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The Effects of Farmyard Manure and Nitrogen Fertilizer on the Performance of Safflower

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ABSTRACT

Low soil organic matter is a prevalent problem in soils with semi-desert climates, which seems to have effects on the efficiency of the utilized chemical fertilizers. The purpose of this experiment was to evaluate the interaction between farmyard manure (FYM_0=0, FYM_{10}=10, and FYM_{20}=20 t ha^{-1}) and nitrogen fertilizer (N_0=0, N_{40}= 40 and N_{80}=80 kg ha^{-1}) on growth ad seed production of safflower in the west of Iran. Results showed that the application of nitrogen at all levels of animal manure increased the height of the plant. The effect of using small amounts of nitrogen (40) was more evident in the conditions of application of animal manure. The application of FYM_{10}+N_{80} increased the number of lateral branches by about 56%. With the increase in nitrogen consumption, the chlorophyll content in the leaves increased linearly. The increasing effect of applying FYM_{20} on chlorophyll content was similar to the application of 40 kg of nitrogen and improved the chlorophyll content by about 26%. Canopy width increased by 80% with the utilization of FYM_{20}+N_{80} compared to the control condition (FYM_0+N_0). Application of FYM_{10} and FYM_{20} increased capitulum diameter by canopy by 40% and 54%, respectively. Altogether, the best safflower performance was achieved under the conditions of using FYM_{20}+N_{80}, which improved the yield by 439 kg ha^{-1} over control. The use of FYM increased the positive effect of nitrogen on leaf chlorophyll, canopy width, and capitulum number and ultimately improved seed yield. Improving soil organic matter is one of the necessities to increase the efficiency of nitrogenous fertilizers in semi-arid areas.

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1. Introduction

Safflower or false saffron *(Carthamus tinctorius* L.) is a plant from the sunflower family (Asteraceae), which, despite its history in the agricultural sector, is currently an underrated crop due to the lack of sufficient information about its agronomic management and its nutrients requirements. This plant is annual and multi-purpose and can be cultivated as a forage, medicinal, oil seed crop, and to extract dye from the petals (Menegaes and Nunes, 2020). Due to its developed and deep roots, safflower originated in the Eastern Mediterranean and seems to be well adapted to semi-arid areas. Data from previous studies showed that most safflower production is concentrated in regions with semi-desert climates where due to the low soil organic matter, high pH, and low soil moisture, the availability of some elements, especially micronutrients and phosphorus, is seriously limited (Janmohammadi and Sabaghnia, 2023).

Soil organic matter (SOM) affects plant growth and performance directly by providing nutrients and indirectly by modulating the chemical, biological, and physical characteristics of the soil. SOM improves the root environment and stimulates plant growth. In addition, SOM increases the ability to hold water in the soil to a significant extent. In addition to improving the stability of agricultural ecosystems, the use of organic fertilizers guarantees an increase in agricultural production in the long term. Preventing excessive grazing of plant residues, the return of them to the soil by reduced tillage, and the use of animal manures, along with the use of correct crop rotations, increase the biological and physicochemical characteristics of the soil. However, the balance of nutrients provided to

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the plant is also very important. Therefore, the interaction between the application of organic amendments, especially animal manure, and the use of chemical fertilizers on the performance of the safflower plant is very important. It seems that the utilization of organic amendments with the adjustments they create in the soil significantly reduces the leaching of elements (Rayne and Aula, 2020).

Even though nitrogen is the most important element affecting growth and development has many effects on quantitative and qualitative aspects, excessive use of this fertilizer leads to a decrease in soil productivity, environmental pollution, and a nutritional imbalance in the soil (Qin *et al*., 2020). However, the utilization of farmyard manure in the semi-arid region can improve soil characteristics, such as structure and promote granulation, water retention, nutrient-holding capacity, and cation exchange capacity, and improve the biological condition of the rhizosphere, increasing the economic crop yield and diminishing the environmental risk of chemical fertilizers (Xiao *et al*., 2017). In addition, increasing carbon sequestration in agricultural soils will largely prevent the occurrence of greenhouse effects and slow down the process of global warming (Paustian *et al*., 2019).

The consumption of inorganic fertilizers increased significantly in the world after the green revolution, however, long-term utilization of chemical fertilizers is insufficient to preserve SOM and required plant nutrients if no organic fertilizer is used for the soil of the fields in the mentioned area (Fan *et al*., 2023). Therefore, the use of high-input production systems should be seriously considered as a management strategy in farms, and the production of products under the conditions of combined application of chemical and organic fertilizers should be emphasized (Wan *et al*., 2021). Although integrated nutrient management should be considered as a principle in semi-arid regions, there is no information about the amount of application of chemical and organic fertilizers.

In this context, it has been reported that the use of 30 t ha^{-1} FYM in the semi-arid areas of northwestern Iran increased the yield by about 50% over control, while the application of chemical fertilizer (NPK) improved the yield by about 17% (Janmohammadi *et al*., 2016). Although the application of FYM improved the soil properties (reduced bulk density, increased soil organic matter, and improved root permeability), the highest achene yield of sunflower was obtained by combined use of FYM and chemical NPK fertilizer (Nouraein *et al*., 2019). Nitrogen fertilizer increased the yield of safflower by increasing the number of branches, while the use of nitrogen together with FYM increased the rate of nitrogen absorption by the plant and improved the morphological and qualitative characteristics of safflower (Saeedi *et al*., 2022). However, there is still no comprehensive information on the reaction of safflower yield components under the conditions of application of different amounts of urea and FYM in semi-arid regions. This experiment aimed to investigate the interaction of nitrogen and FYM utilization on safflower performance.

2. Materials and methods

The field trial was carried out to evaluate safflower seed yield components affected by FYM and nitrogen at a private farm, Doosine region, Baneh, Kurdistan province, Iran (35°59′ N and 45°53′ E, 1615 height above sea level) during the growing season 2020- 2021. Seeds of safflower cultivar "ZY-S" were acquired from Baneh Agricultural Research Station. The seeds were planted manually, in rows with a distance of 50 cm and with a distance of 10 cm on the rows at a depth of 3 cm in late April. The seeds were disinfected with benomyl fungicide before sowing. A split plot arrangement based on RCBD was used to conduct the field experiment and each experimental plot had an area of 16 m^2. Between the experimental plots, one meter was considered as a non-planting margin to prevent the penetration of fertilizers. The main factor includes the application of different levels of FYM as FYM_0: no use of FYM, FYM_{10}: utilization of 10 t ha^{-1}FYM, FYM_{20}: application of 20 t ha^{-1}FYM. The well decomposed FYM which was collected from a calf farm was added to surface soil and mixed with secondary tillage implements one month before seed planting. The properties of FYM are presented in Table 1. The process of decomposition of FYM was carried out by storing them in open space for one year and mixing them in two-month intervals to accelerate microbial activities. Each ton of manure contains 19.8 kg nitrogen, 9.2 kg phosphorus and 20.2 kg potassium.

The soil of the field was sandy clay loam, and its physical and chemical characteristics were pH: 7.68, organic carbon: 0.51%, total nitrogen: 0.26%, $CaCo_3$: 17%, EC: 2.15 ds m^{-1}, Fe: 1.52 ppm, Mn: 7.09 ppm, P:

16.28 ppm, K: 625 ppm. Soil analysis was carried out based on colorimetric spectroscopy methods described by Mouridi et al. (2023). The secondary factor included different levels of nitrogen fertilizer, which consisted of N_0: no use of nitrogen fertilizer, N_{40}: application of 40 kg ha^{-1} of nitrogen through urea fertilizer, and N_{80}: utilization of 80 kg ha^{-1} of nitrogen through urea fertilizer. According to technical recommendations in the region, the use of nitrogen fertilizer was done in three installments, one-third in the planting, one-third in the stem elongation stage, and one-third in the capitulum emergence stage (Peterson and Frye, 1989). The field was monitored weekly and no pest and disease contamination was observed during the growing period. Hand weeding was carried out during the vegetative growth period.

Non-destructive measurement of leaf chlorophyll was performed with the SPAD-502 meter on upper-developed leaves during the capitulum growth stage. The width of the canopy was considered based on the lateral growth of the plant. Assuming the shape of the canopy to be elliptical from above, the diameter of the ellipse was considered as the width of the canopy. The height of the plant was determined as the height of the plant from the ground to the tip of the highest capitulum at the maturity stage. Plants reach to maturity stage approximately 30 days after flowering when most leaves have turned brown. The number of capitula (heads) per plant, capitulum diameter, and the number of branches were counted for ten randomly selected plants before harvesting. After harvesting the plants from 2 m^2 the number of seeds in the capitulum and seed yield were counted. Plants were placed in a drying cabinet at 70°C for 24 h, and the total dry matter (biological yield) was measured through a digital scale. The thousand seed weight was obtained by counting the seeds with a seed counter and weighing them. The harvest index was obtained through the ratio of grain yield to total dry matter. The collected data was analyzed by the SPSS program and evaluated by analysis of variance using the F test for RCBD. Means comparison was carried out by the least significant differences test at a 5% confidence interval.

Table 1. Chemical properties of decomposed FYM used in the experiment.

P (%)	N (%)	K (%)	Ca (%)	OC (%)	pH	EC (ds. m^{-1})	S (%)
0.92	1.98	2.02	1.23	31.02	7.54	3.61	0.38

EC: Electrical Conductivity, OC: Organic Carbon

3. Results and discussion

Analysis of variance (ANOVA) results showed that the application of nitrogen fertilizer significantly affected this trait at the level of 1%, and the application of 80 kg ha^{-1} of nitrogen increased the plant height by 20% compared to the control (Table 2).

Table 2. Mean comparison of growth characteristics of safflower (*Carthamus tinctorius*) under different levels of farmyard manure and nitrogen.

treatment		PHE	SD	GC	PSY	DPW	CNP	SPP
	N_0	57.00^e	7.33^c	72.23^f	18.04^e	45.71^c	12.85^e	564.10^c
FYM_0	N_{40}	64.52^d	7.66^c	76.81^e	21.76^{de}	48.38^c	13.23^{de}	630.52^{bc}
	N_{80}	73.57^a	8.00^{bc}	80.95^{cd}	23.95^d	47.04^c	13.04^{de}	630.52^{bc}
	N_0	59.61^e	8.90^a	77.95^{de}	29.08^c	56.61^b	13.90^{cde}	697.33^b
FYM_{10}	N_{40}	69.47^{bc}	8.78^{ab}	81.66^c	33.59^c	56.71^b	14.52^{abc}	718.29^b
	N_{80}	73.33^{ab}	9.35^a	83.14^{bc}	41.29^b	57.66^{ab}	14.61^{abc}	826.81^a
	N_0	58.09^e	9.10^a	77.42^e	33.19^c	56.42^b	14.28^{bcd}	842.10^a
FYM_{20}	N_{40}	65.85^{cd}	8.74^{ab}	85.52^b	38.82^b	58.81^{ab}	15.61^a	829.79^a
	N_{80}	75.23^a	9.56^a	89.85^a	48.23^a	63.42^a	15.47^{ab}	879.76^a
LSD		4.01	0.88	3.41	4.64	5.97	1.24	94.78
Significance level								
FYM		ns	**	**	**	**	**	**
Nitrogen (N)		**	*	**	**	ns	*	**
FYM ×N		ns	ns	*	ns	ns	ns	ns

PHE: plant height (cm), SD: stem diameter (mm), GC: canopy ground coverage (%), PSY: seed yield of individual plants (g), DPW: plant dry weight (g), CNP: capitula number per plant, SPP: total seed number in individual plant, FYM: farmyard manure. In each trait, the averages with common letters do not have statistically significant differences (P≤0.05).NS, *, and **: not statistically significant, significant at 0.01 and 0.05 level, respectively.

Application of FYM and nitrogen affected the diameter of the stem and the thickest stems were obtained with the application of FYM_{20} + N_{80}. The effects of utilization of low levels of nitrogen (N_{40}) on this trait were not significant. Examining the percentage of ground cover (GC) by canopy showed that the main effects of the application of FYM, nitrogen, and their mutual effects on this trait were significant. The highest GC was recorded in the FYM_{20}+N_{80} application, which was about 18% higher than the control condition (FYM_0+N_0). The greatest effect of nitrogen fertilizer application on GC was recorded under FYM-utilized conditions (Table 2).

Consumption of large amounts of nitrogen (N_{80}) in all conditions of application or non-application of FYM caused an increase in the canopy width. The application of large amounts of FYM increased the chlorophyll content by about 60% compared to the control. However, the use of high levels of nitrogen fertilizer increased canopy width by 35% (Fig. 1). The highest canopy width was achieved by FYM_{80}+N_{80}, which was about 85% higher than the control (FYM0+N0).

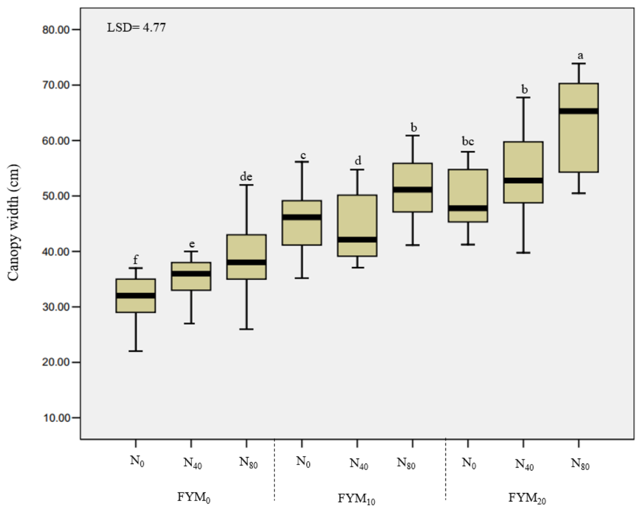

Figure 1. The impact of utilization of different levels of nitrogen and farmyard manure on canopy width of safflower. N0: no application of nitrogen fertilizer, N40, and N80: utilization of 40 and 80 kg nitrogen per hectares FYM0: no application of farmyard manure, FYM10 and 20: application of 10 and 20 t ha^{-1} farm yard manure. Boxes with different letters have statistically significant differences (p<0.05).

Evaluation of the leaf chlorophyll content with SPAD showed that this physiological trait increased strongly with the application of nitrogen fertilizer, however, the effect of nitrogen was more significant under the conditions of no application of FYM (Fig. 2). The highest amount of chlorophyll was recorded under the conditions of application of FYM_{20}+ N_{80}.

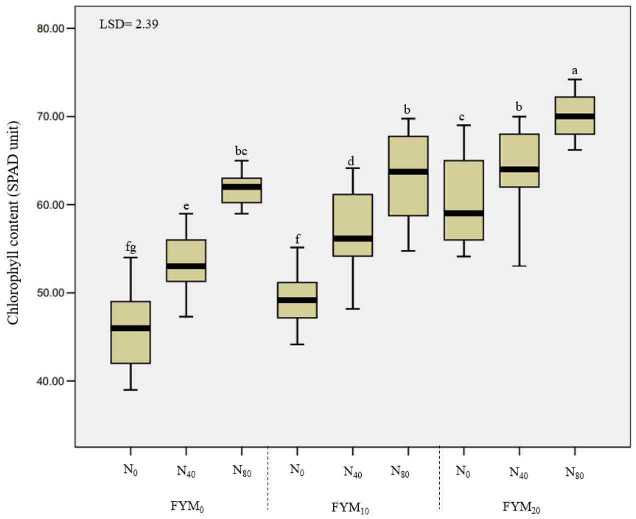

Figure 2. Chlorophyll content of safflower upper leaves under application of different amounts of nitrogen and farmyard manure. Boxes with different letters have statistically significant differences (p<0.05).

The evaluation of the number of secondary branches indicated that the application of nitrogen fertilizer increased this component, but the effects of nitrogen use were more evident under FYM_{10} and FYM_0 (Fig. 3). The highest number of secondary branches was obtained under the FYM_{10} utilized condition (30% higher than the control).

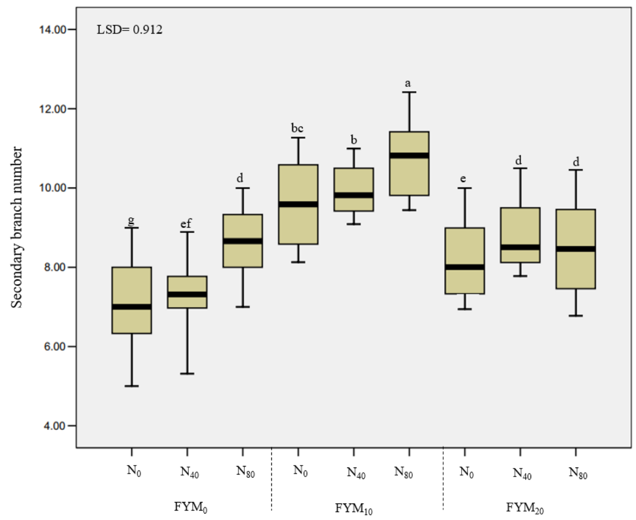

Figure 3. The impact of nitrogen and farmyard manure application on the number of secondary branches in safflower grown in the west of Iran.

The assessment of plant dry weight showed that nitrogen application affected this component only in conditions of high FYM application. However, the use of FYM_{10} and FYM_{20} improved the dry weight of the plant by 19% and 24% over control, respectively (Table 2). The number of capitulum per plant, as one of the most important seed yield components of safflower, was affected by the use of FYM and nitrogen. The application of FYM_{10} and FYM_{20} increased this component by 9 and 15% over control. Utilization of N40 under organic fertilization led to the highest number of capitulum (21% over control). Evaluation of capitulum diameter showed that nitrogen use under FYM_0 increased this trait by about 20%. However, the impact of nitrogen on this trait was not significant under FYM-utilized conditions. Instead, the use of FYM_{10} and FYM_{20} increased the diameter of the capitulum by 32% and 55% over control, respectively (Fig. 4).

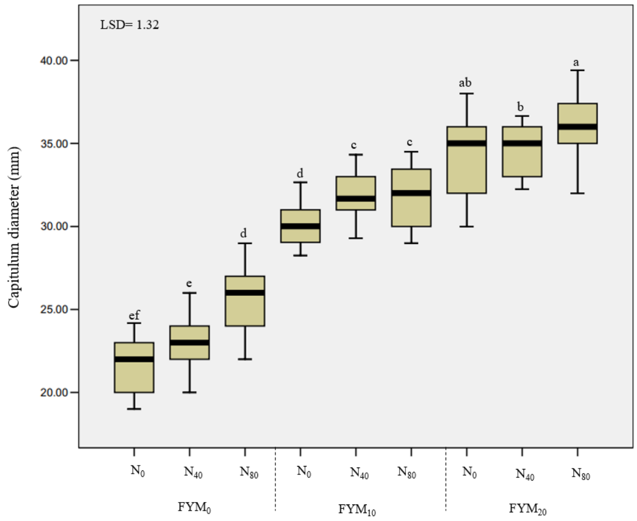

Figure 4. Mean comparison of capitulum diameter of safflower grown under application of various amounts of nitrogen and farmyard manure.

Seed number was affected by both N and FYM, however, the effect of Nitrogen consumption was more noticeable under FYM-applied conditions. The highest seed number was recorded for the plant grown under $FYM_{10}+N_{80}$ which was 50% higher than the control condition (FYM_0+N_0). Examining this trait showed that under the conditions of application of high levels of FYM, no significant difference was observed between nitrogen levels. Seed weight was affected by the application of FYM and nitrogen. However, the effect of FYM was more significant. The use of large amounts of FYM increased the seed weight by about 17% compared to the control (Fig. 5).

The heaviest seeds were obtained under the application of large amounts of FYM. The utilization of N_{80} under the FYM_{10} applied condition caused a decrease in seed weight, which is partly due to the compensatory effects between the number of seeds and the weight of seeds. The evaluation of seed yield showed that the application of nitrogen at all levels of FYM increased the yield. The effect of nitrogen fertilizer was more evident under no farmyard manure application conditions. However, the highest seed yield was obtained under organic fertilization conditions with utilization of N80. The finding showed that fertilizer management improved yield by about 40% (Fig. 6).

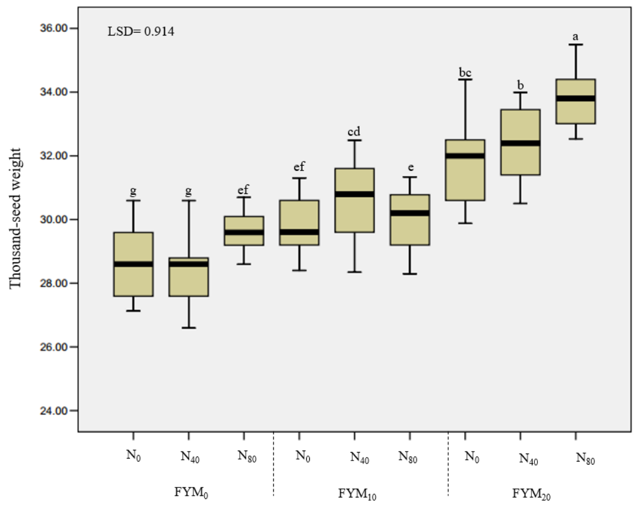

Figure 5. Thousand seed weight of safflower grown under various amounts of nitrogen and farmyard manure.

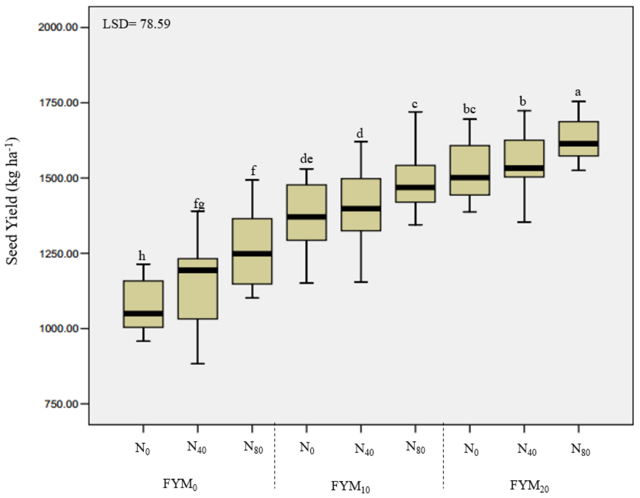

Figure 6. The effects of nitrogen and farmyard manure application of safflower seed yield in the west of Iran.

The results of the experiment indicated that the application of nitrogen significantly increased the longitudinal growth of stems and plant height. However, the application of FYM alone could not have much effect on the height of the plant. These results probably show that the supply of nitrogen through the rotten FYM is not sufficient for the continuation of optimal plant growth. Nitrogen, as one of the most important elements, interacts with the biosynthesis pathways of plant hormones, especially auxin, and by changing the ratio of auxin hormone to abscisic acid, it can affect the plant's longitudinal growth (Vega *et al*., 2019; Mao *et al*., 2022). The growth of stem diameter increased strongly with the application of FYM. This seems to be due to the supply of other elements needed to improve the diameter growth of the stem through animal manures. These results confirmed the previous findings by Lemma (2020). Canopy width and percentage of ground cover by canopy were affected by both fertilizers and the highest efficiency of nitrogen fertilizer was recorded under organic fertilization conditions. These two traits are very important in semi-arid regions because their increase on the one hand causes shading on the ground and reduces the rate of evaporation of moisture stored in the soil, and on the other hand increases the amount of solar radiation received. And it can lead to an increase in photosynthesis and the production of photoassimilates. Obtaining the maximum lateral growth of the canopy with the combined application of nitrogen and manure indicates that the best conditions for plant growth and supply of elements are created in the conditions of improving the physical properties of the soil through manure (Yeshiwas *et al*., 2018). Our previous results also showed that the effects of nitrogen on growth components are strongly dependent on the supply of other elements required for growth, especially micronutrients (Fattahi *et al*., 2018). The improving and synergistic effect of manure on nitrogen was also observed for the biological yield, and the highest dry weight was recorded under the combined application of manure and nitrogen. Improving soil properties such as increasing permeability, increasing water holding capability, increasing cation exchange capacity, and improving granular structure are among the things that can occur in the rhizosphere environment with the application of FYM (Nouraein *et al*., 2019). However, the use of urea fertilizer is the only supplier of nitrogen in the environment surrounding the roots and does not have much effect on the physicochemical properties of the soil (Finch *et al*., 2014). Examining the seed yield components such as the number of heads per plant, diameter of heads, and number of seeds per head indicated that despite the improving effect of nitrogen on the mentioned traits, nitrogen consumption alone could not significantly increase seed yield. The improvement of grain yield with the use of fertilizers can be explained to some extent by the relationship between sink and source. Plant organs involved in photosynthesis and providing photoassimilates are called sources, and organs receiving photosynthetic products such as flowers and seed parts are called sinks (Smith *et al*., 2018). The use of organic and chemical fertilizers in the present research stimulated the growth of vegetative organs and increased the number of lateral branches, and canopy width. In other words, the use of fertilizers in the mentioned conditions has been able to increase the size of the source. However, the application of fertilizers also increased the components of seed yield or in other words the size of the sink, so it can be concluded that in the studied soils, the nutrient deficiencies and the inappropriate condition of the soil caused a simultaneous limitation for the source and the sink. The results of previous research also indicated the improving effect of FYM application on source-sink relationships in plants grown in semi-arid areas (Paustian *et al*., 2019).

4. Conclusion

The findings of the experiment confirmed that the application of farmyard manure and nitrogen fertilizer, especially in large amounts, improved almost all the assessed traits. These outcomes indicate to some extent the inappropriate soil conditions due to the low soil organic matter, which can be solved with the use of animal manure. The important point was that the use of manure or urea chemical fertilizer alone does not have much effect on the growth characteristics and yield of safflower seeds. To increase the effectiveness and efficiency of nitrogen fertilizers, soil conditions must be improved through the use of farmyard manure. In the mentioned experiment, the best plant performance was obtained under the conditions of combined application of 20 t ha^{-1} of farmyard manure and 80 kg ha^{-1} of nitrogen. In summary, it can be suggested that the use of cheap and available organic fertilizers such as FYM, should be considered as a primary principle in plant nutritional management in safflower production.

Conflict of Interests

All authors declare no conflict of interest.

Ethics approval and consent to participate

No human or animals were used in the present research.

Consent for publications

All authors read and approved the final manuscript for publication.

Availability of data and material

All the data are embedded in the manuscript.

Authors' contributions

All authors had an equal role in study design, work, statistical analysis and manuscript writing.

Informed Consent

The authors declare not to use any patients in this research.

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References

Fan H., Zhang Y., Li J., Jiang J., Waheed A., Wang S., Rasheed S.M., Zhang L., Zhang R. 2023. Effects of organic fertilizer supply on soil properties, tomato yield, and fruit quality: a global meta-analysis. Sustainability 15(3): 2556-2563. https://doi.org/10.3390/su15032556

Fattahi M., Janmohammadi M., Dashti S., Nouraein M., Sabaghnia N. 2018. Effects of nitrogen and micronutrients on the growth of safflower under limited water conditions in a high-elevation region. Biologija 64(3): 235-248. https://doi.org/10.6001/biologija.v64i3.3829

Finch H.H.S., Samuel A.M., Lane G.P.F. 2014. 4 - Fertilisers and manures. Lockhart & Wiseman's Crop Husbandry Including Grassland (Ninth Edition): 63-91. https://doi.org/10.1533/9781782423928.1.63

Janmohammadi M., Amanzadeh T., Sabaghnia N., Ion V. 2016. Effect of nano-silicon foliar application on safflower growth under organic and inorganic fertilizer regimes. Botanica Lithuanica 22(1): 53-64. http://dx.doi.org/10.1515/botlit-2016-0005

Janmohammadi M., Sabaghnia N. 2023. Effects of foliar spray of nano-micronutrient and growth regulators on safflower (*Carthamus tinctorius* L.) performance. Plant Nano Biology 5: 100045. https://doi.org/10.1016/j.plana.2023.100045

Lemma D.T. 2020. Determination of optimum farmyard manure rates for growth, yield and yield components of roselle (*Hibiscus sabdariffa* L.). International Journal of Research in Agricultural Sciences 7(5): 243-250. http://ijras.com/administrator/components/com_jresearch/files/publications/IJRAS_914_FINAL.pdf

Mao Y., Chai X., Zhong M., Zhang L., Zhao P., Kang Y., Guo J., Yang X. 2022. Effects of nitrogen and magnesium nutrient on the plant growth, quality, photosynthetic characteristics, antioxidant metabolism, and endogenous hormone of Chinese kale (*Brassica albograbra* Bailey). Scientia Horticulturae 303: 111243. https://doi.org/10.1016/j.scienta.2022.111243

Menegaes J.F., Nunes U.R. 2020. Safflower: importance, use and economical exploitation. Scientia Agraria Paranaensis 19(1): 1-11. https://doi.org/10.18188/sap.v19i1.21250

Mouridi Z.E., Ziri R., Douaik A., Bennani S., Lembaid I., Bouharou L., Brhadda N., Moussadek R. 2023. Comparison between Walkley-Black and Loss on ignition methods for organic matter estimation in different Moroccan soils. Ecological Engineering & Environmental Technology (EEET) 24(4): 235-254. https://doi.org/10.12912/27197050/163121

Nouraein M., Skataric G., Spalevic V., Dudic B., Gregus M. 2019. Short-term effects of tillage intensity and fertilization on sunflower yield, achene quality, and soil physicochemical properties under semi-arid conditions. Applied Sciences 9(24): 5482-5491. https://doi.org/10.3390/app9245482

Paustian K., Larson E., Kent J., Marx E., Swan A. 2019. Soil C sequestration as a biological negative emission strategy. Frontiers in Climate 1: 8. https://doi.org/10.3389/fclim.2019.00008

Peterson G.A., Frye W.W. 1989. Fertilizer nitrogen management. In Developments in Agricultural and Managed Forest Ecology 21: 183-219: 183-219. https://doi.org/10.1016/B978-0-444-87393-4.50013-7

Qin X., Guo S., Zhai L., Pan J., Khoshnevisan B., Wu S., Wang H., Yang B., Ji J., Liu H. 2020. How long-term excessive manure application affects soil phosphorous species and risk of phosphorous loss in fluvo-aquic soil. Environmental Pollution 266: 115304. https://doi.org/10.1016/j.envpol.2020.115304

Rayne N., Aula L. 2020. Livestock manure and the impacts on soil health: a review. Soil Systems 4(4): 64. https://doi.org/10.3390/soilsystems4040064

Saeedi R., Seyyedi A., Parsa Motlagh B., Shekofteh H. 2022. Evaluation of cow manure and different nitrogen sources on yield and nitrogen use efficiency in safflower (*Carthamus tinctorius* L.). Journal of Agroecology 34: 64-72. https://doi.org/10.22067/AGRY.2022.72719.1068

Smith M.R., Rao I.M., Merchant A. 2018. Source-sink relationships in crop plants and their influence on yield development and nutritional quality. Frontiers in Plant Science 9: 1889. https://doi.org/10.3389/fpls.2018.01889

Vega A., O'Brien J.A., Gutiérrez R.A. 2019. Nitrate and hormonal signaling crosstalk for plant growth and development. Current Opinion in Plant Biology 52: 155-163. https://doi.org/10.1016/j.pbi.2019.10.001

Wan L.J., Tian Y., He M., Zheng Y.Q., Lyu Q., Xie R.J., Ma Y.Y., Deng L., Yi S.L. 2021. Effects of chemical fertilizer combined with organic fertilizer application on soil properties, citrus growth physiology, and yield. Agriculture 11(12): 1207. https://doi.org/10.3390/agriculture11121207

Xiao L., Sun Q., Yuan H., Lian B. 2017. A practical soil management to improve soil quality by applying mineral organic fertilizer. Acta Geochimica 36: 198-204. https://doi.org/10.1007/s11631-017-0139-5

Yeshiwas Y., Zewdie B.Y.B., Chekol A., Walle A. 2018. Effect of nitrogen fertilizer and farmyard manure on growth and yield of lettuce (*Lactuca sativa* L.). International Journal of Agricultural Research 13(2): 74-79. https://doi.org/10.3923/ijar.2018.74.79

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