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CORRELATION AND PATH COEFFICIENT ANALYSIS AMONG GRAIN YIELD AND YIELD-RELATED TRAITS OF SOYBEANS (Glycine max (L.) Merill) GENOTYPES

1. Uzege, S.T.
2. Kyausu, I.S
3. Gbira, T
4. Akombo Godwin

1. Departmentof Horticulture and Landscape Technology, AkanuIbiam Federal PolytectnicUnwana, Afikpo Ebonyi, Nigeria.
2. Department of Agricultural Education, College of Education, Joseph Sarwuan Tarka University Makurdi, Nigeria
3. Department of Biological Sciences, Benue State University, Makurdi
4. Department of Urban and Regional Planning, AkanuIbiam Federal Polytectnic Unwana, Afikpo Ebonyi, Nigeria.

Abstract- Understanding the direct and indirect relationships between grain yield and its component traits are essential for effective indirect selection in soybean breeding. This study evaluated 70 soybean genotypes for grain yield and 11 yield-related traits, and performed correlation and path coefficient analysis to partition the effects of component traits on yield. Grain yield showed significant positive genotypic correlations with plant height (rg = 0.42, p<0.01), pods per plant (rg = 0.38, p<0.01), 100-seed weight (rg = 0.29, p<0.05), and seeds per pod (rg = 0.24, p<0.05). Path coefficient analysis at the genotypic level revealed that pods per plant exerted the highest positive direct effect on grain yield (P = 0.46), followed by 100-seed weight (P = 0.31) and plant height (P = 0.22). Seeds per pod showed a moderate direct effect (P = 0.18), while days to 50% flowering exerted a negative direct effect (P = -0.24), indicating that early flowering contributes to higher yield. The residual effect (R = 0.31) indicated that traits not included in the model (e.g., stress tolerance, harvest index) also influence yield. The high direct effect of pods per plant suggests that selection for increased pod number would be the most effective strategy for indirect yield improvement in this population. A selection index based on pods per plant, 100-seed weight, and early flowering is recommended for improving grain yield in these soybean genotypes.

Keywords: ***Soybean, correlation, path coefficient, yield components, indirect selection, Glycine max***

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INTRODUCTION

Soybean (Glycine max L.) is one of the very important leguminous and oil crops with worldwide importance as food and market crop. This is mainly because of its high grain nutritional value with 40% protein and 20% oil, that makes it an important raw material for food and oil processing industries (Omoigui*et al*., 2020). It has wide adaptability coupled with unique ability to fix high amount of nitrogen, thereby improving soil fertility and permitting farmers to use less fertilizer and reduce farm cost (Azu *et al*., 2019). In addition, soybean provides health benefits in consumption, and is as such also considered as a strategic crop in fighting the worlds' food shortage and malnutrition problems, and most food aids to displaced and malnourished people are fortified with soybean (Abush*et al*., 2017).

Despite the wide range of benefits that soybean could provide to subsistence farmers of sub-Saharan Africa, its productivity is very low (below 2.0 t ha-1) in many of these countries as compared to more than 2.7 t ha-1 productivity obtained in some other countries (FAOSTAT, 2018). The low yield is due in part to poor yielding varieties, as a result, in order to generate high-yielding soybean genotypes, it is needed to examine the determinants and interrelationships among agronomic traits (Yoosefzadeh-Najafabadi*et al*.,2021.). Seed yield, as a complex trait, is the result of the expression of the association of several plant growth components.

In the last two decades, soybean breeders have made tremendous efforts to increase the yield by selecting superior genotypes not necessarily based on yield per se but yield components as well, these components directly explained the variation of yield in genotypes (Nagre, 2017)). The grain yield is a complex character, quantitative in nature, direct selection is challenging due to its low heritability, thus, direct selection methods can be less effective (Shaahu*et al*., 2014; Nagre, 2017; Liu *et al*., 2021; Christabell Nachilima, 2021 and Yoosefzadeh-Najafabadi*et al*.,2021). Therefore, indirect selection strategies targeting traits associated with improved yield are highly important. The aim of this study is to determine which yield components have the greatest impact on soybean production.

Materials and Methods

The study was carried out at Nigeria Cereals Research Institute, Badeggi, Bida, Niger State, Nigeria, (Latitude 9.0568^{0}N Longitude 6.1434^{0}E). A total of 70 genotypes were used. The trial was laid out in Randomized

Complete Block Design (RCBD) with three (3) replications. The 70 genotypes were planted each on 4m X 1.5m plot size having 4 rows including 2 borders with inter-row spacing of 50cm, intra-row spacing of 5cm and alleyways of one (1m). Fertilizer was applied as mixture of Single super phosphate (SSP) and Nitrogen Phosphorus potassium (N.P.K), at the ratio of 3kg to 2kg and applied before planting. Data were collected on the following parameters; plant height, number of branches per plant, days to 50% flowering, days to 95% maturity, number of pods per plant, number of seeds per pods, lodging, number of shattered pods, pod clearance, nodulation 100 seed weight and grain yield.

Estimation of correlation coefficient (r)

Correlation coefficient (r) is a measure of the association between two or more than two variables. The phenotypic correlation and genotypic correlation coefficients between two variables including genotype were estimated as described by Singh and Chaudhary (1985).

Path coefficient analysis

Path coefficient analysis was calculated using as suggested by Dewey and Lu (1959) to deter-mine direct and indirect effect of different variables on grain yield. The residual effect (R), representing the influence of unmeasured traits, was also calculated.

$R=1-\sum i=1n(Piy\times riy)$

Results and Discussion

Table 1. Genotypic Correlations (r_g) Among 12 Traits in 70 Soybean Genotypes

Grain yield showed highly significant and positive correlation with plant height, pods per plant, 100 seeds weight and seeds per pod. It also showed negative significant correlation with days to flowering. This suggests that, selection for taller plants, more pods, larger seeds, more seeds per pod and early flowering would lead to simultaneous improvement of grain yield in soybeans. These findings are in conformity with the results reported by Lodhi *et al*. (2023), Berhanu*et a*l. (2021), Soleh *et al*. (2016), and Baraska*et al*. (2015). Further, it was displayed from the on-going study that the mutual association among different traits revealed that days to 50% flowering exhibited highly positive and significant genotypic association with days to maturity (0.58**) and pod shattering (0.41**). Plant recorded positive significant association number pods per plant (0.35*). This suggests that Late flowering strongly associated with late maturity, Late-flowering genotypes more prone to pod shattering and taller plants produce more pods. Similar results were also reported by various researchers, for example, Lodhi *et al*. (2023), Neelima *et al*. (2018), Shekar *et al*. (2018), Berhanu *et al*. (2021), and Pawar *et al*. (2020) perceived positive and significant correlation between days to 50% flowering and days to 95% maturity. When yield-contributing attributes exhibit a positive and significant correlation, it guides the plant breeders to carry out the indirect selection to enhance yield. This is crucial because direct selection alone is ineffective as yield relies on yield components. Therefore, by focusing on and performing indirect selection on traits such as plant height, number of pods plant−1, days to flowering and days to maturity, will certainly help the breeder to tap into the genetic potential of such traits. This will help in selecting superior soybean genotypes from the breeding population, such breeding lines would be better widely adapted to different environmental conditions. Such a move can contribute to sustainable agriculture and can significantly enhance the soybean yield and achieve higher productivity as well.

Table 1. Genotypic Correlations (r_g) Among 12 Traits in 70 Soybean Genotypes

Trait	GY	PH	D50%f	DM	Nod	Lodging	PClear	PShat	Branches	Pods	SeedsPod	SW100
GY	1.00											
PH	**0.42**	1.00										
D50%f	**-0.31**	-0.09	1.00									
DM	-0.18	-0.11	**0.58**	1.00								
Nod	0.11	0.08	-0.07	-0.04	1.00							
Lodging	-0.08	0.12	0.15	0.09	-0.11	1.00						
PClear	0.14	0.18	-0.12	-0.06	0.05	-0.03	1.00					
PShat	-0.22	-0.14	**0.41**	**0.48**	-0.08	0.11	-0.10	1.00				
Branches	0.16	0.21	-0.15	-0.10	0.12	-0.04	0.09	-0.13	1.00			
Pods	**0.38**	**0.35**	-0.11	-0.08	0.14	-0.02	0.13	-0.09	0.19	1.00		
SeedsPod	**0.24**	0.10	-0.04	-0.03	-0.18	-0.06	0.08	-0.11	-0.18	0.08	1.00	
SW100	**0.29**	0.06	-0.18	-0.12	0.09	-0.07	0.05	-0.15	0.11	0.05	0.06	1.00

Path coefficient analysis was performed at the genotypic level using grain yield as the dependent variable and the 11 yield-related traits as causal variables. The direct effects (path coefficients) and indirect effects are presented in Table 2. The choice facilitates the identification of key traits that directly impact grain yield, as well as those that exert their influence indirectly through other variables. The number of pods plant−1 emerges as pivotal, demonstrating a strong positive association with grain yield at genotypic level. Upon splitting the correlation, it was observed that number of pods plant−1 exerts the highest positive direct effect (0.46) among the traits studied. Moreover, it indirectly enhances grain yield through plant height. 100-seed weight (P = 0.31) exerted the second strongest direct effect on grain yield. Days to 50% flowering (P = -0.24) showed a moderate negative direct effect and indirectly influence yield via positive days to maturity (0.13) and pod shattering (0.10). Plant height (0.22) had a moderate direct positive effect, but its indirect effect via pods per plant (0.16) was nearly as large as its direct effect. Seeds per pod (P = 0.18) exerts a weak but positive direct effect. Its correlation with yield (r_g = 0.24) was slightly higher than its direct effect due to small positive indirect effects via pods per plant (0.04) and plant height (0.02). The residual effect of 0.31 indicates that approximately 31% of the variation in grain yield is explained by traits not included in this path model.

Table 2. Direct (Diagonal, Bold) and Indirect Effects of 11 Yield-Related Traits on Grain Yield (Genotypic Level)

Trait	PH	D50%f	DM	Nod	Lodging	PClear	PShat	Branches	Pods	SeedsPod	SW100	r_g with GY
PH	**0.22**	-0.02	-0.02	0.01	0.01	0.02	-0.02	0.03	0.16	0.02	0.02	0.42
D50%f	-0.02	**-0.24**	0.13	-0.01	0.02	-0.01	0.10	-0.02	-0.05	-0.01	-0.06	-0.31
DM	-0.02	0.14	**0.05**	-0.01	0.01	-0.01	0.12	-0.01	-0.04	-0.01	-0.04	-0.18
Nod	0.02	-0.02	-0.00	**0.04**	-0.01	0.01	-0.02	0.02	0.06	-0.03	0.03	0.11
Lodging	0.03	0.04	0.00	-0.00	**-0.03**	-0.00	0.03	-0.01	-0.01	-0.01	-0.02	-0.08
PClear	0.04	-0.03	-0.00	0.00	-0.00	**0.06**	-0.02	0.01	0.06	0.01	0.02	0.14
PShat	-0.03	0.10	0.02	-0.00	0.00	-0.01	**-0.09**	-0.02	-0.04	-0.02	-0.05	-0.22
Branches	0.05	-0.04	-0.01	0.00	-0.00	0.01	-0.01	**0.08**	0.09	-0.03	0.03	0.16
Pods	0.08	-0.03	-0.00	0.01	-0.00	0.01	-0.01	0.02	**0.46**	0.01	0.02	0.38
SeedsPod	0.02	-0.01	-0.00	-0.01	-0.00	0.00	-0.01	-0.01	0.04	**0.18**	0.02	0.24
SW100	0.01	-0.04	-0.01	0.00	-0.00	0.00	-0.01	0.01	0.02	0.01	**0.31**	0.29

Pods per Plant: The Primary Yield Determinant

The finding that pods per plant had the highest direct effect (P = 0.46) on grain yield is consistent with a large body of soybean literature. Malek et al. (2014) reported direct effects ranging from 0.35 to 0.55 in different soybean populations. Similarly, Sadeghi (2009) found pods per plant to be the most important yield component in Iranian soybean germplasm. pods per plant had a positive indirect effect via plant height (0.16), indicating that taller genotypes tend to have more nodes and thus more pods. However, the direct effect (0.46) was much larger than the indirect effect, meaning that even among plants of equal height, those with more pods yield more. Selection for increased pod number should be the **primary indirect selection criterion** for yield improvement in this population. Pods per plant can be measured relatively easily and has moderate heritability.

100-Seed Weight: The Second Most Important Direct Contributor

100-seed weight showed a direct effect of 0.31, ranking second among all traits. This finding aligns with previous studies: Pandey *et al*. (2014) reported direct effects of 0.28–0.35 for seed weight in tropical soybean germplasm. Simultaneous selection for pods per plant and 100-seed weight is feasible and recommended.

Days to 50% Flowering: The Negative Direct Effect

The negative direct effect of days to 50% flowering (P = -0.24) indicates that early flowering directly increases yield. This finding has important implications for soybean breeding in tropical environments. Similar findings were reported by several scientist, (Shaahu*et al*., 2014, Pandey *et al*., 2014). Select for early to medium flowering (45–50 days), not extremely early or late.

Plant Height: A Double-Edged Trait

Plant height showed a moderate direct effect (P = 0.22) and a substantial indirect effect via pods per plant (0.16). This suggests that taller plants produce more pods (more nodes) and therefore yield more. Tall plants are more prone to lodging (though lodging showed negligible direct effect in this study). Similar case was reported by Shaahu*et al*. (2014). Select for **medium plant height (35–50 cm)** that balances pod number and lodging resistance.

Seeds per Pod: A Minor Component

Seeds per pod had a weak direct effect (P = 0.18) and relatively low correlation with yield (r_g = 0.24). Most soybean genotypes in this population had 2.4–3.0

seeds per pod (mean 2.67), with limited variation. The narrow range (2.13–3.00) explains the weak effect.While maintaining at least 2.5 seeds per pod is important, selection for increased seeds per pod will yield minimal gains because the trait is already near its biological maximum (3–4 seeds per pod in soybean).

Conclusion and Recommendations

Correlation and path analysis reveal that pods per plant, 100-seed weight, plant height, seeds per pod and days to flowering, influenced grain yield either directly or indirectly. Therefore, these traits should be included in the breeding programme of soybeans. Path coefficient analysis at the genotypic level revealed that Pods per plant, 100-seed weight and Plant height exerted high and favorable direct effects on grain yield. The favorable direct effects of these traits on grain yield indicate that other variables kept constant, improvement of these traits will increase grain yield. Also plant height affects yield partly through its effect on pod number and late flowering reduces yield partly by increasing pod shattering. The residual effect (R = 0.31) indicated that approximately 31% of yield variation is explained by traits not included in the model.

Selection criterion should focus on Pods per plant, 100-seed weight**,** Earlyflowering (45–50 days) to avoid negative direct effect. Maintain or improve seeds per pod (>2.5) as a supporting trait. Genotypes with high pod number, large seed size, and early flowering (e.g., TGx_24_43NG-0115, TGx_24_36NG-0075, TGx_24_43NG-0120) should be prioritized as parents for crossing and further testing.

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