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Evaluation of spring and winter dormant planting of *Cicer arietinum* under the application of organic and chemical fertilizers

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Summary: Climate change in recent decades and increased concentration of precipitation during cold seasons, changing the planting date of legumes and winter dormant seeding can be a smart-climate agronomic solution. A field experiment was conducted to evaluate planting dates (spring: S and winter: W) and different fertilizer application (control, NPK, farmyard manure, complete chemical fertilizer, biological fertilizer, and nano-structured micronutrients) on chickpea growth and yield characteristics in northwest Iran. Evaluations showed that the chlorophyll content of plants grown in spring planting was higher than in winter planting. The highest number of secondary branches was recorded under S+ farmyard manure conditions (22.9). Although the use of all chemical, organic, and biological fertilizers significantly increased canopy width in spring planting compared to the control, NPK fertilizer had a greater effect on canopy width in winter planting. Not applying fertilizer at both planting dates increased the number of empty pods. Application of biological fertilizer at spring planting resulted in the lowest number of empty pods. The highest biomass and grain yield (430 g m^{-2}) was achieved with NPK application in spring planting. Overall, the results revealed that winter planting was not suitable for the region and the cultivated plant variety, and spring planting resulted in better performance. Dormant winter seeding of chickpea in the studied region requires the use of some other specific agronomic management and improved cultivars.
Keywords: biomass, canopy width, chickpea, chlorophyll, *Cicer arietinum*, dormant seeding, grain yield, pod number

Introduction

Chickpea (*Cicer arietinum*) is an annual plant of the legume family and one of the most important legumes. Chickpea seeds contain a significant percentage of protein and are rich in essential amino acids such as lysine (Begum et al., 2023). This plant is very important in terms of nutritional composition in developing countries for ensuring food security. Archaeological studies indicate that this plant evolved in southern Türkiye and was cultivated in the Mediterranean regions, Syria, and Iran since about 8000 BC (Zhang et al., 2024). However, chickpeas have a wide range of adaptations to different climates, and the most important chickpea-producing countries are India, Australia, Ethiopia, Turkey, Myanmar, Russia, Pakistan, Mexico, Iran, and the United States (Merga & Haji, 2019).

The plant's high adaptability is partly due to its ability to create a symbiosis relationship with the root nodule bacterium *Mesorhizobium ciceri* and provide some of its nitrogen requirements (Adu Oparah et al., 2025). This in turn leads to the formation of 18-32% protein in the seed. However, the formation of this symbiotic relationship requires favorable physical and chemical soil conditions, suitable climatic conditions, and the presence of suitable and compatible strains of Rhizobium bacteria in the soil of the region. If symbiotic conditions are not available, the application of nitrogen fertilizers and other nutrients is necessary (Goyal & Habtewold, 2023).

In most areas, chickpeas are mainly planted in spring. However, in spring cultivation, at the end of the growth period (reproductive growth), chickpeas face high temperatures and dry periods (Rani et al., 2020). Climate change has been more evident in semi-arid regions, with rainfall decreasing significantly and temperatures increasing, especially in late spring and summer (Huang et al., 2016). In recent years, dormant seeding (waiting cultivation) has been introduced as a new cultivation method. Winter sowing or dormant seeding is a climate-smart agriculture technique in which seeds are sown before the ground freezes in winter (Amiri et al., 2024). In this method, the seeds do not germinate due to the lack of a basic temperature for seed germination and seeds remain dormant in the soil. They begin to germinate in late winter or early spring with an increase in temperature. In this method, sowing is usually done when the soil temperature is less than 8 °C (Amiri et al., 2020). In dormant seeding, choosing the right planting date is crucial for the plant. In early winter seeding, the emergence seedlings will be destroyed by the sub-zero temperature. On the other hand, delaying planting may result in the inability to enter the field due to frost or precipitation (Valizadeh et al., 2024). However, in some regions due to severe winter colds and the prevalence of Ascochyta blight caused by *Ascochyta rabiei* (Pass.) Lab, can adversely affect seedling development and final seed yield (Foresto et al., 2023). Therefore, in addition to choosing the correct planting date, it is also important to choose chickpea varieties resistant to Ascochyta blight and consider other climatic and agricultural conditions.

On the other hand, soil conditions in semi-arid regions are another limiting factor for increasing chickpea yield. High pH, low organic matter, unavailability of nutrients in the rhizosphere environment, high soil density, and lack of suitable rhizobium bacterial strains are among the factors that reduce yield (Macil et al., 2020). In such conditions, careful nutritional management and improvement of soil conditions can be fruitful. Although some studies have been conducted on dormancy seeding (Amiri et al., 2020; Rubiales Olmedo et al., 2022; Amiri et al., 2024; Valizadeh et al., 2024), there is still not sufficient information about this subject, especially for relatively high-altitude areas. In addition, the effect of nutritional management practices at different planting dates has not been well studied. The present study aimed to investigate the effect of application of NPK, complete fertilizer, micronutrient, farmyard manure, and biological fertilizers containing beneficial bacteria at winter and spring planting dates on the growth and yield of chickpea in northwest Iran.

Material and Methods

Site description: A field trial carried out to investigate the effect of planting date and chemical, biological, organic, and nano-micronutrient fertilizers on growth and grain yield of chickpea (*Cicer arietinum*) cv. Hashem. This cultivar has high yield and is resistant to Ascochyta Blight. It can also be harvested mechanically by combine harvester. If the climatic conditions are suitable, winter cultivation of this variety is also possible. The height of this variety is 75 cm and in years with high rainfall it reaches 110 cm. This study was conducted in split-plot in randomized complete block design with three replications during 2016-2017 crop growing season in a Research Field in Maragheh, northwest of Iran (37° 23‘N; 46° 16‘E, 1485 meters above sea level). The climate of the region is semi-arid, cold and temperate with an average annual rainfall of 375 mm (73% rain and 27% snow) in winter and early spring. The temperature and precipitation during the are presented in Figure 1.

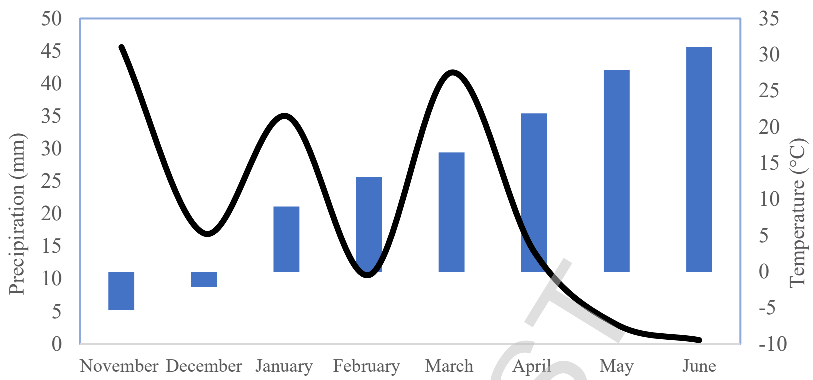

Figure 1. Precipitation (curve) and average air temperature (column chart) during the chickpea growing period in the Maragheh region in northwestern Iran

Soil properties of a field: The results of the field soil analysis before the experiment showed that soil texture was sandy clay loam and its pH was 7.34, EC: 1.06 ds m^{-1}, total nitrogen: 0.058%, organic carbon: 0.41%, available P: 5.67 mg kg^{-1}, K: 214 mg kg^{-1}, Fe: 0.65 mg kg^{-1}, Zn: 1.05 mg kg^{-1}, Mn: 2.46 mg kg^{-1}.

Implementation of experimental treatments: This experiment was conducted to evaluate spring (April) and winter (December) planting dates and different fertilizer applications on chickpea performance. Fertilizer treatments were: 0: control (no fertilizer application), NPK: chemical fertilizer containing 60 kg nitrogen, 45 kg phosphorus and 30 kg potassium, farmyard manure (FYM): 20 t ha^{-1}, complete fertilizer (CF): 20 kg ha^{-1} containing 5% nitrogen, 3% water-soluble phosphorus, 3% potassium, 4.5% iron nanoparticles chelated on EDTA, 8% zinc, 6% calcium, 0.65% copper chelated, 0.7% manganese, 6% magnesium, 0.65% boron, 0.1% molybdenum (produced by Sepehr Paramis, Iran), biological fertilizer (BI), and nano-chelated micronutrient (NM). Biological fertilizers contained phosphorus-solubilizing bacteria, including *Pantoea agglomerans* strain P5 and *Pseudomonas putida* strain P13, as well as nitrogen-fixing *Azotobacter vinelandii* strain O4, which were applied in the pre-planting stage through seed inoculation. Bacterial inoculation before sowing seeds with phosphorus biological fertilizer (containing bacteria *Pantoea agglomerans* strain P5 and *Pseudomonas putida* strain P13) and nitrogen biological fertilizer (*Azotobacter vinelandii* strain O4), F5: soil application of nano-chelates Zinc + Iron + Manganese (Sephehr Paramis, Iran, 4 kg ha^{-1}). To combat weeds, the field was sprayed with trifluralin at a rate of 1.5 liters ha^{-1} one month before planting, and manure was mixed completely and uniformly with the soil of the relevant plots at a depth of 15 cm. Biofertilizer was used at the seed sowing stage (100 grams of each biofertilizer per hectare in combination and by the seeding method). Phosphorus in NPK chemical fertilizer was supplied through triple superphosphate fertilizer, potassium through potassium sulfate, and was used in a strip 3 cm below the seed during planting. Nitrogen in NPK fertilizer was supplied through urea fertilizer, and one-third was used at the planting stage, one-third at the main stem length growth stage, and one-third at the flowering stage. Half of the amounts of complete fertilizers and nano-chelate were used at the planting stage, and the rest was used at the end of the stem elongation stage and the podding stage as a foliar spray. To prevent the spread of fungal diseases, the seeds were disinfected with benomyl fungicide. To ensure germination against the risk of attack by crows and soil pests, two seeds were planted in each pile, and one of the two plants was removed after seedling establishments. Also, weed control was carried out several times during the plant growth period by hand weeding.

Data collection: After the maximum accumulation of dry matter in the grain and before the stem and leaves were completely dry, harvesting was carried out. The date for winter planting was 27 June and the harvest for spring planting was 17 July. At the full maturity stage, plants were randomly harvested through a one-square-meter quadrat and transferred to the laboratory to measure the fresh weight of the shoot. After the samples were dried, the dry weight of the shoot and the yield were weighed. Also, to measure the traits of plant height, number of pods per plant, number of seeds per plant, number of hollow pods per plant, weight of 100-seeds, biological yield, and grain yield at the physiological maturity stage by eliminating the effect of the margin, 15 plants were randomly selected from each experimental plot and the desired traits were measured. A Near-Infrared Whole Grain Analyzer (Zeltex-800, Germany) was used to measure the amount of grain protein. Before the analysis of variance, the normality of the data distribution was examined.

Statistical methods: The experiment was conducted in a split-plot based on a randomized complete block design with 3 replications. The main factor included planting dates (S: spring sowing on April 6, W: winter sowing on December 10). Six sub-plots were allocated to the application of chemical and organic fertilizers. The collected data were analyzed using SAS 9.1 software. Mean values were compared according to Steel and Torrie (1980) by least significant difference (LSD) at $p < 0.05$. The mean comparison was performed by the LSD test. Each experimental plot had dimensions of 4×4 and inter-row spacing was 40 cm and intra-row spacing was 5 cm. The experiment was carried out at a density of 50 plants per square meter and a planting depth of 5 cm.

Results and Discussion

Evaluation of phenological characteristics such as days to flowering (DF) showed that DF in plants planted in winter planting date was about 100 days longer than in spring planting. On the other hand, comparison of mean DF between fertilizer treatments showed that the application of farmyard manure (FYM) caused a slight increase in this component. The application of chemical fertilizers in winter planting date had no effect on DF and only differences between fertilizer treatments and delay due to FYM application in spring planting were observed (Table 1). Means comparison of the plant height under planting dates showed that spring planting resulted in 23% higher plant height compared to winter planting. Stem longitudinal growth is largely influenced by the ratios of phytohormones, especially auxin (Zhang et al., 2022). It seems that the temperature conditions in spring planting increased the biosynthesis or accumulation of this hormone. The use of biological fertilizer (BI) and NM (nano-chelated micronutrient) fertilizers had a greater effect on improving height. Bacterial inoculation was able to meet plant nutritional needs better than other fertilizers. On the other hand, the effect of optimal temperature conditions in spring planting on bacterial activity should not be denied.

The study of canopy width as an important indicator related to lateral vegetative growth showed that in spring seed planting, regardless of the type of fertilizers, the application of chemical, organic or biological fertilizers increased canopy width by 19% compared to the control. However, in winter planting, the use of NPK and BI had a greater effect on canopy width than other fertilizers (Figure 2). The lowest canopy width was observed in no-fertilizer application and winter planting (0+W) or in W+FYM conditions. The reducing effect of FYM can be partly attributed to its effect on increasing soil water retention and soil cooling (Dibakar Mahanta et al., 2013). It seems that the positive effects of manure may be observed over longer time periods.

Table 1. Mean comparison of growth characteristics and yield components of chickpea in spring and winter planting dates with the application of different chemical, organic and biological fertilizers in northwest Iran

Planting date	PH	NPP	PWP	NFP	GNP	DF
S	37.10a	23.72a	12.19a	20.87a	21.41a	53.66b
W	30.32b	21.67b	10.93b	19.35a	19.70a	157.11a
Fertilizers						
0	32.09b	18.35b	9.38c	16.04b	16.43b	105.33b
NPK	34.57ab	24.74a	13.26a	21.72a	21.69a	105.00b
FYM	32.21ab	21.74ab	10.80bc	19.55a	20.38ba	107.00a
CF	33.96ab	22.53a	10.84bc	20.20a	20.69a	105.00b
BI	34.97a	24.86a	12.80ab	21.98a	22.44a	105.00b
NM	34.47a	23.95a	12.30ab	21.16a	21.68a	105.00b
S+0	35.06ab	18.45d	9.477c	15.95e	16.41c	53.00c
S+NPK	37.64a	24.00abc	12.81ab	20.75abcd	19.91abc	53.00c
S+FYM	36.11a	23.61ab	11.40abc	21.26abc	22.72ab	57.00b
S+CF	37.38a	22.48abcd	12.26abc	20.20abcde	20.71abc	53.00c
S+BI	38.36a	26.73a	13.41ab	23.58a	24.43a	53.00c
S+NM	38.06a	27.08a	13.81a	23.45ab	24.25a	53.00c
W+0	29.12c	18.25d	9.29c	16.12de	16.45c	157.66a
W+NPK	31.49bc	25.49ab	13.72a	22.69ab	23.47a	157.00a
W+FYM	28.31c	19.87cd	10.20bc	17.83cde	18.04bc	157.00a
W+CF	30.54c	22.58abcd	9.42c	20.20abcde	20.66abc	157.00a
W+BI	31.58bc	23.00abcd	12.19abc	20.37abcde	20.45abc	157.00a
W+NM	30.89c	20.83bcd	10.79abc	18.87bcde	19.12abc	157.00a
Significance level						
P	<0.001	0.045	0.05	0.09	0.13	<0.001
F	0.18	0.007	0.017	0.011	0.05	0.003
P×F	0.98	0.21	0.46	0.29	0.19	0.001
CV%	7.04	12.83	16.63	13.21	16.19	1.02

Planting date S: spring sowing, W: winter dormant seeding, Fertilizer 0: no-fertilizer application, NPK: contain the elements nitrogen (N), phosphorus (P), and potassium (K), FYM: 20 t ha^{-1} farmyard manure, CF: compete fertilizer fertilizers that contain all three of the plant nutrients, BI: Inoculation of seeds with bacteria before planting with biofertilizers containing phosphate-solubilizing and nitrogen-fixing bacteria. NM: Nanostructured micronutrient fertilizers. PH: Plant height (cm), NPP: number of pods per plant, PWP: pod weight per plant, NFP: number of filled pods per plant, GNP: grain number of pod per plant, DF: days to flowering. At the significance level, p values less than 0.05 ($p < 0.05$) and 0.01 ($p < 0.01$) are significant at 95% and 99%, respectively. The means with various letter in each trait (column) are statistically different.

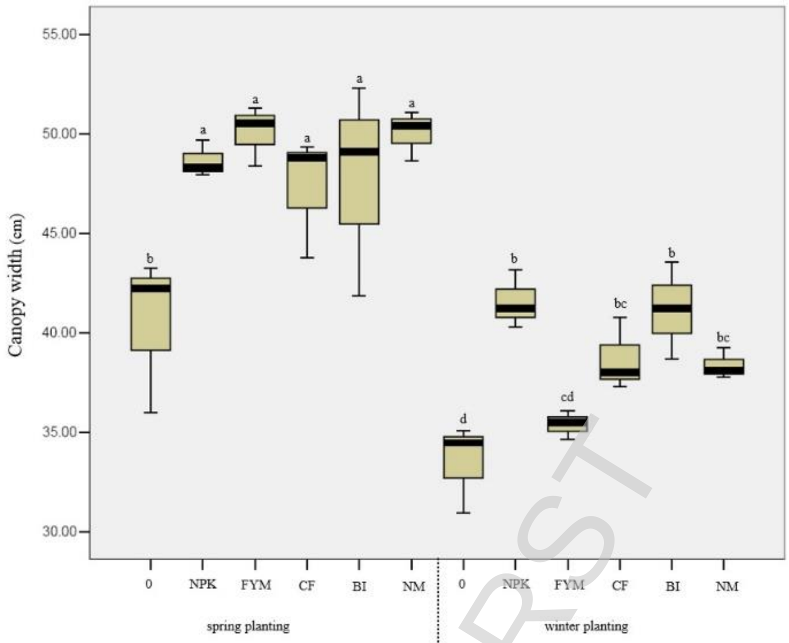

Figure 2. Means comparison of the canopy width of chickpeas planted in winter and spring with the application of different chemical and organic fertilizers in the Maragheh region in northwestern Iran. Boxes with the same letters are not significantly different at the 5% statistical level.
Fertilizer 0: no-fertilizer application, NPK: contain the elements nitrogen (N), phosphorus (P), and potassium (K), FYM: 20 t ha^{-1} farmyard manure, CF: compete fertilizer fertilizers that contain all three of the plant nutrients, BI: Inoculation of seeds with bacteria before planting with biofertilizers containing phosphate-solubilizing and nitrogen-fixing bacteria. NM: Nanostructured micronutrient fertilizers.

The number of pods per plant also showed that spring-planted plants produced 9% more pods than winter-planted plants. Comparing the effects of fertilizer treatments indicated that although all fertilizers increased the number of pods per plant compared to the control, the use of NPK and BI had a more pronounced effect with an increase of 34% and 36%.

The control conditions (no fertilizer) and FYM application in winter sowing had the lowest number of pods. The pod weight (shell + seed) in spring sowing was 17% higher than in winter sowing. The greatest effect on pod weight was achieved through the application of NPK and the use of this fertilizer improved pod weight by 41% compared to the control. The lowest pod weight was recorded under 0+W (9.29 g) and CF+W (9.42 g) conditions.

The interaction effects of planting date × fertilizer treatments were significant at the 5% level. Both planting dates significantly increased the weight of one hundred grains. Also, the application of CF in spring planting resulted in the production of heavier grains (Figure 3). In spring planting, the lowest weight of one hundred grains was recorded under the conditions of FYM application (42.3 g) and in winter planting, the lightest grain was recorded in plants grown without fertilizer application (44.5 g). The higher grain weight in plants grown in winter planting can be attributed to the existence of compensatory effects between yield components (Qulmamatova et al. 2024). In winter planting, other yield components were lower compared to spring planting, and therefore, lower grain production resulted in heavier grains.

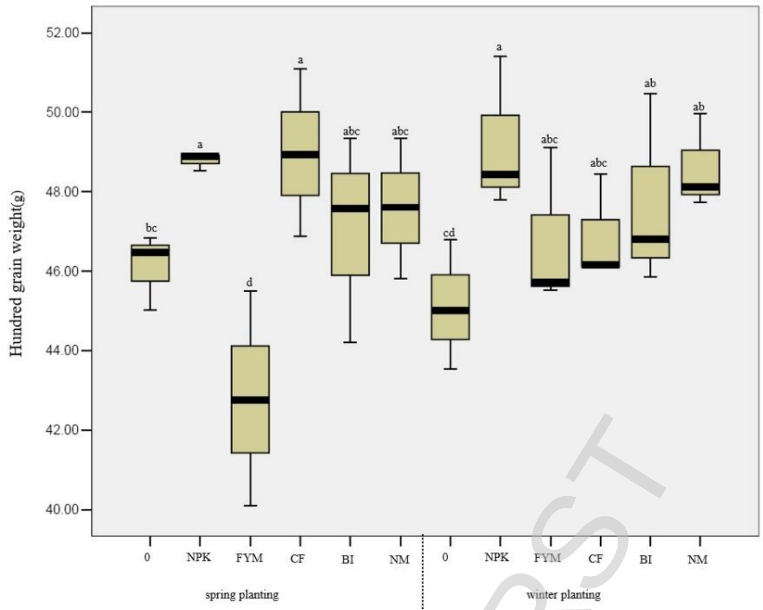

Figure 3. Evaluation of the effect of spring and winter chickpea planting date with the application of various chemical and organic fertilizers on 100-grain weight.

Fertilizer 0: no-fertilizer application, NPK: contain the elements nitrogen (N), phosphorus (P), and potassium (K), FYM: 20 t ha^{-1} farmyard manure, CF: compete fertilizer fertilizers that contain all three of the plant nutrients, BI: Inoculation of seeds with bacteria before planting with biofertilizers containing phosphate-solubilizing and nitrogen-fixing bacteria. NM: Nanostructured micronutrient fertilizers.

The number of pods containing two seeds (fully filled) was affected by fertilizer treatments. Although the application of all fertilizers increased the number of fully filled pods by about 30% on average compared to the control, no significant difference was observed between different chemical, organic and biological fertilizers. In addition to the number of primordia, number of fully filled pod also depends on the supply of photoassimilates to after pollination stage. The interaction of the source-sink relationship and the constraints governing them can play a key role in this component (Smith et al. 2018). Climatic conditions, nutrient availability and moisture conditions can affect primordia formation and seed filling. The number of seeds per plant in plants grown under spring sowing did not differ from those grown under winter sowing. However, fertilizer application increased these components by an average of 31% compared to the control, but no difference was observed between different fertilizers.

The grain yield in spring sowing (380.82 g m^{-2}) was about 27% higher than in winter sowing conditions (298 g m^{-2}). The highest yield was obtained with bacterial inoculation (373.19 g m^{-2}). However, the application of NPK (369.43 g m^{-2}) and NM (356.88 g m^{-2}) also had a significant effect on seed yield (Figure 4). The least effect of fertilizer was due to the application of FYM (281.65 g m^{-2}). In spring sowing, the application of NPK achieved the highest yield (450 g m^{-2}), and in winter sowing, the application of biological fertilizers resulted in the highest yield (347 g m^{-2}).

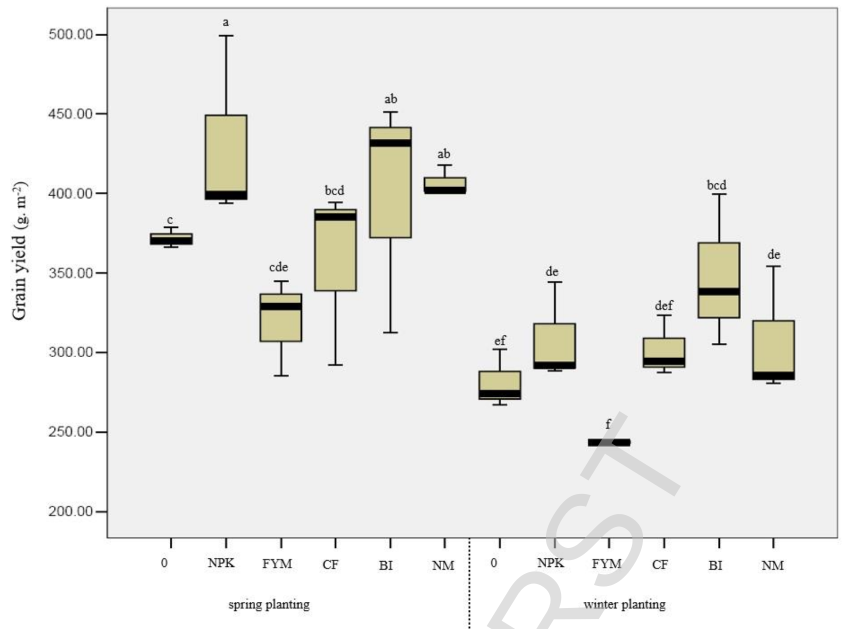

Figure 4. Grain yield of chickpea in spring and winter planting dates with the application of different chemical, organic and biological fertilizers in the northwestern region of Iran.
Fertilizer 0: no-fertilizer application, NPK: contain the elements nitrogen (N), phosphorus (P), and potassium (K), FYM: 20 t ha^{-1} farmyard manure, CF: compete fertilizer fertilizers that contain all three of the plant nutrients, BI: Inoculation of seeds with bacteria before planting with biofertilizers containing phosphate-solubilizing and nitrogen-fixing bacteria. NM: Nanostructured micronutrient fertilizers.

Yield is the result of complex relationships such as the impact of climatic conditions, moisture availability, nutrients, plant hormone ratios, source-sink relationships, plant genetics, plant adaptation to environmental conditions, and the ability of the plant to utilize environmental resources. It seems that in spring sowing, climatic conditions were more conducive to seedling growth and establishment, and with an optimal increase in vegetative growth, the plant entered the reproductive phase with sufficient photoassimilation resources. Although at the end of the reproductive period, climatic conditions in the region were somewhat limiting due to reduced rainfall and increased temperature, spring sowing completed its growth period earlier than winter sowing and was protected from end-of-season damage. Despite rainfall and soil moisture, it seems that the low temperature in the region was one of the main limiting factors for dormant winter seeding.

The protein content in spring sowing was not significantly different from winter sowing. The study of protein content among fertilizer treatments also showed that the highest protein content was recorded with FYM application (24.52%), CF application (23.24%), and nanostructured micronutrients (22.97%). The significant positive effect of manure on protein content can be related to the time of biosynthesis and protein accumulation, which is usually at the end of the growth period (Roy et al. 2010). During this time period, manure has had enough time to decompose and release elements related to protein biosynthesis and accumulation. The lowest protein content was recorded under S+0 (18.41%) and W+BI (19.21%) conditions. Temperature conditions seem to be very important on the protein content of the grain (Han et al., 2025). In spring cultivation, the application of common NPK chemical fertilizers had a significant effect on the protein content of the grain. While in winter cultivation, the greatest effect was obtained with the application of FYM. It is likely that in spring cultivation conditions, the amount of root expansion in the seedling was sufficient and appropriate for the absorption of nitrogen and its use for protein biosynthesis. In addition, in areas with dry and hot periods at the end of the growing season, spring cultivation probably increases the protein content by accelerating the aging process of leaves, breaking down photosynthetic proteins and increasing their re-transport to the filling grains (Carillo, 2025).

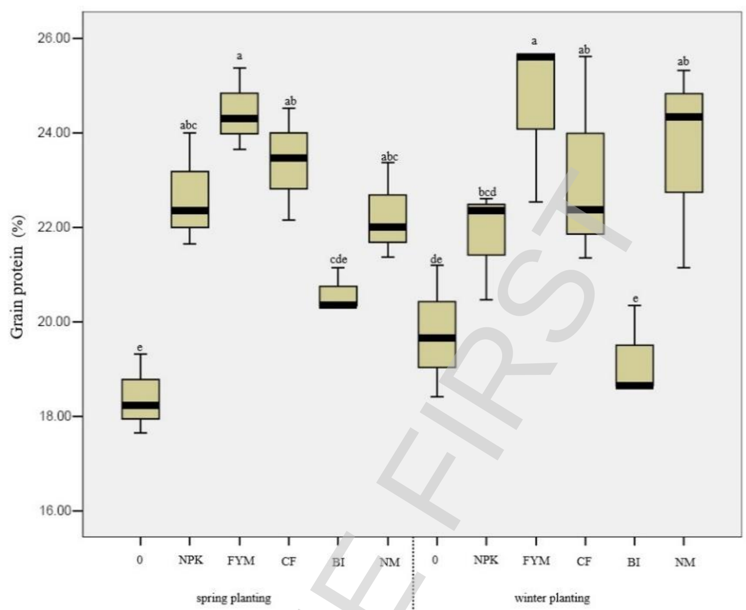

Figure 5. The effect of planting date and application of different fertilizers on the protein content of chickpea seeds in the Maragheh region, Iran.
Fertilizer 0: no-fertilizer application, NPK: contain the elements nitrogen (N), phosphorus (P), and potassium (K), FYM: 20 t ha-1 farmyard manure, CF: compete fertilizer fertilizers that contain all three of the plant nutrients, BI: Inoculation of seeds with bacteria before planting with biofertilizers containing phosphate-solubilizing and nitrogen-fixing bacteria. NM: Nanostructured micronutrient fertilizers.

The first principal component explained 59% of the overall variability; the second principal explained 24.4% of total variability. PCA plot regarding the distribution of combined treatments (planting date and fertilizer) showed that the first component was able to separate the planting dates well and the second component was also able to determine the effect of fertilizer efficiency. The highest effect was recorded under S+NPK, S+NM and S+BI conditions. The weakest performance was recorded in terms of growth characteristics and yield components including W+0, W+FYM and S+0 (Figure 6).

PCA also interpreted the correlation between traits through angular relationships (Figure 7). Sharp angles between the evaluated traits indicate a positive and significant correlation. The highest positive correlation was recorded between grain yield and traits such as plant height, canopy width, percentage of ground cover by canopy, straw yield, above-ground biomass, pod diameter, and plant fresh and dry weight. These traits can be used as biomarkers for yield assessment. Grain protein percentage was negatively correlated with the grain to pod shell ratio. This indicates that as the grain becomes coarser and the share of shell decreases, the protein percentage also decreases.

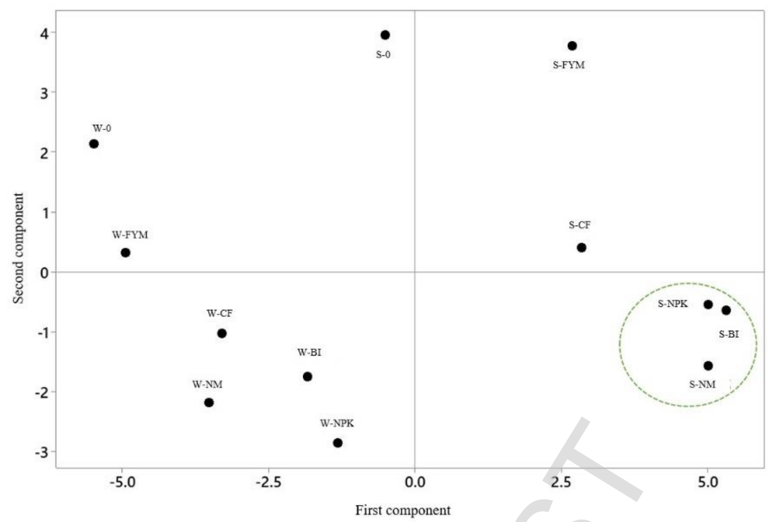

Figure 6. A principal component analysis (PCA) plot to show the similarities of treatments in affecting agronomic traits and chickpea yield under different planting dates in the Maragheh region. Planting date S: spring sowing, W: winter dormant seeding, Fertilizer 0: no-fertilizer application, NPK: contain the elements nitrogen (N), phosphorus (P), and potassium (K), FYM: 20 t ha^{-1} farmyard manure, CF: compete fertilizer fertilizers that contain all three of the plant nutrients, BI: Inoculation of seeds with bacteria before planting with biofertilizers containing phosphate-solubilizing and nitrogen-fixing bacteria. NM: Nanostructured micronutrient fertilizers.

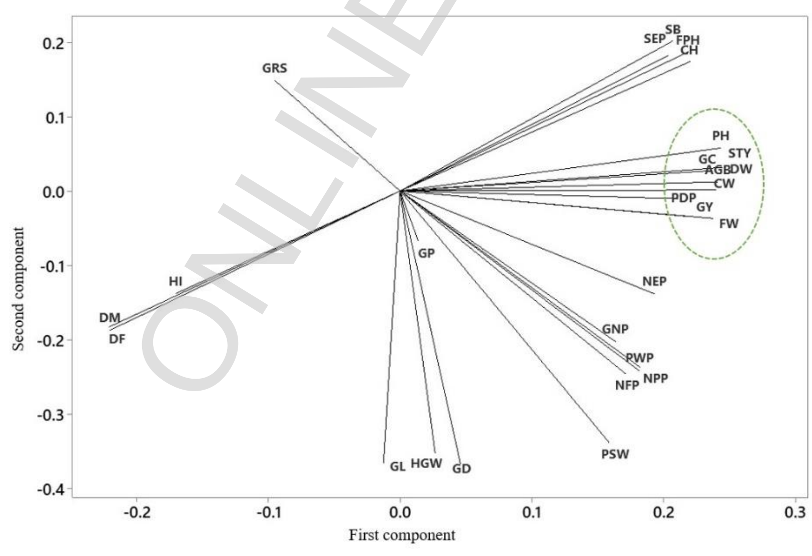

Figure 7. Principal component analysis is used to display the correlation between traits in an angular manner. Traits that are close together have a significant positive correlation.
PH: Plant height (cm), NPP: number of pods per plant, PWP: pod weight per plant, NFP: number of filled pods per plant, GNP: grain number of pod per plant, DF: days to flowering. FPH: first pod height, NEP: number of empty pods, PSW: pod shell weight, HGW: Weight of one hundred grains, GRS: grain ratio to shell, STY: straw yield, GY: grain yield, AGB: above ground biomass, HI: harvest index, DM: day to maturity, GL: grain length, GD: grain diameter, PDP: pod diameter, SEP: seedling emergence percentage, GP: grain protein percentage.

Despite the relative advantage observed in the spring planting date in the present experiment, it seems that this trend may be seen in full irrigation conditions, and under moisture limitation or rainfed conditions, the advantages of winter crops will be more evident due to the major precipitation in winter (Arif et al., 2021). Contrary to the findings, Mart (2022) reported that winter sowing in the Turkish region with irrigation was significantly preferable to spring sowing. Sufficient cold tolerance, sowing seeds after long periods of cold, physical and chemical condition of the soil, rapid seedling establishment, proper distribution of rain during the growing season, and higher rainfall are among the obvious differences between the present findings and other reports.

Conclusion

Although winter sowing has been proposed as a solution to escape late-season dry periods in Mediterranean regions, the results obtained in this experiment showed that the genotype used or the December sowing date could not be successful. Spring planting of chickpea with the application of NPK chemical fertilizer and also by seed inoculation with growth-enhancing bacteria (biological fertilizer) showed higher performance compared to other conditions. The studied region has relatively cold and long winters, therefore, to achieve the benefits of winter chickpea cultivation, cold-tolerant varieties are required and it is possible to postpone cultivation until the end of frost periods.

Author contributions: Conceptualization, M.M., and M.J.; methodology, M.J., A.E., and N.S.; software, N.S. and A.E.; validation, M.M., and N.S.; formal analysis, N.S. and M.J., investigation, M.J.; resources, A.E.; data curation, M.J and M.M.; writing—original draft preparation, M.J.; writing—review and editing, A.E. and N.S.; visualization, A.E.; supervision, N.S. and A.E.; project administration, M.J.

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Competing interests statement: No competing interests were disclosed.

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Evaluacija prolećne i zimske setve vrste *Cicer arietinum* uz primenu organskih i hemijskih đubriva

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Sažetak: Klimatske promene poslednjih decenija i povećana koncentracija padavina tokom hladnih sezona, promena datuma sadnje mahunarki i zimska setva u periodu mirovanja mogu biti pametno klimatsko agronomsko rešenje. Sproveden je terenski eksperiment radi procene datuma sadnje (proleće: S i zima: Z) i različitih primena đubriva (kontrola, NPK, stajnjak, kompletno hemijsko đubrivo, biološko đubrivo i nanostrukturirani mikronutrijenti) na rast i karakteristike prinosa leblebije u severozapadnom Iranu. Evaluacije su pokazale da je sadržaj hlorofila u biljkama gajenim u prolećnoj setvi bio višii nego u zimskoj setvi. Najveći broj sekundarnih grana zabeležen je u uslovima S+ stajnjak (22,9). Iako je upotreba svih hemijskih, organskih i bioloških đubriva značajno povećala širinu nadzemnog dela u prolećnoj sadnji u poređenju sa kontrolom, NPK đubrivo je imalo veći efekat na

širinu nadzemnog dela u ozimoj setvi. Izostanak đubriva u oba datuma setve povećao je broj praznih mahuna. Primena biološkog đubriva u prolećnoj setvi rezultirala je najmanjim brojem praznih mahuna. Najveća biomasa i prinos zrna (430 g m^{-2}) postignuti su primenom NPK u prolećnoj setvi. Generalno, rezultati su pokazali da zimska setva nije bila pogodna za region i gajenu biljnu sortu, a prolećna sadnja je imala bolje rezultate. Ozima setva leblebija u ispitivanom regionu zahteva upotrebu nekih drugih specifičnih agronomskih mera i poboljšanih sorti.
Ključne reči: biomasa, nadzemni deo, hlorofil, *Cicer arietinum*, leblebija, ozima setva, prinos zrna, broj mahuna