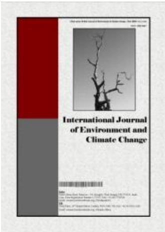

International Journal of Environment and Climate Change

11(12): 44-51, 2021; Article no.IJECC.78067
ISSN: 2581-8627
(Past name: British Journal of Environment & Climate Change, Past ISSN: 2231–4784)

Assesement of Correlation and Path Analyses for Yield and its Componant Traits in Soybean [(*Glycine max* (L.) Merrill]

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJECC/2021/v11i1230555
Editor(s):
(1) Dr. Arjun B. Chhetri, Dalhousie University, Canada.
Reviewers:
(1) Fatemeh Ahmadnia, University of Mohaghegh Ardabili, Iran.
(2) Daisy Leticia Ramirez Monzón, Paraguay.
Complete Peer review History, details of the editor(s), Reviewers and additional Reviewers are available here: https://www.sdiarticle5.com/review-history/78067

Original Research Article

Received 03 October 2021
Accepted 07 December 2021
Published 13 December 2021

ABSTRACT

A study was conducted with an aim to understand character association and cause-effect relationship in Randomized Complete Block Design accommodating 30 genotypes randomly in three replicates. These genotypes evaluated for twenty-seven traits: five phenological, nine agro-morphological, eight physiological traits (from field trial) and five physiological traits (from laboratory experiment) recorded and subjected to statistical and biometrical analyses. Positive association of flowering traits (days to tubercles formation→ days to flower budding→ days to first flowering→ days to cessation) and uncorrelated with days to physiological maturity can be precisely utilized in selection. Late physiological maturity increases seedling dry weight, plant height, clusters and seeds per pod while reduces leaf area index, seed weight and dry matter efficiency. With an increase in primary branches corresponding more secondary branches, cluster/plant, seed weight and effective rainfall use efficiency noticed. Effective rainfall use efficiency positively correlated with primary branches, secondary branches, clusters/plant, germination relative index, seedling length, harvest index. Towards polygenic complex trait seed yield per plant had high positive correlation and highest positive direct effect of effective rainfall use efficiency and vigor index I considered as selection criteria.

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Keywords: Germination; soybean; yielding potential; legumes.

1. INTRODUCTION

Golden bean and miracle crop are most commonly used synonym for soybean. Although it had 40% quality protein (glycine, tryptophan and lysine) and comparatively lesser quantity of (20%) quality oil, it mainly popular as oilseed crop rather than a pulse crop because of its extraordinary oil qualities: no cholesterol, essential heart friendly omega-3 fats etc. It belongs to genus *Glycine*, species *max*, family Leguminosae, sub-family papilinoidae and tribe Phaseoleae. *Glycine* is derived from the Greek word *glykus* which means sweet [1]. The sub genus *Glycine* consists of several (about 22) wild perennial species. Both the species *Glycine max* and *Glycine soja* hybridize readily. Glycine max (diploid) and Glycine soja (diploid), chromosome number 2n=40.

The productivity of soybean is quite low in our country as compare to top soybean producing countries of the world which indicate a considerable scope to enhance yielding potential. However, direct selection for yield alone is usually not very effective or may often be misleading. Hence, selection based on its component character could be more efficient [2,3]. To know contribution of each component traits towards yield, association studies should be conducted. Further path analysis can reveal whether this association is direct from particular trait or indirect through any other component trait(s). So, association and path analysis study of component traits of interest can provide wider understanding towards soybean genetic improvement.

Therefore, present work is one such effort to study association and cause-effect relationship among 27 different characters, as this provides wider scope for selection which is the basic requisite for every crop improvement.

2. MATERIALS AND METHODS

The experiment was carried out during *kharif* , 2019 at the farm of Tirhut College of Agriculture, Dholi (25.5^{0}N, 35.4^{0}S and 52.2m MSL) in Muzaffarpur District (North Bihar) located in eco-geographical region I Sub region IV of Bihar. Thirty entries (including 3 checks) were sown in Randomized Complete Block Design. Each plot consisted three rows of 3meter length. The row to row and plant to plant distance was 45cm and 5cm, respectively. Trial laid out for 27 (22 field and 5 laboratory screening) morpho-physiological traits viz., germination relative index [(%), germinator machine was used and on 13th day the percentage of germination was observed], seedling length (cm), seedling dry weight [(g), electric oven used at 100^{0}C for ten minutes and later at 70^{0}C upto a constant weight], vigor index I [multiple of germination percent and seedling length (cm)], vigor index II [multiple of germination percent and seedling dry weight (g)], formation of flower tubercles (days), flower budding (days), first flowering (days), cessation of flower (days), physiological maturity (days), plant height (cm), main shoot length (cm), primary branches plant^{-1}, secondary branches plant^{-1}, no of clusters plant^{-1}, no of pods cluster^{-1},no of pods plant^{-1}, pod length(cm), no of seeds pod^{-1}, growing degree days(°c), specific leaf weight [(g/cm^2),weighing balance was used to measure leaf dry weight], leaf area index(planimeter was used to measure leaf area), 100-seed weight (g), harvest-index (%), dry matter efficiency(grain yield, straw yield and crop duration was used in calculation), effective rainfall use efficiency (grain yield and effective rainfall data during cropping season was used in calculation), seed yield plant-1 (g). Data for individual characters observed, replication-wise and mean data was used for statistical analyses.

Correlation coefficient were calculated as per Al-jibouri *et al*, [4] and path coefficient analysis were calculated as per Dewey & Lu, [5].

3. RESULTS AND DISCUSSION

3.1 Correlation Coefficient

The result (Table 1) regarding genotypic, phenotypic correlation coefficient showed that, due to influence of environment, mostly the reduced magnitude of phenotypic correlation coefficients observed; although few pairs of traits: Primary branches-Secondary branches, Primary branches-Effective rainfall use efficiency, Dry matter efficiency-Harvest index, Seed yield per plant-Primary branches, Secondary branches-Effective rainfall use efficiency, environment favored resulting in higher magnitude of phenotypic correlation coefficients.

Association studies revealed that, traits related to flowering namely, Days to tubercles formation, Days to flower budding, Days to first flowering, Days to cessation were phenologically in sequence and change accordingly in positive/negative- highly significant/ significant association. Means, with increase or decrease corresponding increase or decrease, in flowering attributes, in the same direction is registered. Interestingly, all these flowering traits exhibited unassociated response with days to physiological maturity; as such it can be modified, independently, without influencing flowering traits.

Physiological maturity, which is very important trait related to adoption of any crop variety fitting well in crop sequences, expressed positive highly significant correlation with plant height, secondary branches per plant, cluster per plant, seed per pod, leaf area index and seed weight. This clearly indicated that by increased physiological maturity duration corresponding increased plant height, secondary branches per plant, cluster per plant, seed per pod, leaf area index and seed weight can be achieved. Contrastingly, dry matter efficiency *i.e.,* per day production of genotype(s) expected to reduce due to negative association.

Taller plant height increases main stem length (Positive significant association), but significantly decreases dry matter efficiency and growing degree days.

Effective rainfall use efficiency reflected its importance towards soybean yielding ability, as it was positive and highly significantly associated with grain yield per plant; along with both branching attributes (primary branches per plant and secondary branches per plant), clusters per plant, seedling length and vigor index-I.

Positive, highly significant association of both branching attributes (primary branches per plant and secondary branches per plant) with grain yield per plant; along with positive, significant association of primary branches per plant with seven morpho-physiological traits like secondary branches per plant, clusters per plant, leaf area index, seed weight, effective rainfall use efficiency. This indicated scope of increasing primary branches per plant for increasing secondary branches per plant, clusters per plant, leaf area index, seed weight and effective rainfall use efficiency; whereas secondary branches per plant had Positive, highly significant association with clusters per plant and effective rainfall use efficiency, thus reflected importance of both branching traits towards grain yield per plant.

Clusters per plant, vigor index-I and Seedling length had highly significant positive correlation with grain yield per plant also exhibited similar association with pods per plant, effective rainfall use efficiency (with clusters per plant); with germination, seedling length and effective rainfall use efficiency (with vigor index-I); effective rainfall use efficiency and vigor index-I with seedling length.

Rest of the character pairs indicated weak inter-relationship or un-correlated response with grain yield per plant or between other traits like flowering traits with days to physiological maturity.

Effective rainfall use efficiency, vigor index-I, seedling length, primary and secondary branches and clusters per plant indicated their importance and desirability towards main goal, the yielding ability; as the genotypes with more seedling length, high effective rainfall use efficiency, more primary and secondary branches and clusters per plant may contribute towards high yielding soybean cultivar development.

In accordance with the above findings in soybean, Significant positive correlation with seed yield per plant have also been reported by Aditya *et al*. [6] and Patil *et al*., [7] (with primary branches per plant); by Koraddi *et al*.,[8] and Mili *et al*.,[9] (with number of branches per plant); by Aditya *et al*. 2011, Koraddi *et al*. ,[8]; and Mili *et al*.,[9] (with number of pods per plant).

3.2 Path Coefficient

Phenotypic path coefficient analysis (Table 2) of different morpho-physiological and yield traits on seed yield per plant revealed that effective rainfall use efficiency had highest positive direct effect followed by vigor index-I and dry matter efficiency which reflected high to moderate positive direct effect towards grain yield per plant. Effective rainfall use efficiency, besides its very high direct effect and highly significant positive correlation with grain yield per plant; had also helped primary branches per plant, seeds per pod and clusters per plant in building –up their positive, significant association with grain yield per plant.

Table 1. Phenotypic and genotypic correlation coefficient for yield and 27 morpho-physiological characters in soybean [*Glycine max* (L.) Merrill]

		DT	DFB	DFF	DC	DPM	PH	MSL	PB	SB	C/ P	P/ C	P/ P	PL	S/ P	GDD	SLW	LAI	SW	HI	DME	ERUE	GER	SL	SDW	V1	V2	GYPP
DT	P	1	0.4656**	0.4254*	0.5567**	0.0896	-0.0453	0.2662	-0.1867	0.0161	-0.0086	-0.0211	-0.2403	-0.1075	-0.1335	-0.0738	-0.06	-0.2068	-0.3592	0.1068	0.0265	-0.1112	-0.1289	-0.1015	-0.2888	-0.161	-0.2868	-0.234
	G		0.6097	0.517	0.6291	0.0785	-0.0405	0.3005	-0.2235	0.1032	-0.0291	-0.103	-0.3266	-0.0644	-0.1983	-0.0642	-0.0536	-0.3278	-0.4044	0.1845	0.0822	-0.1137	-0.112	-0.1383	-0.3415	-0.2014	-0.335	-0.281
DFB	P		1	0.7501**	0.6684**	0.2618	0.3282	0.5371**	0.1069	0.1469	0.4250*	-0.1787	0.1701	-0.3075	-0.2350	-0.2625	0.0371	-0.0257	-0.2067	-0.0403	-0.1934	0.1209	-0.0972	0.1237	-0.0365	0.0666	-0.0567	0.056
	G			0.8319	0.7283	0.2893	0.3885	0.6083	0.2112	0.2584	0.5022	-0.2004	0.2373	-0.3886	-0.3114	-0.2858	0.0268	0.016	-0.2217	-0.0394	-0.2162	0.1873	-0.1486	0.1213	-0.0485	0.0267	-0.0766	0.101
DFF	P			1	0.6630**	0.1395	0.2170	0.5504**	0.0463	-0.1272	0.3037	-0.2610	0.0062	-0.2936	-0.2697	-0.1387	0.1945	-0.1084	-0.2256	0.0112	-0.0916	0.0967	-0.1395	0.1392	0.0104	0.0752	-0.0407	0.031
	G				0.7518	0.1443	0.2053	0.5889	0.0837	-0.1702	0.3721	-0.2727	0.1268	-0.332	-0.3331	-0.1402	0.2102	-0.1724	-0.2408	-0.0221	-0.1206	0.1443	-0.1815	0.1922	0.011	0.0883	-0.0454	0.055
DC	P				1	-0.0247	0.0558	0.2874	-0.0075	-0.0983	0.1855	-0.0441	0.1102	-0.3693*	-0.3085	0.0242	0.2037	-0.1847	-0.2320	0.0693	0.0617	0.064	-0.0757	-0.0176	0.0218	-0.0503	-0.0097	-0.007
	G					-0.0292	0.0552	0.32	-0.0244	-0.1532	0.2152	-0.0758	0.09	-0.3963	-0.3296	0.0294	0.2301	-0.2458	-0.2367	0.0973	0.0811	0.0525	-0.0835	-0.0095	0.0289	-0.0558	-0.005	-0.038
DPM	P					1	0.4003*	0.139	0.2806	0.3998*	0.5510**	-0.1639	0.2527	-0.2138	0.3668*	-0.9978**	0.0494	0.4301*	0.4866**	-0.061	-0.6737**	0.3112	0.1829	0.3138	-0.1287	0.3154	-0.0679	0.293
	G						0.4625	0.161	0.4605	0.5767	0.6655	-0.2125	0.3312	-0.2253	0.4152	-0.9983	0.0499	0.55	0.5039	-0.0758	-0.7063	0.4288	0.213	0.483	-0.1332	0.4664	-0.0695	0.398
PH	P						1	0.6679**	-0.1197	0.018	0.194	-0.2618	0.1643	0.0471	0.019	-0.4179*	0.1139	-0.0149	0.0431	-0.2746	-0.4647**	0.2380	-0.0475	0.3385	0.1895	0.2743	0.1941	0.229
	G							0.7823	-0.128	0.1376	0.2999	-0.3334	0.2202	0.0755	0.0256	-0.4799	0.1339	-0.0226	0.056	-0.3862	-0.5751	0.3793	-0.0476	0.6557	0.2339	0.5182	0.2465	0.355
MSL	P							1	-0.1569	-0.0898	0.1313	-0.3287	-0.0302	-0.0445	-0.1968	-0.1519	0.0729	-0.2512	-0.3661*	-0.1017	-0.177	0.1171	-0.0309	0.2471	0.1666	0.2063	0.153	0.075
	G								-0.2635	-0.1406	0.1854	-0.3934	0.02	-0.0238	-0.2832	-0.172	0.0912	-0.3025	-0.4006	-0.1223	-0.2044	0.1645	-0.0348	0.3887	0.1786	0.3146	0.165	0.105
PB	P								1	0.5700**	0.4511*	0.1827	0.2925	-0.3319	0.0693	-0.2662	-0.0406	0.5089**	0.4203*	0.2326	0.0096	0.5432**	0.1942	0.1522	0.1402	0.2024	0.1466	0.554**
	G									0.4968	0.6939	0.1657	0.5397	-0.6225	0.1636	-0.4457	-0.1049	0.9668	0.6181	0.2861	-0.0758	0.4471	0.3657	0.2729	0.229	0.3975	0.2552	0.476
SB	P									1	0.3673*	0.1152	0.2806	-0.1256	0.1534	-0.3862*	-0.2288	0.3203	0.2631	0.151	-0.131	0.4503*	0.0223	0.1292	-0.0986	0.1116	-0.0763	0.436*
	G										0.4724	0.0954	0.4332	-0.2504	0.2932	-0.5613	-0.3482	0.554	0.3418	0.0741	-0.3051	0.2295	0.1169	0.2633	-0.1075	0.2597	-0.0581	0.221
C/P	P										1	-0.0661	0.5234**	-0.2530	0.1099	-0.5496**	-0.1594	0.3290	0.2314	0.0793	-0.2950	0.4930**	0.1548	0.2473	-0.1344	0.2697	-0.1118	0.496**
	G											-0.128	0.7752	-0.3682	0.1262	-0.6646	-0.1914	0.5814	0.2636	0.0855	-0.374	0.5896	0.1604	0.439	-0.1847	0.435	-0.1627	0.598
P/C	P											1	0.3112	-0.0779	-0.0038	0.1743	-0.1482	0.0013	0.0313	0.3898*	0.4031*	0.1853	-0.1748	-0.1129	0.0967	-0.1568	0.0442	0.163
	G												0.325	-0.1013	0.05	0.219	-0.1841	0.0369	0.0377	0.5702	0.5484	0.2007	-0.1681	-0.1969	0.117	-0.222	0.0663	0.167
P/P	P												1	-0.1215	0.0964	-0.2527	-0.1225	0.3697*	0.1739	0.1443	-0.0574	0.3381	0.0655	0.2118	-0.003	0.2113	0.0082	0.356
	G													-0.2445	0.1627	-0.34	-0.1587	0.4373	0.2464	0.2859	-0.0217	0.5737	0.0658	0.4103	0.0244	0.3812	0.038	0.591
PL	P													1	0.3802*	0.203	0.0938	-0.2135	-0.1383	0.0416	0.1544	-0.1093	-0.2973	-0.0789	-0.3060	-0.1657	-0.3117	-0.010

		DT	DFB	DFF	DC	DPM	PH	MSL	PB	SB	C/ P	P/ C	P/ P	PL	S/ P	GDD	SLW	LAI	SW	HI	DME	ERUE	GER	SL	SDW	V1	V2	GYPP
	G														0.4667	0.2131	0.0839	-0.3021	-0.1527	0.0108	0.1406	-0.2166	-0.3462	-0.1565	-0.3598	-0.2712	-0.3659	-0.199
S/P	P														1	-0.3702*	0.1934	0.2755	0.3354	-0.041	-0.2625	-0.0142	0.0195	0.0807	-0.3135	0.0636	-0.2683	0.010
	G															-0.4192	0.2542	0.3602	0.3646	0.0156	-0.2681	0.0464	0.0424	0.2185	-0.3837	0.1824	-0.3275	0.079

		DT	DFB	DFF	DC	DPM	PH	MSL	PB	SB	C/ P	P/ C	P/ P	PL	S/ P	GDD	SLW	LAI	SW	HI	DME	ERUE	GER	SL	SDW	V1	V2	GYPP
GDD	P															1	-0.0386	-0.4298*	-0.4894**	0.0745	0.6841**	-0.3200	-0.1873	-0.3267	0.1279	-0.3286	0.0673	-0.304
	G																-0.0301	-0.5515	-0.5063	0.0904	0.7173	-0.4424	-0.2204	-0.505	0.1302	-0.489	0.0659	-0.414
SLW	P																1	-0.1981	0.1123	0.0597	0.0118	-0.1005	-0.112	-0.0161	0.0884	-0.0623	0.0704	-0.089
	G																	-0.2649	0.1289	0.0622	0.0118	-0.1652	-0.1584	-0.0211	0.1221	-0.0973	0.0955	-0.152
LAI	P																	1	0.5347**	-0.0587	-0.3042	0.1865	0.1805	0.1309	0.0474	0.1714	0.0782	0.219
	G																		0.6867	-0.0283	-0.3667	0.355	0.3588	0.3538	0.062	0.4511	0.1264	0.401
SW	P																		1	-0.0575	-0.3423	0.2523	0.2053	0.2871	0.099	0.3198	0.1328	0.297
	G																			-0.0685	-0.3695	0.2968	0.2342	0.3982	0.1064	0.4322	0.1439	0.35
HI	P																			1	0.7739**	0.2739	0.1675	-0.1419	0.1407	-0.0653	0.1435	0.232
	G																				0.7585	0.2794	0.1907	-0.247	0.1569	-0.1227	0.1583	0.226
DME	P																				1	-0.0054	0.0104	-0.2985	0.201	-0.2433	0.1653	-0.024
	G																					-0.0927	-0.0035	-0.5087	0.2126	-0.4071	0.1721	-0.110
ERUE	P																					1	0.1962	0.4420*	0.1107	0.4506*	0.1351	0.985**
	G																						0.2892	0.8435	0.1517	0.8285	0.1915	0.979
GER	P																						1	0.2118	0.1827	0.5168**	0.3468	0.230
	G																							0.2021	0.1818	0.5724	0.3299	0.331
SL	P																							1	0.0592	0.9433**	0.1197	0.451*
	G																								0.0338	0.9163	0.0832	0.849
SDW	P																								1	0.1308	0.9798**	0.116
	G																									0.1282	0.9836	0.159
V1	P																									1	0.2347	0.474**
	G																										0.225	0.858
V2	P																										1	0.1434
	G																											0.2018
GYPP	P																											1
	G																											

*** &* Sign for 1% & 5% respectively 1%= 0.463, & 5%=0.361*

Note : DT=Days to tubercle formation , DFB=Days to flower budding, DFF = Days to First flowering, DC=Days to cessation , DPM = Days to Physiological maturity, PH = Plant height (cm), MSL = Main shoot length (cm), PB = Number of primary branches per plant, SB = Number of secondary branches per plant , C/P = Number of cluster per plant, P/C = Number of pods per cluster, P/P = Number of pods per plant , PL= Pod length (cm),S/P=Seed per pod ,GDD=Growing degree days, SLW=Specific leaf weight , LAI=Leaf area index, SW = 100 -seed weight (g), HI = Harvest- index (%), GY = Grain yield per plant(g),DME=Dry matter efficiency, ERUE=Effective rainfall use efficiency, GER=Germination relative index, SL=Seedling length ,SDW=Seedling dry weight , VI=Vigor index I,VII=Vigor index II

Table 2. Phenotypic path coefficient analysis between pairs of 27 morpho-physiological characters in soybean [*Glycine max* (L.) Merrill]

	DT	DFB	DFF	DC	DPM	PH	MSL	PB	SB	C/ P	P/ C	P/ P	PL	S/ P	GDD	SLW	LAI	SW	HI	DME	ERUE	GER	SL	SDW	V1	V2
DT	-0.**1037**	-0.0483	-0.0441	-0.0577	-0.0093	0.0047	-0.0276	0.0194	-0.0017	0.0009	0.0022	0.0249	0.0112	0.0138	0.0077	0.0062	0.0214	0.0373	-0.0111	-0.0028	0.0115	0.0134	0.0105	0.0300	0.0167	0.0297
DFB	-0.0016	-0.**0035**	-0.0026	-0.0023	-0.0009	-0.0012	-0.0019	-0.0004	-0.0005	-0.0015	0.0006	-0.0006	0.0011	0.0008	0.0009	-0.0001	0.0001	0.0007	0.0001	0.0007	-0.0004	0.0003	-0.0004	0.0001	-0.0002	0.0002
DFF	-0.0179	-0.0315	-0.**0420**	-0.0279	-0.0059	-0.0091	-0.0231	-0.0019	0.0053	-0.0128	0.0110	-0.0003	0.0123	0.0113	0.0058	-0.0082	0.0046	0.0095	-0.0005	0.0038	-0.0041	0.0059	-0.0058	-0.0004	-0.0032	0.0017
DC	0.0018	0.0022	0.0022	**0.0033**	-0.0001	0.0002	0.0009	0.0000	-0.0003	0.0006	-0.0001	0.0004	-0.0012	-0.0010	0.0001	0.0007	-0.0006	-0.0008	0.0002	0.0002	0.0002	-0.0002	-0.0001	0.0001	-0.0002	0.0000
DPM	-0.0055	-0.0160	-0.0085	0.0015	**-0.0613**	-0.0245	-0.0085	-0.0172	-0.0245	-0.0338	0.0100	-0.0155	0.0131	-0.0225	0.0612	-0.0030	-0.0264	-0.0298	0.0037	0.0413	-0.0191	-0.0112	-0.0192	0.0079	-0.0193	0.0042
PH	0.0001	-0.0007	-0.0004	-0.0001	-0.0008	**-0.0020**	-0.0013	0.0002	0.0000	-0.0004	0.0005	-0.0003	-0.0001	0.0000	0.0008	-0.0002	0.0000	-0.0001	0.0005	0.0009	-0.0005	0.0001	-0.0007	-0.0004	-0.0005	-0.0004
MSL	0.0041	0.0083	0.0085	0.0044	0.0021	0.0103	**0.0154**	-0.0024	-0.0014	0.0020	-0.0051	-0.0005	-0.0007	-0.0030	-0.0023	0.0011	-0.0039	-0.0056	-0.0016	-0.0027	0.0018	-0.0005	0.0038	0.0026	0.0032	0.0024
PB	0.0035	-0.0020	-0.0009	0.0001	-0.0052	0.0022	0.0029	**-0.0185**	-0.0106	-0.0084	-0.0034	-0.0054	0.0062	-0.0013	0.0049	0.0008	-0.0094	-0.0078	-0.0043	-0.0002	-0.0101	-0.0036	-0.0028	-0.0026	-0.0038	-0.0027
SB	0.0002	0.0014	-0.0012	-0.0009	0.0038	0.0002	-0.0008	0.0054	**0.0095**	0.0035	0.0011	0.0027	-0.0012	0.0014	-0.0036	-0.0022	0.0030	0.0025	0.0014	-0.0012	0.0043	0.0002	0.0012	-0.0009	0.0011	-0.0007
C/P	-0.0003	0.0149	0.0106	0.0065	0.0193	0.0068	0.0046	0.0158	0.0129	**0.0350**	-0.0023	0.0183	-0.0089	0.0038	-0.0192	-0.0056	0.0115	0.0081	0.0028	-0.0103	0.0173	0.0054	0.0087	-0.0047	0.0094	-0.0039
P/C	0.0001	0.0008	0.0012	0.0002	0.0008	0.0012	0.0015	-0.0009	-0.0005	0.0003	**-0.0047**	-0.0015	0.0004	0.0000	-0.0008	0.0007	0.0000	-0.0001	-0.0018	-0.0019	-0.0009	0.0008	0.0005	-0.0005	0.0007	-0.0002
P/P	0.0032	-0.0022	-0.0001	-0.0015	-0.0033	-0.0022	0.0004	-0.0039	-0.0037	-0.0069	-0.0041	**-0.0132**	0.0016	-0.0013	0.0033	0.0016	-0.0049	-0.0023	-0.0019	0.0008	-0.0045	-0.0009	-0.0028	0.0000	-0.0028	-0.0001
PL	0.0016	0.0046	0.0044	0.0055	0.0032	-0.0007	0.0007	0.0049	0.0019	0.0038	0.0012	0.0018	**-0.0148**	-0.0056	-0.0030	-0.0014	0.0032	0.0021	-0.0006	-0.0023	0.0016	0.0044	0.0012	0.0045	0.0025	0.0046
S/P	0.0007	0.0012	0.0013	0.0015	-0.0018	-0.0001	0.0010	-0.0003	-0.0008	-0.0005	0.0000	-0.0005	-0.0019	**-0.0050**	0.0019	-0.0010	-0.0014	-0.0017	0.0002	0.0013	0.0001	-0.0001	-0.0004	0.0016	-0.0003	0.0013
GDD	0.0117	0.0416	0.0220	-0.0038	0.1579	0.0661	0.0240	0.0421	0.0611	0.0870	-0.0276	0.0400	-0.0321	0.0586	**-0.1583**	0.0061	0.0680	0.0775	-0.0118	-0.1083	0.0506	0.0296	0.0517	-0.0202	0.0520	-0.0106
SLW	-0.0023	0.0014	0.0074	0.0078	0.0019	0.0043	0.0028	-0.0015	-0.0087	-0.0061	-0.0057	-0.0047	0.0036	0.0074	-0.0015	**0.0382**	-0.0076	0.0043	0.0023	0.0005	-0.0038	-0.0043	-0.0006	0.0034	-0.0024	0.0027
LAI	-0.0060	-0.0007	-0.0031	-0.0053	0.0124	-0.0004	-0.0072	0.0147	0.0092	0.0095	0.0000	0.0107	-0.0062	0.0079	-0.0124	-0.0057	**0.0289**	0.0154	-0.0017	-0.0088	0.0054	0.0052	0.0038	0.0014	0.0049	0.0023
SW	0.0009	0.0005	0.0005	0.0006	-0.0012	-0.0001	0.0009	-0.0010	-0.0006	-0.0006	-0.0001	-0.0004	0.0003	-0.0008	0.0012	-0.0003	-0.0013	**-0.0024**	0.0001	0.0008	-0.0006	-0.0005	-0.0007	-0.0002	-0.0008	-0.0003
HI	-0.0182	0.0069	-0.0019	-0.0118	0.0104	0.0468	0.0173	-0.0396	-0.0257	-0.0135	-0.0664	-0.0246	-0.0071	0.0070	-0.0127	-0.0102	0.0100	0.0098	**-0.1704**	-0.1319	-0.0467	-0.0285	0.0242	-0.0240	0.0111	-0.0245
DME	0.0054	-0.0392	-0.0185	0.0125	-0.1364	-0.0941	-0.0358	0.0019	-0.0265	-0.0597	0.0816	-0.0116	0.0313	-0.0531	0.1385	0.0024	-0.0616	-0.0693	0.1567	**0.2024**	-0.0011	0.0021	-0.0604	0.0407	-0.0493	0.0335
ERUE	-0.1089	0.1184	0.0947	0.0627	0.3047	0.2331	0.1146	0.5319	0.4410	0.4828	0.1814	0.3311	-0.1070	-0.0139	-0.3134	-0.0984	0.1826	0.2471	0.2682	-0.0053	**0.9793**	0.1921	0.4329	0.1084	0.4412	0.1323
GER	0.0052	0.0039	0.0056	0.0030	-0.0073	0.0019	0.0012	-0.0078	-0.0009	-0.0062	0.0070	-0.0026	0.0119	-0.0008	0.0075	0.0045	-0.0072	-0.0082	-0.0067	-0.0004	-0.0079	**-0.0401**	-0.0085	-0.0073	-0.0207	-0.0139
SL	0.0256	-0.0312	-0.0351	0.0044	-0.0791	-0.0853	-0.0623	-0.0384	-0.0326	-0.0623	0.0285	-0.0534	0.0199	-0.0203	0.0823	0.0040	-0.0330	-0.0724	0.0358	0.0752	-0.1114	-0.0534	**-0.2520**	-0.0149	-0.2378	-0.0302
SDW	-0.0392	-0.0050	0.0014	0.0030	-0.0174	0.0257	0.0226	0.0190	-0.0134	-0.0182	0.0131	-0.0004	-0.0415	-0.0425	0.0173	0.0120	0.0064	0.0134	0.0191	0.0272	0.0150	0.0248	0.0080	**0.1356**	0.0177	0.1328
V1	-0.0482	0.0199	0.0225	-0.0150	0.0944	0.0821	0.0617	0.0605	0.0334	0.0807	-0.0469	0.0632	-0.0496	0.0190	-0.0983	-0.0186	0.0513	0.0957	-0.0195	-0.0728	0.1348	0.1546	0.2822	0.0391	**0.2992**	0.0702
V2	0.0536	0.0106	0.0076	0.0018	0.0127	-0.0363	-0.0286	-0.0274	0.0143	0.0209	-0.0083	-0.0015	0.0582	0.0501	-0.0126	-0.0132	-0.0146	-0.0248	-0.0268	-0.0309	-0.0252	-0.0648	-0.0224	-0.1831	-0.0439	**-0.1869**
GYPP	-0.2343	0.0562	0.0314	-0.0076	0.2935	0.2297	0.0754	0.5547	0.4361	0.4960	0.1636	0.3561	-0.1012	0.0102	-0.3047	-0.0897	0.2192	0.2979	0.2325	-0.0246	0.9857	0.2309	0.4518	0.1160	0.4747	0.1434

R SQUARE=0.9916   RESIDUAL EFFECT =   0.092

Note : DT=Days to tubercle formation , DFB=Days to flower budding, DFF = Days to First flowering, DC=Days to cessation , DPM = Days to Physiological maturity, PH = Plant height (cm), MSL = Main shoot length (cm), PB = Number of primary branches per plant, SB = Number of secondary branches per plant , C/P = Number of cluster per plant, P/C = Number of pods per cluster, P/P = Number of pods per plant , PL= Pod length (cm),S/P=Seed per pod ,GDD=Growing degree days, SLW=Specific leaf weight , LAI=Leaf area index, SW = 100 -seed weight (g), HI = Harvest- index (%), GY = Grain yield per plant(g),DME=Dry matter efficiency, ERUE=Effective rainfall use efficiency, GER=Germination relative index, SL=Seedling length ,SDW=Seedling dry weight , VI=Vigor index I,VII=Vigor index I

High negative direct effect of seedling length, vigor index –II and harvest index towards grain yield per plant had been noticed. Although seedling length expressed significant positive correlation with grain yield per plant, but its high negative direct effect towards grain yield per plant makes this trait ineffective for yield improvement. Very low residual effect might be due to the effective selection of phenol-morpho-physiological traits studied in present research study which expressed very low percentage of unknown-unstudied factors.

Several soybean researchers [7,8,9,10] reported importance of morpho-physiological traits in soybean in terms of correlation and path studies.

Overall Effective rainfall use efficiency and vigor index-I found most effective traits for soybean genetic improvement.

4. CONCLUSION

Present study offers scope for utilizing association (direct or indirect) among 27 characters studied to perform effective selection in 30 soybean genotypes, including three checks, for 27 pheno-morpho-physiological traits for genetic enhancement of soybean. Flowering traits (*i.e.,* Days to tubercles-flower budding-first flower –cessation of flowering) and branching traits (primary and secondary branching) are sequential traits, positive, significantly correlated: means character in early phonological stage affect the characters in later phonological stages, in the same direction. Effective rainfall use efficiency, primary branches, secondary branches, seeding length and clusters per plant were important traits, positively associated with grain yield per plant and also with few other traits of interest. Two physiological traits; Effective rainfall use efficiency (highest positive direct effect) and vigor index-I (positive, moderate direct effect), were most effective yield components and revealed importance of physiological traits for soybean improvement.

ACKNOWLEDGEMENT

Authors are thankful to different crop research stations-IISR Indore, IGKV Raipur, IARI New Delhi, PAU Ludhiana, JNKVV Jabalpur, CSKHPKVV Palampur, GBPUAT Pantnagar, MACS Pune, VPKAS Almora, Amaravati and AU Kota for providing genotypes of soybean.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/78067