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Phenological, agronomic, and yield performance of four local common bean varieties under the agro-climatic conditions of Kabul, Afghanistan

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A B S T R A C T

Common bean is an important legume crop cultivated worldwide and exhibits considerable variation in morphological, agronomic, and adaptive traits. In Afghanistan, diverse local and improved bean varieties are grown under different agroecological conditions and contribute significantly to food security and rural livelihoods. However, limited information is available regarding their phenological, agronomic and yield performance, which hinders the identification and recommendation of high-yielding and well-adapted cultivars. Therefore, the study aimed to evaluate the phenological, agronomic, and yield characteristics of four local common bean varieties and identify the most suitable variety for cultivation under agro-climatic conditions of Kabul, Afghanistan. The four local bean varieties evaluated were Nagrabi Kapisa (red large seed), Badakhshi (spotted large seed), Ghaznichi (red small seed), and Logari (cream-colored small seed). The results indicated that Nagrabi (T1) performed superior to the other varieties in most evaluated parameters. Nagrabi bean variety recorded the highest germination percentage (95%), earliest flowering (40.33 days) and maturity (82.67 days), maximum number of branches per plant (11.73), highest number of pods per plant (16.93), longest pod length (11.51 cm), highest number of seeds per pod (5.23), heaviest 100-seed weight (34.06 g), and the highest seed yield (2630.57 kg ha^{-1}). In contrast, Logari (T4) and Ghaznichi (T3) showed comparatively lower performance in most traits. Based on this study, the Nagrabi variety was identified as the most suitable local bean cultivar for cultivation under the agro-climatic conditions of Kabul.

Keywords: agro-climatic conditions of Kabul, agronomic traits, comparison, local common bean varieties, phenological parameters

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1. INTRODUCTION

Common Bean (*Phaseolus vulgaris L.*) is an important legume crop belonging to the family Fabaceae, widely cultivated across the world due to its high nutritional value, including protein, dietary fiber, vitamins, and essential minerals (Uebersax et al., 2023; Lisciani et al., 2024). It is considered one of the most important food legumes in both developed and developing countries because of its ability to contribute significantly to human nutrition and food security (Lisciani et al., 2024). In addition to its dietary importance, common bean plays a vital role in sustainable agriculture through its ability to fix atmospheric nitrogen, thereby improving soil fertility and reducing dependence on synthetic fertilizers (Karavidas et al., 2022; Cardoso et al., 2024).

Globally, bean production is influenced by environmental conditions, genetic factors, and agronomic practices. The crop shows considerable adaptability to different agro-ecological zones; however, its productivity is strongly affected by water availability, temperature fluctuations, soil fertility, and cultivar selection (Mohammad and Feleke, 2022; Daud et al., 2026). In Afghanistan, common bean is an important component of smallholder farming systems, particularly in regions such as Kabul Province, where farmers cultivate beans for both household consumption and income generation. The crop is favored due to its relatively short growth duration and adaptability to local farming systems. However, productivity remains low and unstable due to environmental stress, limited access to improved varieties, and inadequate agronomic management practices (Sarhadi et al.,2017).

Previous studies have reported significant variation in growth and yield performance of bean genotypes under different environmental conditions. For instance, Sarhadi et al. (2017) evaluated the adaptation of local bean varieties under Kabul climatic conditions and reported considerable differences in phenological behavior and yield potential among varieties. Similarly, studies by Hussaini et al. (2021) indicated that water stress significantly affects growth and yield formation in beans, while Qadiri et al. (2023) highlighted the positive role of integrated nutrient management in improving crop performance. Furthermore, Kargiotidou et al. (2018) emphasized that genetic variability among bean genotypes plays a major role in determining yield and its related components, particularly pod number and seed development. Sadiq et al. (2023) also reported that plant density, cultivar and agronomic practices significantly influence yield potential in bean production systems. Despite these findings, there is still limited and insufficient comparative information on the performance of local bean varieties under the specific agro-climatic conditions of Kabul, particularly regarding detailed evaluation of phenological traits, growth characteristics, and yield components under uniform field conditions. Therefore, systematic evaluation of locally available bean varieties is essential to identify high-performing genotypes suitable for sustainable production in the region.

This study is significant because it provides updated comparative information on the performance of local bean varieties under Kabul conditions, which can support farmers, researchers, and extension workers in selecting high-yielding and well-adapted varieties. The findings will also contribute to improving food security and sustainable agricultural production in the agro-climatic conditions of Kabul.

(Limited information regarding the comparison of phonological, agronomic, and yield characteristics of local bean varieties in the agro-climatic conditions of Kabul). Farmers mainly depend on traditional practices and regional knowledge when selecting varieties, which can lead to low productivity and inefficient resource use. Without experiments, it is difficult to identify which local bean varieties are best suited for Kabul's environment in terms of phonological, agronomic and yield characteristics. This knowledge gap hinders efforts to improve bean production. Therefore, the study aimed to compare the phonological, agronomic and yield characteristics of four local bean varieties under Kabul's climatic conditions to determine the most productive types.

2. MATERIALS AND METHODS

This research was conducted at the Agriculture Faculty research farm of Kabul University, during the summer growth season in two field experiments, location (A) and location (B), from the 28 April

2025 to 29 August 2025. Randomized Complete Block Design (RCBD) was used with three replications. Four local bean varieties were used as treatments: Nagrabi (T1), Badakhshi (T2), Ghaznichi (T3), and Logari (T4). Seeds of these varieties were obtained from local farmers and seed sources within their respective production areas. Each replication consisted of four plots, one for each bean variety, resulting in a total of 12 plots per location. Each plot measured 2 × 2 m (4 m²), the experimental area included four rows which arranged to maintain 50 cm distance between each row and 20 cm distance between each individual plant.

Table 1 Morphological and agronomic characteristics of four local common bean varieties

Variety Name	Seed Size	Seed Color	Growth Habit	Agronomic Characteristics	picture
Nagrabi (Kapisa) common bean variety	Large	Red	Determinate	Early maturing	
Badakhshi common bean variety	Large	Spotted (Ablaq)	Semi-determinate	Intermediate maturity	
Ghaznichi (Maqur) common bean variety	Small	Red	Indeterminate	Late-maturing	
Logari common bean variety	Small	Cream-colored (Shirayi)	Indeterminate	Late-maturing	

Source: The common bean varieties used in this study were obtained from the Badam Bagh Research Directorate, Kabul, Afghanistan, under the Ministry of Agriculture, Irrigation and Livestock (MAIL).

The experimental field was thoroughly prepared through deep ploughing, followed by additional ploughing, hoeing, debris removal, and land leveling to create a fine and uniform seedbed. The field was then divided into three blocks and twelve plots, with furrows prepared for sowing. To enhance soil fertility, 280 kg ha^{-1} of DAP, 1.5 t ha^{-1} of organic manure and 180 kg ha^{-1} of urea were applied, with urea supplied in split doses. Bean seeds were treated with Vitawax fungicide before sowing to protect against soil-borne diseases and improve seedling establishment. A pre-sowing germination test (100 seeds per variety) was conducted under moist tissue conditions at room temperature. Results indicated high seed viability, with germination rates ranging from 96% to 100%, confirming the suitability of all seed lots for field planting. Prior to sowing, the field was irrigated and seeds were

soaked for 18 hours to promote rapid germination. Planting was carried out on 28 April 2025 at a depth of 5 cm, maintaining a spacing of 20 cm between plants and 50 cm between rows. Weed control was performed manually twice during the growing season to reduce competition for resources and maintain field hygiene. Variety-specific seed rates were used, ranging from 25 to 33 kg ha^{-1}. Crop protection measures focused on monitoring and manually controlling cutworm (Agrotis spp.) infestations, which posed a threat to young seedlings. Thinning was conducted 25 days after sowing to maintain the recommended plant spacing and ensure uniform growth. Irrigation management included pre-sowing irrigation followed by regular applications at 7-10 day intervals, resulting in a total of 17 irrigations throughout the growing season to maintain adequate soil moisture and support optimum crop development.

Data on germination, growth, phenology, and yield attributes were collected using standard procedures. Germination percentage was determined 10 days after sowing by counting seeds that produced a visible radicle or shoot and calculating the proportion of germinated seeds relative to the total seeds sown. Days to start flowering and days to start maturity were recorded from sowing to the appearance of the first open flower and the first signs of pod browning, respectively, using observations from five representative plants per plot. Plant height was measured at harvest from the base of the plant to the tip of the main stem on five selected plants, while the numbers of branches and pods per plant were determined by counting all primary and secondary branches and total pods on the same sampled plants. Pod length, pod diameter, and seeds per pod were assessed using ten randomly selected pods from representative plants in each plot, and mean values were calculated. For seed weight, a random sample of 100 seeds from each replication was weighed using a precision electronic balance after harvest, threshing, and cleaning. Seed yield was determined by harvesting a 1 m^2 area within each plot, drying the seeds to a uniform moisture content, recording the seed weight, and converting the values to kilograms per hectare (kg ha^{-1}) using standard conversion methods. All measurements were averaged to obtain representative values for each plot and treatment.

Analysis of variance (ANOVA) was conducted to assess collected data through their Randomized Complete Block Design (RCBD) experimental setup. Mean was compared using the Tukey Honest Significant Difference (HSD) test at the 5% probability level comparisons were conducted to compare the means statistical analysis conducted through STAR (Statistical Tool for Agricultural Research) software.

3. RESULTS

Various plant parameters such as germination percentage (10 DAS), days to flowering, days to maturity, Plant height, branches per plant, pods per plant, pod length, seeds per pod, pod diameter, 100-seed weight, and seed yield (kg ha^{-1}) were evaluated.

3.1 Germination% 10 DAS

Nagrabi demonstrated the highest germination performance, indicating variation in seed vigor and establishment ability, followed by Badakhshi and Ghaznichi, while Logari showed the lowest germination percentage.

Table 2 Comparison of varieties in germination% 10 DAS

Treatments	Germination% 10 DAS
T1 (Nagrabi)	95.0 [a]
T2 (Badakhshi)	77.4 [b]
T3 (Ghaznichi)	67.1 [c]
T4 (Logari)	59.3 [d]

Values presented are treatment means based on three replications (n = 3). Means followed by the same letter within a column are not significantly different at the 5% probability level according to the Tukey Honest Significant Difference (HSD) test (P ≤ 0.05). Different letters within a column indicate significant differences among bean varieties for the respective parameter.

3.2 Phenological parameters

For days to flowering and days to maturity, significant differences ($p \leq 0.05$) were observed between treatments. Nagrabi was the earliest flowering and maturing variety, while Logari and Ghaznichi required a longer time to complete their growth cycle. Badakhshi showed intermediate performance. These differences reflect the genetic variability among the varieties in their growth and developmental characteristics.

Table 3. Comparison of varieties in phenological parameters

Treatments	Days to Flowering	Days to Maturity
T1 (Nagrabi)	40.33 [d]	82.67 [d]
T2 (Badakhshi)	48.43 [c]	89.00 [c]
T3 (Ghaznichi)	60.50 [a]	101.33 [b]
T4 (Logari)	56.67 [b]	110.33 [a]

Values presented are treatment means based on three replications (n = 3). Means followed by the same letter within a column are not significantly different at the 5% probability level according to the Tukey Honest Significant Difference (HSD) test ($p \leq 0.05$). Different letters within a column indicate significant differences among bean varieties for the respective parameters.

3.3 Growth Traits

Significant differences were observed among the varieties for both traits. Logari and Ghaznichi produced the tallest plants, indicating greater vegetative growth, whereas Nagrabi exhibited the shortest plants. In contrast, Nagrabi developed the highest number of branches per plant, while Ghaznichi produced the fewest branches. Badakhshi and Logari showed intermediate branching performance. These results suggest that varietal differences influenced plant architecture, with taller varieties not necessarily producing a greater number of branches.

Table 4. Comparison of varieties in agronomic treats.

Treatments	Plant Height (cm)	Number of Branches Per Plant
T1 (Nagrabi)	37.13 [c]	11.73 [a]
T2 (Badakhshi)	54.67 [b]	9.17 [ab]
T3 (Ghaznichi)	71.07 [a]	4.63 [c]
T4 (Logari)	76.8 [a]	7.47 [b]

Values presented are treatment means based on three replications (n = 3). Means followed by the same letter within a column are not significantly different at the 5% probability level according to the Tukey Honest Significant Difference (HSD) test (P ≤ 0.05). Different letters within a column indicate significant differences among bean varieties for the respective parameters.

3.4 Reproductive characteristics

Table.4 shows significant differences among the bean varieties for yield and yield-related traits. Nagrabi produced the highest number of pods per plant, longest pods, greatest number of seeds per pod, highest 100-seed weight, and the highest grain yield, demonstrating superior yield performance. Badakhshi exhibited intermediate values for most traits and ranked second in grain yield. Ghaznichi showed moderate performance, while Logari recorded the lowest values for most yield components

and consequently produced the lowest grain yield. Pod diameter was generally similar among most varieties, although Logari exhibited a significantly smaller pod diameter. These results indicate that variations in grain yield were largely associated with differences in pod production, seed set, pod size, and seed weight among the tested varieties.

Table 5. Comparison of varieties in reproductive traits

Treatments	Pods per Plant	Pod Length (cm)	Seeds per Pod	Pod Diameter (cm)	100-Seed Weight (g)	Grain yield (kg ha^{-1})
T1 (Nagrabi)	16.93 ^{a}	11.51 ^{a}	5.23 ^{a}	3.53 ^{a}	34.06 ^{a}	2630.57 ^{a}
T2 (Badakhshi)	13.40 ^{b}	9.85 ^{ab}	4.75 ^{ab}	3.32 ^{a}	31.80 ^{ab}	1876.33 ^{b}
T3 (Ghaznichi)	10.37 ^{bc}	8.56 ^{bc}	3.98 ^{bc}	3.34 ^{a}	23.93 ^{c}	1568.00 ^{c}
T4 (Logari)	9.00 ^{c}	6.43 ^{c}	3.37 ^{c}	2.60 ^{b}	25.67 ^{bc}	1231.43 ^{d}

Values presented are treatment means based on three replications (n = 3). Means followed by the same letter within a column are not significantly different at the 5% probability level according to the Tukey Honest Significant Difference (HSD) test ($P \leq 0.05$). Different letters within a column indicate significant differences among bean varieties for the respective parameters.

5. DISCUSSION

Nagrabi showed the highest germination performance, indicating superior seed vigor, faster metabolic activation, and better reserve mobilization during early establishment. This advantage suggests stronger physiological readiness for rapid seedling emergence under agro-climatic conditions of Kabul. Similar genetic control of germination and seed vigor in common bean was reported by Kusaksiz et al. (2022), who emphasized varietal differences in early establishment ability. **(**T3**)** and **(**T4**)** exhibited lower germination percentages within the first 10 days due to their delayed germination behavior and late-maturing nature in some varieties may be associated with reduced seed vigor and sensitivity to environmental conditions, which is consistent with the findings of Teshale et al. (2020), who reported poor establishment under stress-prone environments.

Earliest flowering was exhibited in Nagrabi bean variety, reflecting a shorter vegetative phase and faster transition to reproductive development. This early phenology is advantageous in Kabul's semi-arid climate, where terminal drought or temperature stress can reduce yield in late-maturing types. The early flowering response likely indicates better adaptation and efficient accumulation of thermal units. Raggi et al. (2019) confirmed strong genetic control over flowering time in common bean, while Bhakta et al. (2017) reported that temperature and photoperiod strongly influence floral initiation. Similar variation among growth habits was also observed by Neupane et al. (2011).

The earliest maturity recorded in Nagrabi demonstrates its ability to complete its life cycle efficiently under limited moisture conditions, allowing it to escape late-season stress. This trait is particularly valuable in semi-arid environments where water availability declines toward the end of the growing season. Similar findings were reported by Yanda and Tryphone (2022), who associated early maturity with drought avoidance strategies. Kusaksiz et al. (2022) also noted that early-maturing genotypes are better adapted to short-season environments, whereas late-maturing types prioritize biomass accumulation under favorable conditions.

The tallest plants observed in Ghaznichi and Logari indicate lengthen vegetative growth and more indeterminate growth habit, while Nagrabi showed shorter plant height which could be associated with early maturity and more efficient resource allocation to reproductive organs. Similar patterns were reported by Kusaksiz et al. (2022), who distinguished indeterminate tall types from determinate short types. This suggests that assimilates in Nagrabi are preferentially allocated to reproductive structures rather than vegetative biomass.

Nagrabi produced the highest number of branches, indicating superior plant architecture and greater potential for reproductive site formation. This higher branching capacity directly contributed to increased pod formation and yield potential. Kusaksiz et al. (2022) similarly reported that highly branched genotypes produce more reproductive nodes and higher yields. In contrast, reduced branching in some varieties may be linked to genetic limitations or suboptimal assimilate distribution.

The highest pod number per plant recorded in Nagrabi, which reflects improved flower retention and stronger source–sink relationships during reproductive development. This superiority is likely associated with its higher branching and early flowering traits, which extend pod formation duration. Mekonnen et al. (2019) reported that pod formation is strongly influenced by genotype × environment interaction, while Girma et al. (2021) confirmed that higher branching increases pod production.

Longer pods in Nagrabi indicate better assimilate translocation and stronger reproductive development compared to other varieties. This suggests more efficient nutrient uptake and partitioning during pod filling. Similar effects of favorable agronomic conditions on pod elongation were reported by Olawale et al. (2021) and Singh and Kumar (2019), while Adebayo et al. (2020) emphasized the importance of soil fertility in improving pod structural development.

The highest seed number per pod showed Nagrabi, indicating efficient fertilization and strong assimilate supply during seed formation. This trait reflects better reproductive efficiency and sinks strength. Togay et al. (2005) reported that nitrogen and phosphorus significantly improve seed set, while Khalid et al. (2018) and Kusaksiz et al. (2022) confirmed strong genetic control over this trait. In contrast, Ghaznichi's lower seed set reflects the lower end of reported ranges, likely due to limited resource allocation and suboptimal reproductive efficiency.

Greater pod diameter in Nagrabi and some other varieties indicates improved pod filling capacity and stronger sink development. This trait reflects better nutrient availability and physiological efficiency during reproductive growth. Similar findings were reported by Olawale et al. (2021), who highlighted the role of improved agronomic practices in enhancing pod size, while Singh and Kumar (2019) emphasized genetics and environmental influence on pod structure.

Higher 100-seed weight in Nagrabi indicates superior assimilate partitioning and efficient seed filling during the reproductive stage. This suggests stronger photosynthetic activity and effective translocation of nutrients to developing seeds. Similar variation influenced by genotype and agronomic practices was reported by Sadiq et al. (2023), while Avens (2021) demonstrated the effect of spacing on seed weight.

The highest seed yield in Nagrabi is the cumulative result of its superior performance in all yield components, including higher pod number, better seed set, and higher seed weight. This indicates a well-balanced source-sink relationship and strong adaptation to semi-arid conditions. FAO (2022) reported that environmental conditions and genotype strongly influence bean yield.

6. CONCLUSION

The present study evaluated the performance of four local bean varieties under the agro-climatic conditions of Kabul by assessing germination, phenological, growth traits, and yield components. The results revealed clear and significant variation among the tested varieties; Nagrabi (T1) consistently demonstrated superior performance across nearly all parameters. It achieved the highest germination percentage (95%), indicating excellent seed vigor and viability, and exhibited the earliest flowering (40.33 days) and earliest maturity (82.67 days), which are critical advantages under Kabul's relatively short growing season and water-limited conditions. Moreover, Nagrabi (T1) excelled in yield-contributing traits, recording the highest number of branches per plant (11.73), maximum number of pods per plant (16.93), longest pod length (11.51 cm), highest number of seeds per pod (5.23), heaviest (100) seed weight (34.06 g) and the highest seed yield (2630 kg ha^{-1}). Based on our findings in the research area and agro-climatic conditions of Kabul, we suggest that the Nagrabi (T1) variety of bean showed the best performance. In contrast, Logari (T4) and Ghaznichi (T3) exhibited

weaker performance in most growth and yield parameters, including low germination rates, delayed flowering and maturity, fewer branches, and reduced seeds weight. Their lower adaptability suggests that these varieties are less suited to the specific climatic and soil conditions of Kabul. Badakhshi (T2) showed moderate performance across traits, performing better than Ghaznichi (T3) and Logari (T4) but not reaching the productivity level of Nagrabi (T1). It is recommended to investigate how different fertilization systems, irrigation approaches, and intercropping methods affect plant development in local environments to improve bean production and environmental sustainability.

Author Contributions

Mehrabuddin Rashed contributed to the conceptualization of the study, development of the methodology, experimental design, data collection, data analysis, interpretation of results, and preparation of the original manuscript draft. Abdul Khalil Afghani contributed to the supervision of the research, provided guidance throughout the study, and critically reviewed and edited the manuscript.

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Data Availability Statement
The data supporting the findings of this study are available from the corresponding author upon reasonable request. The dataset is not publicly available because it contains experimental observations and measurements generated during the study and has not been deposited in a public data repository.

Conflict of Interest
The authors declare no conflict of interest.

Artificial Intelligence (AI) Use Statement
The authors declare that no generative artificial intelligence tools were used in the preparation of this manuscript

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