Evaluation Of The Response Of Seed Rate To The Yield Of Lentil (Lens Culinaris) Varieties Under The Agro-Climatic Conditions Of Quetta

Muhammad Affan[1], Abdul Razaq Reki[2], Abdul Ghaffar[3], Nanak Khan[4*], Mohammed Nauman Irshad[5], Muhammad Saddam[6], Hussan Nawaz[7], Zafarullah[8]

[1]Scholar, Department of Agronomy, Balochistan Agriculture College, Quetta, Pakistan
[2]Professor, Department of Agronomy, Balochistan Agriculture College, Quetta, Pakistan
[3]Duty Director, Agriculture Research Institute Quetta, Pakistan
[4]*Assistant Professor, Department of Agronomy, Balochistan Agriculture College, Quetta, Pakistan, email: nanakkhan76@gmail.com
[5]Assistant Professor, Department of Agronomy, Balochistan Agriculture College, Quetta, Pakistan
[6]Department of Agronomy, Agriculture Research Pashin, Pakistan
[7]Agriculture Research Institute Quetta, Pakistan
[8]Department of Agronomy, Balochistan Agriculture College, Quetta, Pakistan

***Corresponding Author:** Nanak Khan
*Assistant Professor, Department of Agronomy, Balochistan Agriculture College, Quetta, Pakistan
Email: nanakkhan76@gmail.com

Abstract:
Improving crop output requires optimizing seed rate, especially in areas with diverse agroclimatic conditions. This study looks at how varying seed rates affect the production of several cultivars of lentils (Lens culinaris) in Quetta, a semi-arid area with variable weather and little precipitation. The best planting density for each of the four lentil cultivars was tested using varying seed rates. Two growing seasons were used for the experiment in order to account for environmental variability. Based on seed rates, the results showed significant variation in yield, with both under- and overseeding resulting in insufficient plant growth and production losses. Varying seed densities required different seed rates to maximize output, highlighting the need to tailor planting density to the unique genetic characteristics of each variety of lentil. The findings suggest that lentil productivity can be significantly increased by adjusting seed rates according to local climatic conditions and varietal kinds. This research provides valuable data for lentil growers in Quetta and similar regions, along with actionable recommendations for increasing yields through optimal seeding rates. To evaluate the long-term effects of varying seed rates on soil health and overall agricultural sustainability in semi-arid settings, more research is suggested.

Keywords: seed rate, agro-climatic conditions, lentils, Quetta, crop optimization

Introduction:
Lentils (Lens culinaris) are an ancient crop, domesticated around 11,000 years ago, and are now recognized globally for their economic, nutritional, and ecological importance (Liber, Duarte et al. 2021). As a member of the legume family, lentils have a unique ability to fix atmospheric nitrogen, which helps to enrich the soil and reduce the need for chemical fertilizers (Meena, Das et al. 2018, El Haddad, Choukri et al. 2021, Sita, Sehgal et al. 2021). This ability positions lentils as a key component of sustainable agricultural systems, particularly in resource-constrained regions where synthetic inputs are limited (Brown , Islam, Gathala et al. 2019). Furthermore, lentils are valued for their nutritional composition, providing a high-quality source of protein, fiber, and essential micronutrients (Khazaei, Subedi et al. 2019, Romano, Gallo et al. 2021). These benefits make lentils a vital food source, particularly in areas where animal protein is less accessible or where plant-based diets predominate.
Despite these advantages, lentil production faces several challenges, particularly in regions characterized by harsh agro-climatic conditions (Sehgal, Sita et al. 2021). In areas like Quetta, which experiences semi-arid weather with erratic rainfall and temperature extremes, optimizing agricultural practices is essential to enhance crop yield and ensure food security. Quetta's climate is marked by long periods of drought, high temperatures during the growing season, and limited soil moisture retention capacity (Ashraf, Arshad et al. 2021). These factors severely constrain crop production, particularly for cool-season crops like lentils, which are sensitive to water availability and heat stress (Ashraf, Arshad et al. 2021). Understanding how to maximize yield under such challenging conditions requires careful consideration of key factors like seed rate, which directly affects plant density, resource competition, and overall crop performance (Fischer, Ramos et al. 2019).
Seed rate is one of the most critical agronomic factors influencing crop yield (Reed, Bradford et al. 2022). The rate at which seeds are sown determines the plant population per unit area, which in turn affects competition for light, water, and nutrients (Reed, Bradford et al. 2022). Insufficient plant density due to low seed rates can lead to underutilization of

available resources, reducing overall yield. Conversely, excessive seeding can result in overcrowded plants, which may compete with each other, leading to stunted growth and yield reduction (Haque and Sakimin 2022). Achieving the optimal seed rate is essential for balancing plant density and ensuring that crops make efficient use of the environmental resources available to them, especially in resource-scarce settings like Quetta.
Previous research has demonstrated that the optimal seed rate can vary significantly based on environmental conditions, crop variety, and cultivation practices (Liliane and Charles 2020, Šarauskis, Kazlauskas et al. 2022). In semi-arid regions like Quetta, where water is a limiting factor and temperatures fluctuate dramatically between seasons, seed rate becomes an even more critical factor in determining crop success. Lentils, being a cool-season crop, are particularly sensitive to heat stress, which can impact various physiological processes, including photosynthesis, water relations, and reproductive development (Bhandari, Sita et al. 2020, Sita, Sehgal et al. 2021, Venugopalan, Nath et al. 2022). High temperatures during the growing season can lead to flower drop, reduced pollen viability, and overall yield loss (Iovane and Aronne 2022). These challenges necessitate a careful balance between seeding density and environmental conditions to optimize plant growth and productivity.

Additionally, different lentil varieties may respond differently to the same seeding rates, given their genetic variability in growth habits, root structures, and nutrient requirements (Priya, Bansal et al. 2021, Pokhrel, Karki et al. 2022). Some varieties may thrive at lower plant densities, while others require higher densities to maximize resource use and yield (Liliane and Charles 2020, Durrani and Ahmed 2022). Therefore, it is crucial to assess the performance of multiple lentil varieties under varying seed rates to identify the most productive combinations for a given set of environmental conditions.

In Quetta, where climate variability and limited water availability pose significant challenges to agriculture, the need for optimized seeding strategies is particularly urgent (Durrani and Ahmed 2022). This study is designed to address this need by evaluating the response of different lentil varieties to varying seed rates under the agro-climatic conditions of Quetta. By testing different seeding densities across multiple growing seasons, the study aims to account for environmental variability and provide robust data on how different seed rates impact yield. The research will focus on identifying the optimal seed rate for each variety, considering both the genetic characteristics of the lentils and the unique environmental constraints of the region.

The study is driven by the hypothesis that lentil varieties will respond differently to varying seed rates in Quetta's semi-arid climate, and that the optimal seed rate for maximizing yield will depend on both the environmental conditions and the genetic traits of the lentil varieties. The research seeks to test this hypothesis by conducting field experiments with different seeding densities and measuring key yield components, such as biomass production, seed size, and overall productivity. In doing so, the study will provide valuable insights into how to optimize lentil cultivation in semi-arid regions and offer practical recommendations for farmers in Quetta and similar environments.
In conclusion, the research addresses a critical gap in understanding the interaction between seed rate and lentil yield in semi-arid regions like Quetta. By exploring the relationship between seeding density, environmental factors, and varietal performance, this study seeks to enhance agricultural productivity and sustainability in challenging climates, contributing to the global effort to improve food systems in the face of climate change and resource scarcity.

Materials and methods
Research area: The field experiment was conducted at the Agriculture Research Institute (ARI) in Quetta on November 14, 2022, to evaluate the impact of seed rate on the yield of lentil (Lens culinaris) varieties under the specific agro-climatic conditions of Quetta. This region is characterized by semi-arid weather conditions, fluctuating temperatures, and variable precipitation, which make it a challenging environment for crop production.
Two lentil cultivars were selected for this study: Local Panjgur black (V1) and Dasht-21 (V2). These varieties were tested under four different seed rates to evaluate their performance. The seed rates used in the experiment were 7 kg acre^{-1} (S1), 10 kg acre^{-1} (S2), 13 kg acre^{-1} (S3), and 16 kg acre^{-1} (S4). This variation in seed rates allowed for the assessment of how planting density influenced the yield and growth of each cultivar under the agro-climatic conditions of Quetta.

Experimental design: The experiment followed a Randomized Complete Block Design (RCBD) with three replications. The experiment involved two lentil varieties (Local Panjgur black and Dasht-21) and four seed rates (7 kg acre^{-1}, 10 kg acre^{-1}, 13 kg acre^{-1}, and 16 kg acre^{-1}). A composite soil sample was collected and analyzed by the ARI Department of Soil and Water Testing. The sandy clay loam soil had a pH of 7.93, an electrical conductivity of 0.98 dS/m, and an organic matter content of 0.68%.
Each plot measured 4 × 4 meters, and the crop was sown with a row spacing of 30 cm. The recommended doses of NPK (20:50:30 kg ha^{-1}) were applied during sowing, and weeding was done regularly. The field was irrigated as necessary throughout the growing season.

Agronomic observations: Five plants were randomly selected and tagged in each plot to record observations on several agronomic traits. The crop was harvested at full physiological maturity, and growth parameters were recorded. Selected plants were harvested manually, and threshing was also done by hand.

Several agronomic characteristics were observed during the experiment. Germination time was recorded, including the time from sowing to germination and the time until 50% of the plants had flowered. The days to maturity were calculated by noting the number of days from sowing to when 90% of the plants showed signs of chlorosis. At maturity, plant height was measured using a measuring tape. The number of pods per plant was recorded by selecting three plants at random from each plot. Similarly, the number of grains per pod was determined from three randomly selected plants. The weight of 100 seeds was measured using a digital balance to assess seed size. After harvesting, the total grain yield was measured and expressed in kilograms per acre.

Quality parameters: The protein content of the lentil samples was determined using the AOAC method (Anon., 1990). This assessment was carried out for each seed rate and variety combination to evaluate the nutritional quality of the lentils.

Statistical analysis: The collected data were subjected to statistical analysis using Statistix 8.1 software. The Least Significant Difference (LSD) test was used to compare treatment means when necessary to determine which seed rates and varieties provided the best performance in terms of yield and agronomic characteristics.

Limitations: Several limitations impacted the study, including the unpredictable nature of Quetta's semi-arid climate, which resulted in variations in temperature and precipitation across the growing seasons. The study was also restricted to two growing seasons, which may not fully capture the long-term effects of varying seed rates on soil health and overall crop sustainability. Furthermore, water availability was a limiting factor, with no controlled irrigation system in place, which might have affected the crop's growth under different seed densities. Additionally, the experiment focused on only two lentil varieties, limiting the generalizability of the results to other cultivars or regions with different climatic challenges.

Results:

The germination period varied significantly among the
lentil varieties and seed rates. The Local Panjgur Black variety germinated faster (5.33 days) than Dasht-21 (7.33 days). Regarding seed rates, 13 kg/acre promoted the quickest germination (5.83 days), followed by 16 kg/acre (5.50 days), whereas lower rates, 10 kg/acre and 7 kg/acre, delayed germination (7.00 days).

Table a: Combined Effects of Lentil Varieties and Seed Rates on Germination Times

Varieties	Seed Rates (kg acre^{-1})	Mean Days to Germinate	Source	DF	SS	MS	F	P
Local Panjgur black	16 kg acre^{-1}	5.00 d	Blocks	2	0.583	0.291		
Local Panjgur black	13 kg acre^{-1}	4.67 d	Lentil Varieties	1	24.000	24.000	82.29	0.000**
Local Panjgur black	10 kg acre^{-1}	5.33 d	Seed Rates	3	11.000	3.667	12.57	0.000**
Local Panjgur black	7 kg acre^{-1}	7.67 b	Lentil Varieties × Seed Rates	3	3.670	1.222	4.19	0.026*
Dasht-21	16 kg acre^{-1}	6.67 c	Error	14	4.080	0.2917		
Dasht-21	13 kg acre^{-1}	6.33 c	Total	23	43.330			
Dasht-21	10 kg acre^{-1}	6.33 c	*Significant at 5%					
Dasht-21	7 kg acre^{-1}	8.67 a	**Highly Significant at 1%**					
Note: Similar letters indicate no significant difference between values.			**Non-Significant = NS**					

* = Significant at 5% **= Highly Significant at 1% Non-Significant= NS

The flowering period varied significantly between the lentil varieties and seed rates. The Local Panjgur Black variety reached 50% flowering earlier (141 days) compared to Dasht-21 (151.33 days). Among seed rates, 13 kg/acre produced the earliest flowering (141 days), followed by 16 kg/acre (145.17 days), with the longest time to flowering recorded at 7 kg/acre (150.33 days).

Table b: Combined Effects of Lentil Varieties and Seed Rates on Days to 50% Flowering

Varieties	Seed Rates (kg acre^{-1})	Mean Days to 50% Flowering	Source	DF	SS	MS	F	P
Local Panjgur black	16 kg acre^{-1}	140.33 e	Lentil Varieties	1	640.667	640.667	209.81	0.000**
Local Panjgur black	13 kg acre^{-1}	135.33 f	Seed Rates	3	294.333	98.111	32.13	0.000**
Local Panjgur black	10 kg acre^{-1}	143.33 de	Lentil Varieties × Seed Rates	3	3.000	1.000	0.33	0.805ns
Local Panjgur black	7 kg acre^{-1}	153.00 ab	Error	14	42.750			
Dasht-21	16 kg acre^{-1}	145.00 cd	Total	23	993.333			
Dasht-21	13 kg acre^{-1}	146.67 c	*Significant at 5%					
Dasht-21	10 kg acre^{-1}	150.00 b	**Highly Significant at 1%**					
Dasht-21	7 kg acre^{-1}	155.67 a	**Non-Significant = NS**					

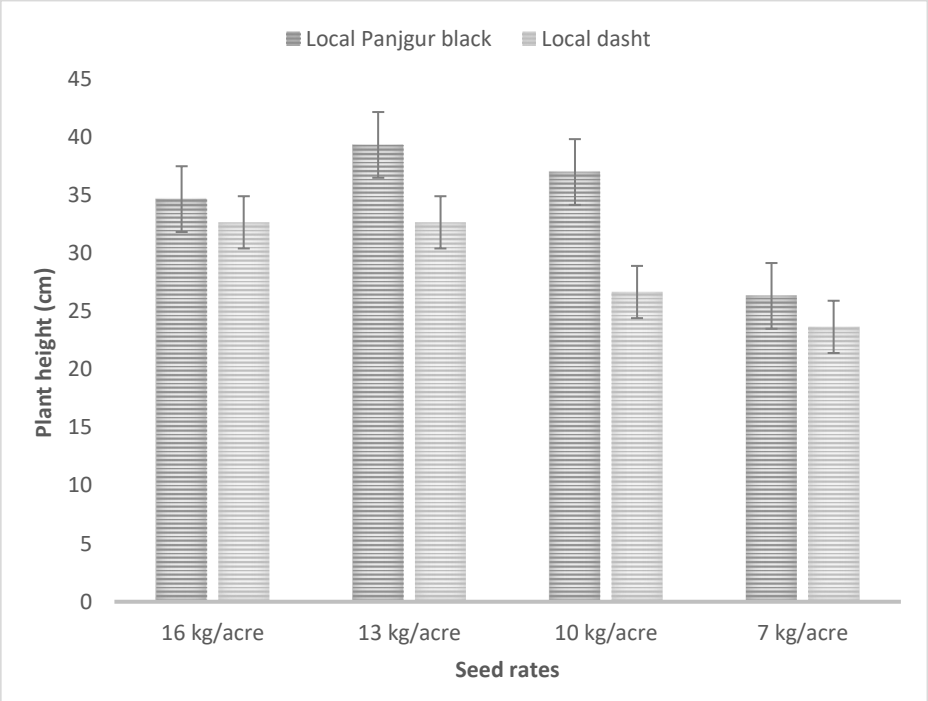
* = Significant at 5% **= Highly Significant at 1% Non-Significant= NS

The Local Panjgur Black variety matured faster (182.75 days) than Dasht-21 (196.33 days). The 13 kg/acre seed rate led to the fastest maturity (181.33 days), whereas the slowest maturity was observed at 7 kg/acre (194.17 days).

Table c: Combined Effects of Lentil Varieties and Seed Rates on Days to 90% Maturity

Varieties	Seed Rates (kg acre-1)	Mean Days to 90% Maturity	Source	DF	SS	MS	F	P
Local Panjgur black	16 kg acre-1	181.33 f	Lentil Varieties	1	1107.04	1107.04	877.28	0.000**
Local Panjgur black	13 kg acre-1	175.67 g	Seed Rates	3	348.46	116.15	92.05	0.000**
Local Panjgur black	10 kg acre-1	185.00 e	Lentil Varieties × Seed Rates	3	30.46	10.15	8.05	0.002**
Local Panjgur black	7 kg acre-1	198.33 a	Error	14	17.67	1.26		
Dasht-21	16 kg acre-1	189.00 d	Total	23	1523.96			
Dasht-21	13 kg acre-1	192.33 c	*Significant at 5%					
Dasht-21	10 kg acre-1	195.33 b	**Highly Significant at 1%**					
Dasht-21	7 kg acre-1	199.33 a	**Non-Significant = NS**					

Figure : varying lentil types' plant heights at varying seeding rates



The plant height showed significant differences among the varieties and seed rates. The Local Panjgur Black reached a height of 34.75 cm, whereas Dasht-21 was shorter at 26.50 cm. The tallest plants were observed at 13 kg/acre (34.75 cm), with decreasing heights observed at lower seed rates.

Table d: Combined Effects of Lentil Varieties and Seed Rates on Mean Plant Height

Varieties	**Seed Rates (kg acre-1)**	**Mean Plant Height (cm)**	**Source**	**DF**	**SS**	**MS**	**F**	**P**
Local Panjgur black	16 kg acre-1	34.67 b	Lentil Varieties	1	408.375	408.375	97.59	0.000**
Local Panjgur black	13 kg acre-1	39.33 a	Seed Rates	3	128.792	42.931	10.26	0.000**
Local Panjgur black	10 kg acre-1	32.44 bc	Lentil Varieties × Seed Rates	3	13.125	4.375	1.05	0.403ns
Local Panjgur black	7 kg acre-1	26.33 de	Error	14	58.583	4.185		
Dasht-21	16 kg acre-1	32.67 bc	Total	23	609.625			
Dasht-21	13 kg acre-1	29.33 cd	*Significant at 5%					
Dasht-21	10 kg acre-1	26.67 de	**Highly Significant at 1%**					
Dasht-21	7 kg acre-1	23.67 e	**Non-Significant = NS**					

Number of Pods per Plant:

The Local Panjgur Black variety yielded the most pods per plant (38.00), while Dasht-21 yielded fewer (27.33). The 13 kg/acre seed rate maximized pod production (40.33), with the least number of pods observed at the 7 kg/acre rate (28.33).

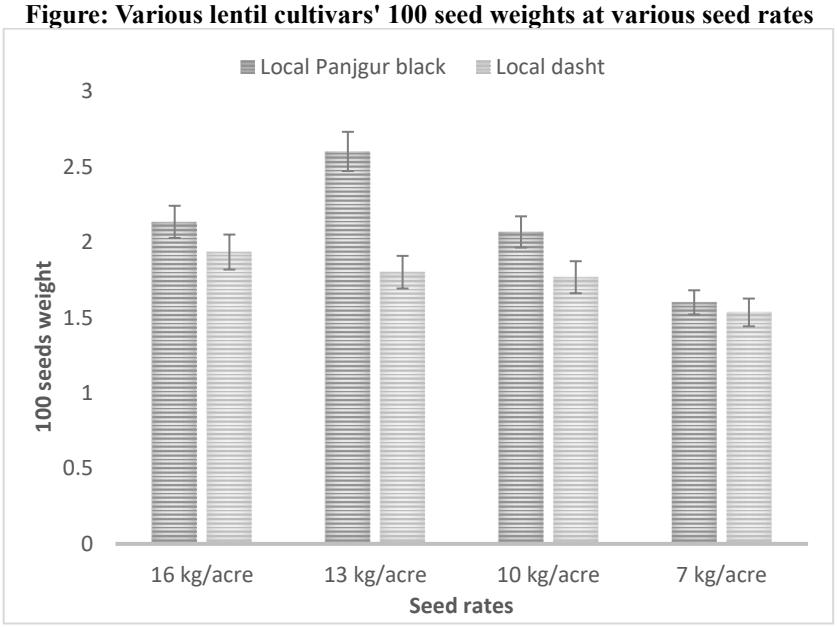
Table: Combined Analysis of the Effect of Lentil Varieties and Seed Rates on Number of Pods per Plant

Varieties	**Seed Rates (kg acre-1)**	**Mean Number of Pods Plant-1**	**Source**	**DF**	**SS**	**MS**	**F**	**P**
Local Panjgur black	16 kg acre-1	36.600 b	Lentil Varieties	1	378.18	378.18	28.49	0.000**
Local Panjgur black	13 kg acre-1	43.000 a	Seed Rates	3	636.32	212.106	15.98	0.000**
Local Panjgur black	10 kg acre-1	30.817 bc	Lentil Varieties × Seed Rates	3	25.84	8.615	0.65	0.596 ns
Local Panjgur black	7 kg acre-1	27.207 cd	Error	14	185.82	13.273		
Dasht-21	16 kg acre-1	29.567 c	Total	23	1227.43			
Dasht-21	13 kg acre-1	31.983 bc	*Significant at 5%					
Dasht-21	10 kg acre-1	22.450 d	**Highly Significant at 1%**					
Dasht-21	7 kg acre-1	21.867 d	**Non-Significant = NS**					
Varieties	**Seed Rates (kg acre-1)**	**Mean Number of Pods Plant-1**	**Source**	**DF**	**SS**	**MS**	**F**	**P**

The Local Panjgur Black variety had more seeds per pod (1.8317) compared to Dasht-21 (1.4850). The highest number of seeds per pod was observed at 13 kg/acre (1.89), with the lowest at 7 kg/acre (1.29).

The Local Panjgur Black had a higher 100 seed weight (2.183 g) compared to Dasht-21 (1.67 g). The highest seed weight was observed at a seed rate of 13 kg/acre (2.20 g), while the lowest weight was recorded at 7 kg/acre (1.73 g).
Grain yield varied significantly between the varieties and seed rates. Local Panjgur Black produced the highest yield (255 kg/acre), while Dasht-21 yielded 152.67 kg/acre. The highest yield was recorded at 13 kg/acre (263.50 kg/acre), with the lowest yield at 7 kg/acre (135.67 kg/acre).

Figure: Various lentil cultivars' 100 seed weights at various seed rates



The Local Panjgur Black had higher protein content (26.89 mg/100 g) than Dasht-21 (25.36 mg/100 g). The 13 kg/acre seed rate showed the highest protein content (26.42 mg/100 g), while the lowest was recorded at 7 kg/acre (25.82 mg/100 g).

Table: Combined Analysis of Protein Content in Lentil Varieties at Different Seed Rates

Varieties	Seed Rates (kg acre-1)	Mean Protein Content (%)	Source	DF	SS	MS	F	P
Local Panjgur black	16 kg acre-1	26.747 b	Lentil Varieties	1	14.0607	14.0607	951.58	0.0000**
Local Panjgur black	13 kg acre-1	27.250 a	Seed Rates	3	1.2243	0.4081	27.62	0.0000**
Local Panjgur black	10 kg acre-1	27.047 a	Lentil Varieties × Seed Rates	3	0.0841	0.0280	1.90	0.1763 NS
Local Panjgur black	7 kg acre-1	26.503 c	Error	14	0.2069	0.0148		
Dasht-21	16 kg acre-1	25.283 ef	Total	23	15.5845			
Dasht-21	13 kg acre-1	25.580 d	*Significant at 5%					
Dasht-21	10 kg acre-1	25.430 de	**Highly Significant at 1%**					

Dasht-21 showed higher carbohydrate content (60.65 mg/100 g) compared to Local Panjgur Black (59.12 mg/100 g). A seed rate of 7 kg/acre resulted in the highest carbohydrate content (60.19 mg/100 g), while 13 kg/acre recorded the lowest (59.59 mg/100 g).

Grain yield showed a strong variation between the lentil varieties and seed rates. Local Panjgur Black produced a higher yield (925.67 kg ha^{-1}) compared to Dasht-21 (781.33 kg ha^{-1}). Among the seed rates, the 13 kg/acre treatment produced the highest yield (966.00 kg ha^{-1}), followed by the 16 kg/acre (888.33 kg ha^{-1}), while the lowest yield was obtained from the 7 kg/acre treatment (761.67 kg ha^{-1}).

Table F: Combined Effects of Lentil Varieties and Seed Rates on Grain Yield (kg ha^{-1})

Varieties	Seed Rates (kg $acre^{-1}$)	Mean Grain Yield (kg ha^{-1})	DF	SS	MS	F	P
Local Panjgur black	16 kg $acre^{-1}$	936.00 ab	1	12892.6	12892.6	156.39	0.000**
Local Panjgur black	13 kg $acre^{-1}$	990.00 a	3	3672.0	1224.0	14.85	0.000**
Local Panjgur black	10 kg $acre^{-1}$	853.33 bc	3	210.0	70.0	0.85	0.485ns
Local Panjgur black	7 kg $acre^{-1}$	833.33 cd	14	1461.7	104.4		
Dasht-21	16 kg $acre^{-1}$	840.67 cd					
Dasht-21	13 kg $acre^{-1}$	842.00 cd					
Dasht-21	10 kg $acre^{-1}$	741.33 de					
Dasht-21	7 kg $acre^{-1}$	690.00 e					

- *Significant at 5%; *Highly Significant at 1%. Non-Significant = NS

1000-Grain Weight (g):

The weight of 1000 grains was also influenced by both variety and seed rate. Local Panjgur Black had a higher 1000-grain weight (34.33 g) than Dasht-21 (31.00 g). Seed rates of 13 kg/acre and 16 kg/acre resulted in higher 1000-grain weights (35.00 g and 33.67 g, respectively), while 7 kg/acre produced the lowest weight (29.67 g).

Table G: Combined Effects of Lentil Varieties and Seed Rates on 1000-Grain Weight (g)

Varieties	Seed Rates (kg acre^{-1})	Mean 1000-Grain Weight (g)	DF	SS	MS	F	P
Local Panjgur black	16 kg acre^{-1}	33.67 b	1	23.667	23.667	26.96	0.000**
Local Panjgur black	13 kg acre^{-1}	35.00 a	3	2.792	0.931	1.06	0.367ns
Local Panjgur black	10 kg acre^{-1}	32.33 bc	3	1.667	0.556	0.63	0.599ns
Local Panjgur black	7 kg acre^{-1}	30.00 c	14	23.625	1.688		
Dasht-21	16 kg acre^{-1}	32.00 bc					
Dasht-21	13 kg acre^{-1}	32.00 bc					
Dasht-21	10 kg acre^{-1}	29.33 cd					
Dasht-21	7 kg acre^{-1}	29.33 cd					

- *Significant at 5%; *Highly Significant at 1%. Non-Significant = NS

The study demonstrated that both lentil varieties and seed rates significantly affect growth, yield, and other agronomic traits of lentil crops. The Local Panjgur Black variety outperformed Dasht-21 in most growth and yield parameters, especially in germination, days to flowering, plant height, number of pods per plant, and grain yield. A seed rate of 13 kg/acre produced the best results across most traits, leading to faster growth, higher yield, and larger grain size.
Based on these findings, Local Panjgur Black, combined with a seed rate of 13 kg/acre, is recommended for achieving optimal lentil production in the study region. Future research could explore different environmental conditions, further optimization of seed rates, and evaluation of other lentil varieties for broader applicability.

Discussion

The results of this study highlight the significant influence of lentil varieties and seed rates on key agronomic parameters, including germination period, flowering, maturity, plant height, pod production, seed quality, and overall grain yield. This discussion will explore the implications of these findings and their relevance to the selection of optimal lentil varieties and seed rates for maximizing productivity in lentil cultivation.

The study observed that the germination period was significantly influenced by both the lentil variety and the seed rate. The Local Panjgur Black variety demonstrated a faster germination time (5.33 days) compared to Dasht-21 (7.33 days), indicating that this variety may be better suited for regions where quick establishment is crucial, such as areas prone to early-season water stress. The faster germination in the Local Panjgur Black variety could be attributed to its genetic characteristics, which promote rapid seedling development.

Moreover, the seed rate also played a critical role, with the 13 kg/acre seed rate promoting the quickest germination (5.83 days), followed closely by 16 kg/acre (5.50 days). In contrast, lower seed rates (10 kg/acre and 7 kg/acre) delayed germination, suggesting that a higher seed density may create more favorable conditions for seed-soil contact and moisture retention, thus accelerating the germination process. These findings align with previous studies that suggest higher seed rates can reduce the time to germination due to increased competition among seedlings, leading to faster root establishment.

The time to 50% flowering was also significantly influenced by both the variety and seed rate. Local Panjgur Black flowered earlier (141 days) compared to Dasht-21 (151.33 days), underscoring its potential as a variety suited for early-season harvest. This characteristic can be particularly advantageous in regions with shorter growing seasons or where early harvest is desired to avoid adverse weather conditions at the end of the growing season.
The seed rate of 13 kg/acre led to the earliest flowering, further supporting the notion that this rate may provide the optimal balance between plant competition and resource availability. Interestingly, the interaction between seed rate and lentil variety was not significant, suggesting that while both factors influence flowering, they do so independently rather than synergistically.

The maturity period showed a clear distinction between the two varieties, with Local Panjgur Black maturing faster (182.75 days) compared to Dasht-21 (196.33 days). Early maturity is a desirable trait in lentil cultivation, as it reduces the risk of crop loss due to late-season environmental stresses such as frost or drought. The faster maturity of Local Panjgur Black enhances its appeal for regions with unpredictable weather patterns, allowing for timely harvesting.
In terms of seed rate, the 13 kg/acre rate again proved optimal, leading to the fastest maturity (181.33 days), while the slowest maturity was observed at 7 kg/acre (194.17 days). These results suggest that lower seed rates may not only delay germination and flowering but also prolong the time to maturity, potentially reducing the overall productivity of the crop.

Plant height is an important agronomic trait that can affect yield and harvest efficiency. The study found that Local Panjgur Black reached a greater height (34.75 cm) compared to Dasht-21 (26.50 cm), which may confer advantages in terms of light interception and photosynthetic capacity. Taller plants are often associated with higher biomass production, which can lead to increased yield.

Interestingly, the tallest plants were observed at the 13 kg/acre seed rate, suggesting that this rate provides the optimal density for plant growth. At lower seed rates, reduced competition may lead to smaller plants, while at higher rates, excessive competition could stunt growth. This finding supports the notion that intermediate seed rates can strike a balance between resource availability and plant competition, promoting healthy plant growth.
The number of pods per plant is a key determinant of yield potential, and the results showed that Local Panjgur Black produced significantly more pods (38.00) compared to Dasht-21 (27.33). This higher pod production is likely a reflection of the variety's superior genetic potential for reproductive development. The 13 kg/acre seed rate again proved optimal, leading to the highest number of pods per plant (40.33), while the 7 kg/acre rate resulted in the fewest pods (28.33).

Seed quality, measured by the number of seeds per pod and 100-seed weight, also favored Local Panjgur Black. This variety produced more seeds per pod (1.8317) and a higher 100-seed weight (2.183 g) than Dasht-21, which is a crucial factor for marketability and overall grain yield. The 13 kg/acre seed rate once again led to the highest seed weight (2.20 g), indicating that this rate promotes not only greater pod production but also superior seed development.
Grain yield is the most critical outcome in lentil production, and the results showed a strong variation between the two varieties and the seed rates. Local Panjgur Black produced a substantially higher yield (925.67 kg/ha) compared to Dasht-21 (781.33 kg/ha), confirming its superior productivity. Among the seed rates, 13 kg/acre resulted in the highest yield (966.00 kg/ha), followed by 16 kg/acre (888.33 kg/ha), while the lowest yield was recorded at 7 kg/acre (761.67 kg/ha).

These findings suggest that the Local Panjgur Black variety, in combination with a seed rate of 13 kg/acre, provides the optimal conditions for maximizing lentil yield. The higher yields observed at this seed rate are likely due to the combination of faster germination, earlier flowering, and superior pod and seed production.
The nutritional analysis revealed that Local Panjgur Black had higher protein content (26.89 mg/100 g) compared to Dasht-21 (25.36 mg/100 g), making it a more nutritious option for both human consumption and animal feed. The 13 kg/acre seed rate also resulted in the highest protein content, further reinforcing its status as the optimal seed rate for both yield and nutritional quality.

Conversely, Dasht-21 had higher carbohydrate content (60.65 mg/100 g) compared to Local Panjgur Black (59.12 mg/100 g), suggesting that it may be more suitable for applications where higher carbohydrate levels are desired. However, the relatively lower yield and protein content of Dasht-21 make it a less favorable option overall for maximizing both productivity and nutritional value.
This study demonstrates that the Local Panjgur Black lentil variety, combined with a seed rate of 13 kg/acre, offers the best balance of early maturity, high plant height, superior pod production, optimal seed quality, and maximum grain yield. These findings have practical implications for lentil farmers in regions with similar growing conditions, as they suggest that selecting the appropriate variety and seed rate can significantly enhance productivity and profitability.
Future research should focus on investigating the performance of these varieties under varying environmental conditions, such as different soil types and moisture levels, to further refine the recommendations for lentil cultivation. Additionally, the potential for breeding programs to enhance the desirable traits observed in Local Panjgur Black should be explored, with the goal of developing even more productive and resilient lentil varieties.

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