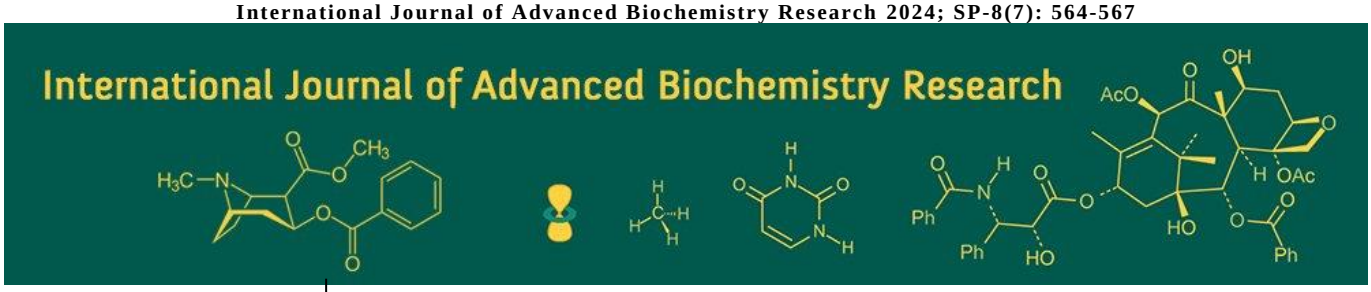

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Decoding yield determinants: Path analysis in soybean [*Glycine max* (L.) Merr.] Germplasm

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Abstract
An experiment entitled "Decoding Yield Determinants: Path Analysis in Soybean [*Glycine max* (L.) Merr.] Germplasm" was carried out during Kharif 2023-24 at the experimental farm of the College of Agriculture, Badnapur. Vasantrao Naik Marathwada Krishi Vidyapeeth Parbhani (M.S). The experiment was laid out in a Randomized Block Design (RBD) with 38 genotypes and two replications to estimate the path analysis for yield-contributing characters in the germplasm of soybean. Among all the characters, the highest positive direct effects were observed for the number of pods per plant, 100-seed weight, number of seeds per pod, and harvest index at both levels. This revealed the true relationship of these characters with grain yield per plant. Hence, direct selection for these traits could be rewarding for the improvement of grain yield.

Keywords: Path analysis studies, soybean, Soybean [*Glycine max* (L.) Merr.], germplasm, variability

Introduction
Soybean (*Glycine max* L. Merril) is the world's most important seed legume, which contributes to 25 % of the global edible oil, about two-thirds of the world's protein concentrate for livestock feeding. soybean has meant to be meat, milk, cheese, bread, and oil. This could well be the reason, why in these countries, it has earned epithets like ''Cow of the field'' or ''Gold from soil''. In India, as on September 2022 area under soyabean during 2022-23 was 120.90 lakh hectares as against 120.86 lakh hectares during 2021-22. Among the states, Madhya Pradesh stood first with 50.18 lakh ha followed by Maharashtra (49.10 lakh ha) while Path coefficient analysis plays a crucial role in this context by dividing correlation coefficients into unidirectional and alternative paths, which enables a more thorough investigation of the particular elements contributing to a given connection.

Materials and Methods
The present investigation was conducted during the Kharif season of 2023 at the experimental farm of the College of Agriculture, VNMKV Parbhani, Maharashtra. The experimental material consisted of thirty-eight genotypes of soybean along with two checks, MAUS 612 and MAUS 158. The evaluation of different genotypes was performed in two replications using a Randomized Block Design (RBD). Each genotype was sown in one row of 3 m length with spacing of 45 cm between rows and 5 cm between plants. Recommended agronomical and plant protection practices were implemented to ensure successful crop cultivation. Observations were recorded for five randomly selected plants from each replication for 10 characters, including days to 50% flowering, days to maturity, plant height (cm), number of branches per plant, number of pods per cluster, number of pods per plant, 100-seed weight (g), seed yield per plant (g), number of seeds per pod, and harvest index (%). To establish a cause and effect relationship, the first step was to partition the genotypic and phenotypic correlation coefficients into direct and indirect effects by path analysis as suggested by Dewey and Lu (1959) [2] and developed by Wright (1921) [12].

Results and Discussion
Path coefficient analysis provides a thorough understanding of contribution of various characters by partitioning the correlation coefficient into components of direct and indirect

effects (Wright, 1921) [12], which helps the breeder in determining the yield components. The aim of this analysis in the present investigation was to demonstrate the significance of path coefficient analysis in determining the true nature of character association. According to Falconer (1960) [4], it is often assumed that association between two characters is an evidence of pleiotropy rather than linkage hence under such complex situations, path coefficient analysis is a powerful tool for studying character association.

Grain yield is a complex character, depend upon other component characters which exert their effect directly and indirectly. Direct effect of any character on grain yield gives an idea about how effective selection can be made to bring improvement in the latter. The indirect effect indicate interrelationship of component characters towards contribution to yield.

Therefore, results pertaining to direct and indirect effect at genotypic levels and phenotypic level is presented in Table 1 and Fig 1. Days to 50 per cent flowering had negative direct effect (-0.084, -0. 145) on seed yield per plant at both genotypic and phenotypic levels. It had positive indirect effect on number of branches per plant (0.002, 0.006), at both levels. However, negative indirect effect through number of pod per cluster (-0.056, -0.106), No of seed per pod (-0.082, -0.050), number of pod per plant (-0.107, -0.054), number of pod per cluster (-0.056, -0.106), 100 seed weight (-0.045,-0.032). while Days to maturity (-0.008, 0.006) shows negative indirect effect at genotypic level and positive indirect effect at phenotypic level on seed yield per plant. Plant height (0.001, -0.00) have positive genotypic effect on yield per plant as well as negative indirect effect at phenotypic effect. (Chandel *et al.* 2017) [7], (T. Machikowa *et al.* 2011) [9].

Plant height recorded positive direct effect at genotypic and negative direct effect at phenotypic effect (0.006, -0.001) on seed yield per plant. Plant height shows negative indirect effect with days to 50 per cent flowering (-0. 012, -0.019), number of pod per plant (-0.088, -0.056), number of pod per cluster (-0.031, -0.064), 100 seed weight (-0.012, -0.008), Harvest Index (-0.027, -0.016), number of branches per plant (-0.003, -0.011), Number of seed per pod (-0.004, -0.002) at genotypic and phenotypic level, it also shows negative indirect effect with days to days to maturity (-0.005) at genotypic level and positive indirect effect (0.005) at phenotypic level. (Khan N.A 2022) [8] (Vasundhara Dangi *et al.* 2021) [10].

Days to maturity showed negative direct effect at genotypic and positive direct effect at phenotypic level (-0.016, 0.014) on seed yield per plant. It shows the negative indirect effect with days to 50 per cent flowering (-0.040, -0.062), Harvest index (-0.017, -0.009), number of pod per plant (-0.124, -0.078), number of branch per plant (-0.001, -0.004), number of pod per cluster (-0.062, -0.125), Number of seed per pod (-0.042, -0.026) 100 seed weight (-0.044, -0.027), on seed yield per plant at both genotypic and phenotypic levels, Plant height (0.002, -0.00) have positive genotypic effect on yield per plant as well as negative indirect effect at phenotypic effect. (Khan N.A 2022) [8].

Number of branches per plant shows positive direct effect (0.009, 0.039), on seed yield per plant at both genotypic and phenotypic levels respectively while number of branches per plant shows positively indirect effect with number of pod per plant (0.047,0.026), 100 seed weight (0.036, 0.027), harvest index (0.008, 0.004). It shows the negative indirect effect with days to 50 per cent flowering (-0.016, -0.024), number of pod per cluster (-0.012, -0.027), at both the levels. Days to maturity have (-0.005, -0.005) negative indirect at genotypic level and positive indirect effect at phenotypic level. Number of branches per plant shows positive indirect effect with days to maturity at genotypic level (0.002) and negative indirect effect at phenotypic level (-0.001) Number of pods per plant had positive direct effect (0.568, 0.239), on seed yield per plant at genotypic and phenotypic levels. This traits had positively indirect effect through days to 50% flowering (0.158, 0.059), plant height (0.209, 0.069), days to maturity (0.085, 0.032), number of branches per plant (0.100, 0.042), number of pods per cluster (0.444, 0.147), 100 seed weight (0.394, 0.117), oil content (0.174, 0.094), on seed yield per plant at both genotypic and phenotypic levels which finally resulted in positive indirect effect (0.645, 0.533) with seed yield per plant at both levels. (Vinod kumar *et al.* 2020) [11].

Number of pods per plant had positive direct effect (0.009, 0.039), on seed yield per plant at genotypic and phenotypic levels. This traits had positively indirect effect through number of pods per plant (0.047, 0.026), 100 seed weight (0.036, 0.027), harvest index (0.008, 0.004), on seed yield per plant at both genotypic and phenotypic levels while Number of pods per plant had negative indirect effect with days to 50 per cent flowering (-0.016, -0.024), number of pods per cluster (-0.012, -0.027), No of seed per pod (-0.055, -0.036) at both levels. Plant height (-0.002, 0.00) have negative genotypic effect on yield per plant as well as positive indirect effect at phenotypic effect. Days to maturity have (0.002, -0.001) positive indirect at genotypic level and negative indirect effect at phenotypic level. (Jain *et al.* 2000) [6] (Dubey *et al.* 2018) [3].

Number of pods per cluster showed positive direct effect (0.220, 0.465) at on seed yield per plant at genotypic and phenotypic levels respectively. This traits had positively indirect effect through number of pods per plant (0.401, 0. 246), 100 seed weight (0.064, 0.044), harvest index (0.088, 0.049), Number of seed per pod (0.123, 0.077), days to 50 per cent flowering (0.021, 0.033)on seed yield per plant at both genotypic and phenotypic levels while Number of pods per cluster showed negative indirect effect with number of branch per plant (-0.001, -0.002) at both the level. Plant height (-0.001, 0.00) have positive genotypic effect on yield per plant as well as negative indirect effect at phenotypic effect. Days to maturity have (0.005, -0.004) positive indirect at genotypic level and negative indirect effect at phenotypic level. (Vinod kumar *et al.*2020) [11]

The association between 100 seed weight was positively direct effect (0.251, 0.187), on seed yield per plant at both genotypic and phenotypic levels. 100 seed weight had positively indirect effect with days to 50 per cent flowering (0.015, 0.025), number of branches per plant (0.001, 0.006), number of pod per cluster (0.056, 0.111), harvest index (0.035, 0.020), Number of seed per pod (0.123, 0.077) at both genotypic and phenotypic levels, while Plant height (-0.00, 0.00) have negative genotypic effect on yield per plant as well as positive indirect effect at phenotypic effect. Days to maturity have (0.003, -0.002) positive indirect at genotypic level and negative indirect effect at phenotypic level. Number of pods per plant (-0.046, -0.032) shows negative indirect effect with 100 seed weight at both the levels. (K.k Chandel *et al.* 2017) [7] (Chavan *et al.*2016) [1]

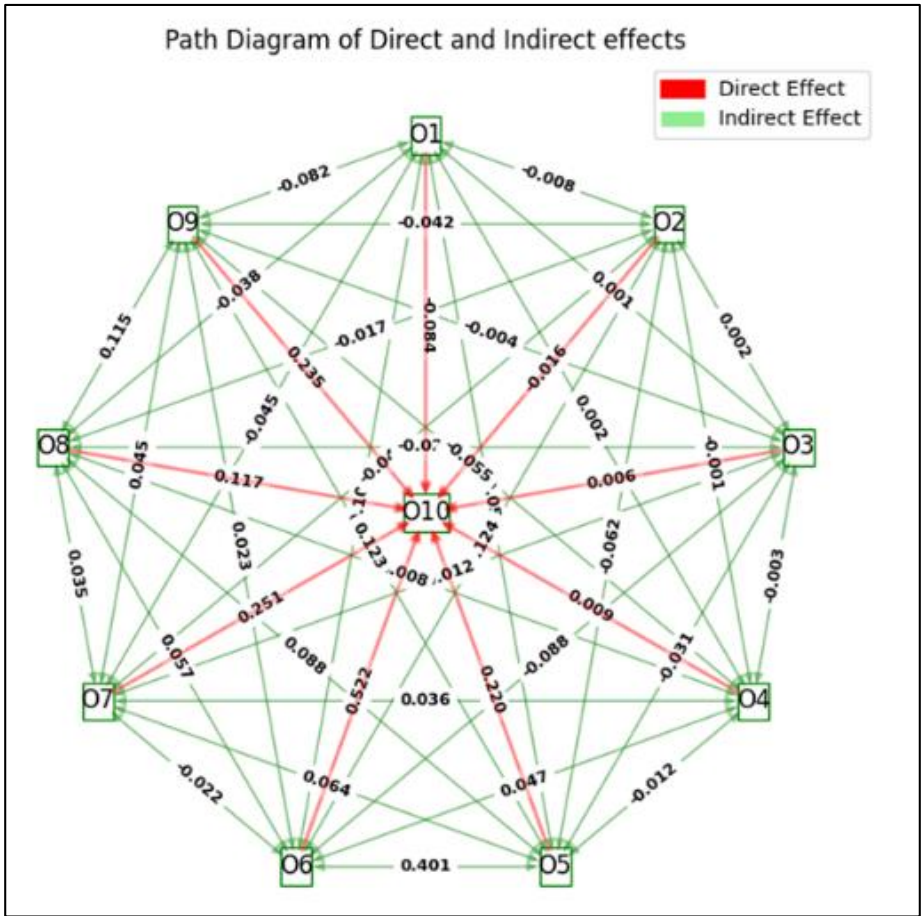
No. of pod per plant had positive direct effect (0.522, 0.339), on seed yield per plant at both genotypic and phenotypic level respectively. No. of pod per plant had showed positive indirect effect with days to 50 per cent flowering (0.017, 0.023), number of branches per plant (0.001, 0.003), number of pod per cluster (0.169, 0.337), harvest index (0.057, 0.027), Number of seed per pod (0.023, 0.012) at both genotypic and phenotypic levels. While it shows negative indirect effect with 100 seed weight (-0.022, -0.018), at both the levels. Plant height (-0.001, 0.00) have negative genotypic effect on yield per plant as well as positive indirect effect at phenotypic effect. Days to maturity have (0.004, -0.003) positive indirect at genotypic level and negative indirect effect at phenotypic level. (Gohil *et al.* 2003) [5] (Jain *et al.* 2000) [6].

Table 1: Genotypic and phenotypic path analysis for Direct (Diagonal) and Indirect (off diagonal) effects of yield Components on seed yield.

Sr. No.	Name of the Character		Days to 50 percent flowering	Days to maturity	Plant height (cm)	No. of branches per plant	No. of pod per cluster	No. of pods per plant (g)	100 seed weight (g)	Harvest Index (%)	No. of seed per pod
1	Days to 50 per cent flowering	G	-0.084	-0.008	0.001	0.002	-0.056	-0.107	-0.045	-0.038	-0.082
		P	-0.145	0.006	-0.000	0.006	-0.106	-0.054	-0.032	-0.017	-0.050
2	Days to maturity	G	-0.040	-0.016	0.002	-0.001	-0.062	-0.124	-0.044	-0.017	-0.042
		P	-0.062	0.014	-0.000	-0.004	-0.125	-0.078	-0.027	-0.009	-0.026
3	Plan height (cm)	G	-0.012	-0.005	0.006	-0.003	-0.031	-0.088	-0.012	-0.027	-0.004
		P	-0.019	0.005	-0.001	-0.011	-0.064	-0.056	-0.008	-0.016	-0.002
4	No. of branches per plant	G	-0.016	0.002	-0.002	0.009	-0.012	0.047	0.036	0.008	-0.055
		P	-0.024	-0.001	0.000	0.039	-0.027	0.026	0.027	0.004	-0.036
5	No. of pods per cluster (g)	G	0.021	0.005	-0.001	-0.001	0.220	0.401	0.064	0.088	0.123
		P	0.033	-0.004	0.000	-0.002	0.465	0.246	0.044	0.049	0.077
6	No. of pod per Plant	G	0.017	0.004	-0.001	0.001	0.169	0.522	-0.022	0.057	0.023
		P	0.023	-0.003	0.000	0.003	0.337	0.339	-0.018	0.027	0.012
7	100 seed weight (g)	G	0.015	0.003	-0.000	0.001	0.056	-0.046	0.251	0.035	0.045
		P	0.025	-0.002	0.000	0.006	0.111	-0.032	0.187	0.020	0.026
8	Harvest Index (%)	G	0.027	0.002	-0.001	0.001	0.165	0.253	0.074	0.117	0.115
		P	0.033	-0.002	0.000	0.002	0.307	0.124	0.050	0.075	0.062
9	No of seeed per pod	G	0.029	0.003	-0.000	-0.002	0.115	0.052	0.048	0.057	0.235
		P	0.048	-0.002	0.000	-0.009	0.236	0.028	0.032	0.031	0.151

Residual effects of 0.05470 and 0.09321

Diagonal entries (bold figures) are direct effects; off diagonal entries are indirect effect components on seed yield.



Harvest index had positive direct effect (0.117, 0.075), on seed yield per plant at both genotypic and phenotypic level respectively. Harvest index had showed positive indirect effect with days to 50 per cent flowering (0.027, 0.033), number of branches per plant (0.001, 0.002), number of pod per cluster (0.165, 0.307), No. of pod per plant (0.253, 0.124), 100 seed weight (0.074, 0.050), Number of seed per pod (0.115, 0.062) at both genotypic and phenotypic levels. Plant height (-0.001, 0.00) have negative genotypic effect on yield per plant as well as positive indirect effect at phenotypic effect. Days to maturity have (0.002, -0.002) positive indirect at genotypic level and negative indirect effect at phenotypic level. (Vasundhara Dangi *et al.* 2021) [10]

No of seed per pod had positive direct effect (0.235, 0.151), on seed yield per plant at both genotypic and phenotypic level respectively. No of seed per pod had showed positive indirect effect with days to 50 per cent flowering (0.029, 0.048), number of pod per cluster (0.115, 0.236), No. of pod per plant (0.052, 0.028), 100 seed weight (0.048, 0.032), harvest index (0.057, 0.031) at both genotypic and phenotypic levels. Plant height (-0.00, 0.00) have negative genotypic effect on yield per plant as well as positive indirect effect at phenotypic effect. Days to maturity have (0.003, -0.002) positive indirect at genotypic level and negative indirect effect at phenotypic level while number of branches per plant (-0.002, -0.009) shows negative indirect effect at genotypic and positive indirect effect at phenotypic level. (K.K Chandel *et al.* 2017) [7].

Conclusion

Among all the characters, highest positive direct effects were observed for number of pods per plant, 100-seed weight, number of seeds per pod, and harvest index at both levels. This revealed true relationship of these characters with grain yield per plant. Hence, direct selection for these traits could be rewarding for improvement of grain yield.

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