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

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## Abstract
Forty-nine soybean (Glycine max (L.) Merrill) genotypes of diverse origin were tested in a 7x7 simple lattice design with the objective of estimating their correlation among some yield related attributes and their path analysis. Analysis of variance revealed that there was statistically significant difference among the genotypes for all of the traits studied except root volume and root dry weight. High phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) was recorded for grain yield, biomass yield, pod number per plant, plant height, total nodules per plant, effective nodules per plant, and harvest index. High heritability, coupled with high expected genetic advance as percent of mean, was observed for harvest index, biomass yield, total nodules per plant, effective nodules per plant, and pod number per plant. Days to 50% flowering, days to pod setting and days to maturity showed positive and significant genotypic and phenotypic association with grain yield. Genotypic path analysis revealed that effective nodules per plant, hundred seed weight, root to biomass ratio, pod number per plant, and plant height exerted the highest positive direct effect.

**Keywords:** Glycine max, Correlation, Path analysis

## Introduction
Soybean *Glycine max* (L.) [Merrill] is thought to be originated in Asia, probably in north eastern China about 2500 B.C. (Poehlman and Sleeper, 1995). Since then, it has spread to different countries in the world and became an established component of world agriculture.

It has been noted as the world's leading source of protein and oil at 40%and 20% respectively (Norman *et al*., 1995; Poehlman and Sleeper, 1995). The meal is likewise rich in minerals, mainly calcium, phosphorus and iron (Ogoke*et al*., 2003).

Since soybean is a legume crop, it has the capability to fix its own nitrogen in association with *Bradyrhizobiurnjaponicum*a bacteria. If soybeans have not been grown on the field or it has been many years since soybeans were raised, an inoculant should be applied at planting to establish the bacteria in the soil (Hoeft et al., 2000).

Soybean is a hot weather crop appropriate for year-round growth in most parts of the tropics. Temperatures of at least $15^0$C are needed to germinate the seed and mean temperatures of 20-25 $^0$C to grow the crop. Soybeans need at least moderate soil moisture in order to germinate and for seedlings to become established, but need dry weather for the production of dry seed. Established soybean plants can endure substantial drought.

Twenty-one African countries now produce soybean. Nigeria has the highest 6-year (2000-05) average production of 486,000 tons on an area of 553,260 hectares, followed by South Africa with 205,270 tons from 122,870 hectares, and Uganda with 155,500 tons from 139,500 hectares (IITA 2008).

In Ethiopia, soybean is grown over wider agro-ecologies especially in low to mid altitude areas (1300 to 1700 masl) that have moderate annual rainfall (500-1500mm) (Gurmu*et al*,. 2009). The area enclosed under soybean is 6,236 hectares and the total making of the crop in the country is 78,989 quintals. The productivity of the crop is 12.67 quintals per hectare (CSA, 2008) which is quite low as compared to the productivity of the crop in the world (FAO, 2009). This is credited to absence of improved varieties, biotic factors such as diseases and insect pests, and abiotic factors. Lack of varieties, tolerant to midseason moisture stress and high yielding varieties tolerant to low phosphorus are among the abiotic constraints. Research on seed quality such as protein, oil, carbohydrate, and anti-nutritional factors is lacking. Moreover, lack of emphasis on using molecular markers as aid to conventional breeding is also worth mentioning (IITA, 2009).

Much efforts had been put into progress of soybean productivity in Ethiopia, since the beginning of soybean breeding in the country (Asfaw*et al.* 2003). As a result some of the varieties have been released. For further improvement of the crop, the knowledge of variability and association of yield and its associated traits is essential. This research was conducted with the objectives of estimating correlation among yield and yield related traits, and study path analysis of the different traits.

## Materials and methods

In this study 49 soybean genotypes were obtained from different sets of soybean variety trial conducted by soybean breeding section of Jimma Agricultural Research Center (JARC), Ethiopia; that were introduced from Asian Vegetable Research Center (AVRDC) and Mozambique. In addition, released varieties of soybean and collections from Ethiopia were also included.

## The Experimental Site

The experiment was conducted at Jimma Agricultural Research Center (JARC). The center is located at $7^0$ 40’9”N latitude and $36^0 47^{'}$6”E longitude at elevation of 1753 m. a. s. l. in south western part of Ethiopia. It is categorized under tepid to cool sub-humid sub agro-ecology zone of the country. The average annual rainfall is 1559 mm. The maximum and minimum temperatures are $26.2^0$C and $11.3^0$C, respectively. The major soil types of the area are chromic Nitosols and Cambisols in the uplands, whereas Fluvisol is the dominant soil type in the bottom land and almost all soil types have pH less than 5.

## Experimental Design Management and Season

The trial was established in the field on the main cropping season of 2015. The experiment was laid out in a 7 X 7 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 = $4.8m^2$ . Planting was done around$10^{th}$June. Rhizobia bacteria were incorporated into the soil based on the standard recommendation per hectare basis to increase nitrogen fixing process by the genotypes to be studied. All experimental factors were applied uniformly to the entire plot.

**Data Analyses**

The data were subjected to statistical analysis of variance as per the simple lattice design for each character by the GLM and ANOVA procedures of SAS (SAS, version 9.2).Efficiency of the simple lattice design relative to RCBD was checked and in most of the response variables the lattice was found to be more efficient than that of the RCBD. Least Significant Difference (LSD) was used to separate the means.

**Results and discussion**

**Genotypic and Phenotypic correlation**

Biomass yield showed positive and significant association with root volume, plant height, pod number per plant, root dry weight and hundred seed weight; whereas, it had negative and significant correlation with harvest index and root to biomass ratio. Days to 50% flowering showed positive and highly significant correlation with days to pod setting, days to maturity, plant height and pod number per plant. Days to 50% flowering displayed negative and significant correlation with total nodules per plant and effective nodules per plant.

Days to pod setting had positive and highly significant correlation with days to maturity, root dry weight and plant height. However, it had negative and significant association with total nodules per plant and effective nodules per plant. Days to maturity had significantly positive correlation with plant height. However, it had negative and significant association with pod number per plant, root dry weight, effective nodules per plant and harvest index.

Plant height had significant and negative correlation with pod length, total nodule per plant and root to biomass ratio. Supportive to the present study Manasa (2008), reported negative and significant association of plant height with pod length in ovate leaflet type of soybean genotypes. Plant height had positive significant correlation with biomass yield.

Effective nodules per plant had positive and significant correlation with total nodules per plant. Pod number per plant had positive and significant correlation with root volume, biomass yield and harvest index. It also showed negatively significant genotypic correlation with root to biomass ratio. Generally, positive and significant association of pairs of characters at phenotypic (Table 1 & 2) and genotypic levels justified the possibility of correlated response to selection. Furthermore, negative correlations prohibit the simultaneous improvement of those traits.

Correlation analysis describes merely the mutual relationship between different pairs of characters without providing the nature of the cause and effect relationships of each character.

Hence, the phenotypic and genotypic correlations were further analyzed by path coefficient analysis technique to partition the correlation coefficient into direct and indirect effects. This allows separation of the direct influence of each component on grain yield production from the indirect influences caused by the mutual relationships among them. Such analysis leads to identification of important traits useful for indirect selection of complex trait such as grain yield (Dewey and Lu, 1959).

**Table 1: Genotypic correlation coefficients at Jimma.**

| Traits | DF | DPS | DM | PH | PPP | PL | BY | TNPP | ENPP | RDW | RV | RBR | HSW | HI | GY |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DF | | 0.88** | 0.63** | 0.40** | 0.30* | -0.11 | 0.26 | -0.50** | -0.38** | 0.28 | 0.24 | -0.19 | -0.16 | 0.20 | -0.48** |
| DPS | | | 0.74** | 0.52** | 0.15 | -0.16 | 0.24 | -0.57** | -0.44** | 0.37* | 0.19 | -0.17 | -0.19 | -0.15 | -0.55** |
| DM | | | | 0.60** | 0.09 | -0.18 | 0.20 | -0.44** | -0.32* | 0.17 | 0.16 | -0.23 | 0.03 | -0.13 | -0.52** |
| PH | | | | | 0.08 | -0.31* | 0.36* | -0.38** | -0.22 | 0.26 | -0.29 | -0.29* | 0.03 | -0.26 | -0.22 |
| PPP | | | | | | -0.19 | 0.33* | -0.13 | 0.03 | -0.02 | 0.30* | -0.40** | -0.22 | 0.53** | -0.05 |
| PL | | | | | | | 0.06 | 0.15 | 0.08 | 0.22 | 0.19 | 0.01 | 0.06 | -0.19 | 0.08 |
| BY | | | | | | | | -0.27 | -0.21 | 0.40** | 0.85** | -0.97** | 0.30* | -0.45** | -0.10 |
| TNPP | | | | | | | | | 0.89** | -0.21 | -0.24 | 0.28* | 0.11 | 0.19 | 0.13 |
| ENPP | | | | | | | | | | -0.17 | -0.24 | 0.21 | -0.09 | 0.17 | 0.14 |
| RDW | | | | | | | | | | | 1.28** | -0.11 | -0.05 | -0.49** | 0.01 |
| RV | | | | | | | | | | | | -0.24 | -0.42** | -0.59** | -0.52** |
| RBR | | | | | | | | | | | | | -0.32* | 0.32* | 0.19 |
| HSW | | | | | | | | | | | | | | 0.04 | 0.12 |
| HI | | | | | | | | | | | | | | | 0.12 |
| 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.**

**Table 2: Phenotypic correlation coefficients at Jimma.**

| Traits | DF | DPS | DM | PH | PPP | PL | BY | TNPP | ENPP | RDW | RV | RBR | HSW | HI | GY |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DF | | | | | | | | | | | | | | | |
| DPS | 0.83** | | | | | | | | | | | | | | |
| DM | 0.62** | 0.72** | | | | | | | | | | | | | |
| PH | 0.35* | 0.50** | 0.56** | | | | | | | | | | | | |
| PPP | 0.24 | 0.11 | 0.06 | 0.07 | | | | | | | | | | | |
| PL | -0.10 | -0.14 | -0.15 | -0.27 | -0.21 | | | | | | | | | | |
| BY | 0.22 | 0.19 | 0.17 | 0.31* | 0.33* | 0.05 | | | | | | | | | |
| TNPP | -0.45** | -0.53** | -0.41** | -0.36* | -0.12 | 0.13 | -0.24 | | | | | | | | |
| ENPP | -0.34* | -0.41** | -0.29* | -0.21 | 0.02 | 0.07 | -0.19 | 0.89** | | | | | | | |
| RDW | 0.17 | 0.17 | 0.08 | 0.08 | -0.03 | 0.10 | 0.28 | -0.09 | -0.07 | | | | | | |
| RV | 0.17 | 0.09 | 0.10 | -0.08 | 0.15 | 0.10 | 0.26 | -0.09 | -0.11 | 0.28 | | | | | |
| RBR | -0.12 | -0.13 | -0.17 | -0.25 | -0.29* | -0.03 | -0.64** | 0.20 | 0.16 | 0.42** | -0.19 | | | | |
| HSW | -0.02 | -0.08 | 0.08 | 0.05 | -0.08 | -0.06 | 0.21 | 0.07 | -0.06 | 0.01 | -0.08 | -0.19 | | | |
| HI | 0.05 | -0.09 | -0.05 | -0.20 | 0.46** | -0.21 | -0.42** | 0.16 | 0.16 | -0.25 | -0.17 | 0.17 | 0.36* | | |
| GY | -0.44** | -0.52** | -0.48** | -0.21 | -0.04 | 0.08 | -0.09 | 0.13 | 0.14 | 0.00 | -0.22 | 0.14 | 0.08 | 0.11 | |

**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.**

The Genotypic direct and indirect effect of different characters on seed yield is presented in Table3. Effective nodules per plant had the highest positive direct effect (0.837). Moreover, the indirect effect via other traits was negative and hence the correlation it had with yield was largely due to the direct effect. This suggests the correlation showed the true relationship and direct selection through this character will be effective (Singh and Chaudhary, 1979).

The high positive direct effect of hundred seed weight on grain yield was counter balanced by indirect negative effects of root to biomass ratio, total nodules per plant, root dry weight and harvest index and reduced the correlation to 0.120.

Total nodules per plant which had the highest negative direct effect revealed prominent indirect effects via days to maturity, effective nodules per plant, days to 50% flowering, days to pod setting, pod length, biomass yield and root volume.

The third highest positive direct effect of root to biomass ratio was counter balanced by indirect negative effects of total nodules per plant, pod number per plant, harvest index, plant height and root dry weight and reduced the correlation to 0.190.

Direct positive effect of pod length on grain yield was counter balanced by indirect negative effects of days to maturity, plant height, root to biomass ratio, biomass yield, total nodules per plant, and hundred seed weight and reduced the correlations to 0.08.

The second highest negative direct effect of harvest index (-0.459) is counter balanced by the indirect positive effect via pod number per plant, biomass yield, root volume, root to biomass ratio, effective nodules per plant, days to maturity and days to pod setting and reduced the correlation to 0.120.

The indirect negative effect of pod number per plant via days to 50% flowering, days to pod setting, days to maturity, harvest index, biomass yield, pod length, root to biomass ratio and harvest index counter balanced the positive direct effect of pod number per plant on grain yield and reduced the correlations to –0.051. The correlation of pod number per plant with grain yield was negative and path analysis showed that the negative correlation was mainly due to the indirect negative effect of the character.

Even though root volume had direct negative effect (-0.269) on grain yield, it was counter balanced by the indirect positive effect via the characters root dry weight, harvest index, total nodules per plant, pod length and plant height as a result the correlation was changed to 0.011. Path analysis showed the positive correlation of root volume with grain yield through indirect effects of other characters.

The direct positive effect of plant height (0.290) was counter balanced by indirect negative effects of days to maturity, root to biomass ratio, biomass yield, days to pod setting, effective nodules per plant, days to 50% flowering, pod length, root volume and root dry weight. The negative correlation of this character was mainly due to the indirect negative effect of other characters.

The positive direct effect of root dry weight (0.214) was counter balanced by the negative indirect effect of root volume, hundred seed weight, root to biomass ratio, effective nodules per plant, biomass yield, plant height, days to maturity, days to flowering and days to pod setting and the correlation was changed to -0.520. Path analysis showed that the negative correlation of root dry weight with grain yield was due to the indirect effects of other characters.

The second highest negative direct effect of days to maturity (-0.615) was counter balanced by positive indirect effect of total nodules per plant, plant height, pod number per plant, root dry weight, hundred seed weight and harvest index, which reduced the correlation to -0.52.

**Table 3: Path coefficients of direct (bold diagonal) and indirect effects (off diagonal) at genotypic level of 15 traits on grain yield on 49 soybean germplasm at Jimma.**

| Traits | DF | DPS | DM | PH | PPP | PL | BY | TNPP | ENPP | RV | RDW | RBR | HSW | HI | rg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **DF** | **-0.201** | -0.101 | -0.384 | 0.115 | 0.177 | -0.014 | -0.059 | 0.568 | -0.314 | -0.074 | 0.050 | -0.119 | -0.121 | -0.001 | -0.48** |
| **DPS** | -0.177 | **-0.115** | -0.454 | 0.152 | 0.089 | -0.020 | -0.053 | 0.639 | -0.367 | -0.100 | 0.041 | -0.111 | -0.141 | 0.071 | -0.55** |
| **DM** | -0.126 | -0.085 | **-0.615** | 0.175 | 0.053 | -0.023 | -0.046 | 0.501 | -0.270 | -0.047 | 0.034 | -0.150 | 0.024 | 0.058 | -0.52** |
| **PH** | -0.080 | -0.060 | -0.370 | **0.290** | 0.050 | -0.039 | -0.081 | 0.424 | -0.183 | -0.069 | -0.062 | -0.188 | 0.026 | 0.119 | -0.22 |
| **PPP** | -0.060 | -0.017 | -0.055 | 0.024 | **0.591** | -0.024 | -0.075 | 0.141 | 0.022 | 0.006 | 0.065 | -0.254 | -0.165 | -0.245 | -0.05 |
| **PL** | 0.022 | 0.018 | 0.113 | -0.089 | -0.111 | **0.127** | -0.014 | -0.165 | 0.062 | -0.059 | 0.040 | 0.007 | 0.043 | 0.089 | 0.08 |
| **BY** | -0.052 | -0.027 | -0.123 | 0.104 | 0.196 | 0.008 | **-0.228** | 0.304 | -0.173 | -0.106 | 0.183 | -0.623 | 0.230 | 0.208 | -0.10 |
| **TNPP** | 0.101 | 0.065 | 0.273 | -0.109 | -0.074 | 0.019 | 0.061 | **-1.130** | 0.747 | 0.056 | -0.051 | 0.177 | 0.081 | -0.089 | 0.13 |
| **ENPP** | 0.076 | 0.050 | 0.199 | -0.063 | 0.016 | 0.009 | 0.047 | -1.008 | **0.837** | 0.046 | -0.052 | 0.132 | -0.072 | -0.078 | 0.14 |
| **RV** | -0.056 | -0.043 | -0.107 | 0.074 | -0.012 | 0.028 | -0.090 | 0.236 | -0.143 | **-0.269** | 0.275 | -0.073 | -0.036 | 0.225 | 0.01 |
| **RDW** | -0.047 | -0.022 | -0.097 | -0.084 | 0.179 | 0.024 | -0.194 | 0.268 | -0.202 | -0.345 | **0.214** | -0.153 | -0.323 | 0.268 | -0.52** |
| **RBR** | 0.037 | 0.020 | 0.144 | -0.085 | -0.234 | 0.001 | 0.222 | -0.312 | 0.172 | 0.030 | -0.051 | **0.640** | -0.247 | -0.148 | 0.19 |
| **HSW** | 0.032 | 0.021 | -0.019 | 0.010 | -0.128 | 0.007 | -0.069 | -0.120 | -0.078 | 0.013 | -0.091 | -0.207 | **0.764** | -0.017 | 0.12 |
| **HI** | 0.001 | 0.018 | 0.078 | -0.075 | 0.315 | -0.025 | 0.103 | -0.219 | 0.142 | 0.132 | -0.125 | 0.207 | 0.029 | **-0.459** | 0.12 |

**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.**

Days to 50% flowering, days to pod setting, days to maturity and biomass yield had negative direct effect on grain yield indicating any increase in these characters affects grain yield in the negative direction. Therefore, selecting genotypes having less number of days to flowering, less number of days to pod setting and less number of days to maturity could be used to improve seed yield in soybean genotypes, as a result of their direct effect on yield.

The residual effect (0.252) indicated that characters which are included in the genotypic path analysis explained (74.80%) of the total variation in grain yield which indicates that there may be some more components that are contributing towards seed yield.

Path analysis (Table 3) indicated selecting genotypes having high root to biomass ratio, hundred seed weight and effective nodules per plant could be used to improve seed yield in soybean genotypes as a result of their direct effect on grain yield.

## Conclusions

Correlation analysis showed that grain yield demonstrated negative and significant association with days to 50% flowering, days to pod setting and days to maturity both at phenotypic and genotypic levels. Grain yield had negative and significant correlation with days to maturity and root to biomass ratio at phenotypic level. Selecting for those traits showing positive and significant correlation coefficient with grain yield supports the possibility to increase grain yield of soybean.

Genotypic correlation coefficients of various characters with seed yield were partitioned into direct and indirect effects. Effective nodules per plant exerted the highest positive genotypic direct effect followed by hundred seed weight, root to biomass ratio, pod number per plant, plant height, root dry weight and pod length. The rest of the characters had negative direct effect on grain yield. Therefore, root to biomass ratio, hundred seed weight and effective nodules per plant were the important contributors to seed yield and these traits could be used as an indirect selection criterion.

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