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Desirable Traits Influencing Grain Yield in Soybean (*Glycine max* (L.) Merrill)

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Abstract

The paper assesses the association among agronomic traits and their relation with grain yield, protein and oil contents to determine those traits that can be used during selection of soybean genotypes for high seed yield. Data for this study was obtained from a field study conducted in 2006 over two locations using 49 genotypes. Protein content was determined using micro Kjeldhal method whereas oil content was determined using Nuclear Magnetic Resonance Spectroscopy. Genetic and phenotypic correlations were calculated followed by path coefficient analysis to partition the correlation coefficients of traits with yield/plant into direct and indirect effects. The genotypic and phenotypic correlation coefficient estimation indicated that seed yield was strongly associated with seeds/plant, pods/plant, seeds/pod, days to maturity and grain filling period. Protein content was strongly correlated with plant height, branches/plant, and days to maturity indicating consideration of these traits during selection for protein. Oil content was not associated with any character except protein content, which has got strong negative association (-0.93). Path coefficient analysis revealed that number of seeds/pod was more important than other traits, hence can be used as number one criterion for indirect selection.

Keywords: Path analysis, soybean, yield related traits

Introduction

Protein and oil are the two most important products of soybean (*Glycine max* L. (Merrill) used in many ways for food, animal feed, and industry. On average, the oil content of soybean seed exceeds 20%, protein content over 40 %, and this protein content in soybean is about twice that of meat, most beans and nuts; and four times that of milk (Iqbal *et al* 2003; Aghai *et al*. 2004; Ogoke *et al.* 2003). The balanced combination of protein, fat and carbohydrate of soybean products serve as a valuable food, feed and bio-feed stocks (Gardner & Pyne 2003). Besides nutritional quality, the crop has great importance to improve the soil nutrient status and farming system when grown solely and/or in combination with other crops.

The introduction of soybean crop to Ethiopia dated back to 1950s with the objective of supplementing the diet of Ethiopians especially during long periods of partial fasting (Asrat 1965). The first effort made under research was to conduct adaptation trial of recommended varieties along with recommended cultural practices in some parts of the country. Soybean breeding program in Ethiopia relies at first place on selecting of genotypes with good yield and secondly for classifying genotypes based on maturity groups (early, medium, and late) to identify environments that the genotypes are best adapted to. For both purposes, germplasm introduction has been the sources of materials from different research organizations like IITA.

Since yield is influenced by different characters, selection for yield *per se* does not give sufficient confidence for selection of genotypes. Hence, correlation analysis helps providing information about the degree of relationship among important crop traits and is used as an index to predict the yield response in relation to the change of a particular trait. According to Watson (1952) indirect selection for seed yield was a function of selection towards the enlargement of the components of seed yield. Thus yield components are further classified (Board *et al*. 1999) into primary, which affects final seed yield (seeds/plant and seed size); secondary, which affects seed number (seeds/pod and pods/plant); and tertiary, that affects pod number (node number, reproductive node number, and pods/reproductive node). However, pods/plant seeds/pod, and seed weight are primary yield components in soybean (Machikowa *et al.* 2003; Graff & Rowland 1987). Seven yield components were found to be influential in soybean (Akheter & Sneller 1996), namely number of plants/unit area, number of main stem nodes/plant, number of pods/node, number of seeds/pod, number of branches/plant, number of pods/branch and mean seed weight. Johnson *et al*. (1955) also reported that agronomic traits like days to flowering, maturity, grain filling period, and shattering resistance are important to affect seed yield. According to their studies using two F_3 populations conducted at two locations showed that selection based on the combination of grain filling period and seed weight can be as effective as selection for yield itself.

The objective of this study was to assess the traits that have to be considered in selecting soybean genotypes for yield and other economic traits under Ethiopian condition.

Materials and methods

Description of experimental sites

The experiment was conducted at two locations Awassa and Gofa in Southern Ethiopia in 2005 main growing season. The two locations vary each other in their geographic position, average annual rainfall they receive, average max and minimum temperature, and soil type (Table 1)

Description of the experimental design

Forty-nine genotypes of soybean, including six registered varieties under production, were grown in 7 x 7 simple lattice design (Allard 1952). The plot size was $4.8m^2$ (3 m long and 1.6 m wide) with four rows. The spacing between plants, rows, plots and blocks was 10cm, 40cm, 80cm and 1m, respectively.

Data measurements

Data were collected both on plot and plant bases. Plot base data parameters were lodging score, shattering score, days to flowering, days to maturity, grain filling period, seed weight, protein content, oil content and seed yield. Data from the rest eight variables (Table 2) were measured on plant basis. Protein content was determined according to the methods of C.G. Youngs as described by Stringam *et al*. (1974). Fatty oil content was determined using Nuclear Magnetic Resonance Spectroscopy.

Statistical analysis

The average data were subjected to standard statistical techniques for analysis of variance for traits studied using SAS (SAS 2001) statistical package. Means were separated following the standard least significant difference (LSD) technique. Correlation coefficients and their significance were computed based on standard method while path coefficients were worked out by the methods used by Dewey & Lu (1959).

Results and discussion

Analysis of variance

Analysis of variance showed that mean squares due to genotypes were highly significant ($p<0.01$) for number of pods/plant, days to flowering, days to maturity, lodging score, pod shattering, seed weight, oil content and seed yield/plant at Awassa (Table 2). Mean squares due to genotypes for grain filling period, seeds/plant, seeds/pod, and harvest index were significant ($p<0.05$) while the mean squares were non-significant for other traits. At Gofa mean squares due to genotypes revealed highly significant difference ($p<0.01$) for 14 traits and significant ($p<0.05$) for grain filling period and harvest index (Table 2). Only crude protein showed non-significant mean square for genotypes.

Days required for flowering, grain filling and maturity were longer at Awassa than at Gofa. On the other hand, seed weight and harvest index were higher for Gofa where the crop completed its cycle within 73 days. The more vegetative growth condition resulted in higher lodging at Awassa while higher average temperature hastened pod shattering at Gofa. Pods/plant and seeds/plant were higher for Hawasa while seeds/pod was higher at Gofa.

Relatively higher protein content and lower oil content was observed in Awassa while the result was vice versa for Gofa (Table 2). In other words the inverse relationship between these two traits was clearly observed in this experimentation. This inverse relationship is further justified by the protein-oil-ratio in which the theoretical ratio is 2:1 (2.0). From this data the ratio for Awassa is higher (2.26) while it is lower for Gofa (1.68). Probably the relative higher temperature (Table 1) at Gofa resulted in lower protein-oil-ratio (< 2.0) and that of the lower temperature at Awassa resulted in higher protein-oil-ratio (> 2.0). This result is in line with report of Yaklich & Vinyard (2004) which indicated that temperatures below the classification values were associated with high protein-to-oil ratios whereas temperatures above the classification values were associated with low protein-to-oil ratios.

Association of seed yield with yield components

On the basis of correlation alone (Table 3) pods/plant, seeds/plant, seeds/pod, and harvest index are highly correlated with seed yield. This shows that selection for these four traits can result in high yielding variety. Board *et al*. (1997) studied soybean populations using two varieties planted in two planting dates and found out that seeds/plant, seeds size, pods/plant are equally important in increasing yield. Days to maturity and grain filling period significantly contributed to yield ($P < 0.05$). This is in agreement with observation of Machikowa *et al.* (2005) who reported that maturity time and time to flowering were closely related to yield and yield components. Voldeng *et al*. (1997) also reported that late maturing varieties out yielded early maturing ones.

Plant height, nodes/plant, branches/plant, and seed weight were weakly and positively correlated with seed yield/plant. In other study positive and significant association of nodes/plant with seed yield/plant was reported by Board *et al*. (1997). The association of seed yield per plant with lodging index, pod shattering, internode length, crude protein and oil content was negative and close to zero. This result was similar to previous work reported by Xinihai *et. al*. (1999) and Johnson *et al*. (1955).

Phenotypic and genotypic correlations

The estimates of genotypic and phenotypic correlation coefficients among 17 pairs of traits are shown in Table 3. Generally, the genotypic correlation coefficients were higher than their respective phenotypic correlation coefficients, which are in agreement with the findings of Johnson *et al*. (1955), Anand & Torrie (1963) and Weber & Moorthy (1952). Weber & Moorthy (1952) explained their result of low phenotypic correlation due to the masking of /or modifying effect/ of environment on the genetic association among traits. Pods/plant seeds/pod and seeds/plant were more closely associated both genotypically and phenotypically with seed yield/plant. Board *et al*. (1999) reported strong positive correlation of seeds/plant with seed yield/plant phenotypically, but genotypically the association was close to zero. Days to maturity was only associated genotypically with seeds/plant. On the other hand, the phenotypic correlation of harvest index with seed yield was higher than genotypic correlation coefficient indicating that the greater contribution of non-additive genetic variance of harvest index. The genetic and phenotypic correlation of plant height with seed yield/plant was very low and close to zero. Oil and protein contents showed no correlation genotypically and phenotypically with seed yield but the genotypic correlation between them were negative and highly significant. Therefore, selection for high oil could result in lower protein content of the seed hence, selection for these traits should depend on the value of the genotype either for protein or oil content.

Days to maturity and grain filling period showed significant positive genotypic correlation and weak positive phenotypic correlation with seed yield/plant indicating that the masking of the environment on the association of traits is large. The genotypic correlation between oil content and harvest index was positive and significant while the phenotypic correlation was close to zero. The genotypic correlation of protein content with plant height, inter node length, days to flowering and days to maturity were positive and significant while negative and significant with pods/plant and harvest index.

The genotypic correlation of harvest index with plant height, branches/plant, nodes/plant, days to flowering, days to maturity and lodging was significant and negative while grain filling period, seed weight and shattering were significant and positive. The genotypic correlation of seed weight with branches/plant, nodes/plant, days to flowering, seeds/plant and seeds/pod was significant and negative. The genetic correlation of seed weight with grain filling period was positive and significant indicating those genotypes take longer period to fill grain have larger seed size. In other words large seeded genotypes tend to flower early and have less branches/plant, nodes/plant, seeds/pod and seeds/plant and take longer time for grain filling.

The genotypic correlation of seeds/plant and seeds/pod with days to flower and mature were positive, and the correlation between the two traits was very high indicating that late maturing genotypes have more seeds/plant and seeds/pod and consequently higher seed yield. This was supported by the significant genotypic correlation of seeds/plant and seeds/pod with seed yield/plant. This was in agreement with the result of Anand & Torrie (1963) and in contrast to the finding of Johnson *et al*. (1955), probably due to the difference in study materials and environment on which experiments were conducted. The genetic correlation of seed size with grain filling period was strong and positive indicating that longer grain filling period results in larger seed size.

A negative genotypic correlation between two desirable traits indicates that increase in one trait would result in the reduction of the other hence; increase or decrease of both traits simultaneously would be difficult. This was clearly revealed in the correlation of oil and protein contents. The strong negative genetic correlation of these traits indicated that it would be very difficult to identify a soybean genotype containing high level of both protein and oil contents rather an increase in one trait would result in the reduction of the other.

Path analysis at phenotypic level

The phenotypic direct effect on yield and phenotypic correlation coefficient with yield of 16 traits and their indirect effects via other independent traits are shown in Table 4. The influences of seeds/plant, seeds/pod, pods/plant and harvest index were large and positive on seed yield/plant. When their direct effect was considered the influence of seeds/pod and pods/plant was positive and large in magnitude. The direct influence of seeds/plant was weak and close to zero while that of harvest index was slightly better. The high correlation of seeds/plant with yield was as a result of indirect positive effects via pods/plant, seeds/pod and harvest index. However, the direct influence of seeds/plant on the response factor (or seed yield/plant) was negligible. On the other hand, the direct effect of seeds/pod on seeds/plant was large and positive. Pods/plant showed strong direct positive effect on yield, which affected yield negatively indirectly through six traits. Therefore, seeds/pod and pods/plant were the two traits that showed the largest direct effect on seed yield/plant.

The secondary yield components namely seeds/pod and pods/plant showed the strongest correlation with yield, influenced seed yield indirectly and negatively via primary yield components namely seeds/plant and seed weight; and indirectly and positively via tertiary yield component namely nodes/plant. Therefore, seeds/pod was more important than the pods/plant in affecting seed yield/plant as a result of higher correlation coefficient and relatively low negative yield component compensation. Board *et al*. (1997) showed that seeds/plant was more important than reproductive nodes/plant and pods/reproductive node and concluded that it would be as good an indirect selection criterion.

Path analysis at genotypic level

At the genotypic level (Table 5) pods/plant, days to maturity, grain filling period, seeds/plant and seeds/pod showed a strong positive correlation with seed yield/plant. Of these five traits pods/plant, grain filling period and seeds/plant showed negative direct effect on seed yield/plant, therefore, these traits are less important. Days to maturity showed strong association with yield, however, its maximum direct positive effect on yield was counterbalanced by its indirect effects through days to flowering and grain filling period. Seed weight was positively correlated with yield but its direct positive effect on yield was nullified because of strong component compensation between indirect negative effects via grain filling period and seeds/pod and positive indirect effect via days to maturity as a result it is less important. Seeds/pod has got strong correlation with yield/plant, and had only strong indirect effect component compensation through days to flowering and days to maturity, and had only slight overall negative effects on yield via other traits. Therefore, seeds/pod was more important than other traits for the genetic improvement of soybean. However, Board *et al*. (1997) concluded from their study that pod/reproductive node was the best indirect selection criterion for genetic studies; although the benefit of this yield component was partially negated by a large negative indirect effect on yield via pod number.

Conclusion

From the present study it is concluded that seeds/pod is the best trait in indirect selection for higher yield of soybean genotypes followed by pods/ plant.

References

Aghai, S.K., Oad, F.C. and Buriro, U.A. (2004). Yield and yield components of inoculated and un-inoculated soybean under varying nitrogen levels. *Asian Journal of Plant Sciences* **3**(3): 370-371.

Akheter, M. and Sneller, C.H. (1996). Genotype by environment interaction and selection of early maturing soybean genotypes. *Crop Science*. **36**: 883-889

Allard, R. W. (1952). The precision of lattice designs with small number of entries in lima bean yield trials. *Agronomy Journal* **44**:200-201.

Anand, S.C. and Torrie, J.H. (1963). Heritability of yield and other traits and interrelationship among traits in the F_3 and F_4 genereations of three soybean crosses. *Crop Sciience* **3**:508-511.

Asrat Feleke (1965). Progress Report on Cereals, Pulses and Oilseeds Research, Branch Experiment Station Debre Zeit Ethiopia.

Bizeti, H.S., Portela de Caravalho, C.G., Pinto de Souza, J.R. and Destero, D. (2004). Path analysis under multicollinearity in soybean. *Brazilian Archives of Biology and Technology* **47**(5): 669-676.

Board, J.E., Kang, M.S. and Harville, B.G. (1997). Path analyses identify indirect selection criteria for yield of late planted soybean. *Crop Sciience* **37**: 879-884.

Board, J.E., Kang M.S. and Harville , B.G. (1999). Path analyses of the yield formation processes for

late-planted soybean. *Agroomy Journal* **91**: 128-135.
Gardner, J.C. & Payne, T.L. (2003). A soybean biotechnology outlook. *AgBioForum*, ***6***(1&2), 1-3. Available on the World Wide Web: http://www.agbioforum.org/.
Graf, R.J. and Rowland, C.G. (1987). Effect of plant density on yield and components of yield of faba bean. *Cannadan Journal of Plant Sciences* **67**: 1-10.
Iqbal, S., Mahmood, T., Tahira, M. Ali, Anwar, M. and Sarwar, M. (2003). Path coefficient analysis in different genotypes of soybean (*Glycine max* (L) Merril). *Pakistan Journal of Biological Science* **6** (12): 1085-1087
Johonson, H.W., Robinson, H.F. and Comostock, R.E. (1955). Genotypic and phenotypic correlations in soybeans and their implication in selection. Agronomy Journal **47**: 477-483.
Machikowa T., Waranyuwat, A. and Laosuwan, P. (2005). Relationships between seed yield and other characters of different maturity types of soybean grown in different environments and levels of fertilizer. *Science Asia* **31**: 37-41
Ogoke, I.J., Carsky, R.J., Togun, A.O. and Dashiell, K.Z. (2003). Maturity classes and P effects on soybean grain yield in the moist savannah of West Africa. *Journal of Agronomy and Crop Sciience* **189**: 422-427.
SAS Institute Inc. (2001). Carry, NC, USA
Stringam, G. R., McGregor, G. R. and Pawlowski D. I. (1974). Chemical and morphological characters associated with seed coat color in rape seed. *Proceedings of Fourth International Rape Seed Congress*, Giessen Germany.
Voldeng, H.D., Cobber, E.R., Hume, D.J., Gillard, C. and Morrison, M.J. (1997). Fifty-eight years of genetic improvement of short season soybean cultivars in Canada. *Crop Science* **37**: 428-431.
Watson, D.J. (1952). The physiological basis of variation in yield. *Advances in Agronomy* **5**:101-145.
Weber, C.R. and Moorthy, B.R. (1952). Heritable and non-heritable relationships and variability of oil content and agronomic characters in the F_2 generation of soybean crosses. *Agronomy Journal* **44:** 202-209.
Yaklich, R.W. and Vinyard, B.T. (2004) A Method to Estimate Soybean Seed Protein and Oil Concentration before Harvest. *Journal of the American Oil Chemists' Society (JAOCS)* **81**: 1021–1027.
Xinhai, Li., Jinling, W., Qingka, Y., Shaojie, J. and Liming, W. (1999). The effect of selection method on the association of yield and seed protein with agronomic characters in an inter-specific cross of soybean. *Soybean Genetics Newsletter*.

Table 1. Description of testing sites

Location	Environmental variables				
	Altitude	Temperature (^oC)		Rain fall (mm)	Soil type
		Max	Min		
Awassa	1700	27.42	12.38	1110	Andosole
Gofa	1400	29.4	17.63	1338.98	Acrisole

Table 2. Mean value, ranges and MS due to genotypes for 17 traits assessed in 49 genotypes of soybean grown at Awassa and Gofa

No	Traits	Awassa		Gofa		MS due to genotype	
		Mean	**Range**	Mean	Range	Awassa	Gofa
1	Plant height	73.44	46.7 - 103.6	45.3	31.4 - 75.6	250.12^{ns}	582.81^{**}
2	Inter node length	7.29	4.47 - 11.61	4.3	3.7 - 5.8	0.092^{ns}	0.107^{**}
3	Branches/plant	5.02	3.70 - 6.60	3.11	2.15 - 6.6	0.0312^{ns}	0.097^{**}
4	Nodes/plant	10.11	7.75 - 12.05	10.1	8.25 -12.3	0.004^{ns}	0.129^{**}
5	Pods/plant	31.62	12.5 - 70.35	23.4	18.6 – 40.0	0.0347^{**}	0.018^{**}
6	Days to flower	59.29	44.5- 76.5	35.0	31.5 - 39.5	111.59^{**}	31.90^{**}
7	Days to maturity	112.45	99.0 - 134.0	73.0	68.5 - 78.5	106.80^{**}	69.03^{**}
8	Grain filling period	53.15	35.0 - 71.0	37.9	34.0 - 41.5	88.186^{*}	28.71^{*}
9	Lodging (1-5)	1.82	1.0 - 4.5	1.35	1.0 - 2.5	0.183^{**}	0.087^{**}
10	Shattering (1-5)	1.35	1.0 - 3.5	2.51	1.0 - 4.5	0.103^{**}	0.143^{**}
11	Number of seeds/plant	70.44	35.5 - 136.9	59.2	30.1 - 158.6	0.031^{*}	0.0398^{**}
12	Number of seeds/pod	2.35	1.03 - 5.88	2.56	1.6 - 7.5	0.075^{*}	0.064^{**}
13	100 seed weight	13.89	7.93 - 22.08	15.3	10.4 - 20.2	12.59^{**}	11.62^{**}
14	Harvest Index (%)	33.72	20.08 - 48.77	46.3	35.6 - 54.9	69.67^{*}	45.11^{*}
15	Crude protein (%)	37.38	26.51 - 48.96	32.9	23.7 - 45.2	40.41^{ns}	38.52^{ns}
16	Oil content (%)	16.54	12.95 - 18.9	19.6	15.1 - 22.7	1.319^{**}	4.64^{**}
17	Seed yield/plant	9.16	4.11 - 17.51	8.9	4.5 - 21. 3	0.23^{**}	0.64^{**}

*, ** stands for significance at 5% and 1%, respectively

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Table 3. Estimates of genotypic (above diagonal) and phenotypic (below diagonal) correlation coefficient among 17 traits in 49 soybean genotypes gown at Awassa and Gofa

No	Traits	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	Plant height		0.996**	0.372**	0.077	0.184	0.779**	0.575**	-0.366**	0.848**	-0.411**	0.098	0.033	-0.237	-0.953**	0.382**	-0.201	0.047
2	Inter node length	0.819**		0.582**	0.130**	-0.062	0.827**	0.760**	-0.131	0.937**	-0.617**	-0.002	-0.036	-0.20	-0.153	0.402**	-0.117	-0.265
3	Branches/plant	0.187	0.148		0.082	0.038	0.732**	0.599**	-0.242	0.241	-0.422**	0.191	0.218	-0.449**	-0.805**	0.391**	-0.129	0.009
4	Nodes/plant	0.562**	0.032	0.110		0.505**	0.817**	0.396**	-0.744**	0.777**	-0.261	0.176	0.078	-0.347**	-0.868**	0.284	-0.147	0.149
5	Pods/plant	0.123	0.046	0.288*	0.189		0.410**	0.487**	0.126	0.105	0.046	0.081	0.711**	-0.062	-0.035	-0.44**	0.213	0.932**
6	Days to flower	0.510**	0.410**	0.207	0.284*	0.108		0.834**	-0.304*	0.465**	-0.645**	0.392**	0.363**	-0.333**	-0.972**	0.44**	-0.245	0.237
7	Days to mature	0.311*	0.217	0.121	0.306*	0.163	0.539**		0.272	0.190	-0.628**	0.433**	0.410**	0.013	-0.756**	0.491**	-0.253	0.490**
8	Grain filling period	-0.110	-0.260	-0.050	-0.089	0.086	-0.295*	0.646**		-0.483**	0.041	0.064	0.075	0.604**	0.391**	0.081	-0.01	0.431**
9	Lodging index	0.469**	0.329*	0.035	0.313*	0.033	0.345**	0.043	-0.264		-0.160	-0.046	-0.105	-0.194	-0.654**	-0.171	-0.272	-0.126
10	Shattering score	-0.233	-0.232	-0.048	-0.120	-0.023	-0.402**	0.354**	-0.036	-0.028		0.068	0.078	-0.063	0.611**	-0.187	-0.183	-0.039
11	Seed/plant	0.099	0.025	0.255	0.159	0.660**	0.184	0.223	0.086	-0.034	-0.013		0.92**	-0.454**	-0.028	-0.228	-0.059	0.749**
12	Seed/pod	0.071	0.009	0.196	0.121	0.468**	0.187	0.216	0.075	-0.061	-0.015	0.965**		-0.518**	-0.055	-0.155	-0.118	0.652**
13	100 SW	-0.055	-0.047	-0.044	-0.038	-0.003	-0.242	0.053	0.279	-0.139	-0.096	-0.173	-0.200		0.55**	0.119	0.109	0.264
14	Harvest index	-0.236	-0.239	-0.020	-0.083	0.334**	-0.373**	-0.103	0.221	-0.247	0.023	0.371**	0.328*	0.236		-0.58**	0.477**	0.186
15	Crude protein	0.068	0.039	0.102	0.009	-0.063	0.145	0.067	-0.055	0.165	0.082	-0.013	0.001	0.063	0.014		-0.93**	-0.192
16	Oil content	-0.165	-0.099	0.001	-0.076	-0.026	-0.123	-0.135	-0.042	-0.138	-0.034	-0.078	-0.082	0.136	-0.074	-0.271		0.0061
17	Seed yield/plant	0.062	-0.019	0.130	0.169	0.666**	-0.017	0.183	0.222	-0.157	-0.096	0.766**	0.699**	0.213	0.627**	0.025	-0.155	

*, ** stands for significance at 5% and 1%, respectively

Table 4. Estimates of phenotypic direct effect (bold and diagonal), phenotypic correlation coefficient between yield and the trait (r_{ph}), and indirect effect of individual trait on yield via other independent traits of 49 genotypes grown at two locations

No	Traits	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	r_{ph}
1	Plant height	**-0.134**	0.143	-0.012	0.102	0.041	0.03	-0.034	-0.009	-0.043	0.013	0.002	0.033	-0.012	-0.07	0.002	0.01	0.062
2	Inter node length	-0.110	**0.174**	-0.01	0.007	0.016	0.024	-0.024	-0.010	-0.030	0.013	0.001	0.004	-0.010	-0.071	0.001	0.006	-0.019
3	Branches/plant	-0.025	0.026	**-0.065**	0.02	0.097	0.012	-0.013	-0.004	-0.003	0.003	0.006	0.090	-0.009	-0.006	0.003	-0.0001	0.130
4	Nods/plant	-0.075	0.007	-0.007	**0.181**	0.064	0.017	-0.033	0.007	-0.029	0.006	0.004	0.056	-0.008	-0.025	0.0002	0.004	0.169
5	Pods/plant	-0.016	0.008	-0.019	0.034	**0.3337**	0.006	-0.018	0.007	-0.003	0.001	0.016	0.215	-0.001	0.097	-0.002	0.002	0.666
6	DF	-0.068	0.072	-0.014	0.051	0.036	**0.058**	-0.059	-0.023	-0.031	0.022	0.004	0.086	-0.052	-0.110	0.004	0.007	-0.017
7	DM	-0.042	0.038	-0.008	0.055	0.055	0.031	**-0.109**	0.051	-0.004	0.020	0.005	0.100	0.011	-0.030	0.002	0.008	0.183
8	GFP	0.015	-0.22	0.003	0.016	0.029	-0.017	-0.070	**0.079**	0.024	0.002	0.002	0.034	0.060	0.065	-0.001	0.002	0.222
9	Lodging	-0.063	0.057	-0.002	0.057	0.011	0.020	-0.005	-0.021	**-0.091**	0.002	-0.001	-0.028	-0.03	-0.073	0.002	0.008	-0.157
10	Shattering	0.031	-0.04	0.003	-0.021	-0.008	-0.023	0.038	-0.003	0.003	**-0.054**	-0.0003	-0.007	-0.021	0.007	-0.002	0.002	-0.096
11	Seeds/plant	-0.013	0.004	-0.017	0.029	0.222	0.011	-0.024	0.007	0.003	0.001	**0.024**	0.443	-0.037	0.12	-0.0003	0.005	0.766
12	Seeds/pod	-0.01	0.001	-0.013	0.022	0.158	0.011	-0.023	0.006	0.006	0.001	0.023	**0.459**	-0.043	0.097	0.00002	0.005	0.699
13	100 SW	0.007	-0.008	0.003	-0.007	-0.001	-0.014	-0.006	0.022	0.013	0.005	-0.004	-0.092	**0.216**	0.7	0.002	0.008	0.213
14	HI (%)	0.032	-0.042	0.001	-0.015	0.113	-0.022	0.011	0.018	0.022	-0.001	0.009	0.151	0.051	**0.295**	0.0003	0.004	0.627
15	Crude protein (%)	-0.009	0.007	-0.007	0.002	-0.021	0.008	-0.007	-0.004	-0.006	0.004	-0.0003	0.001	0.014	0.004	**0.025**	0.016	0.025
16	Oil content (%)	0.022	-0.017	-0.0001	-0.014	-0.009	-0.007	0.015	-0.003	0.013	0.002	-0.002	-0.038	-0.029	-0.022	-0.007	**-0.058**	-0.155

*, ** stand for significance of t test at 5% and 1%, respectively

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Table 5. Estimates of genotypic direct effect (bold and diagonal), phenotypic correlation coefficient between yield and the trait (r_g), and indirect effect of individual trait on yield via other independent traits of 49 genotypes grown at two locations

	Traits	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	r_g
1	Plant height	**0.776**	-0.434	0.163	-0.699	-0.065	-0.509	0.521	0.376	0.12	0.02	-0.042	0.099	-0.504	0.177	0.185	-0.137	0.047
2	Inter node length	0.769	**-0.436**	0.255	-0.733	0.022	-0.711	0.871	0.924	0.132	0.30	0.001	-0.108	-0.425	0.028	0.195	-0.08	-0.265
3	Branches/plant	0.661	-0.254	**0.438**	-0.053	-0.014	-0.332	0.085	0.554	0.034	0.021	-0.081	0.652	-0.955	0.15	0.189	-0.088	0.009
4	Nodes/plant	0.912	-0.493	0.036	**-0.649**	-0.18	-0.461	0.312	0.928	0.11	0.013	-0.075	0.233	-0.738	0.162	0.138	-0.1	0.149
5	Pods/plant	0.327	0.027	0.017	-0.328	**-0.356**	-0.268	0.451	-0.851	0.015	-0.002	-0.034	0.127	-0.132	0.007	-0.213	0.145	0.932**
6	Days to flowering	0.383	-0.361	0.321	-0.53	-0.146	**-0.04**	0.611	0.465	0.066	0.032	-0.166	0.086	-0.708	0.181	0.213	-0.167	0.237
7	Days to maturity	0.021	-0.331	0.262	-0.257	-0.173	-0.886	**0.514**	-0.995	0.027	0.031	-0.183	0.227	0.028	0.141	0.238	-0.172	0.490**
8	Grain filling period	-0.65	0.057	-0.106	0.483	-0.045	0.613	0.396	**-0.688**	-0.068	-0.002	-0.027	0.224	0.284	-0.073	0.039	-0.007	0.431**
9	Lodging score	0.506	-0.409	0.106	-0.504	-0.037	-0.645	0.463	0.094	**0.1414**	0.008	0.019	-0.314	-0.412	0.122	-0.083	-0.185	-0.126
10	Shattering score	-0.73	0.269	-0.185	0.169	-0.016	0.153	-0.767	-0.602	-0.023	**-0.0493**	-0.029	0.233	-0.134	-0.114	-0.091	-0.125	-0.039
11	Seeds/plant	0.174	0.001	0.084	-0.114	-0.029	-0.817	0.182	-0.94	-0.007	-0.003	**-0.423**	0.753	-0.965	0.005	-0.11	-0.04	0.749**
12	Seeds/pod	0.059	0.016	0.096	-0.051	-0.253	-0.091	0.641	-0.102	-0.015	-0.004	-0.39	**0.992**	-0.101	0.01	-0.075	-0.08	0.652**
13	100 Seed weight	-0.421	0.087	-0.197	0.225	0.022	0.34	0.306	-0.871	-0.027	0.003	0.192	-0.55	**0.126**	-0.102	0.058	0.074	0.264
14	Harvest index (%)	-0.692	0.067	-0.353	0.563	0.012	0.343	-0.777	-0.743	-0.092	-0.03	0.012	-0.165	0.169	**-0.186**	-0.266	0.325	0.186
15	Crude protein (%)	0.678	-0.175	0.171	-0.184	0.157	-0.019	0.546	-0.19	-0.024	0.009	0.097	-0.464	0.253	0.102	**0.4845**	-0.633	-0.192
16	Oil content (%)	-0.357	0.051	-0.057	0.095	-0.076	0.136	-0.949	0.147	-0.038	0.009	0.025	-0.353	0.232	-0.089	-0.451	**0.681**	0.0061

*, ** stands for significance of t test at 5% and 1%, respectively