PLANT SCIENCE TODAY
ISSN 2348-1900 (online)
Vol x(x): xx–xx
https://doi.org/10.14719/pst.3304

HORIZON
e-Publishing Group
HePG

RESEARCH ARTICLE

Effect of planting distance and nitrogen fertilizer on the yield and physiological traits of Pinto bean (*Phaseolus vulgaris* L.)

Mohammad Sadiq Merzai[1]*, Mohammad Wali Salari [2] & Rahmatullah Kazimi[3]

[1]Department of Agronomy, Faculty of Agriculture, Daikundi Institute of Higher Education, Nili 4203, Afghanistan
[2]Department of Biotechnology and Seed Production, Faculty of Agriculture, Kabul University, Kabul 1008, Afghanistan
[3]Department of Horticulture, Faculty of Agriculture, Daikundi Institute of Higher Education, Nili 4203, Afghanistan

*Email: m.sadiqmerzai6@gmail.com

OPEN ACCESS

ARTICLE HISTORY

Received: 21 January 2024
Accepted: 11 September 2024

Available online
Version 1.0 : 17 October 2024

Check for updates

Additional information

Peer review: Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

Reprints & permissions information is available at https://horizonepublishing.com/journals/index.php/PST/open_access_policy

Publisher's Note: Horizon e-Publishing Group remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Indexing: Plant Science Today, published by Horizon e-Publishing Group, is covered by Scopus, Web of Science, BIOSIS Previews, Clarivate Analytics, NAAS, UGC Care, etc
See https://horizonepublishing.com/journals/index.php/PST/indexing_abstracting

CITE THIS ARTICLE

Merzai M S, Salari M W, Kazimi R. Effect of planting distance and nitrogen fertilizer on the yield and physiological traits of Pinto bean (*Phaseolus vulgaris* L.) . Plant Science Today (Early Access). https://doi.org/10.14719/pst.3304

Abstract

To investigate the influence of planting distance and nitrogen fertilizer levels on yield and yield components of common bean (*Phaseolus vulgaris* L.) cultivars, a study was conducted in 2021 at the educational and research farm of the Daikundi Higher Education Institute. Employing a Randomized Complete Block Design (RCBD) Split-Plot arrangement with 4 replications, the research examined 4 planting distances (10, 15, 20 and 25 cm) as the primary factor and 3 nitrogen fertilizer levels (0, 50 and 100 kg N/ha) as the secondary factor. The analysis revealed that the highest seed yield for common beans, averaging 1220 kg/ha, was obtained with a planting distance of 25 cm and a nitrogen application rate of 100 kg N/ha. Conversely, the lowest yield, averaging 773 kg/ha, was recorded at the narrowest planting distance of 10 cm without nitrogen fertilization. Agronomic and physiological traits, such as increased total dry matter and leaf relative water content, were observed to positively correlate with grain yield in pinto beans. In contrast, reduced planting row spacing adversely affected seed yield, harvest index, phonological stages and other common bean characteristics, particularly at seeding stage. However, the application of 100 kg N/ha significantly improved certain measured traits. Based on these findings, the study recommends a combined agronomic practice of applying 100 kg N/ha and maintaining a planting row distance of 25 cm for optimal management of common bean crops in the Nili center of Daikundi province.

Keywords

common bean; developmental stage; nitrogen; optimal cultivation distance; physiological traits; seed yield

Introduction

One of the acute nutritional challenges in developing countries is the lack of protein consumption. Therefore, it is crucial to focus on cultivating Pinto beans, which are known for their high protein content, to address this issue (1, 2). Beans are among the most significant legumes and their edible seeds possess the highest nutritional value within this group (1). Given that Pinto beans cover the largest cultivated area and hold the highest economic value among legumes, implementing superior agricultural management is essential to maximize yield potential (2). In a study examining the optimal plant density common bean, *Phaseolus vulgaris* L, yield, traits such as the weight of 100 seeds, number of seeds per pod, plant height, days to flowering and days to maturity were unaffected by plant density. However, while the number of pods per plant decreased, seed yield increased (3). Research on row spacing for bean cultivars indicated that at a 15 cm distance, the number of pods per plant and seeds per pod outperformed those at wider Barbacter spacing, although pod length and seed yield depended solely on the variety (4). In an analysis of physiological traits across 6 varieties of common bean, *Phaseolus vulgaris* L., under different irrigation intervals, control plants were watered every 7 days, whereas stressed plants received water every 21 days. The relative water content, one of the traits examined, showed no significant variation between the varieties under stress and control conditions, demonstrating all varieties' ability to maintain stable relative water content under stress (5).

In a study at various planting distances in bean cultivation, it was found that decreasing the space between rows can enhance the grain yield per unit area (6). Another study investigated cowpeas grown during the vegetative stage—before the flower buds being visible without magnification—and the reproductive stage (7). This research revealed that bean performance in the reproductive stage is highly reliant on water availability, whereas dry conditions during the vegetative stage have a minimal impact on seed performance. The findings suggest that bean seed yield is optimized when irrigation reduction is implemented during the vegetative stage, with adequate soil water supply commencing at the onset of flower bud appearance. The same study also indicated that cultivating plants at narrower row distances results in an even plant distribution, which fosters an ideal planting pattern, enhances nutrient uptake from the soil, minimizes weed competition and increases both light exposure and yield (8). It was also noted that the weight of 100 seeds and the number of seeds per pod are influenced by genetics and plant density does not significantly affect these factors. However, it was observed that increasing plant density leads to higher seed yield, total dry weight, harvest index and number of pods per unit area (9). In an examination of 3 planting distances—30, 45 and 60 cm—across 2 bean varieties, it was reported that reducing row distance and thereby increasing density accelerated the growth rate, with the greatest seed yield achieved at a 30 cm row distance (10).

Numerous studies have found that nitrogen significantly impacts both the quantity and quality of seeds. Research has consistently demonstrated that nitrogen can enhance seed protein content (11). Given the scarcity of comprehensive studies and the significance of the common bean, *Phaseolus vulgaris* L., particularly the pinto bean variety known for its high protein content and economic value, this research was designed to explore the influence of planting distance and nitrogen fertilizer on the performance and yield components of pinto bean cultivars. This study was conducted in the climatic conditions of the Nili region, the central area of Daikundi province.

Materials and Methods

The study was carried out at the research farm of the Daikundi Higher Education Institute, located in Nili, the capital of Daikundi province. The site is situated at an altitude of 33.7264° N latitude and 66.1245° E longitude and it rises 2010 m above sea level. The research was initiated in April 2021. The research area is categorized as semi-arid and cold, with an average annual rainfall of approximately 250 mm (Fig. 1).

Soil of farm

The farm's soil is classified as sandy loam. To evaluate its physical and chemical properties, 5 soil samples were collected in a zigzag pattern from the field at a depth of 30 cm. These samples were combined to form a composite sample for subsequent analysis. The soil at the research farm has a pH level of 8.3, an electrical conductivity of approximately 0.203 Desi Siemens per meter and nitrogen content of 0.0056 %. The experimental design utilized was a split plot within a randomized complete block design with 4 replications. Each replication included 12 plots and each plot contained 5 planting rows, each 3 m long and 2.5 m wide. The spacing between the planting rows was established at 50 cm, with an inter-plant spacing of 10, 15, 20 and 25 cm, yielding plant densities of 20, 14, 10 and 8 plants/m^2 respectively.

Design of research

The research treatments consisted of 4 levels of planting distances: S_1 - the control planting distance (10 cm), S_2 - a planting distance of (15 cm), S_3 - a planting distance of (20 cm) and S_4 - a planting distance of (25 cm). Nitrogen fertilizer was used as a secondary factor at 3 levels: no fertilizer, 50 kg of nitrogen per ha (representing 50 % of the fertilizer requirement) and 100 kg of nitrogen per ha (fulfilling 100 % of the fertilizer requirement). These were applied during planting and at the vegetative growth stage (V_4).

Traits to be measured

To assess the physiological, morphological and agricultural traits in this study, plant sampling was conducted by eliminating the marginal effects at each sampling time across different growth stages. Samples were taken from an area measuring 0.25 × 0.5 m (0.125 m^2) in rows 2-4 of each research plot. Measured traits included seed yield, harvest index, total dry weight, relative leaf water content and phonological stages.

Statistical analysis

Statistical analysis was conducted using MSTAT-C, SAS 9.2 and SPSS software to assess the variance within the data. The comparison of mean values was performed utilizing Duncan's multiple range test and the graphical representation of the results was created with Microsoft Excel. This methodology ensures a robust analysis by combining the strengths of specialized statistical software with the versatility of Excel for visual data presentation.

Results

Seed Yield

The results of the variance analysis indicated that both planting distance and nitrogen fertilizer application significantly affected seed yield, with notable differences observed at 1 % and 5 % levels respectively, as detailed in Table 1. It was found that optimal planting distances can enhance seed yield; the maximum yield of 1219.96 kg/ha was achieved with a planting distance of 25 cm, while the minimum yield of 773.31 kg/ha was recorded at a planting distance of 10 cm in the seeding stage, as shown in Table 2. Furthermore, the application of 100 % nitrogen fertilizer resulted in the highest seed yield of 1039.00 kg/ha, whereas the control treatment, which did not involve any nitrogen fertilizer, yielded the lowest at 921.62 kg/ha. Notably, this outcome was statistically significant when compared to the yield obtained with 50 % nitrogen fertilizer usage, as presented in Table 3.

gen treatment and the 50 % nitrogen fertilizer application, as indicated in Table 3. This suggests that under these conditions, photosynthetic materials are preferentially allocated to the reproductive organs instead of being utilized for vegetative growth, such as the production of stems and structural tissues.

Total Dry Matter

The impact of planting distance on the total dry weight of pinto beans was significant at the 1 % probability level, as indicated in Table 1. The greatest total dry weight recorded was 726.83 g/m^2 at a planting distance of 20 cm, while the lowest was 617.16 g/m^2 at a planting distance of 10 cm, observed during the vegetative phase (refer to Table 2). An examination of dry matter accumulation over various cultivation intervals revealed that, in the initial growth stages, the accumulation was minimal with no significant differences between treatments. However, as growth progressed, the rapid development of the plants highlighted differences and in the final growth stages, the dry matter amount decreased due to leaf senescence, as depicted in Fig. 1 and 2. The highest total dry weight of 724.55 g/m^2 was achieved with the 100 % nitrogen fertilizer treatment, whereas the control treatment, which involved no nitrogen application, resulted in the lowest weight of 594.37 g/m^2. Notably, there was a statistically significant difference between the control treatment and the one involving 50 % of the nitrogen fertilizer application, as detailed in Table 3.

Table 1. The mean square of pinto bean physiology traits under the influence of crop spacing and nitrogen fertilizer treatments.

S. V.	D. F.	Mean square						
		Seed Yield	Harvest index	Total dry matter	RWC	Sowing to flowering	Sowing to pod	Sowing to maturity
Replication	3	30065.58**	1259944135ns	23661.87**	88.06**	3.722*	354.3**	0.909*
Row spacing (a)	3	433991.49**	15438962190**	24460.77**	476.22**	61.000**	743.10**	11.187**
Error (a)	9	4113.39	8564925950	1412.14	4.72	1.425	0.372	0.557
Nitrogen ferti. (b)	2	57533.69*	474872518ns	74024.10**	56.09**	30.437**	10.645*	9.770**
Fert. × RS	6	639.10 ns	202601495ns	746.79 ns	36.1 ns	0.854 ns	0.451 ns	0.104 ns
Error (b)	24	1287.40	201073671	1224.57	57.1	0.500	0.305	0.104
% C. V.	-	3.63	12.17	5.62	27.2	1.279	2.991	1.318

*, ** and ns: indicates significant at probability levels at 5 %, 1 % and ns = non-significant respectively.

Table 2. Comparison of the average physiological traits on the yield of pinto bean in the cropping intervals.

Row Spacing	Seed Yield (kg/ha)	Harvest index	Total dry matter	RWC	Sowing to flowering	Sowing to pod	Sowing to maturity
Distance of (10 cm)	773.3d	43064c	617.1c	47.4d	53.3c	17.5c	23.5 d
Distance of (15 cm)	913.3c	61877b	676.6b	53.9c	53.8c	17.9c	24.1c
Distance of (20 cm)	1043.1 b	114601a	726.8a	62.4 a	55.5b	18.9b	24.4b
Distance of (25 cm)	1219.9a	111640a	662.7b	57.4b	58.3a	19.5a	25.8a

Columns with the same letters do not statistically (Duncan's test) have a significant difference at the 1 % probability level.

Table 3. Comparison of average physiological traits on pinto bean yield at different levels of nitrogen fertilizer.

Different levels of nitrogen fertilization	Seed of yield (Kg/ha)	Harvest index	Total dry matter	RWC	Sowing to flowering	Sowing to podding	Sowing to maturity
Checking (zero kg of nitrogen)	921.6c	89069a	594.3c	53.4c	53.9c	17.6c	23.6c
50 kg N/ha	1001.6b	80058a	693.6b	55.1b	55.1b	18.5b	24.5b
100 kg N/ha	1039.0 a	79260a	724.5a	57.2a	56.6a	19.2a	25.2a

Columns with the same letters do not statistically (Duncan's test) have a significant difference at the 1 % probability level.

Harvest Index (HI)

The effect of planting intervals on the common bean harvest index was significant at 1 % ($p \leq 0.05$) as shown in Table 1. The highest harvest index, 114601 kg/ha, was achieved at a planting distance of 20 cm, while the lowest, 43064 kg/ha, was observed at a planting distance of 10 cm during the granulation stage, detailed in Table 2. In terms of nitrogen application, the highest harvest index recorded was 89069 kg/ha in the control treatment, which involved no nitrogen application and the lowest was 79260 kg/ha when 100 % nitrogen fertilizer was used. There was also a statistically significant difference between the 100 % nitro-

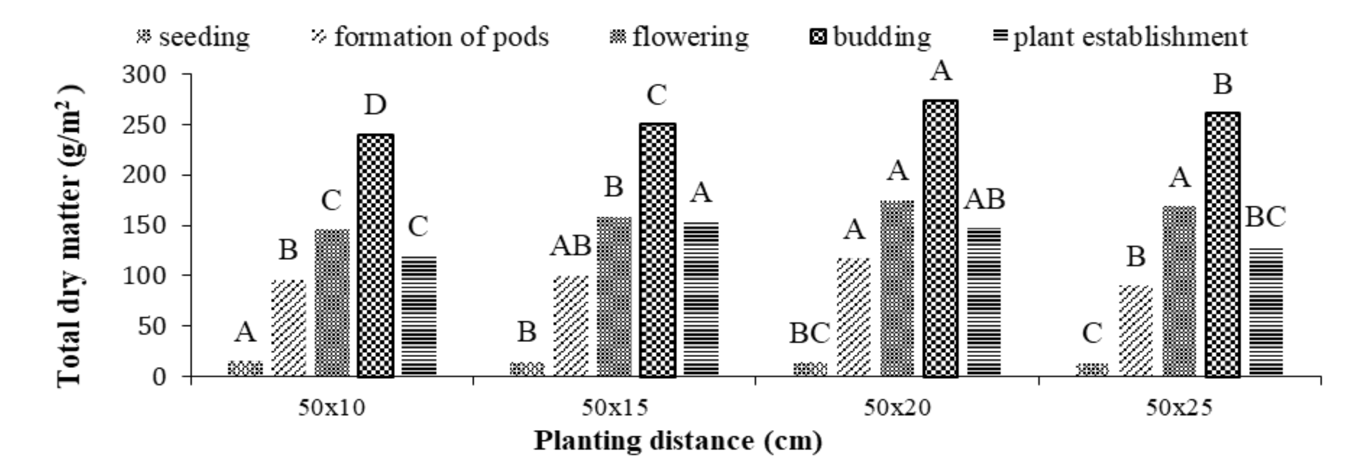

Fig. 1. Presents a comparison of the trend of changes in the dry matter of the whole common bean during various growth stages at different levels of the cropping interval. For all variables sharing the same letter, the differences between the means are not statistically significant. Conversely, if two variables have different

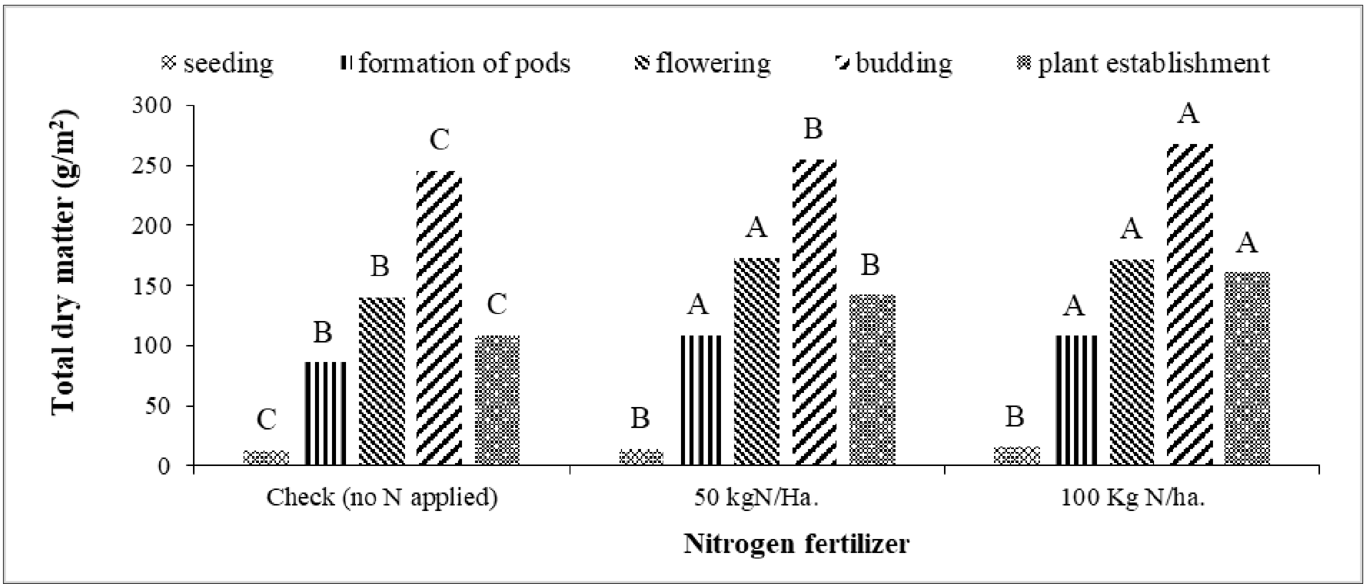

Fig. 2. Illustrates the trend of changes in the dry matter content of the whole common bean plant across various growth stages and at different cropping intervals. It is noted that when variables share the same letter, their mean differences are not statistically significant. In contrast, variables denoted by different letters signify statistically significant differences. This method of notation is instrumental in analyzing the influence of nitrogen levels on the dry matter content of common beans during their developmental phases.

Relative Leaf Water Content (RWC)

The effect of planting distance on the relative water content of pinto beans was significant at the 1 % probability level, as indicated in Table 1. The highest relative leaf water content, 62.41 %, was observed at a planting distance of 20 cm, while the lowest, 47.42 %, occurred at a planting distance of 10 cm during the granulation stage, detailed in Table 2. Furthermore, the treatment with 100 % nitrogen fertilizer yielded the highest relative leaf water content of 57.23 %, in contrast to the control treatment, which had no nitrogen fertilizer applied and recorded a lower content of 53.49 %. Notably, there was a statistically significant difference between the treatment with 100 % nitrogen fertilizer and the one with 50 % nitrogen fertilizer consumption, as shown in Table 3.

The Phonological Stages

The impact of planting distance on the characteristics of days to flowering, podding and full ripening was significant at 5 %, 1 % and 5 % probability levels respectively. Conversely, nitrogen fertilizer had an insignificant effect on the days of flowering and podding at 1 % and 5 % probability levels. Furthermore, the interaction between planting distance and nitrogen fertilizer in the stages of days until flowering, podding and full maturity was found to be insignificant (Table 1). Implementing different planting distances altered the length of days to flowering, pod formation and maturity. Specifically, the longest growth stage duration was 103 days at a planting distance of 25 cm, while the shortest was 95 days at a planting distance of 10 cm, indicating a reduction in days to flowering by 5 days. Additionally, the interval between planting and pod formation extended the podding period (Fig. 3 and 4). The findings suggest that the reproductive stage, which includes pod formation and seed development, is more sensitive to planting distance than the vegetative stage, from planting to flowering. This sensitivity is partly due to a reduction in the number of pods per plant and the weight of one hundred seeds when the planting interval is narrower (Table 2). The combination of planting intervals and nitrogen fertilization extended the duration of these phenological traits, with the longest period occurring with the application of nitrogen fertilizer at 100 kg/ha and the shortest in the control treatment with zero kg of nitrogen per hectare (Table 3).

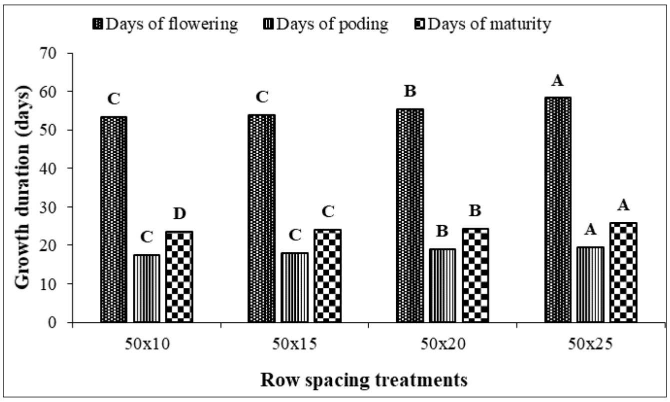

Fig. 3. Presents a comparison of the average effects of row spacing and inter-plant distances on the phenological stages of pinto beans.

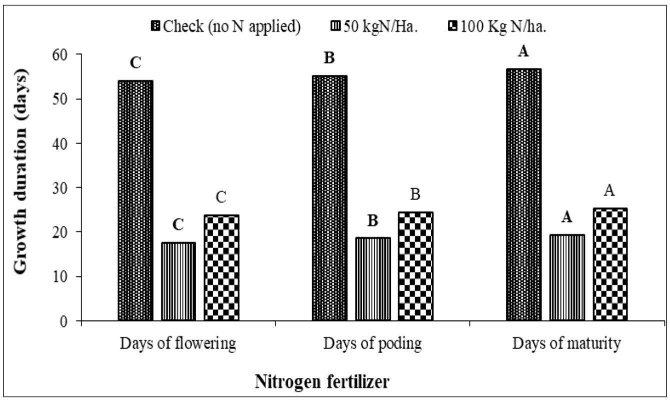

Fig. 4. Comparing the average effect of nitrogen fertilizer on the phonological stages of pinto beans.

Discussion

In the study of density on common bean cultivars, it has been demonstrated that an increase in density leads to a decrease in the characteristics of the day of tillering, the number of pods per plant, the weight of 100 seeds and the percentage of seed protein. However, the seed yield increased due to a rise in the number of pods per unit area (11). Afghanistan's arid and semi-arid climate results in soils with low organic matter and consequently, low nitrogen levels. This deficiency necessitates the supplementation of nitrogen through chemical fertilizers and organic materials (12). It has been observed that improper spacing in cultivation and nitrogen fertilizer application significantly reduces the yield of common beans. This inappropriate spacing also notably affects the seed protein content, plant physiology, morphology, yield and quality of common beans (13). Additionally, nitrogen deficiency has been identified as a limiting factor in the growth and development of leaves in 2 corn genotypes, with a decrease in cell division and elongation pinpointed as the cause of reduced leaf development (14).

Improving the efficiency of nitrogen consumption is a key strategy for developing sustainable agricultural systems, leading to maximum yield with minimal input and nitrogen wastage (15). Surveys indicate that over a 50 % increase in food production performance is attributable to the use of chemical fertilizers. Among these, nitrogen fertilizers contribute more significantly than others; however, their efficiency is unfortunately low, at only 15 %. Research also suggests that the timing of nitrogen application and soil type can influence its effectiveness. Specifically, the positive effects of nitrogen may lead to premature wilting towards the end of the development period, consequently reducing the yield, as indicated by a 16 % decrease (16).

The study's findings indicate that nitrogen absorption escalates as plant growth progresses, persisting up to the pod-filling phase, with the peak absorption occurring between the onset of pod formation and pod filling. Concurrently, as plants grow, the nitrogen concentration in the aerial parts surges, reaching a zenith at the flowering stage and the commencement of pod formation. Subsequently, a decline in nitrogen concentration is observed, although nitrogen absorption—driven by plant growth and the nitrogen content in shoot organs—continues until the plants reach physiological maturity (17). The diminution of nitrogen concentration in the aerial parts post-flowering and during seed filling is likely due to the translocation of nitrogen from the stem and leaves to the developing seeds. In spite of this reduction, nitrogen absorption increases post these stages, attributed to ongoing plant growth, even though the rate of nitrogen absorption does not alter from the pod-filling stage to physiological maturity. It is documented that approximately half of the plant's nitrogen absorption occurs up to the flowering stage, with the remainder transpiring over 30 days culminating in seed maturation (18).

Farmers often hold the belief that higher plant density can lead to increased yields. However, it is important to recognize that beyond an optimal density level, the individual plant weight may decrease significantly, resulting in yield gains attributable solely to the greater number of plants per unit area (19). Research indicates that the correlation between plant density and grain yield varies across different regions and cultivars. Generally, an increase in plant density can initially boost grain yield to a certain degree, after which the yield plateaus. Subsequently, as plant population pressure intensifies, even in the absence of moisture and nutrient limitations, the grain yield can drop sharply (20). Additionally, studies have found that decreasing row spacing from 69 cm to 23 cm and increasing plant density from 25 to 38 plants/m^2 can enhance the yield of white beans, even amidst weed competition (21).

Research has indicated that the harvest index of *Phaseolus vulgaris* decreases with increased planting distances (22). Similarly, it has been reported that the harvest index of soybeans diminishes when the distance between plants is extended during the reproductive stage (23). However, some researchers argue that the selection index is predominantly a genetic characteristic and remains relatively constant (24). The findings also suggest that the reduction in dry weight is contingent upon the proximity of planting. This proximity can adversely affect the plant's capacity to assimilate nutrients, synthesize and translocate biomass, ultimately leading to a reduction in total dry weight (25).

The utilization of nitrogen fertilizer is pivotal in augmenting dry matter production, particularly post-flowering. Nitrogen application in maize enhances dry matter accumulation, with a marked increase observed during the reproductive phase of the battery treatment. Varied bean studies indicate that reduced planting distances lead to a decline in the relative water content of bean foliage (26). Research findings suggest that employing high values of the relative leaf water content index is a recognized method among researchers for selecting superior genetic varieties (27). Furthermore, it has been documented that nitrogen fertilizer application prolongs the cultivation period up to the stages of flowering, pod formation and maturation (28).

Conclusion

The research indicated that the optimal seed yield for common beans was achieved with a planting distance of 25 cm and the application of 100 kg of nitrogen per hectare, resulting in an average yield of 1220 kg/ha. In contrast, the lowest yield was recorded at a planting distance of 10 cm without utilized nitrogen fertilizer, averaging 773 kg/ha. It was observed that agronomic and physiological traits such as increased total dry matter and leaf relative water content positively influenced the grain yield of pinto beans. Conversely, a shorter distance between planting rows negatively impacted seed yield, harvest index, phonological stages and other common bean traits, with the most significant decrease occurring during the seeding stage. Nonetheless, the application of 100 kg of nitrogen per hectare enhanced certain measured traits. Consequently, the study recommends the use of 100 kg of nitrogen per hectare combined with a planting row distance of 25 cm as the most effective crop management practice for common beans in the Nili center of Daikundi province.

Acknowledgements

The authors haven't gotten any funding from institutions or organizations for this research; nonetheless, we have paid for some of the items needed for the experiment from our own pockets.

Authors' contributions

All the authors have contributed to the conceptualization of research work and designing of experiments, execution of field/lab experiments and data collection, analysis of data and interpretation and preparation of the manuscript.

Compliance with ethical standards

Conflict of interest: The research is original and the findings is neither published nor under consideration elsewhere. All the authors that have contributed for preparation of this manuscript do not have any conflict of interest.

Ethical issues: None.

References

1. MK H, MS I, GMC S. Effect of nitrogen and molybdenum on the growth and yield of bush bean (*Phaseolus vulgaris* L). Journal of Agroforestry and Environment. 2008;2(2):p. 95-98.
2. Golchin A, Mousavi S, GhasemiGolezani , Saba J. Relationship between plant density and grain yield of three pinto bean cultivars at different sowing dates. Journal of Agricultural Science. 2008;p. 101-17.
3. Salehi F. Study of plant density in promising red bean lines. The 1st Iranaian Pulses Symposium. 2005.
4. Madani H, Shirzadi M, Darini F. Effect of plant density on yield and yield components of vigna and tepary local beans germplasm in Jiroft, Iran. New Finding in Agriculture. 2008;p. 93-104.
5. Martnez J, Silva H, Ledent J, Pinto M. Effect of drought stress on the osmotic adjustment, cell wall elasticity and cell volume of six cultivars of common beans (*Phaseolus vulgaris* L.). European Journal of Agronomy. 2007;p. 30-38. https://doi.org/10.1016/j.eja.2006.08.003
6. Powelson A, Udy R, Peachy Manath D. Row spacing effect on while mold and snap bean yield. Horticulture Weed Control. 1999; p. 220-27.
7. Ziska L, Hall A, Hoover R. Irrigation management methods for reducing water use of cowpea (*Vigna unguiculata* (L.) Walp.) and lima bean (*Phaseolus lunatus* L.) while maintaining seed yield at maximum levels. Irrigation Science. 1985;p. 223-39. https://doi.org/10.1007/BF00262468
8. Andrade F, Calvio P, Cirilo A, Barbieri P. Yield responses to narrow rows depend on increased radiation interception. Agronomy Journal. 2002;p. 975-80. https://doi.org/10.2134/agronj2002.9750
9. Faraji H, Gholizadeh S, Ouliaei, Azimi G. Effect of plant density on grain yield of three spotted bean *(Phaseolus vulgaris*) cultivars in Yasouj condition. Iranian Journal of Pulses Research.. 2010.
10. Torabi J, Hasanzadeh A, Fayaz moghadam A. Effect of plant 264 population on some morph physiological characteristics of two Common bean (*Phaseolus vulgaris* L.) cultivars. Pajouhesh and Sazandegi. 2004;p. 63-71.
11. Kahrarian B, Fatemi R. The effect of row and planting spacing on yeild in the white bean cv. Danshkadeh.. Iranian Journal of Crop Sciences. 2005.
12. Salehian H, Rafiey M, Fathi G, Siadat S. Effect of plant density on growth and seed yield of colza varieties under Andimeshk conditions. Iranian Crop Sciences Congress. Karaj–Iran. 2002.
13. Bahavar N, Ebadi A, Tobeh A, amaati-e-Somarin S. Effects of nitrogen 272 application on growth of irrigated chickpea (*Cicer arietinum* L.) under drought stress in 273 hydroponics condition.. Research Journal of Environmental Sciences. 2009;p. 448-55. https://doi.org/10.3923/rjes.2009.448.455
14. Zorica J. Investigation of mechanism of leaf growth inhibition in maize. Journal of Agricultural Sciences. 2001;p. 1-16.
15. Ayaz S, McKenzie B, Hill G, McNeil D. Nitrogen distribution in four grain legumes. The Journal of Agricultural Science. 2004;p. 309-17. https://doi.org/10.1017/S0021859604004356
16. Sadras V, Vega C, Andrade F, Uhart S. Reproductive allometry in soybean, maize and sunflower.. Annals of Botany. 1996;85:p. 461-68. https://doi.org/10.1006/anbo.1999.1084
17. Narula N, Kumar V, Behl R, Deubel A. Effect of P-solubilizing *Azotobacter chroococcum* on N, P, K uptake in P-responsive wheat genotypes grown under greenhouse conditions. Journal of Plant Nutrition and Soil Science. 2000;p. 393-98. https://doi.org/10.1002/1522-2624(200008)163:4%3C393::AID-JPLN393%3E3.3.CO;2-N
18. Rendig V, Broadbent F. Proteins and amino acids in grain of maize grown with various levels of applied N. Agronomy Jour-

nal.1979;p.509-12. https://doi.org/10.2134/agronj1979.00021962007100030032x

19. Rao K, Moorthy B, Dash A, Lodh S. Effect of time of transplanting on grain yield and quality traits of Basmati-type scented rice (*Oryza sativa*) varieties in coastal Orissa. Indian Journal of Agricultural Sciences. 1996;p. 333-37.
20. Brothers M, Kelley J. Interrelationship of plant architecture and yield components in the pinto bean ideotype. Crop Science. 1993;p.1234-38. https://doi.org/10.2135/cropsci1993.0011183X003300060024x
21. Malik V, Swanton C, Michaels T. Interaction of white bean (*Phaseolus vulgaris* L.) cultivars, row spacing and seeding density with annual weeds. Weed Science. 1993;p. 62-68. https://doi.org/10.1017/S0043174500057593
22. Bayat A, Sepehri A, Ahmadvand G, Dorri H. Effect of water deficit stress on yield and yield components of pinto bean (*Phaseolus vulgaris* L.) genotypes. Iranian Journal of Crop Sciences. 2010;p. 42-54.
23. Hay R, Porter J. The physiology of crop yield. Blackwell Publishing. 2006.
24. Anibal R, Ginzalez P, Hernandez A, Favelukes G. Comparison of drought tolerance in nitrogen fixing and inorganic nitrogen-grown common Beans. Plant Science. 2000;p. 31-41. https://doi.org/10.1016/S0168-9452(99)00246-0
25. Saedi A, Osmani M, Shams S. Principles of pulses crops. The 1st Afghanaian. 2018.
26. Türkan I, Bor M, Özdemir F, Koca H. Differential responses of lipid peroxidation and antioxidants in the leaves of drought-tolerant *P. acutifolius* Gray and drought-sensitive *P. vulgaris* L. subjected to polyethylene glycol mediated water stress. Plant Science. 2005;p. 223-31. https://doi.org/10.1016/j.plantsci.2004.07.032
27. Jiang Y, Huang B. Osmotic adjustment and root growth associated with drought preconditioning-enhanced heat tolerance in Kentucky bluegrass. Crop Science. 2001; p. 1168-73. https://doi.org/10.2135/cropsci2001.4141168x
28. McKenzie R, Middleton A, Seward K, Gaudiel R, Wildschut C, Bremer E. Fertilizer responses of dry bean in southern Alberta. Canadian Journal of Plant Science. 2001; p. 343-50. https://doi.org/10.4141/P00-106