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THE EFFECT OF ORGANIC SOIL AMENDMENTS AND VITAMIN FOLIAR SPRAY ON CHICKPEA PERFORMANCE

SUMMARY

Soil amendment and foliar feeding of bio-stimulants are considered smart climate management practices in semi-arid regions. Field experiments were conducted to evaluate the effects of different levels of manure application (20 t ha⁻¹: FYM₂₀, no application: FYM₀) and foliar sprays (control or distilled water, vitamin C or acid ascorbic, vitamin B₂, and salicylic acid) in two semi-arid, high-altitude regions in northwestern Iran (M: Maragheh, H: Hashtrud). The results showed that vitamin B₂ application significantly increased plant height. The highest canopy width was recorded with FYM₂₀ application and salicylic acid spray, especially in location H. Foliar spraying of vitamin B₂ and salicylic acid in location M significantly increased the number of secondary branches. Additionally, FYM₂₀ application in Maragheh improved the number of pods and enhanced the effects of foliar sprays. The highest number of pods was recorded with salicylic acid spray in location H. The absence of soil amendment in both regions resulted in the highest number of empty pods, with the highest number observed in the Hashtrud region without spraying. However, vitamin B₂ spraying significantly reduced the number of empty pods. The highest biomass was observed under the vitamin B₂- H-FYM₂₀ condition (1540 kg ha⁻¹) and the lowest under the distilled water-FYM₀-M foliar spraying condition (791.3 kg ha⁻¹). The number of days to flowering in Maragheh was longer than in Hashtrud; however, in Hashtrud, foliar spraying of vitamin B₂ and salicylic acid under organic soil amendment conditions significantly increased the length of the vegetative period. The highest grain yield was recorded in the Hashtrud region with the application of FYM₂₀. Overall, the results indicated the necessity of using organic fertilizers and soil amendments, with all foliar treatments having a stronger effect when manure was applied.

Keywords: biomass, empty pods, length of vegetative period, number of pods per plant, salicylic acid, vitamin B₂

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INTRODUCTION

The world population is increasing and is expected to reach 9.8 billion by 2050, which will greatly increase the demand for food, especially legumes such as chickpeas, due to their high protein content (Amoah *et al.*, 2023). The nutritional value of chickpeas is unique, and their seeds contain 23% protein, 6% crude fiber, 6% soluble fiber, 60% carbohydrates, 3% ash and 5% fat. Given the nature of the amino acids, this plant can be considered a suitable substitute for meat in developing and poor countries (Kumar *et al.*, 2025). Global chickpea production is estimated at 16.8 Mt, harvested from 14.1 Mha of cultivated area. The main chickpea producing countries are India (9.5 Mha cultivated area and 11.03 Mt grain production), Australia (1.03 Mha, 2.26 Mt), Türkiye (460 kha, 575 kt), Ethiopia (207 kha and 443 kt) and Russia (359 kha and 414 kt). Iran is also in ninth place with 429 kha of cultivated area and production equivalent to 181 kt (FAOSTAT, 2026). Chickpea is mainly grown on marginal and relatively low-fertility lands of semi-arid regions and is considered a post-rainy season crop in traditional systems (Phiri *et al.*, 2023). Chickpea has a relatively high adaptability to semi-arid conditions among the legume family, including a relatively short growth period, the ability to biologically fix nitrogen, acceptable cold tolerance, rapid germination and establishment with moisture stored during the rainy season (Fikre *et al.*, 2020). The plant characteristics and high nutritional value of chickpeas have led agricultural experts to suggest it as an alternative to cereal-based farming systems (wheat-barley-fallow) in semi-arid regions (Spalevic *et al.*, 2025).

Climate change is occurring worldwide and this phenomenon is more evident in semi-arid regions and has led to an increase in temperature and a decrease in precipitation over recent decades (Panda *et al.*, 2023). Drought stress and late-season heat in semi-arid regions are one of the main obstacles to increasing crop production. In this context, it seems that the use of climate change-adapted management can improve production rates and the sustainability of agricultural ecosystems in these regions (Janmohammadi and Sabaghnia, 2023). However, poor soil quality in semi-arid regions is another limiting factor for chickpea production in these regions. The trend of climate change and incorrect agricultural management and tillage in these regions have caused a significant decrease in soil organic matter content. Animal manure is one of the accessible, inexpensive and desirable organic fertilizers for providing nutrients and improving the physical and chemical conditions of the soil (Rezaei *et al.*, 2025). The use of animal manure can solve physical problems such as soil compaction and density, low ventilation, improper structure, and lack of porosity. The use of livestock manure can improve soil water retention capacity, increase cation exchange capacity, and improve the biological conditions of the rhizosphere environment (Fattahi *et al.*, 2023).

Due to the increase in air temperature, especially at the end of the growing season and the significant decrease in precipitation, changes in precipitation patterns and unpredictability of precipitation due to climate change, it seems necessary to use some methods to alleviate drought and heat stress (Tahasin *et al.*, 2024). In this regard, some researchers have reported that foliar spraying of non-

enzymatic and stimulating compounds such as ascorbic acid, vitamin B₂ and salicylic acid can improve plant growth under drought stress conditions (Nouri *et al.*, 2022; Zahid *et al.*, 2023; Jalili *et al.*, 2023). Ascorbic acid, a water-soluble compound with low molecular weight, protects plant tissues as a scavenger of reactive oxygen species. It also seems that ascorbic acid plays a role as an intermediary and messenger in regulating the biosynthesis of phytohormones (Akram *et al.*, 2017). Salicylic acid is a phenolic compound produced in the root and can affect the process of root growth and development in the rhizosphere environment, the absorption of ions, their transfer to the shoot and the photosynthesis process (Olennikov *et al.*, 2025). Salicylic acid also as a potent messenger under drought stress conditions, affects many aspects of plant growth and development and can prevent the occurrence of secondary oxidative stress. Riboflavin or vitamin B₂ is a water-soluble and heat-stable compound and plays a key role in the biosynthesis of flavin mononucleotide and flavin adenine dinucleotide (Jiadkong *et al.*, 2024). This vitamin plays a role in the process of light perception and electron transfer in the light reactions of photosynthesis. Vitamin B₂ also participates in the biosynthesis of chlorophyll and carotenoid pigments (Wu *et al.*, 2024).

In semi-arid regions where chickpeas are cultivated, climate change has degraded soil quality and, simultaneously, drought stress and elevated temperatures at the end of the growing season have hindered plant growth. Therefore, soil amendment through the application of animal manure and foliar feeding with biostimulants appears to mitigate the adverse effects of climate change. Although some short- and long-term effects of manure application on soil conditions and chickpea plant growth in semi-arid regions have been investigated, there is still no comprehensive and significant information on the effectiveness of external application of vitamins and stimulants under organic soil amendment conditions. Therefore, the present experiment was aimed to investigate the effect of FYM application and foliar application of non-enzymatic stimulants such as salicylic acid, ascorbic acid, and vitamin B₂ on chickpea growth and yield in two regions in northwestern Iran.

MATERIAL AND METHODS

Characteristics of the study sites

In this experiment, the effect of fertilizer and foliar application of vitamins and non-enzymatic stimulants on agronomic and physiological traits of chickpea was investigated in a split plot in a randomized complete block design with 3 replications in the spring and summer of 2023 in the two regions of Maragheh and Hashtrud. Maragheh region is located on the southern slope of Mount Sahand (37°23' N, 46°16' E, 1400 m above sea level). The climate of this semi-arid region tends to be cold and the annual precipitation was 330 mm, of which 90 mm fell during the chickpea growth period. The lowest air temperature was -5°C in December and the highest temperature was 36°C in June. The soil of this location was sandy loam, pH: 7.96, organic matter content: 0.92%, electrical conductivity 1.47 dS m⁻¹, total nitrogen: 0.06%, phosphorus and potassium content were 5.67 and 332 mg kg⁻¹, respectively. Hashtrud region is on the

northwest side of Mount Sahand (37°31' N; 46°53' E, 1800 m above sea level) and the climate of this mountainous region is semi-arid. The lowest temperature was -9 °C during January and the highest temperature was 34 °C during August. The soil of the sandy loam region was pH: 7.26, electrical conductivity 0.94 dS m⁻¹, organic matter content: 1.71%, total nitrogen: 0.46%, and phosphorus and potassium content were 11.5 and 412 mg kg⁻¹, respectively.

Planting seeds and implementing treatments

Seeds of the Kabuli chickpea, Jam variety, were obtained from Seed and Plant Improvement Institute, Karaj, Alborz, Iran. In late February, secondary tillage was performed to break clods and form ridge and furrow using furrower cultivator sweep. Seeds were sown by hand at 8cm intra row spacing and 40cm inter row spacing respectively with a depth of 5 cm. Seeds were sown in the first decade of April. Immediately after sowing in both areas, all plots were irrigated with a drip tape irrigation system connected to a well water source. Vegetative growth was based on rainfall and without irrigation, and three irrigations were performed during the reproductive stages with a height of 100 mm. To control weeds, three hand weeding were performed during the vegetative and early reproductive stages.

The experiment was conducted as a split plot (4×2) based on a randomized complete block design. The main plots were the levels of manure including FYM₀: no application and FYM₂₀: application of 20 t ha⁻¹ of farmyard manure. Farmyard manure was collected from a beef cattle farm and after storage for 9 months in a depot, it was allowed to decompose and its microbial load was reduced. Some of the chemical characteristics of the manure used were pH: 6.81, EC: 4.04 ds m⁻¹, organic matter content: 26.43%, total nitrogen content: 1.87%, phosphorus content: 1.53 mg kg⁻¹, available potassium content: 265 mg kg⁻¹, C/N: 14.32, and calcium content: 193.7 mg kg⁻¹. During October, initial tillage was carried out using a Moldboard plow to a depth of 30 cm. After defining the boundaries of the main plots (5×20 m), manure was distributed on the soil surface and then mixed with the soil to a depth of 15 cm using a mini rotavator.

Subplots with an area of 20 m² (4×5 m) were assigned to 4 foliar spray treatments including control (spray solution with distilled water), ascorbic acid, salicylic acid and vitamin B₂. The chemicals used in foliar spray were obtained from Merck Germany with a purity of 99%. The concentration of all foliar spray solutions was 1 mM. Spraying was repeated during the stem elongation, early podding and grain filling stages. Foliar sprays were carried out in the early morning using a motorized backpack sprayer. During foliar spray, all plant parts were sprayed with the solutions and spraying continued until droplets dripped from the leaves.

Measurement of agronomic traits

The depth of the roots was assessed with a ruler inserted through the hole in the pit beside the plant following irrigation during the flowering phase. Canopy width and plant height were measured with a meter when the plants reached full maturity. At the maturity stage, to determine grain yield and yield components,

chickpea plants were cut from each experimental unit by quadrat sampling in 3 m² of the ground surface with a sickle, and components such as the number of pods per plant, the number of empty pods, biological yield, grain yield, and 100-grain weight were determined. The harvest index was calculated from the ratio of grain yield to biological yield.

Statistical analysis

Following data collection and a normality assessment, analysis of variance was performed using SAS version 9.1 software. The mean comparisons were conducted using the LSD test. Graphs were created to compare the means utilizing Statistica software. Principal component analysis (PCA) was carried out using Genstat software.

RESULTS AND DISCUSSION

Table 1. The effect of foliar spraying of vitamins and stimulants and application of FYM on phenological, morphological characteristics and yield components of chickpea in two semi-arid regions of Iran

Treatments		DF	CW	PH	RD	EP	SNP	HSW	SY
Maragheh	FYM ₀ C	66.67cd	22.66i	26.33fg	15.00gh	5.60gh	9.80ef	40.17ab	285.17f
	FYM ₀ Asc	71.00a	24.66ghi	25.00g	15.75fg	6.30fgh	10.64ef	38.01b	285.00f
	FYM ₀ B ₂	68.33abc	27.89fgh	27.77efg	13.55h	7.54efgh	11.76ef	39.24ab	315.00ef
	FYM ₀ SA	70.67ab	23.33hi	25.33g	15.05gh	8.86defgh	10.08ef	40.85a	288.00f
	FYM ₂₀ C	68.33abc	30.40ef	29.20def	17.60cde	6.38fgh	8.87f	38.15b	371.67def
	FYM ₂₀ Asc	69.67ab	30.13f	31.20cde	17.40def	3.73h	11.20ef	38.67ab	359.67def
	FYM ₂₀ B ₂	68.00bc	31.73ef	30.00de	21.20a	6.37fgh	13.44de	40.36ab	416.33cde
	FYM ₂₀ SA	70.00ab	34.87de	31.73cd	19.20bc	7.46fgh	16.99cd	38.87ab	447.50cd
Hashtrud	FYM ₀ C	58.00hi	28.67fg	34.67c	13.44h	30.00a	17.73c	24.90d	429.17cd
	FYM ₀ Asc	60.67fgh	32.22ef	39.11b	16.05efg	19.35bc	20.07bc	26.38cd	490.00bc
	FYM ₀ B ₂	61.33fg	31.22ef	39.22b	18.33cd	14.31cdefg	19.51bc	26.10cd	561.00ab
	FYM ₀ SA	63.00efg	32.33ef	40.11b	16.38efg	21.22abc	22.49ab	26.07d	592.83ab
	FYM ₂₀ C	57.00i	37.00cd	41.68ab	14.89gh	17.14bcde	22.12ab	24.68e	659.50a
	FYM ₂₀ Asc	60.33gh	44.61ab	44.85a	16.68defg	17.42bcd	25.01a	25.85de	636.33a
	FYM ₂₀ B ₂	64.33de	41.31bc	44.85a	20.29ab	25.12ab	19.41bc	24.49e	646.00a
	FYM ₂₀ SA	63.33ef	48.11a	41.80ab	16.49efg	15.48bcdef	22.40ab	27.96c	644.00a
Significance level									
S		<.0001	<.0001	<.0001	0.3829	<.0001	<.0001	<.0001	<.0001
FYM		0.7204	<.0001	<.0001	<.0001	0.2974	0.0059	0.411	<.0001
S×FYM		0.4759	0.0083	0.6263	<.0001	0.6887	0.8724	0.5925	0.5277
F		<.0001	0.0014	0.0378	<.0001	0.6347	0.0709	0.0852	0.0726
S×F		0.0035	0.0509	0.2327	0.0011	0.4753	0.1203	0.1489	0.9148
FYM×F		0.417	0.0292	0.6112	0.0021	0.1428	0.2492	0.7255	0.5885
S×FYM×F		0.1715	0.4946	0.0499	0.0335	0.0754	0.0149	0.0355	0.0453

FYM₀: No farmyard application, FYM₂₀: application of 20 t ha⁻¹ farmyard manure, S: site, F: foliar spray, S₀: distilled water, S₁: micronutrients, S₂: silicon dioxide nano particles. DF: days to flowering, PH: height of the plant (cm), RD: rooting depth (cm), EP: number of the empty pod per plant, SNP: seed number per plant, HSW: hundred seed weight (g). Within each column, means that share the same letter are not statistically significant at the 5% level. The table's final rows display F values of ANOVA. F-values below 0.01 and 0.05 indicate statistical significance at the 1% and 5% levels, respectively.

The evaluation of phenological stages indicated that days to flowering (DF) was 69.08 days in Maragheh (M) and 61.00 days in Hashtrood (H). However, days to podding (DP) did not differ significantly between the two regions. Days to maturity (DM) was 6 days higher in Hashtrood (100.70 days) and 6 days higher than in Maragheh. Among the treatments, foliar spraying of ascorbic acid (Asc) increased the length of the plant's vegetative period. The highest DF was recorded in M-FYM₀-Asc (71 days) and the lowest in H-FYM₂₀-C (57.00 days) (Table 1). The highest DM was observed in H-FYM₂₀ with vitamins or salicylic acid (Sa) spray. FYM application prolonged the vegetative growth period and increased DM.

Lateral canopy growth in plants grown in Hashtrood region was 30% higher than in Maragheh. FYM application also increased this component by 33% compared to the control condition. The widest canopy was recorded in H-FYM₂₀-Sa (48.11 cm). In M-FYM₀ condition, vitamin B₂ spray resulted in the highest lateral growth and widest canopy (Table 1). Foliar spraying of Asc and Sa were the most effective among the foliar spray treatments. The triple effects of site (S), foliar spraying (F) and manure (FYM) on plant height were significant at the 5% level. In M-FYM₀, vitamin B₂ spray significantly increased plant height. However, under M-FYM₂₀ condition, the effect of Sa spray on plant height was more evident than other treatments. In Hashtrood region, the application of manure significantly increased plant height. In this area, the application of FYM improved the effectiveness of foliar spraying treatments on plant height. FYM application increased rooting depth by 16% compared to the control condition. In H-FYM₂₀ condition, foliar application of vitamin B₂ and Sa increased rooting depth by about 25% compared to distilled water spray condition. Among the foliar application treatments, vitamin B₂ significantly increased rooting depth. The highest rooting depth was recorded in H-FYM₂₀-B₂ (20.29 cm).

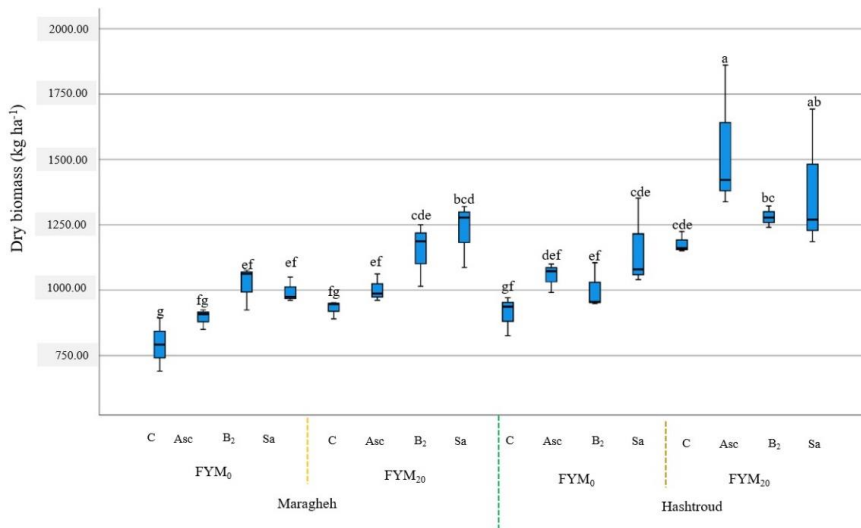


Figure 1. Chickpea biomass affected by locations, FYM application, and different foliar spray treatments

Comparison of plant dry biomass among regions and treatments showed that plants grown in Hashtroud region produced 18% more biomass than Maragheh region with biomass equivalent to 1188 kg ha^{-1} . Foliar application of Sa, vitamin B₂ and Asc increased biomass by 25%, 17% and 15% compared to control. Biomass of plants grown under FYM application conditions was 1211 kg and 23% higher than FYM₀ conditions (978 kg ha^{-1}). The highest biomass was recorded in H-FYM₂₀-Asc (1540 kg ha^{-1}) and in H-FYM₂₀-Sa (1382 kg ha^{-1}). Vitamin B₂ spray had a greater effect on biomass in M-FYM₀ (Figure 1).

The pod number analysis showed that in M-FYM₀ conditions, foliar spraying of Asc and Sa increased this component by 12% compared to the control. FYM application increased the pod number by 33% compared to the control. Under M-FYM₂₀ conditions, spraying of Sa, Asc, and vitamin B₂ increased the pod number by 48%, 20%, and 46%, respectively, compared to the control. In Hashtroud region, the effectiveness of Sa was greater than other foliar spraying treatments, and the highest pod number was recorded in H-FYM₂₀-Sa (109.86) and the lowest in M-FYM₀-C (38.72) (Fig. 2).

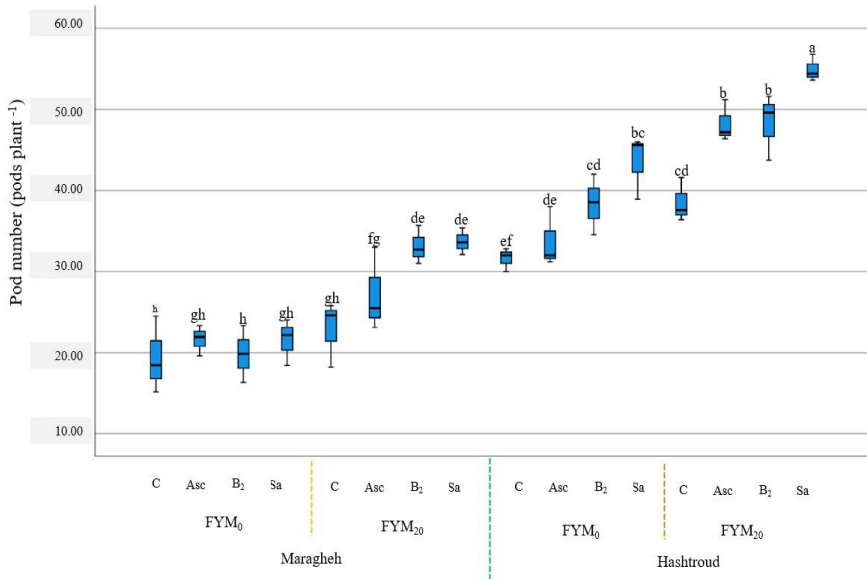


Figure 2. Number of pods per chickpea plant grown under conditions of application of FYM levels and foliar application of vitamins and stimulants in two semi-arid regions in northwestern Iran. C: spray of distilled water as check or control, Asc: acid ascorbic, B₂: vitamin B₂, SA: acid salicylic

The unfilled or empty pod number (EP) in Hashtroud region (20.66) was about three times that of plants grown in Maragheh region (6.52). Foliar application of Asc reduced the EP number by 25%. Spraying of salicylic acid and vitamin B₂ reduced the EP number by about 10%.

The highest EP number was recorded in H-FYM₀-C (30) and the lowest in M-FYM₂₀-Asc (3.72). Foliar application of Sa, Asc and vitamin B₂ increased the seed number per plant by 18%, 8% and 6%, respectively, compared to the control condition. Application of FYM increased the seed number by 14% compared to the control. The seed number in plants grown in Hashtroud region was 81% higher than that in Maragheh region. The effect of foliar application of vitamin B₂ was greater in M-FYM₀ conditions than in other treatments. Under M-FYM₂₀ conditions, Sa spray had the greatest improving effect. In Hashtroud region, Asc spray increased the number of seeds compared to other foliar spray treatments.

The triple effects of S×FYM×F on hundred grain weight (HSW) were significant. HSW in Maragheh region was 52% higher than Hashtroud. Among the foliar spray treatments, the highest HSW was obtained through Sa spray (33.42 g), which was 4% higher than the control condition. The heaviest grains were obtained in M-FYM₀-Sa (40.85 g) and the lightest grains were obtained in H-FYM₂₀-C (24.68 g) and H-FYM₂₀-B₂ (24.49 g). Also, the triple effects of S×FYM×F on grain yield were significant at the 5% statistical level. The highest grain yield was recorded in H-FYM₂₀ with about 640 kg ha⁻¹. The lowest yield was obtained in M-FYM₀ (280 kg ha⁻¹). FYM application increased grain yield by 117 kg ha⁻¹ compared to the control condition. The average grain yield in Hashtroud region (582.35 kg ha⁻¹) was 68% higher than Maragheh region (346.04 kg ha⁻¹). Among Sa foliar spray treatments, vitamin B₂ had the highest yield of 493 kg ha⁻¹ and 484 kg ha⁻¹, respectively. The highest harvest index was recorded in H-FYM₂₀-C (56.19%), H-FYM₀-B₂ (55.96%). The lowest harvest index was obtained in M-FYM₀ with vitamin and Sa foliar sprays (Fig. 3).

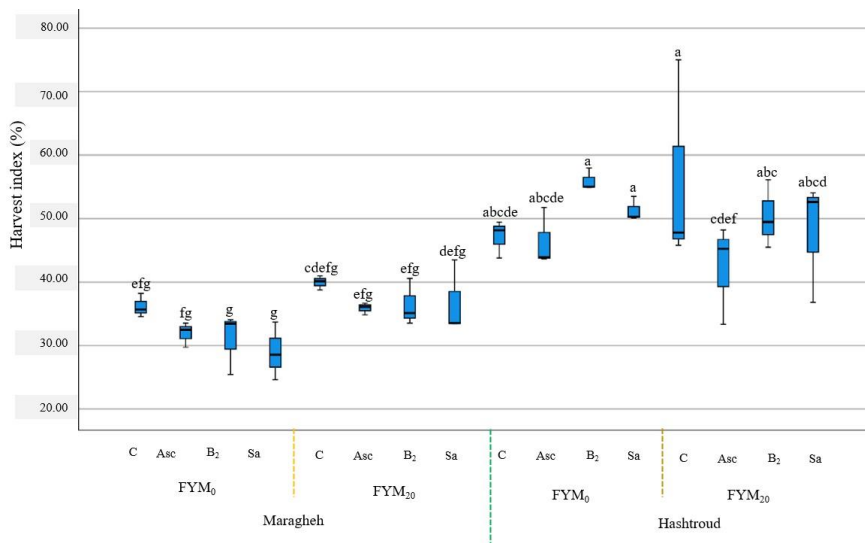


Figure 3. The effect of FYM application and different foliar spray treatments on chickpea harvest index in two regions in northwestern Iran

The clustering of treatment combinations is shown in Fig. 4. The clusters indicate that the groupings were mostly based on regions and FYM application. The first group included M-FYM₀, which resulted in low values for most of the evaluated traits. The second group included M-FYM₂₀, which significantly improved growth and yield compared to the first group. Sa foliar spray had a slightly better effect compared to other foliar spray treatments in M-FYM₂₀ conditions. In H-FYM₀ conditions, the lack of vitamin or Sa application was separated from the others (fourth group). The degree of improving effect of foliar treatments in Hashtroud region on vegetative components and yield components was similar to FYM application. The fifth group included the best treatment combinations and included vitamin or Sa spray, in H-FYM₂₀ conditions (Fig. 4).

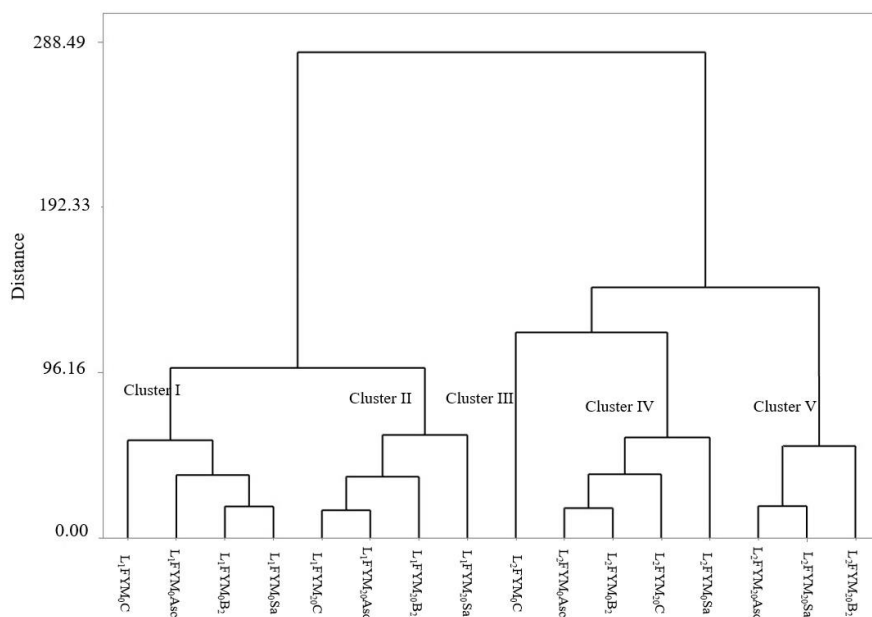


Figure 4. Grouping of treatment combinations including levels of FYM application and foliar spraying with vitamins and stimulants in terms of similarity in affecting phenological and agronomic traits of chickpea in two semi-arid regions of Iran

Grouping of evaluated agronomic, phenological and yield components from similarity in the effects of the studied treatments showed that the responses in traits such as plant height, grain yield, number of pods, number of seeds per plant, canopy width, biomass, number of lateral branches, days to maturity, height of the first pod, number of empty pods, and harvest index were similar and were placed in the first group. These traits showed the best performance in Hashtroud region with FYM application and Asc and Sa spray. The second group included the number of primary branches, rooting depth, pod shell weight,

number of filled seeds per pod, and days to podding. These traits showed the highest values under H-FYM₀-Sa or H-FYM₀-Asc conditions. The third group included pod weight, 100-seed weight, and days to flowering, the highest values of which were recorded under M-FYM₂₀-Sa and M-FYM₂₀-B₂ conditions (Fig. 5).

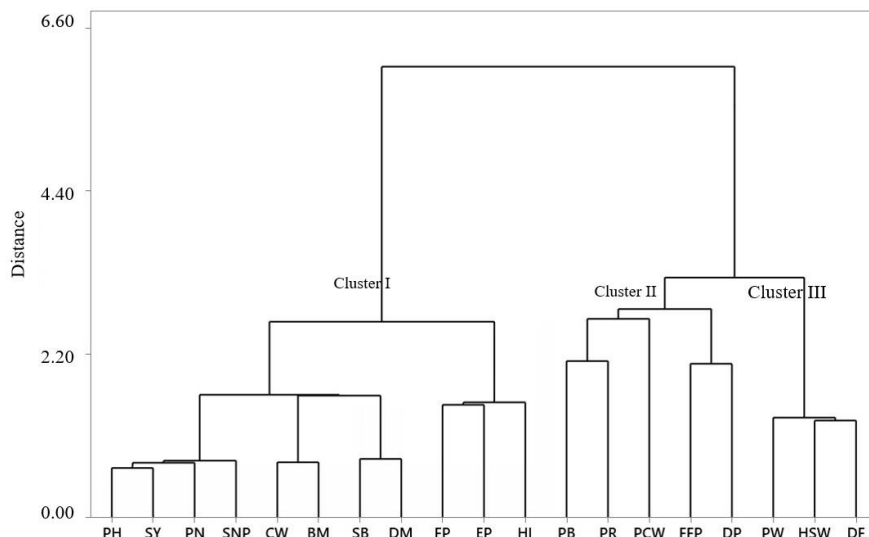


Figure 5. Clustering agronomic and morphophysiological traits of chickpea in terms of similarity in response to FYM application and foliar spraying of vitamins and stimulants. PH: plant height, SY: grain yield, PN: number of pods, SNP: number of seeds per plant, CW: canopy width, BM: biomass, SB: number of lateral branches, DM: days to maturity, FP: height of the first pod, EP: number of empty pods, HI: harvest index, PB: number of primary branches, PR: rooting depth, PCW: pod shell weight, FFP: number of filled seeds per pod, DP: days to podding, PW: pod weight, HSW: 100-seed weight, DM: days to flowering

A brief comparison of the two regions studied indicated that both regions had low soil quality and a lack of organic matter was evident. However, soil quality was lower in the Maragheh region. The Hashtrood region, with its higher altitude than Maragheh, as well as higher rainfall and more suitable distribution, had more suitable climatic conditions. The Hashtrood region has a longer growing season and the end-of-season drought begins a little later. In the Maragheh region, the improper distribution of rainfall and the sharp increase in temperature at the end of the chickpea growing season are among the factors that seem to have reduced the efficiency and effectiveness of foliar spray treatments. Although many of the improving effects of FYM application appear in the long term, the results obtained here confirmed the findings of Nouraein *et al.*, (2019) regarding the short-term positive effects of livestock manure on improving soil properties and crop growth. FYM application enhanced the aspects of vegetative

growth such as height, canopy width, and rooting depth in the short term. The results indicate that the poor soil conditions of the two semi-arid regions enhanced after FYM application. Previous results of researchers have shown that FYM application improved plant growth by improving soil structure, improving permeability, and adjusting chemical and biological conditions of the rhizosphere. However, some of the high vegetative growth and grain yield in Hashtrood region was due to slightly better soil conditions and higher rainfall during the chickpea growing season. In Maragheh region under FYM₀ conditions, the effectiveness of solution treatments was insignificant, and among them, foliar application of vitamin B₂ was able to improve vegetative growth components to some extent. Vitamin B₂ plays a role in improving photosynthesis and as an elicitor in stimulating resistance through the production of some compounds related to redox regulation. It seems that considering the role of Vitamin B₂ in energy production, osmotic regulation, and cofactor of many key enzymes involved in root growth, its external application can stimulate root growth. FYM application in Maragheh region increased the effect of salicylic acid on developmental characteristics and yield components. Previously, researchers had shown that salicylic acid, by stimulating defense processes, the production of photosynthetic pigments such as chlorophyll and carotenoids, increases photosynthetic production and ultimately improves plant growth. The findings of this experiment showed that to increase the effectiveness of foliar spraying of vitamins and stimulants, soil conditions and the rhizosphere environment must first be improved. Poor soil conditions in semi-arid regions, including compaction, low organic matter content, high soil pH, and availability of elements, are among the limitations that reduce the growth of agricultural crops. The limitations mentioned can reduce the effectiveness of foliar spraying treatments. The results of Ali *et al.*, (2023) also showed that the use of FYM increases the efficiency of salicylic acid spray on corn growth and yield.

The highest vegetative growth after FYM application was recorded in Hashtrood region with foliar application of ascorbic acid and salicylic acid and in Maragheh region with foliar application of salicylic acid and vitamin B₂. These findings indicate that in addition to soil conditions, climatic factors can also affect the efficiency of foliar application treatments. Early onset of flowering in Hashtrood region resulted in a significant portion of reproductive growth being completed before the onset of the hot and dry period at the end of the season. Another limitation of chickpea production in semi-arid Mediterranean regions is the interaction of sensitive reproductive periods with heat stress and late-season drought (Naveed *et al.*, 2025). The results obtained showed that for semi-arid regions with relatively poor soil, foliar application of vitamin B₂ can provide increased yield by improving root growth and seedling establishment. Increasing rooting depth in semi-arid regions is a key trait for roots to access moisture stored in the soil. Therefore, vitamin B₂ can be included in the category of climate-smart compounds. Among the foliar spray treatments, the most effective was obtained with the use of ascorbic acid and salicylic acid. Both of the aforementioned

compounds, with their antioxidant activities and scavenging of reactive oxygen species, can prevent the occurrence of oxidative stress. In the aforementioned areas, high radiation levels, high temperatures, and drought are factors that, in addition to directly affecting the reduction of plant growth and yield, also reduce the yield of agricultural products through the occurrence of oxidative stress. The use of animal manure in the aforementioned areas increased the effectiveness of foliar spray treatments by providing part of the nutritional needs and improving plant establishment.

CONCLUSIONS

Soil conditions in both regions indicated low soil organic matter and the need for soil amendment. The application of farmyard manure (FYM) and foliar spray treatments improved the phenological aspects, vegetative growth, and yield components of chickpea. In the Maragheh region, salicylic acid and ascorbic acid spray increased vegetative growth and delayed flowering, while FYM application accelerated flowering. The impact of FYM on phenology was more pronounced in the Hashtrood region. Foliar spray treatments and FYM application also increased the number of days to maturity. Salicylic acid spray and FYM application boosted both the longitudinal and lateral growth of plants. Additionally, vitamin B₂ spray increased rooting depth, with this effect being enhanced by FYM application. Foliar application of biostimulants combined with animal manure enhanced the foliar uptake of salicylic acid in the Maragheh region. In the Hashtrood region, the use of all vitamins and stimulants significantly increased chickpea seed yield. Considering the significant increase in grain yield under the same irrigation conditions with the application of animal manures and foliar feeding of biostimulants, these management practices improved water use efficiency. Water use efficiency in the Hashtrood region was higher than in the Maragheh region.

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