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Correlation and path analysis studies for morpho-physiological parameters in soybean (*Glycine max* (L.) Merrill)

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Abstract
Morpho-physiological traits, if correlated with grain yield in soybean, can be used as indirect selection for yield. The path coefficient analysis helps to partition correlation coefficient into direct and indirect effects and can be used to supplement information on correlation coefficients. Days to 50% flowering, days to maturity were found to have negative but highly significant correlation with seed yield under variable photoperiod. Number of pods per plant (60 DAS & 90 DAS) and oil content exhibited positive and significant correlation with seed yield. In path analysis, dry matter, Leaf area (60 DAS) and relative growth rate (RGR) had positive and direct effect towards seed yield. However, direct and indirect effects of yield attributing traits on seed yield from vegetative to harvesting phase are presented in Table 23. 100 seed weight (g) exhibited positive but lowest direct effect towards seed yield. Days to maturity, biological yield (kg/plot), plant height (30 DAS) and harvest index recorded high and positive direct effects while rest of the characters recorded negative direct effect towards seed yield.

Keywords: Soybean, morpho-physiological traits, correlation, path analysis

Introduction
Cultivation of soybean in India was negligible in 1970s picked up recently. In India, during *kharif* 2019-20, area under soybean was 107.62 lakh ha, yield 836 kg/ha while production was 89.94 lakh MT. In Maharashtra, the area under soybean crop during *Kharif 2019*-20, was 37.37 lakh ha, with yield 971 kg/ha along with production of 36.30 lakh MT. In Marathwada region of Maharashtra state, the area under soybean crop was 17.99 lakh ha, with productivity of 855 kg/ha and production 16.2 lakh MT (SOPA, Databank 2019).
The soybean growth and development are affected due to environmental factors, temperature, photoperiod and planting date. Planting at appropriate time of a crop leads to optimum yield. Reduced yields consequent upon late plantings during vegetative and reproductive periods may results from shorter day lengths (Board and Settimi, 1986) and decreases the growth period from emergence to R5 (Fehr and Caviness, 1977) resulting in too less vegetative growth for optimum yield (Egli *et al*. 1987). On the other hand, genotype adaptability to a specific region influences soybean physiology which affected by growth habit and planting date (Pedersen and Lauer, 2004). Early planting of soybean genotypes results in more nodes and a greater number of pods, higher seed weight (Woong and Takeo, 2006; Boquet and Clawson, 2007). Considering the constraints in the production of potential of a soybean, it is worthy to study the influence of different photoperiod condition on the production potential of soybean. It is also utmost important to understand the physiological basis of yield variation due to changes in photoperiod condition, since a simple description growth and yield without the context of growing condition is inadequate. The present knowledge of the physiology of yield and inter- relationship of source-sink and physiological characters with the environment is meager.
Most of the soybean genotypes are sensitive to photoperiod and different maturity groups are expected to have differential response to photoperiod. It is also utmost important to understand the physiological basis of yield variations due to changes in photoperiod conditions.
Morpho-physiological traits, if correlated with grain yield in soybean, can be used as indirect selection for yield. The path coefficient analysis helps to partition correlation coefficient into direct and indirect effects (Saleem *et al*. 1999) [1] and can be used to supplement information on correlation coefficients. The correlation of yield with yield components and morphological traits has been studied extensively and used as a tool to improve seed yield of soybean (Mallik

et al. 2006) [2]. But correlations among different characters can vary under different environments.

In this context the present investigation was undertaken to study correlation of seed yield with morpho-physiological traits in advanced breeding lines of soybean during post-rainy season.

Materials and Methods

The experimental materials comprised of 75 soybean breeding lines (F7) (Table 1) derived from four different crosses along with five checks *viz*; MAUS 162, MAUS 612, JS 93-05, JS 95-60, JS 97-52 and one parent i.e., AGS 25. These breeding lines were developed at Indian Institute of Soybean Research, Indore. Material was sown in randomised block design with two replication following 45 X 5 cm spacing. The experiment was conducted at AICRP on Soybean, VNMKV, Parbhani during post rainy season of 2018 on medium black clay type of soil. The crop was raised following all the agronomical practices recommended for soybean. All the statistical analysis were carried out using R-package and AGRISTAT software (R Core Team, 2020; Manivannan, N.2014) [5, 4].

Table 1: Details of breeding lines used in this experiment

SN.	Genotypes	SN	Genotype	SN	Genotype
1	49 GH 58-1	31	416-25-119	61	51-8-64
2	49 GH 4/2	32	416-25-93	62	51 PB-48/2
3	49 PB -69/1	33	416-25-73	63	51 PB-39/3
4	49 PB -109	34	416-25-65	64	51 PB-39/1
5	49 GH 98	35	416-25-12	65	51PB-2
6	49 GH 41	36	416-25-A	66	51-8-29
7	49 GH -106	37	416-25-89	67	51PB-35/4
8	49 PB -5	38	416-25-120	68	51-W-12
9	49 GH -23	39	416-25-7	69	51PB-111/1
10	49 PB-6(1)LJ	40	416-25-103	70	51PB-1
11	49 PB-124/3	41	C 75-5	71	51PB-66/1
12	49 PB-124/2	42	C 75-50	72	51PB-12/2
13	49 PB124/1	43	C 75-1	73	51 W 36
14	49 PB-6/2	44	C 75-32	74	51PB48/1
15	49 GH-69/3	45	C 75-67	75	51PB- 3/1
16	49 GH-194/2	46	C 75-54	76	JS 93-05 (C)
17	49GH-101/1	47	C 75-53	77	JS 95-60 (C)
18	49 PB-4/2	48	C 75-80	78	JS 97-52 (C)
19	49 PB-69/2	49	C 75-26	79	MAUS 162 (C)
20	49 GH192/2	50	C 75-48	80	MAUS 612 (C)
21	416-25-5	51	C 75-43	81	AGS 25 (C)
22	416-25-2	52	C 75-8		
23	416-25-74	53	C 75-44		
24	416-25-112	54	C 75-65		
25	416-25-57	55	C 75-35		
26	416-25-33	56	C 75-27		
27	416-25-20	57	C 75-58		
28	416-25-122	58	C 75-22		
29	416-25-56	59	C 75-23		
30	416-25-49	60	C 75-49		

Table 2: Monthly Average Photoperiod/Day-length (hrs.) at AICRP on Soybean, VNMKV, Parbhani

Month	Sunrise (AM)	Sunset (PM)	Day Length (hrs)
October – 18	6:30	6:05	11:35
November – 18	6:33	5:55	11:27
December – 18	6:38	5:40	11:02

Results

The data on Pearson's correlation between seed yield and morpho-physiological traits are presented for post rainy season in Figure 4.3 and 4.4. Seed yield (kg/plot) had highly significant and positive correlation with dry matter (30 DAS) and relative growth rate (RGR-60DAS). However, it had positive significant correlation with dry matter (60 DAS), dry matter (90 DAS), leaf area (30 DAS), absolute growth rate (AGR), net assimilation rate (NAR – 30 DAS & 90 DAS). While, rest of the characters possessed non-significant association with seed yield.

Seed yield (kg/plot) had highly significant and negative correlation with days to 50% flowering and days to maturity. However, seed yield possessed positive and highly significant correlation with number of pods per plant and biological yield (kg/plot) and harvest index. The direct and indirect effects of morpho-physiological traits on seed yield from vegetative to harvesting phase are presented in Table 4.18. Dry matter, Leaf area (60 DAS) and relative growth rate (RGR) had positive and direct effect towards seed yield. However, direct and indirect effects of yield attributing traits on seed yield from vegetative to harvesting phase are presented in Table 4.19. 100 seed weight (g) exhibited positive but lowest direct effect towards seed yield. Days to maturity, biological yield (kg/plot), plant height (30 DAS) and harvest index recorded high and positive direct effects while rest of the characters recorded negative direct effect towards seed yield.

Discussion

In post rainy season, seed yield (kg/plot) had highly significant and positive correlation with dry matter (30 DAS) and relative growth rate (RGR-60DAS). However, it had positive significant correlation with dry matter (60 DAS), dry matter (90 DAS), leaf area (30 DAS), absolute growth rate (AGR), net assimilation rate (NAR – 30 DAS & 90 DAS). While, rest of the characters possessed non-significant association with seed yield. However, seed yield (kg/plot) had highly significant and negative correlation with days to 50% flowering and days to maturity. However, seed yield possessed positive and highly significant correlation with number of pods per plant and biological yield (kg/plot) and harvest index (Shree *et al*., 2017) [9].

Days to 50% flowering, days to maturity were found to have negative but highly significant correlation with seed yield under variable photoperiod. Number of pods per plant (60 DAS & 90 DAS) and oil content exhibited positive and significant correlation with seed yield. However, considering direct and indirect effects under variable seasons, the morpho-physiological traits *viz;* dry matter (g), absolute growth rate, relative growth rate and net assimilation rate while seed yield and its components *viz;* days to 50% flowering, days to maturity, number of pods per plant and oil content may be considered for improvement of soybean (Kothule *et al*., 2003; Baig *et al*., 2017) [6, 8].

In path analysis, dry matter, Leaf area (60 DAS) and relative growth rate (RGR) had positive and direct effect towards seed yield. However, direct and indirect effects of yield attributing traits on seed yield from vegetative to harvesting phase are presented in Table 23. 100 seed weight (g) exhibited positive but lowest direct effect towards seed yield. Days to maturity, biological yield (kg/plot), plant height (30 DAS) and harvest index recorded high and positive direct effects while rest of the characters recorded negative direct effect towards seed yield (Kothule *et al*., 2003; Baig *et al*., 2017) [6, 8].

Table 3: Pearson's Correlation (Post-rainy season) of seed yield with morpho- physiological traits from vegetative to harvesting stage

Traits	Dry Matter 30	Dry Matter 60	Dry Matter 90	Leaf Area 30	Leaf Area 60	Leaf Area 90	AGR 30	AGR 60	AGR 90	RGR 30	RGR 60	RGR 90	NAR 30	NAR 60	NAR 90	SYP
Dry Matter 30		0.386***	0.249*	0.216	0.088	-0.157	0.981***	0.314**	0.162	0.994***	0.197	0.046	0.976***	0.247*	0.144	0.287***
Dry Matter 60	0.386***		0.528***	0.115	0.013	-0.066	0.388***	0.993***	-0.077	0.391***	0.928***	-0.397***	0.363***	0.953***	-0.098	0.26*
Dry Matter 90	0.249*	0.528***		-0.072	-0.063	0.004	0.25*	0.507***	0.557***	0.27*	0.463***	0.325**	0.263*	0.509***	0.53***	0.23*
Leaf Area 30	0.216	0.115	-0.072		0.753***	0.251*	0.19	0.117	0.061	0.189	0.163	-0.014	0.014	-0.088	-0.091	0.008
Leaf Area 60	0.088	0.013	-0.063	0.753***		0.33**	0.051	0.004	-0.044	0.069	0.033	-0.093	-0.077	-0.217	-0.191	0.008
Leaf Area 90	-0.157	-0.066	0.004	0.251*	0.33**		-0.166	-0.08	-0.077	-0.178	-0.07	-0.091	-0.215	-0.128	-0.277	-0.136
AGR 30	0.981***	0.388***	0.25*	0.19	0.051	-0.166		0.322**	0.169	0.973***	0.219*	0.045	0.963***	0.259*	0.157	0.281
AGR 60	0.314**	0.993***	0.507***	0.117	0.004	-0.08	0.322**		-0.099	0.316***	0.962***	-0.419***	0.288**	0.959***	-0.116	0.274*
AGR 90	0.162	-0.077	0.557***	0.061	-0.044	-0.077	0.169	-0.099		0.181	-0.107	0.922***	0.155	-0.107	0.968***	0.234*
RGR 30	0.994***	0.391***	0.27*	0.189	0.069	-0.178	0.973***	0.316***	0.181		0.19	0.066	0.976***	0.256*	0.17	0.275*
RGR 60	0.197	0.928***	0.463***	0.163	0.033	-0.07	0.219*	0.962***	-0.107	0.19		-0.428***	0.161	0.894***	-0.122	0.32**
RGR 90	0.046	-0.397***	0.325**	-0.014	-0.093	-0.091	0.045	-0.419***	0.922***	0.066	-0.428***		0.055	-0.39***	0.914***	0.136
NAR 30	0.976***	0.363***	0.263*	0.014	-0.077	-0.215	0.963***	0.288**	0.155	0.976***	0.161	0.055		0.264*	0.17	0.244*
NAR 60	0.247*	0.953***	0.509***	-0.088	-0.217	-0.128	0.259*	0.959***	-0.107	0.256*	0.894***	-0.39***	0.264*		-0.095	0.208
NAR 90	0.144	-0.098	0.53***	-0.091	-0.191	-0.277	0.157	-0.116	0.968***	0.17	-0.122	0.914***	0.17	-0.095		0.231*
SYP	0.287***	0.26*	0.23*	0.008	0.008	-0.136	0.281	0.274*	0.234*	0.275*	0.32**	0.136	0.244*	0.208	0.231*	

Note: *, ** indicates the correlation significant at 0.05 and 0.01 probability level.

AGR 30 = Absolute growth rate after 30 days of sowing, AGR 60 = Absolute growth rate after 45 days of sowing, AGR 90 = Absolute growth rate after 90 days of sowing, RGR 30 = Relative growth rate after 30 days of sowing, RGR 60 = Relative growth rate after 60 days of sowing, RGR 90 = Relative growth rate after 90 days of sowing, NAR 30 = Net assimilation rate after 30 days of sowing, NAR 60 = Net assimilation rate after 60 days of sowing, NAR 90 = Net assimilation rate after 90 days of sowing, SYP = Seed yield (kg/plot)

Table 4: Direct and indirect effects of morpho-physiological traits on seed yield from vegetative to harvesting phase (Post-rainy season)

Traits	DM 30	DM 60	DM 90	LA 30	LA 60	LA 90	AGR 30	AGR 60	AGR 90	RGR 30	RGR 60	RGR 90	NAR 30	NAR 60	NAR 90	SYP
DM 30	3.788	0.151	0.086	-0.046	0.003	-0.003	-4.510	0.064	0.069	0.822	0.034	-0.163	-0.152	-0.203	0.029	0.290*
DM 60	1.256	0.456	0.264	0.014	-0.002	0.000	-1.499	0.253	0.187	0.280	0.138	-0.431	-0.067	-0.905	0.050	0.255*
DM 90	0.780	0.287	0.420	0.022	-0.002	-0.003	-0.926	0.159	-0.289	0.170	0.089	-0.053	-0.045	-0.566	-0.050	0.236*
LA 30	0.386	-0.014	-0.021	-0.452	0.036	-0.021	-0.467	-0.013	0.004	0.071	-0.004	-0.004	0.173	0.242	0.073	-0.034
LA 60	0.286	-0.022	-0.020	-0.451	0.036	-0.020	-0.349	-0.016	-0.010	0.046	-0.005	0.013	0.177	0.257	0.066	-0.022
LA 90	0.494	0.005	0.055	-0.385	0.029	-0.024	-0.594	-0.004	-0.062	0.101	0.002	0.001	0.145	0.175	0.073	0.046
AGR 30	3.788	0.152	0.086	-0.047	0.003	-0.003	-4.510	0.064	0.071	0.822	0.034	-0.164	-0.152	-0.203	0.030	0.294*
AGR 60	0.949	0.453	0.262	0.023	-0.002	0.000	-1.134	0.255	0.189	0.213	0.140	-0.431	-0.057	-0.915	0.048	0.266*
AGR 90	-0.397	-0.129	0.184	0.003	0.001	-0.002	0.482	-0.073	-0.659	-0.092	-0.037	0.576	0.022	0.266	-0.144	-0.105
RGR 30	3.787	0.155	0.087	-0.039	0.002	-0.003	-4.508	0.066	0.074	0.823	0.036	-0.169	-0.154	-0.214	0.029	0.289*
RGR 60	0.928	0.453	0.270	0.011	-0.001	0.000	-1.105	0.257	0.176	0.211	0.139	-0.432	-0.050	-0.912	0.047	0.310**
RGR 90	-0.914	-0.291	-0.033	0.003	0.001	0.000	1.095	-0.163	-0.561	-0.206	-0.089	0.676	0.045	0.575	-0.132	-0.257*
NAR 30	2.365	0.125	0.078	0.320	-0.027	0.014	-2.812	0.059	0.061	0.522	0.029	-0.126	-0.244	-0.348	-0.035	0.249*
NAR 60	0.818	0.440	0.254	0.117	-0.010	0.005	-0.977	0.249	0.187	0.188	0.135	-0.414	-0.091	-0.938	0.033	0.251*
NAR 90	-0.655	-0.134	0.125	0.195	-0.014	0.011	0.792	-0.073	-0.561	-0.143	-0.038	0.527	-0.051	0.184	-0.169	-0.116

R = -0.033

Note: *, ** indicates the correlation significant at 0.05 and 0.01 probability level.

AGR 30 = Absolute growth rate after 30 days of sowing, AGR 60 = Absolute growth rate after 45 days of sowing, AGR 90 = Absolute growth rate after 90 days of sowing, RGR 30 = Relative growth rate after 30 days of sowing, RGR 60 = Relative growth rate after 60 days of sowing, RGR 90 = Relative growth rate after 90 days of sowing, NAR 30 = Net assimilation rate after 30 days of sowing, NAR 60 = Net assimilation rate after 60 days of sowing, NAR 90 = Net assimilation rate after 90 days of sowing, SYP = Seed yield (kg/plot)

Table 5: Pearson's Correlation (Post-rainy) of seed yield with its component traits from vegetative to harvesting stage

Traits	Days to 50% flowering	Days to Maturity	PH 30	PH 60	PH 90	Pods 90	V100 SW	BYP	HI	SYP
Days to 50% flowering		1***	-0.016	-0.262*	0.018	-0.166	-0.161	-0.283*	-0.119	-0.307**
Days to Maturity	1***		-0.016	-0.262*	0.018	-0.166	-0.161	-0.283*	-0.119	-0.307**
PH 30	-0.016	-0.016		0.356***	0.381***	0.216	0.001	-0.074	0.068	-0.046
PH 60	-0.262*	-0.262*	0.356***		0.295***	0.048	-0.021	0.096	0.07	0.111
PH 90	0.018	0.018	0.381***	0.295**		0.032	-0.195	-0.033	0.016	-0.027
Pods 90	-0.166	-0.166	0.216	0.048	0.032		0.255*	0.573***	0.124	0.59***
V100 SW	-0.161	-0.161	0.001	-0.021	-0.195	0.255*		0.206	-0.046	0.176
BYP	-0.283*	-0.283*	-0.074	0.096	-0.033	0.573***	0.206		-0.039	0.912***
HI	-0.119	-0.119	0.068	0.07	0.016	0.124	-0.046	-0.039		0.364***
SYP	-0.307*	-0.307*	-0.046	0.111	-0.027	0.59***	0.176	0.912***	0.364***	

Note: *, ** indicates the correlation significant at 0.05 and 0.01 probability level.

PH 30 = Plant height after 30 days of sowing, PH 60 = Plant height after 60 days of sowing, PH 90 = Plant height after 90 days of sowing, Pods 90 = Number of Pods per plant after 90 days of sowing, BYP = Biological Yield, HI = Harvest Index, 100 SW = 100 seed weight, SYP = Seed Yield (Kg/plot)

Table 6: Direct and indirect effects of yield attributing traits on seed yield from vegetative to harvesting phase (Post-rainy season)

Traits	DF	DM	PH 30	PH 60	PH 90	Pods 90	BYP	HI	100 SW	SYP
DF	-0.1303	0.1422	-0.0002	0.0020	0.0011	-0.0006	-0.2889	-0.0569	-0.0022	-0.3434**
DM	-0.1303	0.1422	-0.0002	0.0020	0.0010	-0.0006	-0.2892	-0.0554	-0.0022	-0.3422**
PH 30	0.0019	-0.0017	0.0135	-0.0032	-0.0098	0.0007	-0.0683	0.0199	0.0000	-0.0486
PH 60	0.0326	-0.0359	0.0054	-0.0079	-0.0098	0.0004	0.1379	0.0535	0.0001	0.1874
PH 90	0.0065	-0.0065	0.0063	-0.0037	-0.0213	0.0002	0.0360	0.0276	-0.0017	0.0553
Pods 90	0.0286	-0.0312	0.0033	-0.0012	-0.0015	0.0029	0.5735	0.0582	0.0032	0.6486**
BYP	0.0410	-0.0447	-0.0010	-0.0012	-0.0008	0.0018	0.9188	-0.0001	0.0023	0.9317**
HI	0.0207	-0.0219	0.0008	-0.0012	-0.0016	0.0005	-0.0003	0.3590	-0.0012	0.3595**
100 SW	0.0274	-0.0298	0.0000	-0.0001	0.0035	0.0009	0.2102	-0.0431	0.0103	0.1767

R = 0.449

Note: *, ** indicates the correlation significant at 0.05 and 0.01 probability level.

DF = Days to 50% flowering, DM = Days to maturity, PH 30 = Plant height after 30 days of sowing, PH 60 = Plant height after 60 days of sowing, PH 90 = Plant height after 90 days of sowing, Pods 90 = Number of Pods per plant after 90 days of sowing, BYP = Biological Yield, HI = Harvest Index, 100 SW = 100 seed weight, SYP = Seed Yield (Kg/plot).

Conclusion

It can be concluded that for selection of better genotypes under variable season, the following important characters *viz;* dry matter, absolute growth rate, relative growth rate, net assimilation rate, leaf area, days to 50% flowering, days to maturity, harvest index, biological yield may be considered since, these parameters were found to have significantly correlated with seed yield. Of the evaluated 81 genotypes (75 + 5 checks + 1 parent) it is found that genotypes *viz;* 49P-124/3, 51-8-64, 51-8-29, 51-PB-111/1, 51-PB-66/1, 51-PB-48/1, 51-PB-3/1, C75-50, C75-1, C75-32, C75-43, C75-8, C75-44, C75-58, 416-25-89 and 416-25-7 are superior in terms of seed yield.

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