Research Article

Effect of Sowing Methods on Growth, Yield, and Quality of Kidney Bean in the Pothohar Region

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Abstract |As a legume crop, kidney beans (*Phaseolus vulgaris L.*) are important for Pakistan's increased food security and nutrition. Better agronomic practices are required since suboptimal sowing methods have generally lowered the crop's quality and output. This research evaluates the impact of different sowing techniques on the growth, yield, and quality of kidney beans in order to identify the most effective method for improving crop performance in the Pothohar region. This study examined the effects of two sowing techniques ridge sowing and flat sowing on the growth, production, and quality of the kidney bean variety "Gorilla." The research was carried out at the National Agricultural Research Centre (NARC), Islamabad by using a Randomized Complete Block Design (RCBD). Grain weight (32.63 g vs. 22.20 g), number of pods per plant (11.00 vs. 5.00), number of grains per pod (6.37 vs. 3.47), germination percentage (92.00% vs. 86.00%), and grain yield (2112.30 kg ha^{-1} vs. 1751.00 kg ha^{-1}) were all significantly increased by ridge sowing in comparison to flat sowing, according to the results. However, there were no appreciable differences between the two approaches in terms of plant height (46.03 cm vs. 44.67 cm) or protein content (23.16% vs. 22.80%). The results demonstrate how ridge seeding is superior for enhancing crop performance, nitrogen uptake, and soil conditions. According to the study's findings, ridge sowing is a viable agronomic technique for raising kidney bean quality and productivity in the Pothohar area. It provides a long-term way to overcome yield constraints and promote food security.

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Introduction

Food legumes are the cheapest source of protein after cereals. Their dehulled seeds are called pulses. Pulses protein is inevitable in countries like Pakistan, as animal protein being expensive, is unaffordable by major section of population. Pulses area in Pakistan, during 2022-23, was 1,185 thousand

hectares (GoP, 2022-23). One of the most significant legume crops grown worldwide, the common bean (*Phaseolus vulgaris L.*) is essential to nutrition and food security (Smith *et al.*, 2015). Among food legumes, the kidney bean (*Phaseolus vulgaris L.*) stands out due to its high nutritional value, global adaptability, and economic relevance. It is a rich source of plant-based protein, complex carbohydrates, dietary fiber, iron, folate, and essential amino acids making it an excellent substitute for animal protein in low-income populations (Broughton *et al.*, 2003; Blair *et al.*, 2010). In Pakistan, where a large portion of the population cannot afford meat regularly, kidney beans play a vital role in improving dietary diversity and combating protein-energy malnutrition (Akib *et al.*, 2021). Moreover, kidney beans contribute to soil fertility through biological nitrogen fixation, supporting sustainable farming systems and reducing dependence on chemical fertilizers (Graham and Vance, 2003).

Kidney beans are grown extensively throughout Pakistan's agro-ecological zones, especially in Khyber Pakhtunkhwa, Punjab, and the country's north. They provide a significant source of dietary fiber, essential amino acids, and plant-based protein (Khan *et al.*, 2018). "Gorilla" is one of the kidney bean cultivars that has drawn the most attention because of its exceptional nutritional value, versatility, and high yield potential. Nonetheless, agronomic procedures like planting methods have a big impact on its output.

Planting techniques and field layout have been extensively researched as critical elements influencing crop quality, yield, and growth (Ahmed *et al.*, 2019). In areas with thick soil textures and sporadic waterlogging, ridge planting has been suggested as a way to improve aeration, root development, and water management (Hussain *et al.*, 2020; Zhang *et al.*, 2023). Plain field agriculture, on the other hand, is frequently used but may result in less than ideal plant development because of inadequate drainage and compacted soil (Ali *et al.*, 2021). The advantages of ridge planting in legumes, such as increased germination rates, plant height, and grain yield, have been documented in a number of studies (Zafar *et al.*, 2017; Rahman *et al.*, 2016; Martínez *et al.*, 2024).

With little application of contemporary agronomic approaches to maximize crop production, Pakistani agriculture is heavily reliant on traditional agricultural methods (Rehman *et al.*, 2019; Fatima *et al.*, 2024). Improving kidney bean yield through better cultural practices is crucial to meeting local consumption and export demands given the rising need for crops high in protein. According to earlier studies, ridge cultivation improves nutrient uptake and water use efficiency, which eventually results in improved grain filling and protein accumulation in legumes (Shah *et al.*, 2021; Aslam *et al.*, 2022; Osei *et al.*, 2023). In order to determine the most effective agronomic approach for optimizing yield and quality, a comparative analysis of ridge and plain field cultivation for the kidney bean variety Gorilla is essential.

The objective of the study was to identify the most effective sowing method for improving the productivity and quality of kidney beans under the agro-ecological conditions of the Pothohar region. Germination percentage, plant height, number of pods per plant, number of grains per pod, 100-grain weight, grain yield, and protein content are the main factors that are examined. The results of this study will help provide evidence-based suggestions for enhancing kidney bean output in Pakistan and other agro-ecological zones of a similar nature.

Materials and Methods

Experimental site and design

In the spring season of 2023, the experiment was carried out at the National Agricultural Research Centre (NARC), located in Islamabad. The site is roughly 540 meters above sea level and is situated in latitude 33.6844° N and longitude 73.0479° E. Subtropical, semi-arid climate with moderate springtime rainfall is the region's classification. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications to evaluate the effect of two cultivation methods (ridge and flat field) on the performance of the kidney bean variety "Gorilla."

Soil characteristics

Before sowing, soil samples were collected and analyzed for physicochemical properties. The soil was classified as sandy clay loam, with the following characteristics:

Crop sowing and agronomic practices

Sowing was carried out on March 3, 2023, using the dibbling method. The recommended plant-to-

plant distance of 10 cm and row-to-row distance of 45 cm were maintained, as per standard agronomic recommendations for kidney beans in Pakistan. The seed rate was 80 kg/ha to ensure optimal plant population.

Fertilizer application
A balanced fertilizer dose was applied as per recommendations for leguminous crops:

Nitrogen (N): 25 kg/ha
Phosphorus (P_2O_5): 60 kg/ha
Potassium (K_2O): 40 kg/ha
Fertilizers were applied in the form of Urea, DAP (Di-ammonium Phosphate), and SOP (Sulfate of Potash). All phosphorus and potassium were applied at the time of sowing, while nitrogen was split into two doses half at sowing and the remaining at the vegetative stage.

Irrigation and crop management
The crop was irrigated at critical growth stages, including germination, flowering, and pod development. A total of five irrigations were applied during the growing season. Weed control was carried out manually twice at 20 and 40 days after sowing.

Pest and disease management
To control insect pests, Chlorpyrifos 40EC (2.5 L/ha) was applied at the early pod formation stage. The crop was regularly monitored for fungal infections, and Mancozeb (2 g/L) was sprayed to prevent fungal diseases.

Weather conditions
During the cropping season (March to July 2023), the temperature varied between 12˚C and 36˚C, with an average relative humidity of 55%. Rainfall was recorded at 320 mm, contributing to soil moisture availability.

Harvesting and data collection
The crop was harvested on July 20, 2023, when 90% of the pods matured. Data were recorded for the following parameters:

Germination percentage (%)
Plant height (cm)
Number of pods per plant
Number of grains per pod
100-grain weight (g)
Grain yield (kg/ha)
Protein content (%)

Methods for Recording Parameters

Each parameter was recorded using standard agronomic and laboratory techniques to ensure accuracy and reliability. The following methods were used:

Germination percentage (%)
Germination percentage was calculated 10 days after sowing (DAS) by counting the number of germinated seeds in each plot using the following formula.

Germination Percentage = (Number of seeds germinated / Total seeds sown) × 100

Plant height (cm)
Ten randomly selected plants from each plot were measured from the base of the stem to the tip of the main shoot using a measuring scale. The average height was recorded at 50% flowering stage (around 45 days after sowing).

Number of pods per plant
At maturity, ten randomly selected plants from each treatment were harvested. The total number of pods per plant was counted manually, and the average value was recorded.

Number of grains per pod
From the harvested pods, ten pods were randomly selected from each plot, and the number of grains in each pod was counted manually. The mean value was calculated and recorded.

100-grain weight (g)
Randomly selected, sun-dried 100 grains from each replication were weighed using a digital weighing balance with an accuracy of 0.01 g. The recorded weight was used to estimate the overall seed size and density.

Grain yield (kg/ha)
After harvesting, the total grain weight per plot was recorded and converted to kilograms per hectare (kg/ha) using the following formula:

Grain Yield (kg/ha) = (Grain weight per plot (kg) / Plot area (m^2) × 10,000

Table 1: *Comparison of flat vs. ridge sowing in terms of grain yield and protein content of Kidney bean from previous literature*

Author(s) and year	Grain yield (kg/ha)		Protein content (%)		Reference
	Flat sowing	Ridge sowing	Flat sowing	Ridge sowing	
Sharma *et al.*, 2025	1,701	2,071	21.9	23.1	Sharma *et al.* (2025).
Basu *et al.*, 2023	1,480	1,680	22.0	23.5	Basu, *et al.* (2023)
Karavidas *et al.*, 2022	1,223	1,570	22.5	23.8	Karavidas *et al.* (2022)
Choudhary *et al.*, 2020	1,458	1,781	22.8	24.0	Choudhary *et al.* (2020)

Protein content (%)

Protein content was determined using the Kjeldahl method, which measures total nitrogen content in the grains. The total nitrogen percentage was multiplied by the conversion factor 6.25 to estimate protein content:

$$\text{Protein Content (\%)} = \text{Total Nitrogen (\%)} \times 6.25$$

Statistical analysis

The collected data were analyzed using Analysis of Variance (ANOVA) to assess the significance of different treatments. Means were compared using Least Significant Difference (LSD) test at a 5% significance level (Steel & Torrie, 1980). Statistical analysis was performed using Statistix 8.1 software to determine the treatment effects on kidney bean growth and yield parameters

Results and Discussion

The table presents the effects of two sowing methods, flat sowing and ridge sowing, on various growth and yield parameters of the kidney bean variety "Gorilla." With statistically significant differences in germination percentage, number of pods per plant, number of grains per pod, grain weight, and grain yield, ridge sowing outperformed flat sowing in the majority of criteria. However, there were no appreciable variations in plant height or protein content between the two seeding techniques.

Compared to flat sowing (86.00%), ridge sowing produced a noticeably higher germination percentage (92.00%). This is due to ridge sowing's enhanced soil aeration and drainage, which improves seed-soil contact and lowers the chance of waterlogging, resulting in a more conducive microenvironment for seed germination. Kumar *et al.* (2018) reported similar results, emphasizing the advantages of ridge seeding in raising legume germination rates. The sowing technique, however, had no discernible effect on plant height; flat and ridge sowing recorded 44.67 cm and 46.03 cm, respectively. This is likely because plant height is more strongly influenced by genetic potential and prevailing environmental conditions than by sowing methods, as noted by Singh *et al.* (2020).

Ridge sowing produced substantially more pods per plant (11.00) than flat sowing (5.00). Ridge seeding encourages greater plant growth and pod production by facilitating improved root development and nutrient uptake, which is associated to this improvement. Ridge seeding enhances soil structure and nutrient availability, which increases legume pod yield, according to Ali *et al.* (2019). In a similar vein, ridge planting produced a notably greater quantity of grains per pod (6.37) than flat sowing (3.47). This is likely due to ridge sowing's ability to improve soil aeration, root proliferation, and nutrient availability, which collectively enhance photosynthate partitioning towards reproductive organs, thereby promoting better pod filling and grain development. Similar findings were reported by Meena *et al.* (2021), who noted that ridge seeding in kidney beans improved the amount of grains per pod.

Table 2: *Physicochemical properties of the soil*

Soil property	Value
pH	7.8
Electrical Conductivity (EC)	0.34 dS/m
Organic Matter	0.87%
Nitrogen (N)	0.05%
Phosphorus (P)	7.2 mg/kg
Potassium (K)	98 mg/kg

Additionally, ridge planting produced a substantially larger grain weight (32.63 g) than flat sowing (22.20 g). Higher grain weight and greater grain filling were

Table 3: *Impact of sowing methods on yield and quality attributes of kidney bean*

Treatments	Parameters						
	Germination %	Plant height (cm)	Number of pods (plant^{-1})	Number of grains (pod^{-1})	Grain weight (g)	Grain yield (kg ha^{-1})	Protein content
Flat sowing	86.00 b	44.67NS	5.00NS	3.47 b	22.20 b	1751.00 b	22.80NS
Ridge sowing	92.00 a	46.03	11.00	6.37 a	32.63 a	2112.30 a	23.16
$LSD_{0.05}$	4.96	---	---	3.01	7.90	148.27	---

probably caused by ridge sowing's increased nutrient and water availability. Similar results were published by Yadav *et al.* (2017), showing that ridge seeding increases the grain weight of legumes. As a result, the grain yield from ridge sowing was substantially higher (2112.30 kg ha) than that from flat sowing (1751.00 kg ha).The combination of larger grains in ridge sowing, more pods per plant, more grains per pod, and higher germination all helped to enhance the yield.Additionally, Kumar *et al.* (2018) discovered that ridge seeding greatly increases legume production.
However, there was no discernible difference in the protein content between the two seeding techniques, with ridge sowing recording 23.16% and flat sowing recording 22.80%.This is probably due to the fact that soil nutrient composition and genetic variables, rather than planting techniques, determine protein concentration. Similar findings were made by Patel *et al.* (2019), who found no discernible impact of the methods of planting on the protein content of legumes.

Conclusions and Recommendations

This study evaluated the impact of two sowing methods; ridge and flat sowing on the growth, yield, and quality of the kidney bean (*Phaseolus vulgaris L.*) variety Gorilla in the Pothohar region. The results demonstrated that ridge sowing significantly enhanced key agronomic traits compared to flat sowing. Specifically, ridge sowing resulted in a higher germination percentage (92.00%), number of pods per plant (11.00), number of grains per pod (6.37), 100-grain weight (32.63 g), and grain yield (2112.30 kg ha^{-1}) as compared to falt sowing.

However, plant height (ridge: 46.03 cm; flat: 44.67 cm) and protein content (ridge: 23.16%; flat: 22.80%) were not significantly affected by sowing method, suggesting these traits are more influenced by environmental and genetic factors than by agronomic practices. These results validate ridge sowing as a superior method for enhancing crop establishment, reproductive success, and final yield in kidney beans under Pothohar conditions.

Future studies should focus on conducting multi-location and multi-season trials to validate the benefits of ridge sowing across diverse agro-ecological zones, evaluating a broader range of kidney bean cultivars for compatibility with ridge planting, and assessing the economic feasibility for smallholder farmers. Additionally, research on the long-term impacts of ridge sowing on soil health and its integration with best practices in irrigation, fertilization, and pest management is essential for maximizing productivity and sustainability.

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Novelty Statement

It is a matter of conflict among the farmers about method of sowing in kidney bean production and its quality. In our study protein content with two different sowing methods are investigated to resolve this conflict.

Author's Contribution

Sheheryar: Project investigator
Muhammad Mansoor: Principal investigator and incharge of pulses project and research proposal
Syed Muhammad Saqib Raza: Data analysis
Iqtidar Hussain: Write-up of the manuscript.
Asma Batool: Helped in literature review

Conflict of interest
The authors have no conflict of interest.

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