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Study of growth–yield associations in soybean (*Glycine Max L.*) using correlation, correlogram and regression analysis

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Abstract

Soybean, also known as the “Wonder crop” or “Golden bean” is one of the world’s most versatile leguminous crops. The present study was conducted *kharif* season of 2023 and 2024 at the STCR farm, Department of Soil Science, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra (India). The study investigated relationship between various growth parameters and grain yield soybean. The experiment was conducted in randomised block design (RBD), with twelve treatments replicated thrice. The growth parameters recorded were initial plant population, final plant population, plant spread, plant height, number of functional leaves, number of branches at 30, 45, 60 and 90 DAS along with seed yield, straw yield and biological yield. The correlation coefficient results showed that every growth-yield character which included initial and final plant population, plant spread, plant height, number of functional leaves, number of branches, seed yield, straw yield and biological yield in soybean correlated positively with each other. It was highlighted that seed yield had near-perfect correlation with yield parameters whereas lowest correlation coefficient of seed yield was observed with plant population. Regression study showed that plant spread, plant height, number of functional leaves and number of branches had positive R^2 with seed yield throughout the growth stages which was recorded highest at 60 DAS ($R^2 = 0.96, 0.95, 0.85$ and 0.95 , respectively). The results from correlogram analysis showed that denser plant spread, taller plant height along with higher number of functional leaves and branches of plants of soybean significantly enhanced yield of soybean.

Keywords: Correlation, correlogram, growth, regression, soybean, yield

Introduction

Soybean, also known as the “Wonder crop” or “Golden bean” is one of the world’s most versatile leguminous crops. It has tremendous importance in agriculture because of its higher oil (16-21%) and protein (36-42%) content (Imas and Magen, 2007) ^[7]. As per FAO, based on its productivity, soybean was classified as world’s fifth largest crop in terms of agricultural productivity (Yusefi-Tanha *et al.*, 2020) ^[20]. Being originated in China, soybean is cultivated across the world on more than 136.19 million hectare area, with Brazil followed by USA being its topmost producers. Around the globe, India ranks fourth and fifth in terms of area and production of soybean, respectively (Soybean outlook, 2024) ^[18]. According to the reports by Directorate of Agriculture and Farmers Welfare, during 2024-25, leading states across India in soybean production were Maharashtra (74.03 lakh tonne) followed by Madhya Pradesh (52.85 lakh tonne), Rajasthan (11.74 lakh tonne) and Karnataka (4.82 lakh tonne). Based on its myriad form of uses and remarkable economic impact, soybean has emerged as a promising crop for India’s agricultural sector.

Among the essential nutrients, Nitrogen (N) plays a vital part in soybean crop’s growth and yield. Apart from being a part of chlorophyll, a photosynthetic pigment, it governs vegetative growth and imparts green color to soybean (Begum *et al.*, 2015) ^[3]. On the other hand, Phosphorous (P) has crucial role in soybean growth, especially in initial stages as well as nodule and pod development. Whereas Potassium (K) plays central role in maintaining plant cell’s water balance, activation of enzymes involved in various physiological processes and reducing

the risks of insect and pest attacks, etc. Among these essential nutrients, soybean has ability to fix atmospheric nitrogen with the help of its root nodules and regulates half of its nitrogen demand for vegetative and reproductive growth (Alam *et al.*, 2009). However, remaining requirement of N along with P and K is fulfilled from soil. Hence, to produce sufficient biomass which will further lead to higher yields, it is essential to judiciously manage and satisfy nutrient requirements by soybean crop. In the view of above situation, understanding the relationships between crop growth characters and yield based on application of fertilizers is essential for optimizing soybean productivity.

Several previous studies conducted in various crops have shown that yield and performance of these crops is directly as well as indirectly affected by various growth parameters and environmental factors (Mahmood *et al.*, 2025, Sangothari and Radhamani, 2025, Vennila, 2024, Panda *et al.*, 2015, Sokoto *et al.*, 2012) [12, 16, 19, 14, 17]. For this, studies based on correlation and regression analyses help by providing crucial insights into how individual morphological and physiological characteristics interact and influence yield. As per the findings of Dixit and Dubey (1984), correlation studies provide thorough information about the influence of various genetic factors and environmental conditions on grain yield. Correlation analysis offers delineation of nature and strength of relationship between growth and yield traits whereas regression analysis helps in further predicting influence of multiple growth variables on yield outcomes. For instance, study conducted by Nachiketa *et al.* (2025) [13] revealed significant associations between various growth factors and yield traits influencing productivity in Pigeon pea (*Cajanus cajan* L.). Sangothari and Radhamani (2025) [16] observed that most of growth parameters including plant height, dry matter production, pods plant⁻¹, seeds pod⁻¹ of blackgram had stronger and positive correlation with grain yield.

Despite the numerous studies on crop yield association with growth characters, there is continuing need to evaluate these dynamics specifically across various growth stages. With this in view, present study has been conducted to analyse the relationship between various growth parameters and grain yield soybean.

Materials and Methods

Location and treatment details

The present field experiment was conducted during *kharif* season of 2023 and 2024 at the STCR farm, Department of Soil Science, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra (India). Geographically, the experimental site is located at 19° 34' N latitude and 74° 64' E longitude.

Climate

The data on important climatic parameters was recorded during the crop growth period (*kharif* season of 2023 and 2024) and acquired from Meteorological Observatory of Mahatma Phule Krishi Vidyapeeth, Rahuri (M.S.). From the data, it was observed that during the crop growing period of *kharif* 2023 and 2024, average values of maximum and minimum temperatures were 32.0°C and 23.8°C in 2023 and 31.0°C and 22.6°C in 2024. Whereas total daily rain observed was 22.0 mm and 36.3 mm in *kharif* season of 2023 and 2024, respectively. In general, the climatic conditions observed during the experimental period were found favorable for crop growth.

Soil

The experimental field was uniformly levelled, having medium

deep black soil belonging to Inceptisol order and silty clay loam texture. The soil was slightly alkaline in reaction with normal EC. From the initial chemical analysis of experiment field soil (0-15 cm depth), fertility status revealed low available nitrogen and phosphorous (168 and 14.33 kg ha⁻¹, respectively) whereas very high available potassium content (434 kg ha⁻¹).

Crop Variety and management

KDS-992 (*Phule durva*) is a soybean variety widely cultivated in Maharashtra, particularly during the *kharif* season, due to its stronger adaptability and good performance under regional agro-climatic conditions. For two-year study, the soybean was sown on 10 July and 28 June 2023 and 2024, respectively with the spacing of 45 cm × 5 cm.

Experimental details

The experiment was conducted in randomised block design (RBD), with twelve treatments replicated thrice. The treatments included, T₁-control; T₂-25:0:0 N:P₂O₅:K₂O kg ha⁻¹; T₃-50:0:0 N:P₂O₅:K₂O kg ha⁻¹; T₄-0:50:0 N:P₂O₅:K₂O kg ha⁻¹; T₅-0:75:0 N:P₂O₅:K₂O kg ha⁻¹; T₆-0:0:30 N:P₂O₅:K₂O kg ha⁻¹; T₇-0:0:45 N:P₂O₅:K₂O kg ha⁻¹; T₈-25:75:0 N:P₂O₅:K₂O kg ha⁻¹; T₉-50:50:0 N:P₂O₅:K₂O kg ha⁻¹; T₁₀-50:75:0 N:P₂O₅:K₂O kg ha⁻¹; T₁₁-25:75:45 N:P₂O₅:K₂O kg ha⁻¹ and T₁₂-50:75:45 N:P₂O₅:K₂O kg ha⁻¹ + 10 t ha⁻¹ farmyard manure (GRDF).

Growth and yield analysis

The growth parameters which were recorded during the crop growth interval were initial plant population, final plant population, plant spread, plant height, number of functional leaves, number of branches at 30, 45, 60 and 90 days after sowing (DAS). Plant population within each net plot area was initially counted at 14 DAS and again just before the time of harvest; this count was converted on hectare basis and plant population was worked out in percentage values as well. Plant height of crops was measured from ground surface to topmost fully opened leaf of the main stem. Plant spread was recorded by measuring horizontal spread of plant in two perpendicular directions (east-west and north-south) followed by computation of average of these values. Number of functional leaves and number of branches were counted manually by randomly selecting five healthy plants from each plot and tagging them for observations.

At harvest, seed yield and straw yield of five randomly selected plants, from each net plot was recorded and converted into per-hectare basis. Similarly, the biological yield of soybean was calculated by harvesting, drying and weighing of above-ground biomass of these crop plants.

Statistical analysis

The recorded data from the present study was tabulated by using MS EXCEL software followed by performing correlation and regression analysis to determine relationship between growth and yield of soybean, with the significance level set at 95% confidence level ($P < 0.05$). Further, correlogram analysis, a graphical tool was used in this study. Correlograms are visual illustrations which make it easier to interpret the relationship between growth and yield attributes of crops (Graffelman *et al.*, 2023) [6]. In the present study, correlogram analysis was performed in GRAPES (General R-based analysis platform empowered by statistics) software platform which is widely used in agricultural research for different statistical analyses.

Results and Discussion

The correlation coefficient regression and correlogram analysis

of pooled data from two-year study on growth parameters including initial and final plant population, plant spread, plant height, number of functional leaves, number of branches with seed yield, straw yield and biological yield of soybean is presented in Table 1, 2 and Figure 1, respectively.

Plant population

Initial and final plant population of soybean was found positively correlated with growth characters such as plant spread ($p < 0.01$, $r = 0.899$), plant height ($p < 0.01$, $r = 0.943$), number of functional leaves ($p < 0.01$, $r = 0.836$) and number of branches ($p < 0.01$, $r = 0.759$). Among these growth parameters, highest correlation of plant population was found with plant height while lowest correlation was found with number of branches of soybean. Results revealed that, plant population also positively correlated with seed yield ($p < 0.01$, $r = 0.866$), straw yield ($p < 0.01$, $r = 0.848$) and biological yield ($p < 0.01$, $r = 0.856$). The regression analysis revealed that both initial and final plant population had positive R^2 with seed yield ($R^2 = 0.75$). These associations of plant population with growth and yield determining characters of soybean indicated that higher plant populations densities helped in improving overall growth and yield of crops. These results were supported by Nachiketa *et al.* (2025) [13] and Kumakech *et al.*, (2024) [10].

Plant spread

Table 1 showed positive and strong correlation between plant spread of soybean with growth and yield parameters which included plant population ($p < 0.01$, $r = 0.899$), plant height ($p < 0.01$, $r = 0.982$), number of functional leaves ($p < 0.01$, $r = 0.961$), number of branches ($p < 0.01$, $r = 0.951$), seed yield ($p < 0.01$, $r = 0.981$), straw yield ($p < 0.01$, $r = 0.977$) and biological yield ($p < 0.01$, $r = 0.979$). This suggested that plants with wider canopy spread captured more sunlight causing increase in area available for photosynthetic activity, resulting in more productivity. Similar results are consistently reported in findings by Mahendraraj *et al.* (2024) [11] and Dash *et al.* (2024) [4]. Findings from regression study showed highest R^2 between plant spread and seed yield ($R^2 = 0.96$) at 60 DAS, which is peak maturity stage in soybean. These findings are supported by Amarullah *et al.* (2016) [1] and Apea-Bah *et al.* (2011) [2].

Plant height

Plant height had a positive correlation with growth and yield parameters which included plant population ($p < 0.01$, $r = 0.943$), plant spread ($p < 0.01$, $r = 0.982$), number of functional leaves ($p < 0.01$, $r = 0.916$), number of branches ($p < 0.01$, $r = 0.897$), seed yield ($p < 0.01$, $r = 0.971$), straw yield ($p < 0.01$, $r = 0.962$) and biological yield ($p < 0.01$, $r = 0.967$). Table 2 revealed positive R^2 between plant height and seed yield at all growth stages. However highest R^2 was observed at 60 DAS ($R^2 = 0.95$) of soybean crop. According to Jakhad *et al.* (2025) [8], tall plants have more vegetative vigour which subsequently leads to more productivity and grain yield by plants. Results from present study suggested that taller plants had positive associations with yield of soybean which was found highest at peak maturity stage of plant growth. Similar results are consistently reported in findings by Zhange *et al.* (2021) in maize.

Number of functional leaves per plant

Strong correlation between number of functional leaves per plant and growth-yield characters of soybean including plant population ($p < 0.01$, $r = 0.836$), plant spread ($p < 0.01$, $r =$

0.961), plant height ($p < 0.01$, $r = 0.916$), number of branches ($p < 0.01$, $r = 0.973$), seed yield ($p < 0.01$, $r = 0.916$), straw yield ($p < 0.01$, $r = 0.915$) and biological yield ($p < 0.01$, $r = 0.916$) were observed in Table 1. Among the growth parameters, highest correlation coefficient of number of functional leaves per plant was found with number of branches while lowest correlation was found with plant population of soybean. The regression analysis revealed that number of functional leaves per plant had positive R^2 with seed yield across the growth stages, which was highest at 60 DAS ($R^2 = 0.85$). These association between number of functional leaves per plant and growth-yield characters of soybean revealed that leaf development in plants is closely linked to growth and yield (Zhange *et al.* (2021).

Number of branches per plant

Number of branches per plant in soybean had a positive correlation with growth and yield characters as observed in Table 1. The correlation coefficient observed between number of branches per plant and growth-yield characters included plant population ($p < 0.01$, $r = 0.759$), plant spread ($p < 0.01$, $r = 0.951$), plant height ($p < 0.01$, $r = 0.897$), number of functional leaves ($p < 0.01$, $r = 0.973$), seed yield ($p < 0.01$, $r = 0.937$), straw yield ($p < 0.01$, $r = 0.943$) and biological yield ($p < 0.01$, $r = 0.940$). From the close perusal of these results, it was revealed that across the growth parameters, highest correlation coefficient of number of branches per plant was found with number of functional leaves per plant while lowest correlation was found with plant population of soybean. Table 2 revealed positive R^2 between Number of branches per plant in soybean and seed yield at all growth stages. However highest R^2 was observed at 60 DAS ($R^2 = 0.95$) of soybean crop. These substantial associations indicate that increased number of branches as growth of plant succeeds led to near-perfect correlation of number of branches with growth-yield characters. Similar results were reported by Nguyen *et al.* (2022) in maize. According to study conducted by Nachiketa *et al.* (2025) [13], greater number of branches per plant result in improved reproductive sink, leading to increased pod and ultimately seed production in pigeon pea. Similar results were reported by Pranati *et al.*, 2024 [15].

Seed yield

The correlation coefficient among seed yield and other growth-yield characters is presented in Table 1. A thorough examination of the data revealed that seed yield had positive correlation coefficient growth and yield characters that included plant population ($p < 0.01$, $r = 0.866$), plant spread ($p < 0.01$, $r = 0.981$), plant height ($p < 0.01$, $r = 0.971$), number of functional leaves ($p < 0.01$, $r = 0.916$), number of branches ($p < 0.01$, $r = 0.937$), straw yield ($p < 0.01$, $r = 0.999$) and biological yield ($p < 0.01$, $r = 1.000$). Among these parameters, seed yield had perfect of correlation with biological yield whereas lowest correlation coefficient of seed yield was observed with plant population. These results emphasised that seed yield in crops are closely linked with total biomass produced by plants and reported by Pashawar *et al.*, (2024) and Nachiketa *et al.* (2025) [13] while working on Pigeon pea.

Straw yield

Straw yield of soybean was positively correlated with plant population ($p < 0.01$, $r = 0.848$), plant spread ($p < 0.01$, $r = 0.977$), plant height ($p < 0.01$, $r = 0.962$), number of functional leaves ($p < 0.01$, $r = 0.915$), number of branches ($p < 0.01$, $r = 0.943$), seed yield ($p < 0.01$, $r = 0.999$) and biological yield ($p <$

0.01, $r = 1.000$). Results indicated perfect correlation of straw yield with seed yield and biological yield. Similar results were reported by Pashawar *et al.*, (2024) and Nachiketa *et al.* (2025)^[13], suggesting close association between yield contributing parameters in plants. However, among these parameters, lowest correlation of straw yield was observed with plant population (Table 1).

Biological yield

Biological yield of soybean was found positively correlated with every growth and yield parameter (Table 1). Results showed that the observed correlation coefficients between biological yield and other parameters included, plant population ($p < 0.01$, $r = 0.856$), plant spread ($p < 0.01$, $r = 0.979$), plant height ($p < 0.01$, $r = 0.967$), number of functional leaves ($p < 0.01$, $r = 0.916$), number of branches ($p < 0.01$, $r = 0.940$), seed yield ($p < 0.01$, $r = 1.000$) and straw yield ($p < 0.01$, $r = 1.000$). Close association of biological yield of soybean with growth parameters emphasized the positive effect of improvement in vegetative and reproductive structure of plant on overall biomass accumulation by plant, as reported by Nachiketa *et al.* (2025)^[13] and Kandarkar *et al.* (2020)^[9].

Authors' contributions

SA executed the research work, analysed the data and drafted the initial manuscript, VP supervised the research work and

reviewed the manuscript, RT, SK, SS, MP, BK,NG and MJ reviewed the manuscript. All authors read and approved the final manuscript.

Conflict of interest

Authors do not have any conflict of interests to declare.

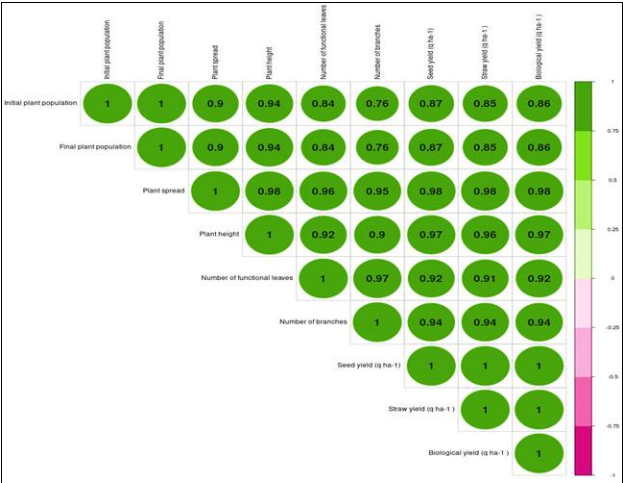


Fig 1: Correlogram analysis of relationship between growth characters and yield attributes of soybean

Table 1: Correlation coefficient between crop growth characters with yield attributes of soybean

	1	2	3	4	5	6	7	8	9
1 Initial plant population	1.000**								
2 Final plant population	1.000**	1.000**							
3 Plant spread (cm)	0.899**	0.899**	1.000**						
4 Plant height (cm)	0.943**	0.943**	0.982**	1.000**					
5 Number of functional leaves (plant ⁻¹)	0.836**	0.836**	0.961**	0.916**	1.000**				
6 Number of branches (plant ⁻¹)	0.759**	0.759**	0.951**	0.897**	0.973**	1.000**			
7 Seed yield (q ha ⁻¹)	0.866**	0.866**	0.981**	0.971**	0.916**	0.937**	1.000**		
8 Straw yield (q ha ⁻¹)	0.848**	0.848**	0.977**	0.962**	0.915**	0.943**	0.999**	1.000**	
9 Biological yield (q ha ⁻¹)	0.856**	0.856**	0.979**	0.967**	0.916**	0.940**	1.000**	1.000**	1.000**

* Correlation is significant at the 0.05 level, ** correlation is significant at the 0.01 level.

Table 2: Regression between soybean plant growth parameters with seed yield

Sr. No.	Growth parameter	Regression equation	R ²
1.	Initial plant population	y = 0.0016x - 627.41	0.75
2.	Final plant population	y = 0.0016x - 624.13	0.75
3.	Plant spread (30 DAS)	y = 1.789x - 14.718	0.93
4.	Plant spread (45 DAS)	y = 1.557x - 24.872	0.94
5.	Plant spread (60 DAS)	y = 1.58x - 39.649	0.96
6.	Plant spread (90 DAS)	y = 1.3065x - 41.824	0.95
7.	Plant height (30 DAS)	y = 0.6585x + 0.1473	0.93
8.	Plant height (45 DAS)	y = 0.6478x - 9.1319	0.94
9.	Plant height (60 DAS)	y = 0.6106x - 19.707	0.95
10.	Plant height (90 DAS)	y = 0.6277x - 21.811	0.92
11.	Number of functional leaves (30 DAS)	y = 15.382x - 25.369	0.67
12.	Number of functional leaves (45 DAS)	y = 7.0557x - 75.48	0.71
13.	Number of functional leaves (60 DAS)	y = 4.7796x - 89.485	0.85
14.	Number of functional leaves (90 DAS)	y = 3.3088x - 38.327	0.82
15.	Number of branches (30 DAS)	y = 15.532x - 25.82	0.69
16.	Number of branches (45 DAS)	y = 8.6039x - 19.303	0.84
17.	Number of branches (60 DAS)	y = 28.548x - 175.23	0.95
18.	Number of branches (90 DAS)	y = 26.353x - 153.66	0.93

Conclusion

The present study conducted in soybean assessed various growth and yield contributing characters to analyse their association

with each other using correlation, correlogram and regression studies. Positive correlation was observed between every growth and yield parameter, which included initial and final plant

population, plant spread, plant height, number of functional leaves, number of branches with seed yield, straw yield and biological yield. From the above study, it was discovered growth-yield parameters of soybean plants showed positive association with each other. This association was observed higher between plant height, plant spread, number of branches per plant and number of functional leaves per plant at maturity stages of soybean and seed yield. It was highlighted from the study that taller and plants having higher canopy spread along with larger number of functional leaves and branches positively linked with yield characters of soybean plants.

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