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Impact of improved agronomic approaches on yield and quality of soybean [*Glycine Max* (L.) Merrill] under northern transition zone of Karnataka

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ABSTRACT

Soybean (*Glycine max* (L.) Merrill) is one of the most important crops globally due to its dual significance as a source of protein and oil. In India, soybean cultivation plays a crucial role in meeting the dietary protein needs and is also a significant cash crop for farmers. The northern transition zone of Karnataka, characterized by its unique agro-climatic conditions, presents an interesting context for soybean cultivation. However, despite of its importance, soybean production faces several challenges, including the choice of suitable varieties and crop geometries to maximize both yield and quality. Keeping these in view, field experiment was conducted during kharif 2022 under rainfed ecosystem of Dharwad. Twelve treatments comprising three varieties (DSb 21, KDS 726 and KDS 753) and four planting geometries (22.5 × 10 cm, 30 × 10 cm, 37.5 × 10 cm and 45 × 10 cm) were laid out in split plot design. Result of these experiment revealed that significant difference on performance of soybean were observed due to varieties and planting geometries. KDS 753 and KDS 726 had significantly higher seed yield 21.88 q ha⁻¹ and 20.86 q ha⁻¹, respectively compared to DSb 21 (18.17 q ha⁻¹). KDS 753 being on par with KDS 726 showed significantly higher oil content with an increase of (1.47 %) compared to DSb 21. While, among the planting geometries 45 × 10 cm being on par with 37.5 × 10 cm performed best on growth and yield of soybean. Among the interactions, variety KDS 753 along with spacing of 45 × 10 cm recorded higher seed yield (24.98 q ha⁻¹) and straw yield (28.54 q ha⁻¹) and was closely followed by the same variety at 37.5 × 10 cm spacing.

Keywords: Soybean, Variety, Planting geometry, Yield, Rainfed

Introduction

Soybean (*Glycine max*), a primary oilseed crop originating from East Asia, plays critical role in India's agriculture. Beyond its global standing, soybean's significance in India is underlined by its nutritional richness, featuring 40 % protein, 20 % oil and 6.4 % lysine content, accompanied by essential vitamins and minerals Chauhan *et al.* (2005) [1]. This crop serves not only as a nutritional powerhouse but also contributes ecologically by fixing atmospheric nitrogen (35-140 kg ha⁻¹), reducing the need for synthetic fertilizers and enhancing soil fertility. Its versatility in acclimating to various climatic conditions establishes it as a significant contender well-matched for the evolving environmental dynamics in this specific region.

Globally, soybean takes the lead as the primary oilseed crop, contributing 61 % to the total oilseeds production. While Brazil leads in production, India's 3 % contribution underscores its indispensable role in the nation's agricultural fabric. In Karnataka, where soybean spans 0.43 million hectares, yielding 0.44 million tonnes (Annon., 2022) [2]. The cultivation of oilseeds, particularly soybean, holds critical significance for India's edible oil production. Our study integrates scientific insights, emphasizing the testing of soybean varieties that demonstrate resilience and adaptability to the changing climatic conditions of the northern transition zone of Karnataka.

The challenges identified, such as the failure by farmers in the northern transition zone of Karnataka to cultivate adapted varieties with proper row spacing, hinder optimal production. The low productivity of the crop is due to several constraints; among them genotypes and their spacing are important (Dhaliwal *et al.*, 1995) [3]. Achieving an optimal plant density becomes imperative, maximizing resource utilization such as water, nutrients, light and CO₂ resulting in higher crop productivity. Acko *et al.* (2009) [4] reported that optimal row spacing and cultivar selection are crucial for attaining high yield and producing quality soybean seeds. Cultivating resistant, high-yielding varieties with appropriate planting geometry is crucial for unlocking the maximum yield potential of soybean crops, particularly in the context of the changing climatic conditions of the northern transition zone of Karnataka. Optimizing plant population and adopting suitable agronomic practices emerge as pivotal factors influencing growth and yield enhancement (Billore *et al.*, 2000) [5]. Early and medium maturity with stress-resistant genotypes, known for their adaptability to diverse farming conditions, offer promising solutions for changing climatic conditions. This research aims not only to contribute to

the general understanding of soybean production but also to provide region-specific insights crucial for sustainable and optimized cultivation practices in the face of evolving climates.

Material and Methods

To investigate how various plant geometries impact the growth and yield of soybean varieties, an experiment conducted during *kharif* 2022 season at the Main Agricultural Research Station of the University of Agricultural Sciences in Dharwad (latitude of 15°29' North and longitude of 74°58' East), *Karnataka*, India under rainfed condition. During the crop growth period, the total rainfall received at Main Agricultural Station, Dharwad was 574 mm in 37 rainy days. Mean monthly relative humidity of 87.1, 86.55, 82, 76.7 and 58 respectively were observed during July, August, September, October and November months which was congenial for crop growth. While, mean maximum temperature ranged from 26.6-29.5 °C and minimum temperature varied from 16.5-20.5 °C which fall within the range of optimum temperature (15-32 °C) requirement of soybean crop. The experimental field was laid out in the split-plot design in 4.5 × 5.0 m² gross plot size with twelve treatment combinations comprising three varieties, M₁-DSb 21, M₂-KDS 726 and M₃-KDS 753 as main plot and four geometries S₁-22.5 × 10 cm, S₂-30 × 10 cm, S₃-37.5 × 10 cm and S₄-45 × 10 cm as sub-plot. The soil of the experimental field was clayey, with pH of 7.1, EC of 0.33 dS m⁻¹, organic carbon (0.45 %). Farm yard manure at recommended dose of 6.25 t ha⁻¹ was applied uniformly and incorporated into the soil before 15 days of soybean sowing. Urea, di-ammonium phosphate (DAP) and muriate of potash (MOP) were used as sources of N, P₂O₅ and K₂O at recommended doses of 40:80:25 kg ha⁻¹, respectively. Applied entire doses as basal. On July 22, 2022, the crop was planted with seeds treated with rhizobium and PSB culture @ 150 grams per 10 kilograms of seeds, employing geometry levels. Pre-emergence herbicide application of Pendimethalin 30 EC @ 3.25 l ha⁻¹ was sprayed after sowing in order to keep the field free from weeds during initial crop growth. Later, hand weeding followed by inter cultivation were carried out at 45 and 60 days after sowing, the inter-cultivation was carried out using cycle weeder and blade hoe. Five plants chosen randomly within the net plot area were tagged and utilized for observing various growth parameters throughout the crop's growth stages, as well as for assessing yield parameters at the time of harvest. The data obtained from the experiment was analyzed statistically using the Analysis of Variance (ANOVA) method, following the methodology recommended by Gomez and Gomez *et al.*, 1984 [6]. The 'F' test will be conducted at a 5% level of significance to determine the significance level. The standard error of the mean and coefficient of variability were calculated for the set of observations for each characteristic at the 5 % level of significance.

Results and Discussions

Yield and yield parameters

Varieties

The experiment evaluated the performance of three soybean varieties, namely DSb 21, KDS 726 and KDS 753, with a focus on understanding genetic variability and its influence on key yield parameters. Throughout the study, KDS 753 and KDS 726 consistently demonstrated superior performance compared to DSb 21 across various growth and yield parameters, underscoring the impact of specific genotype on enhanced traits. Regarding the seed yield, KDS 753 (21.88 q ha⁻¹) and KDS 726 (20.86 q ha⁻¹) significantly outperformed over DSb 21, which recorded the lowest seed yield (18.17 q ha⁻¹). Additionally, KDS 753 exhibited significantly higher values in 100-seed weight (15.85 g), number of pods per plant (50.63) and seed yield per plant (21.57 g) compared to DSb 21, but it was on par with the variety KDS 726 indicating that the genetic traits of KDS genotypes contributed to superior pod development, seed weight and overall crop yield. These findings align with prior studies by Pawar *et al.*

(2015) [7] and Nayak *et al.* (2020) [8]. Furthermore, the genotypes exerted noticeable influences on yield components, with KDS 753 displaying superiority in yield per plant, seed yield per hectare and biological yield per hectare. KDS 726 closely followed KDS 753 in performance, indicating that their genetic characteristics contribute to efficient resource utilization and allocation, resulting in increased overall biomass and yield production. The observed higher pod numbers, seed weight and biomass accumulation in these specific cultivars are consistent with genetic traits influencing yield potential, as supported by studies conducted by Raghuvanshi *et al.* (2017) [9], Anusha *et al.* (2021) [10] and Smith *et al.* (2022) [11]. This comprehensive analysis highlights the significance of genetic factors in shaping soybean cultivar performance and yield outcomes, providing valuable insights into the completed experiment.

Planting geometry

Top of Form

The crop geometry with dimensions of 45 × 10 cm exhibited significantly higher seed yield (22.67 q ha⁻¹) and straw yield (26.37 q ha⁻¹). In contrast, the narrowest spacing of 22.5 × 10 cm yielded the lowest seed yield (16.70 q ha⁻¹) and straw yield (20.64 kg ha⁻¹). This rise in seed yield can primarily be attributed to an increased number of pods per plant and higher seed weight per plant. Similar findings were also documented by Angadi (2016) [12] and Anusha *et al.* (2021) [10]. As the row spacing increased from 22.5 × 10 cm to 30 × 10 cm, 37.5 × 10 cm and finally to 45 × 10 cm, there was a notable and significant rise in both the number of pods per plant and seed yield per plant. Among the different spacing, the arrangement of 45 × 10 cm stood out with the highest recorded number of pods per plant (52.09) and seed yield per plant (15.64 g).

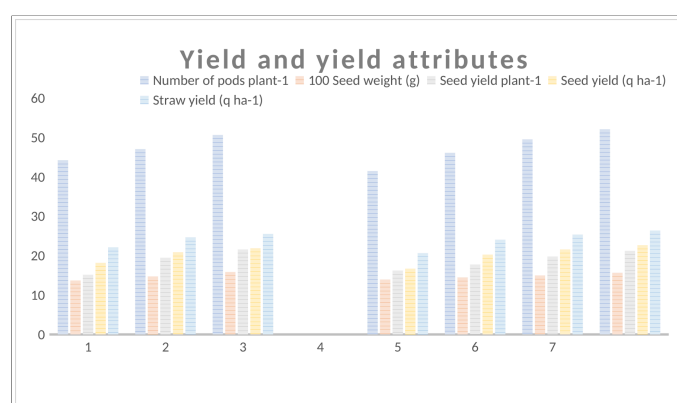


Figure 1. Effect of varieties and planting geometry on yield attributes of soybean

Note: M₁, M₂ and M₃ represent soybean varieties (M₁: DSb 21, M₂: KDS 726, M₃: KDS 753); S₁, S₂, S₃ and S₄ represent planting geometries (S₁: 22.5 × 10 cm, S₂: 30 × 10 cm, S₃: 37.5 × 10 cm, S₄: 45 × 10 cm).

The variations observed in pods per plant could potentially be attributed to the corresponding variations in the number of branches. The wider row spacing, as evident in the 45 × 10 cm arrangement, allowed each plant ample room for robust vegetative and reproductive growth. This, in turn, led to a higher count of branches per plant, facilitating an enhanced capacity for pod bearing. The advantage of wider spacing includes reduced plant competition and improved availability of light, moisture and nutrients, all contributing to a more favourable source-sink relationship. This environment ultimately results in an increased number of pods per plant and consequently a higher seed yield per plant. These findings resonate with the results reported by Malek *et al.* (2012) [13], Sivakumar *et al.* (2018) [14] and Keisham *et al.* (2021) [15]. The increase in pods plant-1 with respect to increase in row-to-row spacing was also reported by Khubele (2015) [16] and Angadi (2016) [12]. Upon evaluation, the results pertaining to the weight of 100 seeds were determined to be statistically non-signifi

cant across various spacing configurations. However, it is important to note that the spacing of 45×10 cm recorded a numerically higher test weight (15.64 g). These findings lend support to those previously reported by Singh (2011) [17] and Patel *et al.* (2022).

Interactions

The interaction between soybean varieties and planting geometries showed significant impact on the performance of soybean. Among the treatment combinations, the variety KDS 753 along with the planting geometry of 45×10 cm performed best on several key parameters including seed yield (24.98 q ha^{-1}) and straw yield (28.54 q ha^{-1}) which was statistically on par with the same variety at 37.5×10 cm. While, the variety DSb 21 sown with the geometry level of 22.5×10 cm had lowest seed yield (15.34 q ha^{-1}). Similar results were also reported by Angadi (2016) [12]. Significantly higher seed yield was recorded in the treatment involving the KDS 753 genotype when planted with spacing configuration of 45×10 cm, outperforming

other treatment combinations. This increase in yield can be attributed to the inherent advantage of this particular genotype in achieving an optimal yield across different spacing conditions. Although narrower spacing led to a higher plant population per unit area, this approach failed to surpass the yield obtained from the lower population under wider spacing. This discrepancy can be attributed to the significantly lower yield attributes recorded at closer spacing, which were unable to compensate adequately for the superior yield attributes generated per individual plant at the lower population within wider spacing. In the context of all three varieties, including DSb 21, KDS 726 and KDS 753, an intriguing pattern emerges when considering the influence of plant spacing on seed yield. As plant spacing widens, there is significant increase in seed yield per hectare. This phenomenon suggests that all varieties derive benefits from expanded plant spacing, potentially facilitating improved light penetration and mitigating competition for essential resources among neighbouring plants.

Table 1. Yield and yield attributes of soybean as influenced by varieties and geometries

Treatments	Number of pods plant ⁻¹	100 Seed weight (g)	Seed yield plant ⁻¹ (g)	Seed yield (q ha^{-1})	Straw yield (q ha^{-1})
Main plot (M): Varieties					
M ₁ : DSb 21	44.22b	13.70b	15.13b	18.17b	22.12b
M ₂ : KDS 726	47.05ab	14.72ab	19.47a	20.86a	24.66ab
M ₃ : KDS 753	50.63a	15.85a	21.57a	21.88a	25.53a
S.E.m. $\pm$	1.38	0.57	0.83	0.67	0.92
Sub plot (S): Geometry					
S ₁ : 22.5×10 cm	41.46b	13.94a	16.20c	16.70c	20.64c
S ₂ : 30×10 cm	46.11ab	14.47a	17.73bc	20.25b	24.05b
S ₃ : 37.5×10 cm	49.52a	14.97a	19.76ab	21.59ab	25.35ab
S ₄ : 45×10 cm	52.09a	15.64a	21.20a	22.67a	26.37a
S.E.m. $\pm$	1.66	0.65	0.78	0.62	0.78
Interaction: (M $\times$ S)					
M ₁ S ₁	39.5f	13.33c	13.13f	15.34g	19.46f
M ₁ S ₂	43.6d-f	13.56c	14.10ef	18.38ef	22.32d-f
M ₁ S ₃	45.6c-f	13.7c	16.18d-f	19.21d-f	23.12c-e
M ₁ S ₄	48.16b-d	14.2a-c	17.13de	19.74c-e	23.58c-e
M ₂ S ₁	40.66ef	14.06bc	16.95de	17.16fg	21.09ef
M ₂ S ₂	46.8bc-e	14.13bc	18.17cd	20.85cd	24.65b-d
M ₂ S ₃	49.51b-d	14.8a-c	20.35bc	22.13bc	25.89a-c
M ₂ S ₄	51.21a-c	15.9a-c	22.39ab	23.29ab	27.00ab
M ₃ S ₁	44.23d-f	14.43a-c	18.51cd	17.61e-g	21.36ef
M ₃ S ₂	47.93b-d	15.73a-c	20.93bc	21.53b-d	25.19b-d
M ₃ S ₃	53.46ab	16.4ab	22.75ab	23.42ab	27.03ab
M ₃ S ₄	56.89a	16.83a	24.08a	24.98a	28.54a
S.E.m. $\pm$	2.88	1.13	1.36	1.07	1.35

*Means followed by the same alphabet (s) within a column are not significantly differed by DMRT ($P = 0.05$)

Quality parameters

Varieties

With respect to oil and protein content, the oil content of the three varieties, DSb 21, KDS 726 and KDS 753 was found to be 16.54 %, 17.68 % and 18.15 %, respectively. KDS 753 showed significantly higher oil content with an increase of 1.47 % compared to DSb 21. The elevated oil content exhibited by KDS 753 could be attributed to its genetic makeup, likely favouring a heightened lipid biosynthesis pathway. This aligns with prior research, including the work of Rani (2000) [18] and Vyas *et al.* (2014) [19] which illuminated the genetic traits capability of boosting both oil content and yield. However, oil

content of all the genotypes were lower than its potential due to late sowing and heavy rainfall occurred at pod development and maturity stages. Among the varieties, KDS 753 exhibited the highest protein content (38.88 %). In contrast, DSb 21 had the lowest protein content (36.41 %). However, the differences in protein content between varieties were not statistically significant. The protein yield, which represents the actual amount of protein obtained per hectare, varied significantly among the varieties. Comparable result was noticed by Meshram *et al.* (2014) [20]. The heightened protein content witnessed in KDS 753 suggests the presence of advantageous genetic traits, these collective insights underscore the dominant role genetics plays in shaping protein related characteristics in soybean crops.

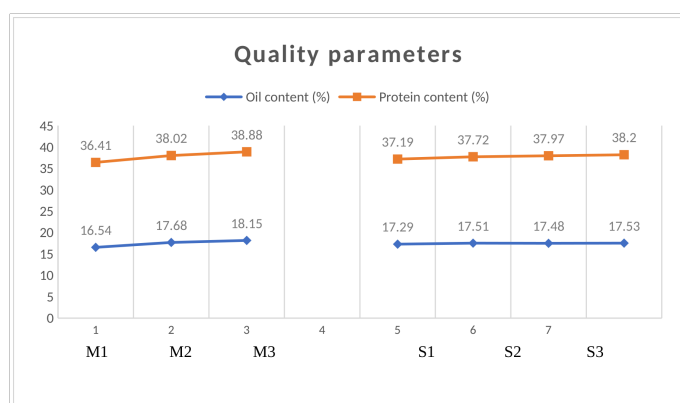


Figure 2. Effect of varieties and planting geometry on oil and protein content of soybean

Note: ‘M’ denotes soybean varieties, viz., M₁: DSb 21, M₂: KDS 726 and M₃: KDS 753; ‘S’ denotes planting geometries, viz., S₁: 22.5 ×

10 cm, S₂: 30 × 10 cm, S₃: 37.5 × 10 cm and S₄: 45 × 10 cm.

Planting geometry

Spacing did not exert significant influence on protein and oil content. Nevertheless, it is important to highlight that the wider spacing of 45 × 10 cm exhibited notably higher protein yield (868 kg ha⁻¹) and oil yield (399 kg ha⁻¹). The higher protein and oil yield achieved under this treatment can be attributed to the higher seed yield, as it directly contributes to the higher protein and oil yield. Remarkably similar results were also documented by Halvankar *et al.* (1999) [21], Vyas *et al.* (2014) [19] and Patel *et al.* (2022).

Interactions

Among the treatment combinations, the variety KDS 753 when sown with the planting geometry of 45 × 10 cm recorded significantly higher oil yield (456 kg ha⁻¹) and protein yield (981 kg ha⁻¹) compared to other treatments which was statistically comparable with the same variety at planting geometry of 37.5 × 10 cm. These increase in protein and oil yield can be attributed directly to the higher seed yield.

Table 2. Oil and protein content of soybean as influenced by varieties and geometries

Treatment	Oil content (%)	Oil yield (kg ha ⁻¹)	Protein content (%)	Protein yield (kg ha ⁻¹)
Main plot (M): Varieties				
M ₁ : DSb 21	16.54c	301b	36.41a	662b
M ₂ : KDS 726	17.68b	369a	38.02a	794a
M ₃ : KDS 753	18.15a	398a	38.88a	852a
S.E.m. ±	0.40	13	1.30	30
Sub plot (S): Geometry				
S ₁ : 22.5 × 10 cm	17.29a	290b	37.19a	622c
S ₂ : 30 × 10 cm	17.51a	356a	37.72a	765b
S ₃ : 37.5 × 10 cm	17.48a	379a	37.97a	822ab
S ₄ : 45 × 10 cm	17.53a	399a	38.20a	868a
S.E.m. ±	0.82	15	1.32	33
Interaction: (M×S)				
M ₁ S ₁	16.39a	251e	35.81a	549f
M ₁ S ₂	16.69a	307de	36.32a	668d-f
M ₁ S ₃	16.46a	316cd	36.57a	703de
M ₁ S ₄	16.61a	328cd	36.93a	729c-e
M ₂ S ₁	17.51a	300de	37.33a	641ef
M ₂ S ₂	17.67a	369bc	38.08a	794b-d
M ₂ S ₃	17.78a	393b	38.29a	847bc
M ₂ S ₄	17.74a	413ab	38.38a	894ab
M ₃ S ₁	17.97a	316cd	38.43a	677d-f
M ₃ S ₂	18.18a	391b	38.76a	835bc
M ₃ S ₃	18.20a	426ab	39.06a	915ab
M ₃ S ₄	18.25a	456a	39.28a	981a
S.E.m. ±	1.43	25	2.29	58

*Means followed by the same alphabet (s) within a column are not significantly differed by DMRT ($P = 0.05$) DAS- Days after sowing

Conclusions

In conclusion, the comprehensive analysis of soybean cultivation strategies reveals the significant performance of the KDS 753 variety, particularly when paired with the optimal spacing of 45 × 10 cm. This combination showcases higher seed yield and superior quality. Highlighting the significance of customized cultivation methods, incorporating KDS 753's genetic attributes, optimal spacing and resource efficiency. In essence, KDS 753 emerges as a promising option for soybean cultivation, effectively balancing yield improvement and economic viability.

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