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Character Correlation and Path Analysis for Yield and Yield related Components in Soybean (*Glycine max* L.) Genotypes

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Abstract
Ninetyone varieties of released soybean (Glycine max (L.) Merrill) genotypes and collections from Mozambique and Ethiopia were evaluated in a 9x9 simple lattice design. All the characters demonstrated highly significant difference (P<0.01) among the tested genotypes indicating the presence of adequate variability that can be exploited through selection. Days to 50% flowering, days to pod setting and days to maturity showed positive and significant genotypic and phenotypic correlation with grain yield. Pod number per plant had the highest positive direct effect (0.792) on grain yield, followed by hundred seed weight (0.546), biomass yield (0.227), days to 50% flowering (0.180) and plant height (0.094). Path analysis showed that the positive and significant correlation of pod number per plant with grain yield was the true relationship. The study presented that since no one trait was unequivocally important for the yield, selection should be based on simultaneous consideration of various characters.

Keywords: Glycine max, Correlation, Path analysis

Introduction
Soybean (*Glycine max* (L) Merrill) is considered a miracle crop due to its extraordinary qualities. The seed contains 40 to 42% good quality protein and 18 to 22% oil comprising 85% unsaturated fatty acids and is free from cholesterol along with ample mineral elements, so it is highly desirable for human diet (Antalina*etal*., 1999).

The majority of the soybean crop is processed into oil and meal. Oil extracted from soybeans is made into shortening, margarine, cooking oil, and salad dressings. Soybeans account for 80 percent or more of the edible fats and oils consumed in the United States. Soy oil is also used in industrial paint, varnishes, caulking compounds, linoleum, printing inks, and other products. Development efforts in recent years have resulted in several soy oil-based lubricant and fuel products that replace non-renewable petroleum products (Gibson and Benson, 2005).

In Ethiopia, soybean is grown over wider agro-ecologies ranging from low to mid altitude areas (500 to 1700 m.a.s.l) that have considerable annual rainfall of 500-1500mm

(Gurmu et al,. 2009). Currently a fraction of land is devoted for soybean production in the country (6,236 hectares) with a total production of 78,989 quintals. With productivity of 12.67 quintals per hectare (CSA, 2008) the country still lags behind the world average productivity (FAO, 2009). Low productivity of the crop is associated with lack of improved varieties, diseases and insect pests, and other environmental factors.

Diseases such as rust, red leaf blotch, frog-eye leaf spot, bacterial pustule, bacterial blight, and soybean mosaic virus are problems to be resolved in soybean. Soybean rust (*Phakopsorapachyrhizi*) particularly is the most destructive foliar disease of soybean in recent times, and can cause 50–60% yield loss. It is a major disease worldwide. Among insect pests, pod sucking and defoliating insects are major constraints (IITA, 2009).

Grain yield, as in other crops, is a complex character, which is dependent on a number of factors. To increase its yield, the study of direct and indirect effects of yield components offer the basis for its successful breeding program and thus increase of seed yield can be more effectively undertaken on the basis of performance of yield components and selection for closely related traits.

Materials and methods

In this exercise 91 released varieties of soybean and collections from Ethiopia were used. The materials used ranged from early maturing groups to late maturing groups.

The Experimental Site

Research workoutwas conducted at Assossa Agricultural Research Center. The center is located at latitude of 10^{0}03'12'' N and longtiude: 34^{0},59'48''E at an elevation of 1950 m. a. s. l. in western part of Ethiopia, 656 km away from the capital Addis Ababa. And it is categorized under Hot to warm moist lowland plain, Tepid to cool humid, sub humid lowland plain, Tepid to cool sub humid mountain. The area receives mean annual rainfall of about 950 mm. Maximum and minimum temperatures of the site are 34.4^{0}c and 9^{0}c, respectively. The major soil type of the area is Nitosol with pH of 5.8.

Experimental Design and Management

This experiment was conducted on the main cropping season of 2015. The experiment was laid out in a9 X 9 simple lattice design with two replications. The plot size was three rows of 4m length with 0.6m row spacing i.e. 4m x 0.6m = $4.8m^2$. Rhizobia bacteria (*Rhizobium japonicum*) were incorporated in to the soil to increase Nitrogen fixation by the genotypes to be studied. All experimental factors were applied uniformly to the whole plot.

Data Analyses

The data collected were statistically analyzed using the Analysis of Variance (ANOVA) procedures. The treatment means were separated using the Least Significance Difference (LSD) at 5% level of probability.

Results and discussion

Genotypic and Phenotypic correlation

Grain yield displayed positive and highly significant association with pod number per plant, biomass yield and hundred seed weight at phenotypic and genotypic level (Table 1 and 2). Moreover, grain yield had positive significant association with root dry weight at genotypic level. Therefore, improving one or more of the characters could result in high grain yield in the soybean genotypes. Similar report was also given byQi Yang and Jinling Wang (2000), Parameshwar (2006), Rajanna*et al.* (2000) and Malik *et al.*, (2006).

In harmony with this study Ojo (2003) and Shivakumar (2008), reported significantly positive correlation of grain yield with pod number per plant in soybean genotypes studied at phenotypic level. Root dry weight had positive non- significant correlation with grain yield at phenotypic level. The negative correlation of grain yield with days to maturity and root to biomass ratio implies the improvement of one character affects the others in the opposite direction making it impractical to improve the characters simultaneously. In contrary to the present study Ramana*et al*. (2000) and Bangar*et al*. (2003) reported positive significant correlation of grain yield with days to maturity.

Days to maturity presented positive and significant phenotypic correlation with plant height, days to 50% flowering and days to pod setting. However, it had negative and significant association with pod per plant and harvest index. This result is in harmony with the finding of Dev Vart*et al.*, (2005) where negative association of days to maturity with harvest index is reported. In contrary to the present study Mukhekar (2004) reported negative significant association of days to maturity with plant height in soybean genotypes.

Total nodule per plant correlated positively and significantly with effective nodules per plant, plant height, days to 50% flowering and biomass yield, it had negative and significant association with root to biomass ratio. Days to pod setting had positive and significant association with plant height, days to 50% flowering and days to maturity.

Biomass yield showed positive and significant correlation with total nodules per plant, effective nodules per plant, root volume, root dry weight, hundred seed weight and plant height. While it showed negative and significant association with root to biomass ratio. Kausar (2005) from the study on genetic variability of F3 populations of two crosses involving three diverse parents of soybean reported positive and significant phenotypic correlation of biomass yield with plant height.

Plant height had positive and significant association with effective nodules per plant, days to 50% flowering, biomass yield, while it had negative significant association with root to biomass ratio. This finding is in agreement with the report of Manasa (2008), where positive and significant association of plant height with days to flowering is reported.

Pod number per plant had positive and negative significant association with harvest index and days to maturity, respectively. In contrary to the present study Ramgiry and Raha (1999) reported significantly negative association of number of pods per plant with harvest index at phenotypic level in 64 soybean genotypes studied. Root dry weight had positive and significant association with root to biomass ratio.

Days to maturity demonstrated positive and significant correlation with plant height; while it showed negative and significant correlation with pod number per plant, root dry weight and harvest index. This finding is in contrary to the report of Manasa (2008) where days to maturity had positive and significant association with pod number per plant and harvest index.

Total nodules per plant showed positive and significant correlation with effective nodules per plant, days to 50% flowering and plant height. However, it had negative significant association with root to biomass ratio. Biomass yield had positive and significant association with total nodules per plant, effective nodules per plant, root volume, hundred seed weight, plant height, root dry weight and days to 50% flowering; while it showed negative and significant association with root to biomass ratio and harvest index.

Table 1: Genotypic correlation coefficients at Assosa (2015).

Traits	DF	DPS	DM	PH	PPP	PL	BY	TNPP	ENPP	RV	RDW	RBR	HSW	HI	GY
DF		0.62**	0.39**	0.50**	-0.30*	-0.12	0.35*	0.47**	0.40**	0.20	0.09	-0.28	0.14	-0.24	0.06
DPS			0.31*	0.31*	-0.20	-0.18	0.13	0.14	0.10	0.05	0.18	-0.16	0.04	-0.20	0.01
DM				0.37*	-0.53**	-0.14	0.09	0.22	0.22	0.18	-0.44**	-0.25	-0.14	-0.47**	-0.33*
PH					-0.22	-0.18	0.55**	0.46**	0.36*	0.29*	0.15	-0.42**	0.28	-0.25	0.20
PPP						0.14	-0.14	-0.21	-0.28	-0.07	0.13	0.17	-0.07	0.79**	0.38**
PL							-0.22	-0.05	0.07	-0.40**	-0.30*	-0.06	0.20	0.32*	-0.09
BY								0.56**	0.42**	0.56**	0.32*	-0.80**	0.53**	-0.33*	0.50**
TNPP									0.95**	0.12	-0.16	-0.53**	0.24	-0.28	0.03
ENPP										0.08	-0.23	-0.44**	0.26	-0.26	-0.08
RV											0.51**	-0.16	0.20	-0.16	0.12
RDW												0.43**	0.24	-0.08	0.33*
RBR													-0.39**	0.21	-0.36*
HSW														0.29*	0.39**
HI															0.25
GY															

DF=Days to 50% flowering, DPS=Days to 50% pod setting, DM=Days to maturity, PlH=Plant height, PPP=Pod per plant, PL=Pod length, BY=Biomass yield, TNPP=Total nodules per plant, ENPP=Effective nodules per plant, RV=Root volume, RDW= Root dry weight, RBR=Root to biomass ratio, HSW=Hundred seed weight, HI=Harvest index, GY=Grain yield

Table 2: Phenotypic correlation coefficients at Assosa (2015).

Traits	DF	DPS	DM	PH	PPP	PL	BY	TNPP	ENPP	RV	RDW	RBR	HSW	HI	GY
DF															
DPS	0.62**														
DM	0.38**	0.30*													
PH	0.50**	0.30*	0.36*												
PPP	-0.25	-0.19	-0.51**	-0.22											
PL	-0.10	-0.15	-0.11	-0.15	0.15										
BY	0.26	0.09	0.07	0.41**	-0.09	-0.10									
TNPP	0.46**	0.13	0.22	0.45**	-0.21	-0.06	0.42**								
ENPP	0.40**	0.09	0.21	0.35*	-0.28	0.03	0.31*	0.94**							
RV	0.20	0.05	0.17	0.26	-0.05	-0.35*	0.39**	0.11	0.06						
RDW	0.04	0.08	-0.23	0.09	0.06	-0.17	0.33*	-0.08	-0.11	0.20					
RBR	-0.25	-0.15	-0.23	-0.36*	0.15	-0.09	-0.52**	-0.47**	-0.39**	-0.12	0.43**				
HSW	0.14	0.05	-0.12	0.27	-0.07	0.11	0.35*	0.21	0.23	0.20	0.16	-0.32*			
HI	-0.24	-0.20	-0.46**	-0.24	0.77**	0.27	-0.26	-0.28	-0.26	-0.15	-0.05	0.17	0.30*		
GY	0.06	0.01	-0.33*	0.20	0.37*	-0.08	0.36*	0.03	-0.08	0.11	0.20	-0.31*	0.37**	0.25	

DF=Days to 50% flowering, DPS=Days to 50% pod setting, DM=Days to maturity, PlH=Plant height, PPP=Pod per plant, PL=Pod length, BY=Biomass yield, TNPP=Total nodules per plant, ENPP=Effective nodules per plant, RV=Root volume, RDW= Root dry weight, RBR=Root to biomass ratio, HSW=Hundred seed weight, HI=Harvest index, GY=Grain yield

Plant height had positive and significant correlation with days to pod setting, biomass yield, effective nodules per plant and root volume. However, it had negative significant correlation with root to biomass ratio. Similar to the present study Gadde (2006), reported positive significant genotypic correlation of plant height with days to pod setting in the same crop.

Effective nodules per plant showed positive and significant correlation with biomass yield and total nodules per plant while it showed negative and significant correlation with root to biomass ratio. Pod number per plant showed positive and significant correlation with harvest index. Pod number per plant showed negative significant association with days to 50% flowering and days to maturity. Root to biomass ratio had negative and significant correlation with plant height, biomass yield and hundred seed weight. Root dry weight had positive and significant correlation with biomass yield, root volume and root to biomass ratio.

Generally, positive and significant association of pairs of characters at phenotypic and genotypic levels justified the possibility of correlated response to selection. Furthermore, negative correlations prohibit the simultaneous improvement of those traits.

Path Coefficient Analysis

Path co-efficient analysis measures the direct and indirect effect for one variable upon another and permits the separation of the correlation co-efficient into components of direct and indirect effect (Dewey & Lu, 1959). Present research work is one of such efforts to study the genetic variability and performance in soybean genotypes.

Pod number per plant (Table 3) had the highest positive direct effect (0.792) on grain yield followed by hundred seed weight (0.546), biomass yield (0.227), days to 50% flowering (0.180) and plant height (0.094). Path analysis showed that the positive and significant correlation of pod number per plant with grain yield was the true relationship. Similar results were reported by Haghi*et al.,* (2011), Gupta (2008) and Arshad *et al,* (2006) on the same crop. In contrary to the present result Iqbal *et al,* (2003) and Agdew and Getnet (2005) reported negative direct effect of pod number per plant on grain yield of soybean genotypes.

The highest negative direct effect of harvest index (-0.536) was counter balanced by the favorable indirect effect of pod number per plant, hundred seed weight, days to maturity and total nodules per plant and the correlation was reduced to 0.250. This finding is in harmony with the report of Agdew and Getnet (2005) and Haghi et al, (2011) where harvest index had negative direct effect on soybean yield. In contrary to the present finding Shivakumar (2008) reported positive direct effect of harvest index on grain yield of soybean.

The second highest positive direct effect of hundred seed weight (0.546) was counter balanced by the indirect negative effects of the characters biomass yield, root to biomass ratio, effective nodules per plant, pod number per plant, pod length, plant height, days to pod setting, and days to 50% flowering. Similar results were reported by Agdew and Getnet (2005), Shivakumar (2008) and Arshad *et al,* (2006) in soybean genotypes. Path analysis showed that correlation explained the true relationship of these two characters. In contrary to the present finding Haghi*et al,* (2011) and Gupta (2008) reported negative direct effect of hundred seed weight on grain yield on the same crop.

The third highest positive direct effect of biomass yield (0.227) showed significant positive correlation with grain yield and path analysis showed that the correlation explained the true relationship of the character with grain yield.

Table 3: Path coefficients of direct (bold diagonal) and indirect effects (off diagonal) at genotypic level of 15 traits on grain yield on 91 soybean germplasm tested at Assosa (2015).

Traits	DF	DPS	DM	PH	PPP	PL	BY	TNPP	ENPP	RV	RDW	RBR	HSW	HI	rg
DF	**0.180**	-0.036	-0.071	0.047	-0.206	0.023	0.080	-0.109	-0.053	-0.037	-0.009	0.037	0.078	0.131	0.06
DPS	0.112	**-0.057**	-0.056	0.029	-0.159	0.035	0.029	-0.032	-0.013	-0.010	-0.017	0.022	0.024	0.106	0.01
DM	0.069	-0.017	**-0.184**	0.034	-0.420	0.028	0.020	-0.052	-0.028	-0.035	0.042	0.033	-0.074	0.252	-0.33*
PH	0.089	-0.018	-0.067	**0.094**	-0.173	0.036	0.125	-0.108	-0.047	-0.055	-0.015	0.055	0.153	0.132	0.20
PPP	-0.047	0.011	0.098	-0.021	**0.792**	-0.028	-0.031	0.049	0.037	0.013	-0.013	-0.023	-0.036	-0.426	0.38**
PL	-0.021	0.010	0.025	-0.017	0.108	**-0.201**	-0.050	0.013	-0.009	0.078	0.029	0.008	0.108	-0.173	-0.09
BY	0.063	-0.007	-0.016	0.052	-0.107	0.044	**0.227**	-0.132	-0.056	-0.109	-0.031	0.106	0.287	0.178	0.50**
TNPP	0.084	-0.008	-0.041	0.043	-0.167	0.011	0.128	**-0.234**	-0.125	-0.024	0.015	0.070	0.130	0.150	0.03
ENPP	0.072	-0.006	-0.040	0.034	-0.223	-0.014	0.096	-0.221	**-0.132**	-0.015	0.023	0.058	0.144	0.140	-0.08
RV	0.034	-0.003	-0.033	0.027	-0.052	0.081	0.127	-0.028	-0.010	**-0.194**	-0.049	0.021	0.107	0.088	0.12
RDW	0.017	-0.010	0.080	0.014	0.103	0.060	0.072	0.037	0.031	-0.099	**-0.097**	-0.057	0.133	0.041	0.33*
RBR	-0.051	0.009	0.047	-0.039	0.137	0.012	-0.181	0.124	0.058	0.030	-0.041	**-0.132**	-0.215	-0.112	-0.36*
HSW	0.026	-0.003	0.025	0.026	-0.052	-0.040	0.119	-0.056	-0.035	-0.038	-0.024	0.052	**0.546**	-0.154	0.39**
HI	-0.044	0.011	0.087	-0.023	0.631	-0.065	-0.076	0.065	0.034	0.032	0.007	-0.028	0.157	**-0.536**	0.25

DF=Days to 50% flowering, DPS=Days to 50% pod setting, DM=Days to maturity, PlH=Plant height, PPP=Pod per plant, PL=Pod length, BY=Biomass yield, TNPP=Total nodules per plant, ENPP=Effective nodules per plant, RV=Root volume, RDW= Root dry weight, RBR=Root to biomass ratio, HSW=Hundred seed weight, HI=Harvest index.Residual effect = 0.296

This result is in harmony with the findings of Showcat and Tyagi (2006) and Shivakumar (2008) where positive direct effect of biomass yield is reported in soybean genotypes.

However, root dry weight, root volume, total nodules per plant and days to pod setting had showed negative direct effect on grain yield. They only contributed to grain yield mainly via their positive indirect effect with other characters.

Days to maturity, pod length, effective nodules per plant and root to biomass ratio had negative direct effect on grain yield. Moreover, their correlation with grain yield is negative which suggested any increase in these characters affects grain yield in the negative direction. Showkat and Tyagi, (2010) reported negative direct effect for days to maturity and pod length in 40 soybean genotypes. The residual effect (0.231) indicated that characters which are included in the genotypic path analysis explained (76.6%) of the total variation in grain yield which indicates that there may be some more components that are contributing towards seed yield.

Path analysis indicated selecting genotypes having high number of pods per plant, biomass yield and hundred seed weight could be used to improve seed yield in soybean genotypes as a result of their direct effect on grain yield.

Conclusion

The results of analysis for variance of each location presented that the genotypes were significantly different at $P<0.01$ for all characters except that grain yield demonstrated positive significant association with pod number per plant, hundred seed weight and biomass yield at genotypic and phenotypic level; and with root dry weight at phenotypic level. Grain yield had negative and significant correlation with days to maturity and root to biomass ratio at phenotypic level. Selection of those traits that demonstrated positive and significant correlation coefficient with grain yield, supports the possibility of an in increase grain yield of soybean.

The highest direct seed yield were observed to be exerted by pod number per plant followed by hundred seed weight, biomass yield, days to 50% flowering, and plant height. The rest of the characters had negative direct effect on grain yield. Therefore, pod number per plant, hundred seed weight and biomass yield were the important contributors to seed yield and these traits could be used as an indirect selection criterion.

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