167	0.351*	-0.011	0.587**	1											
PM	-0.353*	-0.018	0.026	-0.086	0.427**	0.064	1										
CHL	0.075	0.103	-0.051	-0.203	-0.077	-0.051	0.134	1									
NPP^{-1}	0.145	0.246	0.445**	0.182	-0.030	0.269	-0.126	0.051	1								
$NSPL^{-1}$	0.197	0.297*	0.462**	0.223	-0.102	0.289	-0.159	0.068	0.931**	1							
$Nspod^{-1}$	0.104	0.176	0.230	-0.251	-0.389**	-0.029	-0.269	0.025	0.068	0.294	1						
PBN	0.100	-0.023	0.304*	0.161	0.000	0.192	0.096	-0.187	0.057	0.132	0.203	1					
TDW	0.158	-0.100	0.248	0.291	0.067	0.194	-0.082	-0.254	0.267	0.301*	-0.004	0.077	1				
SY	0.157	-0.137	0.117	0.233	-0.247	-0.039	-0.184	-0.041	0.463**	0.417**	0.067	-0.071	0.213	1			
BY	0.035	-0.144	0.054	0.219	-0.230	-0.235	-0.346*	-0.400**	0.214	0.220	0.154	0.020	0.517**	0.238	1		
TW	0.302*	-0.209	-0.197	0.197	-0.092	-0.071	-0.111	0.193	-0.030	-0.028	-0.141	-0.176	-0.054	0.305*	0.036	1	
HI	0.484**	-0.173	-0.195	0.172	-0.247	0.032	-0.170	0.118	0.023	0.053	-0.116	-0.150	0.030	0.370*	-0.072	0.690**	1

*= Singnificant at 5% df, **= Significant at 1% df

PH = Plant height, NL = No. of leaves, NB = No. of branches, LA = Leaf area, DFI = Days to flower initiation, DTF = Days to 50% flowering, PM = Physiological maturity, CHL = Chlorophyll value (SPAD), NPP^{-1} = No. of pod per plant, NSP^{-1} = No. of seed per plant, $NSPod^{-1}$ = No. of seed per pod, TDW = Total dry weight, SY = Seed yield, BY = Biological yield, TW = Test weight, HI = Harvest index.

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