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Effects of Biological and Chemical Sources of Fertilizers on Sunflower Yield and its Components

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Abstract: Bio-fertilizers could improve nutrient availability and reduce the need to use chemical fertilizers and hold a great promise to improve crop yields. This study evaluated the individual and combined effects of bio-fertilizers and compare their efficiency with nitrogen and phosphorus chemical fertilizers on the yield of sunflower (*Helianthus annuus* L.) in the 2017-18 crop year in Hamedan, Iran. The experimental design includes a combination of two factorial experiments including (a) the application of the chemical nitrogen ($N_0=0$, $N_1=45$, $N_2=90$ kg ha⁻¹), and phosphorus ($P_0=0$, $P_1=40$, $P_2=80$ kg ha⁻¹) fertilizers, and (b) the application of nitrogen-fixing bacteria included *Azospirillum* and *Azotobacter* ($BN_0=0$, $BN_1=0.5$, $BN_2=1$ L ha⁻¹), and phosphate-solubilizing bacteria included *Pseudomonas* and *Bacillus* ($BP_0=0$, $BP_1=0.5$, $BP_2=1$ L ha⁻¹) bio-fertilizers that each executed in a 3 × 3 design with nine treatments and a randomized complete block designs with three replicates within the same field. Results indicated that the chemical N and P fertilizers significantly increase the grain yield, 1000-grain weight, plant dry weight, protein percentage, and harvest index. Furthermore, bio-fertilizers significantly increase the grain yield and harvest index. The result shows employing bio-fertilizers with nitrogen-fixing bacteria and phosphate-solubilizing bacteria improves the growth and yield characteristics of sunflower. Sunflower oil yield was similar among all treatments and ranged from 2.22 to 5.7 t ha⁻¹. There was no significant interaction in grain yield between chemical and biofertilizer treatments and ranged from 5.12 to 5.88 t ha⁻¹. A similar result between treatments with the chemical fertilizers and bio-fertilizers suggests bio-fertilizers are suitable alternatives to chemical fertilizers.

Key words: Biofertilizer, growth-promoting bacteria, nitrogen fixation, oilseed, sustainable agriculture.

The ever increasing demand for food as an outcome of population growth in recent decades suggests the optimal application of chemical and biological fertilizers to achieve maximum crop yield (Raei *et al.*, 2013). The occurrence of environmental and economic issues caused by the loss of chemical nitrogen fertilizers because of ammonia sublimation, denitrification, nitrate leaching, volatilization, etc. has led chemical fertilizers to be substituted with nitrogen-fixing biologic systems as a part of sustainable agriculture programs (Raei *et al.*, 2013). An essential requirement of farm planning is to evaluate various plant-nutrition systems that will affect crop quality by impacting the plant's vegetative and reproductive growth period and the balance between them. The sunflower is a native plant of the central regions of America (Kiani *et al.*, 2016). After soybean

(*Glycine max*), groundnut (*Arachis hypogaea*), and rapeseed (*Brassica napus*), sunflower ranks fourth among annual oil-producing plants in terms of oilseed production (Khandekar *et al.*, 2018). Sunflower is a very demanding plant in terms of soil elements so that a balance between nutritional elements is an imperative factor for maximizing the grain yield (Khodaei-Joghan *et al.*, 2017). The area under sunflower cultivation has been increased because of its adaptation to different climatic and soil conditions worldwide (Forleo *et al.*, 2018). Nutrient deficiency is one of the primary reasons for the low yield of sunflowers. Using the right proportion and optimum quantity of essential macro-and micro-nutrients is the key factor for boosting and sustaining crop productivity. Nitrogen is the most limiting nutrient in sunflower production, which results in the decline of sunflower production. Therefore, fertilizer management is one of the most important

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factors in the successful cultivation of crops, altering yield quality and quantity (Mehmood *et al.*, 2018). Over application of N fertilizer increases fertilizer costs, N losses to the environment, and negatively affects sunflower seed quality (Jami *et al.*, 2017). The application of bio-fertilizers and bacterial products has advantages over common chemical substances. The bacteria not only increase the availability of soil nutrients, but also enhances plant productivity through the biological nitrogen fixation and solubilization of phosphorous and potassium, the control of pathogenic agents, and the production of growth-regulating and stimulating hormones (Sinha *et al.*, 2010). Bio-fertilizers also help plant health and crop yield, intended to proffer long-lasting solutions to the problems associated with the continuous use of chemical fertilizers by enhancing soil fertility to increase crop productivity (Adeniji *et al.*, 2019).

Farnia and Moayedi (2015) showed that the application of N and P bio-fertilizers on sunflower improves morphological characteristics and makes longer phonological stages compared with no bio-fertilizer, and eventually has a better impact on seed yield. Another study shows the effects of Nitroxin bio-fertilizer increases the seed yield of sunflower by 28% compared with no-fertilizer treatment (Bahamin *et al.*, 2014).

Moghimini *et al.* (2012) found that Nitroxin increases the grain yield elevation of safflower (*Carthamus tinctorius*) by fixing nitrogen and producing growth-stimulating hormones. Ahmad *et al.* (2010) have also reported similar results. Azarpour *et al.* (2012) showed the application of Nitroxin improves the growth characters and yield in soybean cultivars. Ardakani *et al.* (2011) showed that inoculating wheat seeds with *Azospirillum* increases the NPK (nitrogen-phosphorus-potassium) absorption rate. Vyas (2005) and Yadav *et al.* (2011) has also reported that microbial inoculation reduces the need to apply chemical nitrogen fertilizers significantly.

Banari *et al.* (2015) investigated the impact of a bio-fertilizer (Fertile2) on the yield and

Table 1. The physical and chemical properties of the soil

Soil texture	Sand (%)	Silt (%)	Clay (%)	Available K (ppm)	Available P (ppm)	Total N (%)	OC (%)	EC (dS m ⁻¹)	TNV (%)	pH
Loam	49	29.2	21.8	39.4	8.2	0.08	0.81	1.4	0.81	8.0

TNV: Total neutralizing value

yield components of durum and bread wheat. They found that phosphorus bio-fertilizer could partially replace phosphorus fertilizers without yield reduction. Moreover, Yadav *et al.* (2009) and Shabani *et al.* (2015) applied a combination of phosphorus solubilization bacteria and showed a synergistic impact on the plant's phosphorus concentrations. Their observation was explained by the positive contribution of plant growth-promoting rhizobacteria (PGPR) to nutrient plant uptake, improving the intake of mineral elements, including phosphorus. Also, Zarabi *et al.* (2011) identified a positive influence of micro-organisms capable of phosphorus solubilization on elevated growth and phosphorus uptake in maize plants.

To better understand the effects of bio-fertilizers on sunflower, we carried out a study to investigate the impact of bio-fertilizer compounds. We investigated the quantitative and qualitative yield of sunflower by the employment of bio-, chemical, and no- fertilizers. The primary objective of this research is to compare the effect of chemical fertilizers and bio-fertilizers on the quantitative and qualitative yield of sunflower. The primary objective of this research is to determine an optimal application of nitrogen and phosphorus chemical fertilizers as well as nitrogen-fixing and phosphate-solubilizing bio-fertilizers at rates that are used in this experiment and to compare the effect of chemical fertilizers and bio-fertilizers on the quantitative and qualitative yield of sunflower.

Materials and Methods

Field crop specifications

This research was carried out on a field crop in the Ekbatan Research Station at the Agriculture and Natural Resources Research Center of Hamedan in 2017 crop-year. The laboratory analysis was performed in the Central Laboratory of the College of Aburairhan at the University of Tehran, Iran. The studied region is semi-arid based on De Martonne's climatic classification. Table 1 presents the physical and chemical properties of the field

soil. Soil sampling was performed via pre-cultivation composite sampling from 0 to 30 cm depths and the soil texture was determined as loam with low clay and high sand percentage with a high pH of 8.0 (moderately alkaline).

Experiment design

The current research was conducted as a combination of two factorial experiments comprising an experiment based on the application of nitrogen (N) and phosphorous (P) chemical fertilizers (as a 3 × 3 design with nine treatments) and another experiment based on the application of nitrogen-fixing (BN) and phosphate-solubilizing (BP) bio-fertilizers (as a 3 × 3 design with nine treatments), both as randomized complete block designs with three repetitions in a 1900 m² land and all treatments randomized within the same field. The chemical factorial treatments included three rates of chemical nitrogen fertilizers (0, 45, and 90 kg pure N ha⁻¹) from a Urea source and three rates of chemical phosphorus fertilizers (0, 40, and 80 kg pure P ha⁻¹) from a Triple Superphosphate (TSP) source. The bio-fertilizer factorial treatments included three rates of bio-fertilizers with nitrogen-fixing bacteria (0, 0.5, and 1 L ha⁻¹) from a Nitroxin source and three rates of bio-fertilizers containing phosphate-solubilizing bacteria (0, 0.5 and 1 L ha⁻¹) from a Biophosphorus source. Each experimental plot comprises four ridges with 60 cm spacing and one cultivated row on each ridge. Each plot was 6 m long, with 120 plants per plot. We spaced plots 120 cm from each other, and the distance between the blocks was 2 m.

Land preparation

The land preparation, including surface tillage, disking and land rating was performed. A longitudinal furrow was created beside the ridges for the placement of chemical fertilizers. Different amounts of phosphorus fertilizers were added to specified plots at the time of cultivation. Various amounts of nitrogen fertilizers upon the target treatments were apportioned between the time of cultivation stage and the 6-8 leaf stage and added to the specified plots.

Sunflower seed cultivation

The sunflower seeds used in this research study were of the *Eroflor* hybrid type. Seed

planting was performed manually on the rows at a 2-3 cm depth and 20 cm spacing. Three to four seeds were planted in each spot. Irrigation was carried out immediately after cultivation to ensure the even germination of seeds.

Bio-fertilizer treatments

The Nitroxin bio-fertilizer, as the inoculant (0, 0.5 and 1 L ha⁻¹), is a combination of nitrogen-fixing bacteria, including the *Azotobacter* and *Azospirillum* genera, with 10⁸ live and active bacteria per milligram of inoculant for each of the bacteria genera. The Biophosphorus fertilizer, as the inoculant (0, 0.5 and 1 L ha⁻¹), is a combination of phosphate-solubilizing bacteria. It comprises the *Pseudomonas* and *Bacillus* genera, with 10⁷ live and active bacteria per milligram of inoculant for each of the bacteria genera. The proper amounts of bio-fertilizers for each of the treatments were calculated and added to the seeds. Inoculation was carried out by dipping the sunflower seeds in the cell suspension for 4 hours at 28°C before sowing according to the manufacturer's recommendation. The bacteria used in this study were supplied by the Mehr Asia Biotechnology Company, Tehran, Iran. Seed inoculation was carried out an hour before cultivation and drying in the shade.

Chemical treatments

We performed pre-cultivation fertilization of 87 and 174 kg ha⁻¹ to provide the respective 40 kg and 80 kg of pure phosphorus per hectare from the triple superphosphate chemical fertilizer with a purity degree of 46 per cent (46% P₂O₅). Also, we added the urea chemical fertilizer with a purity degree of 46% (46% N) to the soil in two rounds, once in pre-cultivation and again in the 6-8 leaf stage at 98 and 196 kg urea per hectare, for the target treatments as a strip next to the rows.

Maintenance

We carried out the crop maintenance comprising irrigation, weeding, and thinning (at the 3-4 leaf stage) upon the field requirements.

Harvesting

The harvesting process was carried out from the two middle rows of each plot in a 2 m length after eliminating the marginal effects from both sides of the cultivation lines. The final

harvesting was carried out with the appearance of signs of complete maturity in sunflower (browning of the undersides of the receptacle and the involucral bracts) and the physiological maturity of seeds on September 30.

Laboratory measurements

We cut the plants above the ground to determine their dry weight. Samples were oven-dried at 70°C for 72 h to estimate yield and yield components. Then the dried weight was measured by using a digital weighing scale. We used three random samples to determine the dry weight of the plant, 1000-grain weight, and grain yield. The 1000-grain weight was counted with a laboratory seed counter. After yield determination, the seeds were analyzed for their physical characteristics (kernel percentage and hull-kernel ratio) and chemical characteristics (oil and protein percentages). To calculate the hull-kernel ratio and kernel percentage, seed samples of each treatment were weighed and peeled manually, then the seed kernel and hull were weighted by the scale and the percentage was taken. The oil percentage was determined via a Soxhlet device and an ether solvent. We calculated the oil yield by multiplying the oil percentage by the grain yield in each treatment. The grain protein percentage was measured via the Bradford protein assay and using a SPECT device. The harvest index (HI) was calculated by dividing grain yield (Y) by total biomass (Yt) as $HI = Y / Y_t$.

Table 2. Variance analysis of measured parameters of sunflower

SOV	df	Means of square								
		1000-grain weight	Hull-kernel ratio	Plant dry weight	Kernel (%)	Protein (%)	Oil (%)	Oil yield	Harvest index	Grain yield
Rep		7.447	0.003	1.993	9.805	0.453	1.8002	0.004	6.843*	0.128
Chemical fertilizer										
N	2	36.614**	0.0077**	4.63**	26.418**	9.291*	11.928*	0.044	6.536*	0.752**
P	2	56.569**	0.0023	2.46**	3.195	8.269*	1.766	0.039	6.57*	0.36*
N×P	4	4.906	0.0002	0.21	0.414	0.81	0.159	0.002	4.104*	0.013
Bio-fertilizer										
BN	2	47.925**	0.007**	3.191*	31.775**	8.594*	3.748	0.072	15.761**	0.412*
BP	2	16.119*	0.0009	0.147	6.657	2.112	8.683	0.019	4.606*	0.653**
BN×BP	4	11.932	0.0006	0.639	3.072	0.193	0.645	0.02	0.416	0.137
Chemical vs. bio-fertilizers	1	0.012	0.0022	0.043	15.388	16.555**	0.546	0.029	1.513	0.135
Error	34	6.936	0.0009	0.692	5.069	2.181	4.134	0.036	1.356	0.113
CV (%)		4.33	10.714	6.233	2.889	8.62	4.55	9.26	3.22	6.14

*: Significant at 0.05 level, **: Significant at 0.01 level.

Statistical analysis

We analyzed data with the analysis of variance (ANOVA) procedure of the statistical analysis system, SAS (Ver 8.2) and MSTATC. Normality test of the residuals checked by a UNIVARIATE procedure in SAS program. The significance of differences among main treatment effects and their interaction were determined by Duncan’s multiple range test (DMRT) with a significance testing level of $P = 0.05$.

Results and Discussion

Analysis of variance of the measured characteristics

Table 2 presents the variance analysis of the measured parameters with different fertilizers. Evaluating the interaction effect of chemical fertilizers versus bio-fertilizers revealed that only the protein content (per cent) was significant ($P = 0.01$).

1000-grain weight

The variance analysis for chemical nitrogen (0-90 kg ha⁻¹) and phosphorus (0-80 kg ha⁻¹) rates showed an increase in the 1000-grain weight (Table 3). Also, the change of the chemical nitrogen and phosphorous on the 1000-grain weight was significant ($P = 0.01$). A similar type of finding was reported by Gharali and Nasrollahzadeh (2018) and investigated the

Table 3. The average measured characteristics of sunflower in treatments using the chemical and bio-fertilizers

Treatments	1000-grain weight (g)	Hull-kernel ratio	Plant dry weight (t ha ⁻¹)	Kernel percent-age	Protein percent-age	Oil percent-age	Oil yield (t ha ⁻¹)	Harvest index (%)	Grain yield (t ha ⁻¹)
Chemical fertilizer									
N ₀	58.47b	0.297a	12.905a	77.11a	16.54b	45.76a	2.34a	35.28b	5.12b
N ₁	61.29ab	0.291a	13.020a	78.15a	17.94ab	45.04a	2.42a	36.93a	5.39ab
N ₂	62.38a	0.243b	14.200b	80.46b	18.52a	42.84b	2.48a	36.46ab	5.80a
P ₀	58.03b	0.295a	12.970a	77.93a	16.66b	45.25a	2.35a	35.12ab	5.21b
P ₁	61.12ab	0.272a	13.180a	78.68a	17.76ab	44.44a	2.41a	36.43b	5.39ab
P ₂	63.00a	0.264a	13.960b	79.11a	18.57a	43.94a	2.48a	37.12a	5.61a
Bio-fertilizer									
BN ₀	58.63a	0.320a	12.670a	75.30a	15.56b	45.00a	2.36a	34.6a	5.19b
BN ₁	60.25b	0.288b	13.43ab	77.47b	16.61ab	44.87a	2.48a	35.82b	5.63ab
BN ₂	63.18b	0.262b	13.840b	79.05b	17.51a	43.83a	2.54a	37.24c	5.88a
BP ₀	59.51a	0.298a	13.244a	76.68a	16.10a	45.65a	2.41a	35.22b	5.26b
BP ₁	60.40a	0.293a	13.245a	76.88a	16.51a	44.31a	2.49a	35.79ab	5.54a
BP ₂	62.14a	0.278a	13.460a	78.26a	17.07a	43.74a	2.48a	36.65a	5.80a

Means in each column, which have at least one common letter are not significantly different at the 5% level of probability (by Duncan’s test).
N₀, N₁ and N₂= 0, 45 and 90 kg ha⁻¹, respectively; BP₀, BP₁ and BP₂= 0, 0.5, 1 L ha⁻¹, respectively.
P₀, P₁ and P₂= 0, 40, 80 kg ha⁻¹, respectively; BN₀, BN₁ and BN₂= 0, 0.5, 1 L ha⁻¹, respectively.

effects of nitrogen on sunflowers. They showed there is a direct relationship between nitrogen and the 100-grain weight, which is consistent with our current study.

The comparison of Nitroxin and Biophosphorus rates showed that the increase of bio-fertilizers from 0 to 1 L ha⁻¹ increases the 1000-grain weight. Effects of nitrogen and phosphorous bio-fertilizers on the 1000-grain weight were significant at 1 and 5% probability levels, respectively (Table 2). The application of bio-fertilizers considerably increases 1000-grain weight of sunflower (Gharali and Nasrollahzadeh, 2018). The group comparison in Table 2 also showed that there is no significance difference between the chemical and bio-fertilizer treatments in terms of 1000-grain weight. The maximum 1000-grain weight as expressed in Table 4 was obtained for N₂P₂ treatment (65.33 g) of the chemical treatments and BN₂BP₂ treatment (65.0 g) of the bio-fertilizer treatments.

Hull-Kernel ratio

The variance analysis results showed the effect of chemical nitrogen and Nitroxin on the Hull-Kernel ratio was significant at a 1% probability level (Table 2). The variance

analysis from the group comparison of the chemical treatments with the bio-fertilizer treatments did not show a significant difference (Table 2). The maximum Hull-Kernel ratio was found in the N₀P₀ treatment (0.306) between the chemical treatments (except, N₁P₀ =0.32) and the BN₀BP₀ treatment (0.32) between the bio-fertilizer treatments (Table 4). Since the main purpose of sunflower cultivation is oil extraction, the use of fertilizers can reduce the ratio of the hull to the kernel in this plant and increase oil yield production (Akbari *et al.*, 2009). The highest hull-kernel ratio is related to the control treatment and other treatments followed a downward trend (Javanmard and Shekari, 2016), which is consistent with the results of the present study.

Plant dry weight

According to Table 2, the effect of applying chemical nitrogen and phosphorous rates on the dry weight shows a very significant difference at a 1% probability, and a significant difference at a 5% probability is also observed for bio-fertilizer containing nitrogen-fixing bacteria. The maximum dry weight (14.52 t ha⁻¹) was noticed in the N₂P₂ treatment (Table 4). The comparison of means showed that a

Table 4. The mean comparison of chemical fertilizer and bio-fertilizer treatments

Treatments	1000-grain weight (g)	Hull-Kernel ratio	Plant dry weight (t ha ⁻¹)	Kernel percentage	Oil percentage	Oil yield (t ha ⁻¹)	Harvest index (%)	Grain yield (t ha ⁻¹)
Chemical fertilizer								
N ₀ P ₀	56.66	0.306	12.54	76.60	46.30	2.24	33.88	4.84
N ₀ P ₁	59.55	0.293	12.48	77.31	45.54	2.34	35.67	5.15
N ₀ P ₂	59.22	0.292	12.68	77.43	45.44	2.44	36.28	5.38
N ₁ P ₀	58.66	0.320	12.66	77.78	45.43	2.39	37.61	5.26
N ₁ P ₁	60.78	0.284	12.70	77.88	45.24	2.42	35.91	5.36
N ₁ P ₂	64.44	0.269	13.69	78.78	44.46	2.46	37.28	5.55
N ₂ P ₀	58.78	0.260	14.34	79.41	44.03	2.43	36.86	5.53
N ₂ P ₁	63.05	0.238	13.73	80.84	42.56	2.46	34.70	5.68
N ₂ P ₂	65.33	0.232	14.52	81.12	41.93	2.55	37.82	5.90
Bio-fertilizer								
BN ₀ BP ₀	55.66	0.320	12.40	75.68	46.21	2.22	34.25	4.81
BN ₀ BP ₁	58.33	0.317	13.29	74.63	44.83	2.48	34.15	5.53
BN ₀ BP ₂	61.89	0.310	12.32	75.60	43.97	2.39	35.40	5.44
BN ₁ BP ₀	60.00	0.294	13.11	76.79	46.00	2.41	34.75	5.25
BN ₁ BP ₁	61.21	0.288	13.54	77.07	44.95	2.55	36.11	5.68
BN ₁ BP ₂	59.55	0.281	13.64	78.01	43.66	2.50	36.62	5.70
BN ₂ BP ₀	62.89	0.278	14.21	77.57	44.83	2.59	36.68	5.81
BN ₂ BP ₁	61.66	0.275	13.56	78.41	43.16	2.46	37.12	5.70
BN ₂ BP ₂	65.00	0.230	13.76	81.16	43.58	2.57	37.92	5.90

N₀, N₁ and N₂= 0, 45 and 90 kg ha⁻¹, respectively; BP₀, BP₁ and BP₂= 0, 0.5, 1 L ha⁻¹, respectively.
P₀, P₁ and P₂= 0, 40, 80 kg ha⁻¹, respectively; BN₀, BN₁ and BN₂= 0, 0.5, 1 L ha⁻¹, respectively.

rise in Nitroxin and Biophosphorus levels (0 to 1 L ha⁻¹) increases the dry weight (Table 3). The maximum dry weight (14.21 t ha⁻¹) was obtained for the bio-fertilizer treatment i.e. BN₂BP₀ treatment combination (Table 4). Kandil *et al.* (2004) reported that the use of biological fertilizers in sugar beet significantly increased plant dry weight. Zarei *et al.* (2012) stated that bio-fertilizers had a positive impact on plant growth and increased plant dry weight.

Kernel percentage

The effect of various chemical nitrogen and Nitroxin rates on the kernel percentage was significant (P=0.01) (Table 2). However, the effect of various rates of chemical phosphorous and Biophosphorus was not significant. The comparison of means for the chemical fertilizers and bio-fertilizers revealed that by increasing their rates of application, the kernel percentage showed an increasing trend (Table 3). The maximum kernel percentage, obtained for the chemical and biological treatments, was that of the N₂P₂ and BN₂BP₂ combination

treatments with the average values of 81.12 and 81.16, respectively, and the minimum number of kernel percentage was found in N₀P₀ (76.6%) and BN₀BP₀ (75.68%) control treatments (Table 4). The group comparisons between the chemical and bio-fertilizer treatments didn't show a significant difference (Table 2). Roshdi *et al.* (2009) reported that the use of nitrogen fertilizers increases the percentage of grain kernels in sunflower cultivars due to the availability of nutrients. Abbasdokht *et al.* (2017) found that increasing the level of N fertilizer from 60 to 120 kg ha⁻¹ increased the kernel percentage.

Harvest index

Results of the variance analysis of the effect of chemical nitrogen and phosphorous on the harvest index (HI) were significant (p=0.05) (Table 2). The maximum HI was obtained for chemical nitrogen @ 45 kg ha⁻¹ treatment (36.39%), while the minimum was @ 0 kg N ha⁻¹ treatment (35.28%) (Table 3). The effect of various nitrogen and phosphorous bio-

fertilizers on HI was significant at 1 and 5% probability levels, respectively (Table 2). The comparison of average the HI also showed that this index increased with the rising of the Nitroxin and Biophosphorus levels (0 to 1 L ha⁻¹) (Table 3). A study by Raissi *et al.* (2012), reported the use of phosphate-solubilizing bacteria increases the HI of corn by increasing grain yield, as compared to biological yield. Therefore, it can be stated that growth-promoting bacteria increase the harvest index by influencing the apportionment of shrub dry weight and allocating more dry weight to the grain, which is consistent with the results of the present study. Phosphate solubilizing bacteria increase plant growth through the production of plant hormones such as indole acetic acid, in this way, they affect the early stages of plant growth and the roots occupy a larger volume of soil, then root surface increases for nutrients uptake (Mehnaz and Lazarovits, 2006). The chemical fertilizer treatments compared with the bio-fertilizers treatments did not show a significant difference at a 5% probability (Table 2). The maximum HI belongs to the N₂P₂ treatment (37.82%) among the chemical treatments and the BN₂BP₂ treatment (37.92%) among the bio-fertilizer treatments (Table 4).

Grain protein percentage

The variance analysis implies the effect of chemical nitrogen and phosphorus on the protein percentage was significant at a 5% probability, whereas their interaction effects were not significant. The results showed that rises of nitrogen and phosphorus level from 0 to 90 kg ha⁻¹ and 0 to 80 kg ha⁻¹, respectively, increases the grains' protein percentage (Table 3). Different studies (Li *et al.*, 2017; Mojaddam, 2017) reported similar results showing nitrogen fertilizers significantly affect the protein content and increase its value (Li *et al.*, 2017) and increase grain yield and protein percentage (Mojaddam, 2017). Adding chemical P increased sunflower protein content which could be due to improved N uptake by the crop because of P's role in root development. Sharma (2002) reported that one of the advantages of feeding the plants with phosphorus is to create deeper and more abundant roots. Phosphorus causes early ripening in plants, decreasing grain moisture, and improving crop quality (Malakooti, 2000)

The variance analysis illustrated the effect of various Nitroxin on protein percentage was significant (P=0.05). Although the increase in the Biophosphorus level rises the protein percentage, the results were not statistically significant. The results showed that the increase in Nitroxin and Biophosphorus from 0 to 1 L ha⁻¹ leads to an increase in the grain protein content (Table 3). In general, it can be concluded that the synergistic effect of bio-fertilizers, may have resulted from their ability to increase the availability of N and P in soil, which causes improved seed quality (Saeidi *et al.*, 2018).

The variance analysis from the group comparison of chemical treatments showed a very significant difference (P=0.01) compared with the bio-fertilizer treatments. It indicates that the bio-fertilizer treatments (with a mean of 16.56%) increase the protein content at a lower rate compared with the chemical treatments (with a mean of 17.67%) (Table 3). The maximum protein percentage was obtained for N₂P₂ treatment (19.2%) between the chemical treatments and the BN₂BP₂ treatment (18.32%) for the bio-fertilizer treatments (Table 5).

Grain oil percentage

Results of the effect of chemical nitrogen dose on sunflower grain oil percentage were significant (P=0.05) (Table 2). The result showed an increase in nitrogen and phosphorus level in both chemical and biological sources, ultimately showing a decreasing trend in the grain oil percentage (Table 3). Investigating the effect of fertilizer treatments and the qualitative characteristics of sunflower, Khodaei-Joghan *et al.* (2017) reported a negative significant correlation between the protein percentage and the grain oil percentage. The physiological reason for a negative correlation between oil and protein synthesis is the competition for carbon during the metabolism of carbohydrates because the amount of carbohydrates required for protein synthesis is lower than that of oil synthesis. Therefore, the employment of nitrogen fertilizer increases the synthesis of proteins compared to the synthesis of fatty acids (Mohammadi *et al.*, 2013). The result found that the increase of the Nitroxin and Biophosphorus from 0 to 1 L ha⁻¹ resulted in reduced grain oil percentage (Table 3). The oil reduction from the abundant application of chemical nitrogen fertilizers has been reported in other studies.

Table 5. The average interaction effect of chemical fertilizer and bio-fertilizer treatments on the protein percentage

Treatments	Protein Percentage
Chemical fertilizer	
N ₀ P ₀	15.65de
N ₀ P ₁	16.33abcde
N ₀ P ₂	17.60abcde
N ₁ P ₀	16.37abcde
N ₁ P ₁	18.50abc
N ₁ P ₂	18.87ab
N ₂ P ₀	17.90abcde
N ₂ P ₁	18.39abcd
N ₂ P ₂	19.20a
Bio-fertilizer	
BN ₀ BP ₀	15.33e
BN ₀ BP ₁	15.52de
BN ₀ BP ₂	15.82cde
BN ₁ BP ₀	16.14cbde
BN ₁ BP ₁	16.63abcde
BN ₁ BP ₂	17.07abcde
BN ₂ BP ₀	16.85abcde
BN ₂ BP ₁	17.36abcde
BN ₂ BP ₂	18.32abcd

Dissimilar letters indicate significant differences at the 5% level.
N₀, N₁ and N₂= 0, 45 and 90 kg ha⁻¹, respectively;
BP₀, BP₁ and BP₂= 0, 0.5, 1 L ha⁻¹, respectively;
P₀, P₁ and P₂= 0, 40, 80 kg ha⁻¹, respectively;
BN₀, BN₁ and BN₂= 0, 0.5, 1 L ha⁻¹, respectively.

For example, Munir *et al.* (2007) found that the minimum oil percentage exists in an integrated treatment and the maximum oil percentage is in the control treatment. The variance analysis from the group comparison of the chemical treatments with the bio-fertilizer treatments did not show a significant difference (Table 2). The maximum grain oil amount was in the N₀P₀ treatment (46.3%) between the chemical treatments and the BN₀BP₀ treatment (46.21%) between the bio-fertilizer treatments (Table 4). Comparing the bio-fertilizer and chemical treatments does not show any significant difference (P=0.05) (Table 2). Yousefpoor and Youdi (2014) reported the increase of chemical fertilizers initially increases the oil percentage to a certain extent but eventually decreases.

Grain oil yield

The result showed that the increase of the chemical nitrogen and phosphorus does not

significantly change grain oil yield, though oil yield showed an increasing trend. The group comparison of chemical treatments with the bio-fertilizer treatments does not show a statistically significant difference (Table 2). More details have been provided in Zamanian and Yazdandoost (2021). When nitrogen increased, grain protein content and oil yield increased; however, grain oil percentage decreased (Ali and Ullah, 2012; Heidari and Bagheri, 2016). Rastgo *et al.* (2014) reported that the application of nitrogen fertilizers causes the oil percentage reduction and increases the oil yield and grain protein percentage in safflower, which is consistent with the results of the present study.

Grain yield

Table 2 showed that the effect of various amounts of bio-fertilizer on grain yield was significant with 5 and 1% probability for the Nitroxin and Biophosphorus, respectively. The use of nitrogen and phosphorus from chemical and biological sources increased grain yield (Table 3). More details have been provided in Zamanian and Yazdandoost (2021). Fazeli *et al.* (2012) reported that the use of phosphate solubilizing bacteria in sesame plants has significantly increased seed yield and yield components compared to the control treatment. Hashemi and Mojaddam (2015) showed that both triple superphosphate fertilizer and Barvar2 bio-fertilizer significantly increase the grain yield. Investigations declared that the results of the present study are consistent with those of previous studies brought about in the related fields. Higher seed and stalk yields of sunflower obtained with different treatments were mainly due to improvement in yield components (Thavyaprakash and Senthilkumar, 2003).

Correlation analysis of characteristics

Evaluating the correlation between the measured characteristics comprising grain yield, oil yield, oil percentage, protein percentage, thousand-grain weight, hull-kernel ratio, kernel percentage, plant dry weight, and the grain yield showed a positive correlation between harvest index and all assessed characteristics, except for hull-kernel ratio and oil percentage. As evident in Table 6, the oil yield characteristic (0.95) has the highest rate of positive and significant correlation with grain yield. The results showed a significant

Table 6. Correlation analysis of characteristics for the chemical fertilizer and bio-fertilizer treatments

Treatments	1	2	3	4	5	6	7	8	9	
1000-grain weight	1	1								
Hull-Kernel ratio	2	-0.74**	1							
Plant dry weight	3	0.60**	-0.78**	1						
Kernel percentage	4	0.68**	-0.93**	0.66**	1					
Protein percentage	5	0.73**	-0.85**	0.61**	0.86**	1				
Oil percentage	6	-0.70**	0.69**	-0.67**	-0.65**	-0.60**	1			
Oil yield	7	0.75**	-0.60**	0.75**	0.48*	0.54*	-0.64**	1		
Harvest index	8	0.61**	-0.52*	0.53*	0.64**	0.65**	-0.53*	0.61**	1	
Grain yield	9	0.81**	-0.70**	0.80**	0.60**	0.62**	-0.84**	0.95**	0.64**	1

positive correlation between oil yield and the 1000-grain weight (Buttar and Uppal, 1998), kernel percentage, plant dry weight, protein percentage, grain yield, and harvest index characteristics. The highest negative correlation was found between the hull-kernel ratio and kernel percentage (-0.93). The harvest index also showed a significant negative correlation with the oil percentage and hull-kernel ratio characteristics.

Conclusion

The excessive application of chemical fertilizers is leading to environmental and health problems. Using bio-fertilizers leads to establishing pollution-free, environmentally friendly, and sustainable agriculture systems. The results based on a one-year study showed that the protein percentage was most promising for 80 kg of pure phosphorous per hectare, compared with all other rates. Furthermore, the 1 L per hectare of Nitroxin fertilizer exhibited the most suitable for the thousand-grain weight and harvest index characteristics. Also, 90 kg of pure nitrogen per hectare was the best for the plant's dry weight and kernel percentage characteristics. The effect of fertilizer treatments showed a significant negative correlation between the protein percentage and the grain oil percentage. Furthermore, the application of *Azotobacter* and *Azospirillum* with and without *Pseudomonas* and *Bacillus* increased the 1000-grain weight, plant dry weight, kernel percentage, protein percentage, oil yield, grain yield, and harvest index. Among all experimental characteristics, the interactions between chemical fertilizer and bio-fertilizer treatments were significant only for grain protein percentage. This study strongly supports the positive impact of

nitrogen-fixing and phosphate-solubilizing bio-fertilizers on grain yield and harvest index. To better identify the efficiency of fertilizers in different conditions for future research, we suggest a change in the fertilizer amount and more diverse sources of chemical fertilizers and bio-fertilizers.

References

Abbasdokht, H., Afshari, H., Oji, E. and Taheri, S.H. 2017. Effect of seed priming and different levels of nitrogen application on quantitative and qualitative yield of sunflower (progress cultivar). *Journal of Crop Physiology* 8(29): 105-120.

Adeniji, A.A., Loots, D.T. and Babalola, O.O. 2019. *Bacillus velezensis*: Phylogeny, useful applications, and avenues for exploitation. *Applied Microbiology and Biotechnology* 103(9): 3669-3682.

Ahmad, A.G., Orabi, S. and Gaballah, A. 2010. Effect of Bio-N-P fertilizer on the growth, yield and some biochemical component of two sunflower cultivars. *International Journal of Academic Research* 4(2): 271-277.

Akbari, P., Ghalavand, A. and Modarres Sanavi, S.A.M. 2009. Effects of different nutrition systems (organic, chemical and integrated) and biofertilizer on yield and other growth traits of sunflower (*Helianthus annuus* L.). *Journal of Sustainable Agriculture and Production Science* 1(19): 83-93.

Ali, A. and Ullah, S. 2012. Effect of nitrogen on achene protein, oil, fatty acid profile, and yield of sunflower hybrids. *Chilean Journal Agricultural Research* 72(4): 564-567.

Ardakani, M.R., Mazaheri, D., Mafakheri, S. and Moghaddam, A. 2011. Absorption efficiency of N, P, K through triple inoculation of wheat (*Triticum aestivum* L.) by *Azospirillum brasilense*, *Streptomyces* sp., *Glomus* intraradices and manure application. *Physiology and Molecular Biology of Plants* 17(2): 181-192.

Azarpour, E., Moradi, M. and Bozorgi, H.R. 2012. Effects of vermicompost application and seed

- inoculation with biological nitrogen fertilizer under different plant densities in soybean [*Glycine max* (L.) cultivar, Williams]. *African Journal of Agricultural Research* 7(10): 1534-1541.
- Bahamin, S., Sohrab, M., Mohammad, A.B., Behroz, K.T. and Qorbanali, A. 2014. Effect of biofertilizer, manure and chemical fertilizer on yield and reproductive characteristics of sunflower. *International Journal of Environmental and Agriculture Research* 3(1): 36-43.
- Banari, M., Fathia, G., Gharineh, M.H., Abdali, A. and Yazdan Penah, S. 2015. The effect of bio-fertilizer (Phosphate Barvar2) on the yield and yield components of bread wheat and durum in Ahvaz region. *Scientific Journal of Crop Science* 4 (4): 43-49.
- Buttar, G.S. and Uppal, H.S. 1998. Correlation and path coefficient studies in sunflower. *Annals of Arid Zone* 37(1): 83-87.
- Farnia, A. and Moayedi, M. 2015. Study on some morphological characteristics and phonological stages of sunflower (*Heliantus annuus* L.) under application of bio-fertilizers. *International Journal of Biosciences* 6(5): 317-323.
- Fazeli, S.F., Nezami, A., Parsa, M. and Kafie, M. 2012. Evaluated of yield and yield component in 43 variety of sesame in state of saline. *Iranian Journal of Field Crops Research* 3: 378-386.
- Forleo, M.B., Palmieri, N., Suardi, A., Coaloa, D. and Pari, L. 2018. The eco-efficiency of rapeseed and sunflower cultivation in Italy. Joining environmental and economic assessment. *Journal of Cleaner Production* 172: 3138-3153.
- Gharali, A. and Nasrollahzadeh A.A. 2018. The effect of application using nitragin and nitroxin biofertilizers on reduce the use of nitrogen chemical fertilizer in sunflower cultivation (*Helianthus annuus* L.). *Environment Conservation Journal* 19(1&2): 39-46.
- Hashemi, S.M. and Mojaddam, M. 2015. The effects of triple superphosphate fertilizer and biological phosphate fertilizer (fertile 2) on yield and yield components of sesame in Hamidiyeh weather conditions. *Indian Journal of Fundamental and Applied Life Sciences* 5(1): 2231-6345.
- Heidari, M. and Bagheri, A. 2016. Effect of different rates of nitrogen and zinc fertilizers on qualitative and quantitative characteristics of sunflower seeds. *Journal of Crop Production and Processing* 5(18): 29-277.
- Jami, M.G., Ghalavand, A., Modarres-Sanavy, S.M.A. and Mokhtassi-Bidgoli, A. 2017. Evaluation of agronomic characteristics and seed quality of sunflower in response to different regimes of nitrogen, irrigation and zeolite. *Journal of Crops Improvement* 9(4): 1011-1031.
- Javanmard, A. and Shekari, F. 2016. Improvement of seed yield, its components and oil content of sunflower (*Helianthus annuus* L.) by applications of chemical and organic fertilizers. *Journal of Crop Ecophysiology* 10(37(1)): 35-56.
- Kandil, A., Badawi, M.A., El-Mursy, S.A. and Abdou, U.M.A. 2004. Effect of planting dates, nitrogen levels and biofertilization treatments on growth attributes of suger beet (*Beta vulgaris* L.). *Scientific Journal of King Faisal University (Basic and Applied Sciences)* 5(2): 227-236.
- Khandekar, S.D., Ghotmukale, A., Dambale, A.S. and Suryawanshi, S.B. 2018. Response of Kharif sunflower to biofertilizers and different fertilizer levels. *International Journal of Current Microbiology and Applied Sciences* 6: 1558-1563.
- Khodaei-Joghan, A., Aghaalikhani, M., Gholamhoseini, M., Atae, R., Sorooshzadeh, A. and Ghalavand, A. 2017. Effect of fertilizer treatments and irrigation regimes on seed yield and seed quality characteristics of sunflower. *Crops Improvement* 20(1): 219-233.
- Kiani, M.Z., Arshad, A., Tariq, S. and Ishtiaq, H. 2016. Economic analysis of biofertilizer inoculation for sunflower (*Helianthus annus* L.) production under saline sodic conditions. *Journal of Agricultural Research (Lahore)* 54(3): 395-406.
- Li, W.P., Shi, H.B., Zhu, K., Zheng, Q. and Xu, Z. 2017. The quality of sunflower seed oil changes in response to nitrogen fertilizer. *Agronomy Journal* 109(6): 2499-2507.
- Malakooti, M.J. 2000. *Sustainable Agriculture and Yield Increment by Optimum Fertilizer Utilization in Iran*, 2nd Ed. Agricultural Extension Publications, Iran.
- Mehmood, A., Saleem, M.F., Tahir, M., Sarwar, M.A., Abbas, T., Zohaib, A. and Abbas, H.T. 2018. Sunflower (*Helianthus annuus* L.) growth, yield and oil quality response to combined application of nitrogen and boron. *Pakistan Journal of Agricultural Research* 31(1): 86-97.
- Mehnaz, S. and Lazarovits, G. 2006. Inoculation effects of *Pseudomonas putida*, *Gluconacetobacter azotocaptans* and *Azospirillum lipoferum* on corn plant growth under greenhouse conditions. *Microbial Ecology* 51: 326-335.
- Moghimi, F., Yousefirad, M. and Karimi, M. 2012. Effects of nitroxin biological fertilizer and EDTA on nitrogen concentration, yield and yield components of safflower (Mexican cultivar). *Annals of Biological Research* 3(12): 5724-5728.
- Mohammadi, K., Heidari, G., Javaheri, M., Rokhzadi, A., Karimi Nezhad, M.T., Sohrabi, Y. and Talebi, R. 2013. Fertilization affects the agronomic traits of high oleic sunflower hybrid in different tillage systems. *Industrial Crops and Products* 44: 446-451.
- Mojaddam, M. 2017. Effect of drought stress on physiological characteristics and seed yield of sunflower at different rates of nitrogen. *Journal of Crop Production* 9(4): 121-136.

- Munir, M.A., Malik, M.A. and Saleem, M.F. 2007. Impact of integration of crop manuring and nitrogen application on growth, yield and quality of spring planted sunflower (*Helianthus annuus* L.). *Pakistan Journal of Botany* 39(2): 441-449.
- Raei, Y., EshaghiSardrood, S.N., BagheriPirooz, A. 2013. The effects of chemical and biological fertilizers application on forage sorghum (*Sorghum bicolor* L.) yields of different harvests. *Bumshenasi Keshavarzi Journal* 5(3): 231-242.
- Raissi, A., Galavi, M., Ramroudi, M., Mousavi, S. and Rasoulizadeh, M. 2012. Effects of phosphate bio-fertilizer, organic manure and chemical fertilizers on yield, yield components and seed capabilities of Isabgol (*Plantago ovate*). *International Journal of Agriculture and Crop Sciences* 24: 1821-1826.
- Rastgo, B., Ebadie, A. and Parmoon, G.H. 2014. Investigation the effect of using nitrogen on yield and storage compositions of safflower grain (*Carthamus tinctorius* L.). *Crop Physiology Journal* 6(21): 85-102.
- Roshdi, M., Doust Sanam, R., Khalili Mahaleh, J. and Haji Hasani Asl, N. 2009. Effects of plant density and defoliation during development stages on yield and yield components of sunflower. *Agroecology Journal (Journal of New Agricultural Science)* 5(15): 41-54.
- Saeidi, M., Raei, Y., Amini, R., Taghizadeh, A. and Pasban-Eslam, B. 2018. Changes in fatty acid and protein of safflower as response to biofertilizers and cropping system. *Turkish Journal of Field Crops* 23(2): 117-126.
- Shabani, G., Ardakani, M.R., Chaichi, M.R., Friedel, J.K. and Khavazi, K. 2015. Effect of different fertilizing treatments on nutrient uptake in annual medic (*Medicago scutellata* cv. Robinson) under irrigated and dry farming systems. *Journal of Agricultural Science and Technology* 17: 299-310.
- Sharma, AK. 2002. *Bio-fertilizers for Sustainable Agriculture*. Agrobios Indian Publications.
- Sinha, R.K., Valani, D., Chauhan, K. and Agarwal S. 2010. Embarking on a second green revolution for sustainable agriculture by vermiculture biotechnology using earthworms: Reviving the dreams of Sir Charles Darwin. *Journal of Agricultural Biotechnology and Sustainable Development* 2(7): 113-128.
- Thavaprakash, N. and Senthilkuma, G. 2003. Stem diameter and head diameter in relation to yield of sunflower as influenced by nitrogen and phosphorus fertilizers. *Annals of Arid Zone* 42(2): 193-196.
- Vyas, S.P. 2005. Interactive effects of nitrogen and bio-fertilizers on Indian mustard. *Annals of Arid Zone* 44: 147-150.
- Yadav, B.K., Niwas, R., Yadav, R.S. and Tarafdar, J.C. 2009. Effect of Chaetomium globosum inoculation and organic matter on phosphorus mobilization in soil and yield of clusterbean. *Annals of Arid Zone* 48: 41-44.
- Yadav, S., Yadav, J. and Singh, S.G. 2011. Performance of Azospirillum for improving growth, yield and yield attributing characters of maize (*Zea mays* L.) in presence of nitrogen fertilizer. *Research Journal of Agricultural Sciences* 2(1): 139-141.
- Yousefpoor, Z.A. and Youdi, R. 2014. Effect of nitrogen and phosphorus bio chemical fertilizers on quantitative and qualitative yield of sunflower. *Journal of Agricultural Knowledge and Sustainable Production* 1: 96-112.
- Zamanian, M. and Yazdandoost, M. 2021. Influence of chemical fertilizers and bioinoculants on growth and yield of sunflower (*Helianthus annuus* L.). *Journal of Central European Agriculture* 22(2): 317-328.
- Zarabi, M., Alahdadi, I., Akbari, G.A. and Akbari, G.A. 2011. A study on the effects of different biofertilizer combinations on yield, its components and growth indices of corn (*Zea mays* L.) under drought stress conditions. *African Journal of Agricultural Research* 6(3): 681-685.
- Zarei, I., Sohrabi, Y., Heidari, G.R., Jalilian, A. and Mohammadi, K.H. 2012. Effects of biofertilizers on grain yield and protein content of two Soybean (*Glycine max* L.) cultivars. *African Journal of Biotechnology* 11(27): 7028-7037.

