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Influence of different sources of nitrogen fertilizer and weed control on yield, yield components and some qualitative traits of chickpea (*Cicer arietinum* L.) cultivars under dryland conditions of Khorramabad

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Abstract: A field experiment was conducted to evaluate yield, yield components, and some qualitative traits of chickpea (*Cicer arietinum* L.) cultivars under nitrogen fertilizers and weed control in dryland conditions of Khorramabad during the 2017 - 2018 growing season. Treatments were arranged in split-split-plot based on a randomized complete block design with three replications. The main factor included F1: control (without fertilizer); F2: bio-fertilizer (*Rhizobium*); F3: 100 % chemical fertilizer and F4: integration of bio-fertilizer + 50 % chemical fertilizer; sub-factor consisted of three cultivars of chickpea (Adel, Mansour, and Arman) and sub-sub-factor included weeds control (weeding) and weed infested (non-weeding). The results indicated that nitrogen fertilizers, especially the integration of bio-fertilizer + 50 % chemical fertilizer, had a positive effect on all studied traits. The highest number of pods per plant, grain yield, and biological yield were obtained from the Arman cultivar with the application of bio-fertilizer + 50 % chemical fertilizer and for the same cultivar under weed control conditions. The maximum number of pods per plant (28.2) and amount of grain protein content (25.3 %) were obtained by integrating of bio-fertilizer + 50% nitrogen chemical fertilizer and weeds control. In general, the Arman cultivar has priority over other cultivars for the grain yield under Khorramabad climate conditions, and integration of bio-fertilizer + 50 % chemical fertilizer could be considered as a means to reduce the consumption of chemical fertilizers for sustainable agriculture.

Key words: chickpea; grain protein; grain yield; hectoliter mass; *Rhizobium*; weed control

Vpliv različnih dušikovih gnojil in uravnavanja plevelov na pridelek, komponente pridelka in kakovostne lastnosti sort čičerke (*Cicer arietinum* L.) v sušnih razmerah Khorramabada

Izvleček: Za ovrednotenje pridelka, njegovih komponent in nekaterih kakovostnih lastnosti sort čičerke (*Cicer arietinum* L.) je bil izveden poljski poskus z gnojenjem z različnimi dušikovimi gnojili in načini zatiranja plevelov v sušnih razmerah Khorramabada v rastnih sezonah 2017 in 2018. Obravnavanja so bila izvedena kot popolen naključni bločni poskus z deljenkami s tremi ponovitvami. Glavna obravnavanja so bila: F1: kontrola (brez gnojil); F2: biognojila (*Rhizobium*); F3: 100 % mineralna gnojila in F4: integracija biognojil + 50 % mineralnih gnojil. Podobravnavanja so obsegala tri sorte čičerke (Adel, Mansour in Arman) in dva načina uravnavanja plevelov (zatiranje, kontrola). Rezultati so pokazali, da je imelo gnojenje z dušikovimi gnojili, še posebej hkratna uporaba biognojil z dodatkom 50 % mineralnih gnojil, pozitiven učinek na vse preučevane lastnosti. Največje število strokov na rastlino, največji pridelek zrnja in biološki pridelek so bili doseženi pri sorti Arman pri uporabi biognojil z dodatkom 50 % mineralnih gnojil in zatiranju plevelov. Podobno sta bila največje število strokov na rastlino (28,2) in največja vsebnost beljakovin v zrnju (25,3 %) dosežena pri hratni uporabi biognojil in 50 % mineralnih dušikovih gnojil in zatiranju plevelov. V splošnem se je sorta Arman izkazala v pridelku zrnja boljše kot ostale v podnebnih razmerah Khorramabada in hkratno uporabo biognojil z dodatkom 50 % mineralnih gnojil lahko smatramo kot primeren način gnojenja za zmanjševanje porabe mineralnih gnojil v trajnostnem kmetijstvu.

Ključne besede: čičerka; beljakovine v zrnju; pridelek zrnja, hektoliterska masa; *Rhizobium*, pletev

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1 INTRODUCTION

Chickpea (*Cicer arietinum* L.) is the third main grain legume in the world, with an annual global production of 14.24 million tons from an area of 14.79 million ha (FAO, 2018). It is an essential component of the agricultural system in all over Iran, because this crop fits well in rotation patterns and can grow under low fertility and different soil and climate conditions. The main provinces producing chickpeas in Iran are Lorestan and Kermanshah (Mekuanint et al., 2018). The potential yield of chickpea cultivars is approximately 4 t ha^{-1}, while the average national yield is about 533 kg ha^{-1} (Khorsandi et al., 2016). The gap between actual and potential yields is mainly due to poor crop management such as imbalanced use of fertilizer, the lack of effective rhizobial strain, unavailability of high-quality seeds, and also damages caused by pests and diseases (Togay et al., 2008; Mekuanint et al., 2018). Moreover, Iran has nitrogen deficient soil and therefore, plants use a low amount of nitrogen which affects physiological processes and decreases photosynthesis activities, production of assimilate and biomass, and eventually yield (Ghilavizadeh et al., 2013).

Application of chemical fertilizers, especially macronutrients, can generally increase biomass production by 2-3 times (Elliott and Abbott, 2003), that is the reason why farmers are applying high amounts of chemical fertilizers, which are very costly and hazardous to the environment. Therefore, alternative sources of chemical fertilizers and the application of organic fertilizers (e.g., bio-fertilizers) are considered as options for sustainable agriculture to improve soil quality in modern agriculture (Chen et al., 2014; Meena et al., 2015). The utilization of bio-fertilizer (e.g., *Rhizobium* species) has become of paramount importance in the agriculture for their potential role in food safety, improving crop yield, and decreasing greenhouse gas emissions (Ghilavizadeh et al., 2013; Raei et al., 2015). The absence of compatible strains and low population of *Rhizobium* in the soil are essential limitations for nodule formation in chickpea (Kantar et al., 2010; Wolde-Meskel et al., 2018). Inoculation with effective strains at planting time is recommended if the population density of compatible rhizobia is less than 50 cells per gram of soil (Thies et al., 1991a, b; Wolde-Meskel et al., 2018). Previous studies showed that inoculation of chickpea seeds with *Rhizobium* could increase plant growth, grain yield, and biomass yield (Funga et al., 2016; Khaitov et al., 2016; Tena et al., 2016; Wolde-Meskel et al., 2018).

The weak ability of chickpea crops to compete with weeds is a vital issue in low input and organic farming systems (Melander, 1993). The critical period of weed interference in chickpea is 15 to 60 days after sowing in Iran, and the presence of weed at this time can cause severe loss of the yield (Mohammadi et al., 2005; Gupta et al., 2016). Hence, weed control needs to be undertaken during the initial periods of chickpea growth. Hand weeding is a well-proven effective method of weed control in chickpea fields in Iran. But implementation of this method is costly for farmers and can be used on small farms (Mohammadi et al., 2005). Mousavi (2010) reported that by twice weeding, the grain yield of chickpea was significantly increased (by 174 %) compared to weed infested treatment. The objective of this study was to determine the effects of bio-fertilizer and weed control and their interactions on yield, yield components, and some qualitative traits of chickpea in Khorramabad condition.

2 MATERIALS AND METHODS

2.1 LOCATION AND PLANT MATERIALS

This study was conducted in the Experimental Farm of the Pole Baba Hossein, Khorramabad, Iran (33°25′N, 48°19′E, and altitude 1,171 m), during the 2017 - 2018 growing season. The meteorological data during the experimental period are presented in Table 1. Physical and chemical characteristics of soil at the depth of 0-40 cm are shown in Table 2. Chickpea seeds were planted in early January 2018 in plots, consisting

Table 1: Khorramabad meteorological station monthly statistics in the experiment period

Month	Precipitation (mm)	Maximum temperature (°C)	Minimum temperature (°C)	Average temperature (°C)
Jan	50.1	23.5	- 4.3	7.6
Feb	68.7	21.6	- 4.3	8.3
Mar	62.7	23.5	1.1	11.7
Apr	103.7	30.3	3.3	15.2
May	151.7	30.0	5.6	17.2
Jun	12.1	37.0	11.8	24.6

of six 2-meter rows spaced 30 cm apart. The intra-row plant spacing was 10 cm. Hand weeding was done in weed control treatments during the growing season.

2.2 TREATMENTS AND EXPERIMENTAL DESIGN

The experiment was conducted as split-split-plot based on Randomized Complete Blocks Design (RCBD) with three replications. The main factor included F1: control (without application of fertilizer); F2: bio-fertilizer (*Rhizobium*); F3: 100 % nitrogen chemical fertilizer and F4: integration of bio-fertilizer + 50 % nitrogen chemical fertilizer. Sub-factor consisted of chickpea cultivars (Adel, Mansour, and Arman), and sub-sub-factor included weed control (weeding) and weed infestation (non-weeding).

2.3 FERTILIZER AND MICROBIAL INOCULA

Before cultivation, 100 kg ha^{-1} triple superphosphate was added to all plots according to the soil test. With the last plowing before planting, 50 and 25 kg N ha^{-1} as urea were added to 100 % chemical fertilizer and integration of bio-fertilizer + 50 % chemical fertilizer, respectively. The strain of the used *Rhizobium* bio-fertilizer was *Mesorhizobium* ciceri SWRI-3 which consisted of 10^8 colony forming units/ml (CFU ml^{-1}) inoculant and was purchased from Soil and Water Research Institute, Karaj, Iran. Before planting, the seeds were mixed entirely with bio-fertilizer and kept for half an hour in the shade to dry. The liquid bio-fertilizer (*Rhizobium*) was applied at the amount of 2 l ha^{-1}. The dried seeds were planted in early January.

2.4 TRAITS MEASUREMENT

The traits measured in this study included plant height, number of pods per plant, 100-grain mass, grain yield, biological yield, harvest index, hectoliter mass, and grain protein content. Five plants from each plot were selected randomly to determine the plant height and number of pods per plant. To measure the 100-grain mass, five samples containing 100 grains were randomly collected from each plot, and their mass was recorded. To measure the hectoliter mass, a container with known mass and volume was completely filled with the chickpea seeds (Singh and Goswami, 1996; Kordi and Ghanbari, 2019). After filling the container, excess seeds were removed by passing a flat stick across the top surface. The seeds were not compacted in any way. The container was weighed on a digital balance (Model GT2100, Germany) reading to 0.01 g. Hectoliter mass (ρb) was calculated by the ratio of seeds mass in the container (M_b) to its volume (V_b):

$$\rho b = \frac{M_b}{V_b}$$

The ρb was recorded from the average of 10 samples for each treatment.

To measure the grain yield, all plants in the one meter-length center of two rows located in the middle of each plot were taken, and grain yield was recorded with a portable balance and calculated based on 12 % seed moisture. To measure the dry biological yield, including aerial parts and roots, the samples were dried in an oven at 75 °C for 72 h and then weighed. The harvest index (*HI*) was accounted as follows:

$$HI = (\text{Grain yield} / \text{Biological yield}) \times 100$$

For determination of crude protein content, the nitrogen content of grains was obtained by the Kjeldahl method (digestion of organic matter with sulfuric acid in the presence of a catalyst; rendering the reaction product alkaline; distillation and titration of the liberated ammonia; and calculation of the nitrogen content) (Jensen, 1996). Crude protein content (*Cp*) of grain was determined as:

$$Cp = 6.25 \times C2$$

where *C2* is the total grain nitrogen concentration on a dry matter.

2.5 DATA ANALYSIS

SAS (version 9.1) and MSTAT-C statistical softwares were used for the analysis of variance (ANOVA)

Table 2: Physical and chemical analysis of soil before the experiment

Soil texture	Clay (%)	Silt (%)	Sand (%)	pH	EC (dS m^{-1})	Total N (%)	Available P (ppm)	Available K (ppm)
Clay loam	31.2	42.0	26.8	7.97	1.04	0.11	6.1	430

and comparisons of means, respectively. Duncan's multiple range test, at $p \leq 0.05$, was used to rank the differences among means. The graphs were drawn by Excel, and error bars were assigned based on standard error (SE).

3 RESULTS AND DISCUSSION

3.1 PLANT HEIGHT

The result of variance analysis showed that plant height was affected by fertilizer, cultivar, and weeding. The interaction effect of cultivar × weeding was significant on the mentioned trait (Table 3). In all studied cultivars, the plant height under weed infested treatment was lower than that under weed control conditions. This decrement was 12.8, 8.7, and 17 % in Adel, Mansour, and Arman cultivars, respectively. The highest plant height (66.0 cm) was obtained by the Arman cultivar under weed control conditions (Figure 1). It has been reported that weed competition has a negative effect on plant height in chickpea (Ratnam et al., 2011). Weeds compete with crops for essential nutrients, available water, and light used for photosynthesis (Merga and Alemu, 2019), and reduce crop yield. The results of previous experiments also indicated that hand weeding increased the plant height of chickpea (Rathod et al., 2017).

Among fertilizer treatments, the highest (59.4 cm) and the lowest (54.3 cm) plant height were related to the integration of bio-fertilizer + 50 % nitrogen chemical fertilizer and control (without fertilizer) treatments, respectively (Figure 2). Application of *Rhizobium* (F2), 100 % chemical fertilizer (F3), and integration of *Rhizobium* + 50 % nitrogen chemical fertilizer (F4) increased the plant height by 5.5, 5.9, and 9.2 %, respectively, compared to the control treatment (without fertilizer). These results are in line with the findings of Amany (2007) and Caliskan et al. (2008), who reported that plant height increased with the application of nitrogen fertilizer. Khan et al. (2017) stated that the application of *Rhizobium* increases the plant height of chickpea. The solubilizing ability of *Rhizobium* species may increase nitrogen availability in the soil, and the plants can uptake the required amount of nutrients (Khaitov and Abdiev, 2018).

3.2 NUMBER OF PODS PER PLANT

According to the results of variance analysis (Table 3), the number of pods per plant was affected by simple effects of fertilizer, cultivar, and weeding as well as the interaction effects of fertilizer × cultivar, fertilizer × weeding, and cultivar × weeding (Table 3). In all studied cultivars, maximum pods per plant were observed by applying of *Rhizobium* + 50 % nitrogen chemical fertilizer. On the other hand, the Arman cultivar had the highest pods per plant under all fertilization treat-

Table 3: Analysis of variance of grain yield, yield components and some qualitative traits of chickpea cultivars

		Mean squares							
Source of variation	df	Plant height	Pods per plant	100-grain mass	Grain yield	Biological yield	Harvest index	Hectoliter mass	Grain protein content
Replication	2	9.5 ^{ns}	13.8 ^{ns}	0.6 ^{ns}	691.8 ^{ns}	15477.4 ^{ns}	0.5 ^{ns}	0.00002 ^{ns}	0.5 ^{ns}
Fertilizer (F)	3	77.6**	85.8**	46.0**	602344.3**	2911530.8**	35.85**	0.0006*	33.3**
Error 1	6	4.3	1.5	0.6	4618.3	6240.8	3.15	0.00007	0.3
Cultivar (C)	2	798.7**	86.3**	218.6**	419913.9**	5485802.1**	16.8**	0.0008**	6.6**
F × C	6	9.2 ^{ns}	5.0*	3.7**	23171.4**	61900.3*	15.6**	0.00003 ^{ns}	0.4 ^{ns}
Error 2	16	4.4	1.7	0.7	2488.9	19679.5	1.4	0.00003	0.2
Weeding (W)	1	1111.9**	1106.5**	67.9**	4262226.7**	11947331.1**	531.4**	0.002**	10.7**
F × W	3	6.4 ^{ns}	30.5**	0.1 ^{ns}	2078.9 ^{ns}	32900.8 ^{ns}	3.1 ^{ns}	0.00003 ^{ns}	0.5*
C × W	2	53.2**	15.7**	6.9*	47801.8**	120062.7*	15.3**	0.00002 ^{ns}	0.7*
F × C × W	6	7.2 ^{ns}	2.8 ^{ns}	0.5 ^{ns}	3261.5 ^{ns}	9939.7 ^{ns}	0.9 ^{ns}	0.000006 ^{ns}	0.1 ^{ns}
Error 3	24	3.0	1.9	1.5	4502.6	27361	2.6	0.00002	0.2
C.V (%)	---	3.0	6.5	3.7	4.9	4.0	4.9	0.6	1.7

*,** and ns show significant difference at probability of 5 %, 1 % and no significant difference, respectively

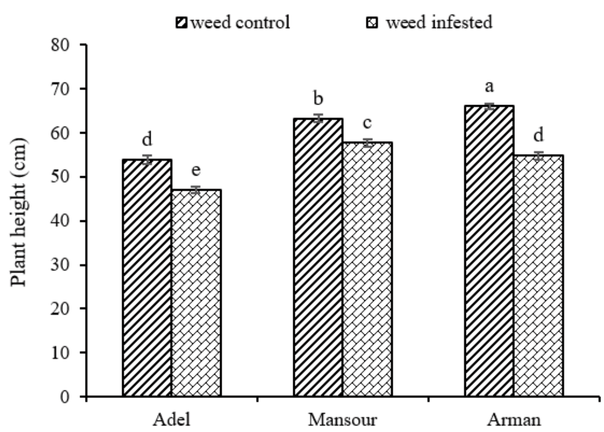

Figure 1: Plant height of chickpea cultivars under weed control and weed infested conditions.
Different letters indicate a significant difference at $p \leq 0.05$ (Duncan test)

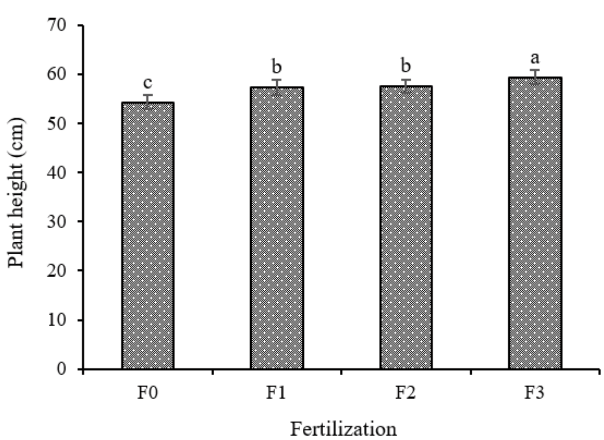

Figure 2: Plant height of chickpea under different nitrogen sources.
F0, F1, F2, F3: Control, bio-fertilizer, 100 % chemical fertilizer, and bio-fertilizer + 50 % chemical fertilizer, respectively.
Different letters indicate a significant difference at $p \leq 0.05$ (Duncan test)

ments. Adel cultivar without fertilization had the lowest number of pods per plant (16.3), whereas the highest pods number per plant (26.6) was obtained by the Arman cultivar with the application of *Rhizobium* + 50 % nitrogen fertilizer (Figure 3). The number of pods per plant generally depends on the cultivar (Ayaz et al., 2004). It is also affected by environmental factors and management practices (Knott, 1987). Yadav et al. (2011) reported that seed inoculation with *Rhizobium* enhanced nodulation, growth, and yield of legumes. Increasing the number of pods per plant under inoculation treatment can be due to the effect of *Rhizobium* on N, P, and K uptake, some enzyme activities, and root development (Wu, 2000). Many studies found positive effects of *Rhizobium* inoculation on the number of pods per plant in chickpea (Meena et al., 2013; Khaitov et al., 2016).

The result of mean comparisons of fertilizer × weeding showed that in all fertilizer treatments, especially the application of 100 % chemical fertilizer, weed control increased the pods number per plant compared to weed infested treatment. This increment was 43.2, 28.6, 69.9, and 40.8 % under F0, F1, F2, and F3 treat-

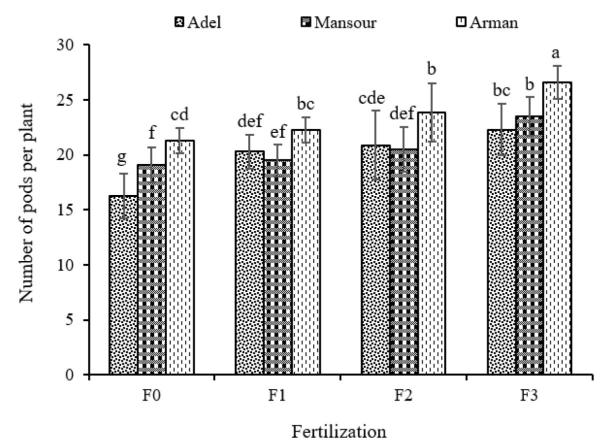

Figure 3: Number of pods per plant of chickpea cultivars under different nitrogen sources.
F0, F1, F2, F3: Control, bio-fertilizer, 100 % chemical fertilizer, and bio-fertilizer + 50 % chemical fertilizer, respectively.
Different letters indicate a significant difference at $p \leq 0.05$ (Duncan test)

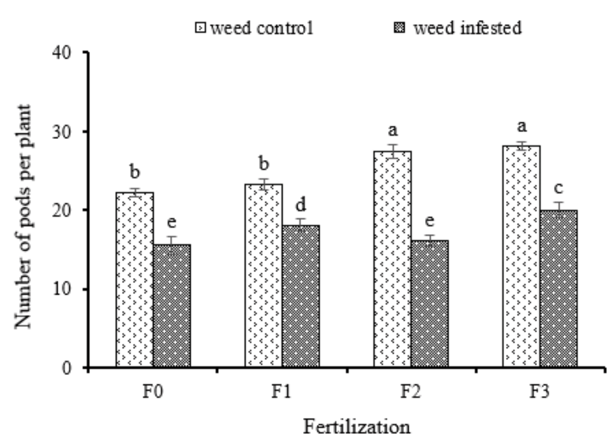

Figure 4: Number of pods per plant of chickpea under different nitrogen sources and weed control and weed infested conditions.
F0, F1, F2, F3: Control, bio-fertilizer, 100 % chemical fertilizer, and bio-fertilizer + 50 % chemical fertilizer, respectively.
Different letters indicate a significant difference at $p \leq 0.05$ (Duncan test)

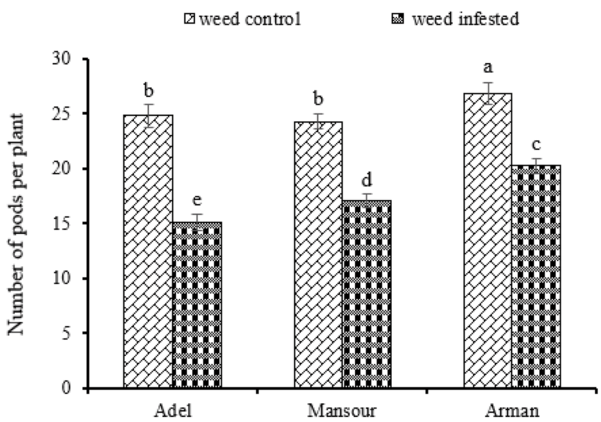

Figure 5: Number of pods per plant of chickpea cultivars under weed control and weed infested conditions.
Different letters indicate a significant difference at $p \leq 0.05$ (Duncan test)

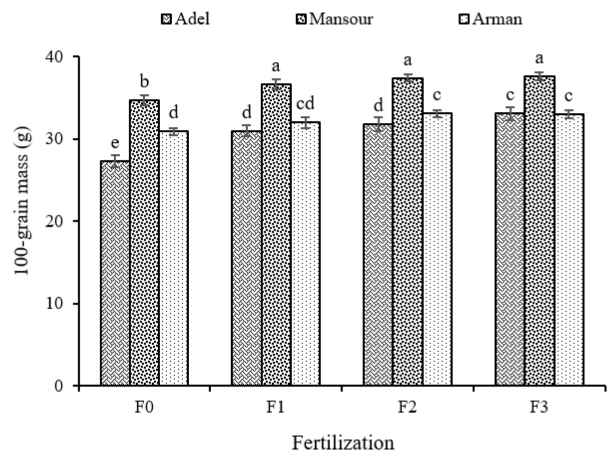

Figure 6: 100-grain mass of chickpea cultivars under different nitrogen sources.
F0, F1, F2, F3: Control, bio-fertilizer, 100 % chemical fertilizer, and bio-fertilizer + 50 % chemical fertilizer, respectively.
Different letters indicate a significant difference at $p \leq 0.05$ (Duncan test)

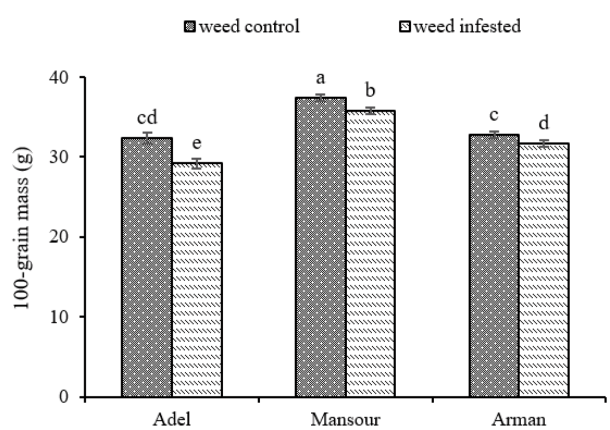

Figure 7: 100-grain mass of chickpea cultivars under weed control and weed infested conditions.
Different letters indicate a significant difference at $p \leq 0.05$ (Duncan test)

ments, respectively. Integration of *Rhizobium* + 50 % nitrogen chemical fertilizer combined with weed control produced the highest number of pods per plant (28.2), while the lowest number was related to weed infested treatment without fertilizer (15.5) (Figure 4). The number of pods per plant is one of the most important factors affecting the yield of pulse crops such as chickpea. The availability of nitrogen may reduce the weed competition pressure in the crops (Shafiq et al., 1994). Togay et al. (2008) reported that the plants from inoculated seeds with *Rhizobium* had a higher number of pods per plant compared to the control.

In all cultivars, weeding improved the number of pods per plant. However, the positive effect of weeds control on pods per plant in the Adel cultivar was higher than the other cultivars. The highest number of pods per plant (26.8) was obtained in the Arman cultivar under weed control conditions (Figure 5). The higher number of pods per plant in weed control conditions could be due to the lack of competition of weeds with chickpea plants in the field. Chickpea is sensitive to weed interference due to its slow growth rate and limited leaf development at the early stage of crop growth and establishment (Kaushik et al., 2014).

3.3 100-GRAIN MASS

Based on the results of variance analysis (Table 3), simple effects of fertilizer, cultivar, and weeding were significant on 100-grain mass. Also, the interaction effects of fertilizer × cultivar and cultivar × weeding were significant for this trait (Table 3). The mean comparisons of fertilizer × cultivar showed that in all fertilizer treatments, the maximum 100-grain mass belonged to the Mansour cultivar. In all three cultivars, the minimum 100-grain mass was related to control treatment (without fertilizer) (Figure 6). Increasing 100-grain mass under inoculation treatment can be due to the improved traits such as leaf area and photosynthetic pigments, which finally causes an increase in photosynthetic products (Nyoki and Nakidemi, 2016).

The 100-grain mass of chickpea under weed control conditions was higher than under weed infested treatment in all studied cultivars, especially the Adel cultivar. The highest (37.4 g) and lowest (29.2 g) 100-grain mass were achieved from the Mansour cultivar under weed control conditions and the Adel cultivar under weed infested treatment, respectively (Figure 7). Most weeds exhibit faster initial growth than crops such as chickpea, thereby inhibiting crop growth, which might affect photosynthesis and crop yield (Tepe et al., 2011). It appears that some factors like nutrient deficiency and the level of plants competition over light and nutrient resources under weed infested treatment could be considered as reduction factors for production.

3.4 GRAIN YIELD

Fertilizer, cultivar, and weeding had significant effects on the grain yield of chickpea. The interaction effects of fertilizer × cultivar and cultivar × weeding were also significant for grain yield (Table 3). The result of mean comparisons showed that the application of nitrogen fertilizer, especially *Rhizobium* + 50 % nitrogen chemical fertilizer, increased grain yield in all three cultivars. The highest grain yield (1662.5 kg ha^{-1}) was related to the Arman cultivar with applying *Rhizobium* + 50 % nitrogen chemical fertilizer (Figure 8). Inoculation of chickpea seeds with *Mesorhizobium* ciceri strain resulted in a 23 % increase in grain yield compared to the control treatment (without fertilizer). In the present research, increment of the grain yield resulted from the application of different nitrogen sources in studied cultivars, especially the Arman cultivar, may be due to the more plant height and number of pods per plant in this condition (Figures 1, 2, 3). It seems that the positive effects of *Rhizobium* inoculation on chickpea can be a result of nitrogen supply for the crop (Togay et al., 2008). The effect of *Rhizobium* bacteria on plant growth is not only through nitrogen fixation, but it is also associated with the ability of the *Rhizobium* bacteria to synthesize phytohormones like auxin. Some phytohormones, including auxin, enhance root growth and development as well as promoting water and nutrients uptake (Werner and Newton, 2005). It has been reported that inoculation of chickpea seeds with *Rhizobium* improves grain yield by 9.6 - 27.9 % (Gupta and Namdeo, 1996). Increasing the nitrogen rate from 0 to 50 kg N ha^{-1} significantly improved the number of pods per plant, 1000-grain mass, grain yield, biological yield, and harvest index in chickpea (McKenzie and Hill, 1995). There is a negative correlation between soil mineral nitrogen content and the number or mass of rhizobia nodes, meaning that high mineral nitrogen reduces rhizobia activity (Flajšman et al., 2020).

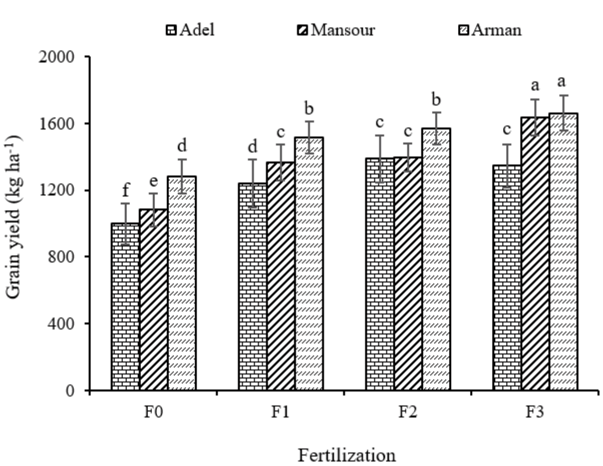

Figure 8: Grain yield of chickpea cultivars under different nitrogen sources.
F0, F1, F2, F3: Control, bio-fertilizer, 100 % chemical fertilizer, and bio-fertilizer + 50 % chemical fertilizer, respectively.
Different letters indicate a significant difference at $p \leq 0.05$ (Duncan test)

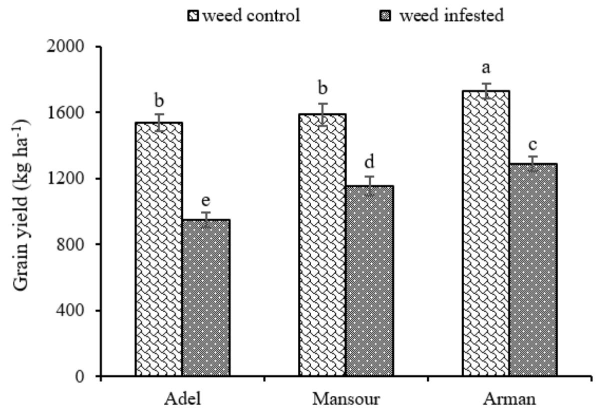

Figure 9: Grain yield of chickpea cultivars under weed control and weed infested conditions.
Different letters indicate a significant difference at $p \leq 0.05$ (Duncan test)

Mean comparisons indicated that in all studied cultivars, especially the Adel cultivar, weed control increased chickpea grain yield compared to weed infested treatment. The highest (1726.5 kg ha^{-1}) and the lowest (948 kg ha^{-1}) grain yields were achieved from the Arman cultivar with weed control and Adel cultivar under weed infested treatment, respectively. Weed control led to a 62.2, 37.4, and 34 % increase in grain yield of the Adel, Mansour and Arman cultivars, compared to weed infested treatment, respectively (Figure 9). This result indicates that poor weed management is one of the major grain yield limiting factors in chickpea. It has been reported that weed interference can decrease chickpea yield by more than 85 % (Ratnam et al., 2011).

3.5 BIOLOGICAL YIELD

The biological yield was significantly affected by simple effects of fertilizer, cultivar and weeding as well as interaction effects of fertilizer × cultivar and cultivar × weeding (Table 3). Similar to grain yield (Figure 8), the biological yield of chickpea cultivars increased with the application of nitrogen fertilizers. In all studied cultivars, applying nitrogen fertilizer (especially *Rhizobium* + 50 % nitrogen chemical fertilizer) enhanced biological yield compared to the control (Figure 10). The maximum (5104.1 kg ha^{-1}) and minimum (3139.2 kg ha^{-1}) biological yields were recorded for the Arman cultivar with the application of *Rhizobium* + 50 % nitrogen chemical fertilizer and the Adel cultivar without fertilizer (control), respectively (Figure 10). Nitrogen is one of the most essential nutrients with a considerable effect on plant growth and productivity (Tripathi et al., 2015). The production of phytohormones by *Rhizobium* species enhances root growth and development through improved water and nutrients uptake (Spaepen et al., 2009). According to Khaitov and Abdiev (2018), the combined application of bio-fertilizer and nitrogen fertilizer leads to a positive impact on basic metabolism, grain yield, and biomass. These results show that the integration of bio-fertilizer and nitrogen chemical fertilizer can be useful for crops production. Togay et al. (2008) found that inoculation of chickpea seeds with *Rhizobium* has significantly increased the plant height, number of branches per plant, and biological yield. Namvar et al. (2011) reported that the application of nitrogen increases the production of total dry matter in plants, which can be caused by increasing the plant height (Figure 2), number of branches per plant, and number of pods per plant (Figure 3) that eventually results in high grain and biological yields (Figures 8, 10).

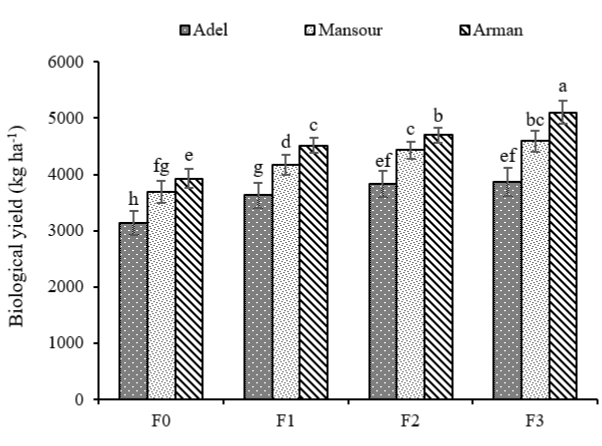

Figure 10: Biological yield of chickpea cultivars under different nitrogen sources.
F0, F1, F2, F3: Control, bio-fertilizer, 100 % chemical fertilizer, and bio-fertilizer + 50 % chemical fertilizer, respectively.Different letters indicate a significant difference at $p \leq 0.05$ (Duncan test)

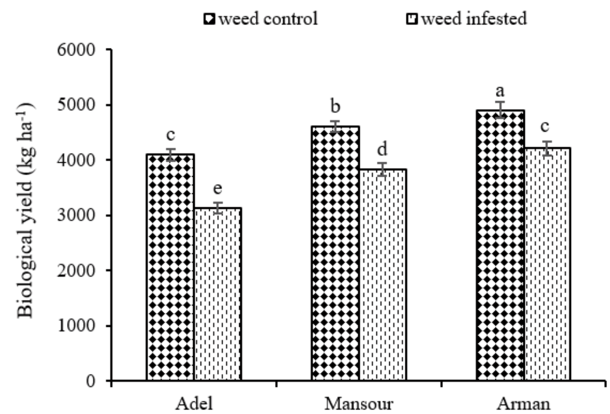

Figure 11: Biological yield of chickpea cultivars under weed control and weed infested conditions.
Different letters indicate a significant difference at $p \leq 0.05$ (Duncan test)

Weeds control increased biological yield compared to weed infested treatment in all three cultivars of chickpea. This increment was 31, 20.2, and 16.6 % in the Adel, Mansour, and Arman cultivars, respectively. The highest biological yield (4908.5 kg ha^{-1}) was obtained by the Arman cultivar under weed control conditions (Figure 11). Chickpea is highly susceptible to weed competition due to its slow growth rate and short stature at the early stage of crop growth and establishment (Singh et al., 2017). Therefore, under weed control conditions, soil moisture and nutrients are provided for the crop to increase biological yield (Khan et al., 2002).

3.6 HARVEST INDEX (*HI*)

The data presented in Table 3 showed that simple effects of fertilizer, cultivar, and weeding were significant on the harvest index. The interaction effects of fertilizer × cultivar and cultivar × weeding were also significant for the mentioned trait (Table 3). The application of different nitrogen sources improved the harvest index. The highest harvest index (35.8 and 35.4) was achieved by the Adel cultivar with the application of 100 % nitrogen chemical fertilizer and the Mansour cultivar with the application of *Rhizobium* + 50 % chemical nitrogen fertilizer, respectively (Figure 12). Malik et al. (2006) reported that inoculation of soybean seeds with *Rhizobium* has significantly increased the harvest index. On

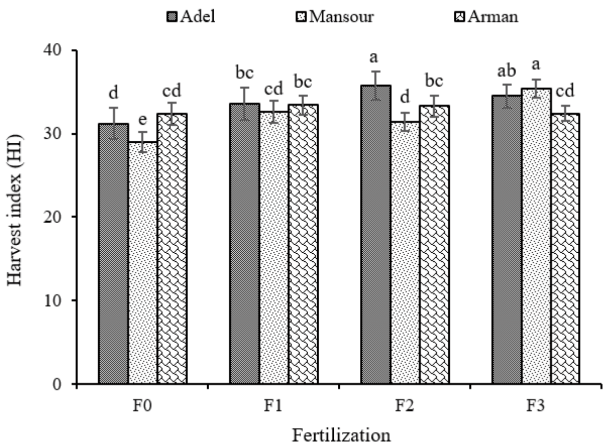

Figure 12: Harvest index response of chickpea cultivars to different nitrogen sources.
F0, F1, F2, F3: Control, bio-fertilizer, 100 % chemical fertilizer, and bio-fertilizer + 50 % chemical fertilizer, respectively.Different letters indicate a significant difference at $p \leq 0.05$ (Duncan test)

the other hand, Flajšman et al. (2019) showed that the soybean harvest index was not influenced by bacteria seed inoculation. Weed control led to a 24.2, 14.7, and 15.4 % increase in harvest index in the Adel, Mansour, and Arman cultivars, respectively, compared to weed infested treatment. The highest harvest index (37.4) was obtained by the Adel cultivar under weed control conditions (Figure 13). Pooniya et al. (2009) found that weed management played an important role in improving the harvest index in the chickpea. According to the results of this research, it seems that weed control had a greater effect on grain yield than biological yield.

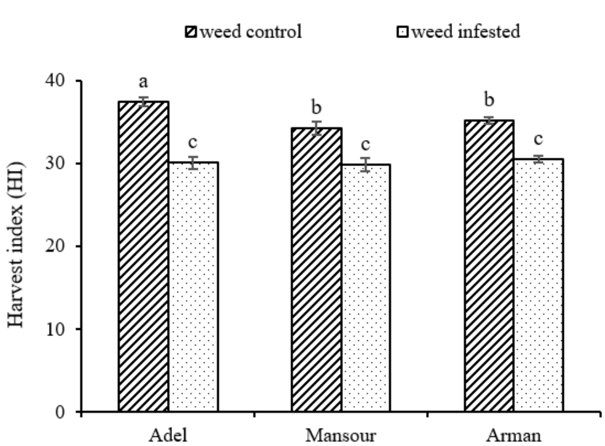

Figure 13: Harvest index of chickpea cultivars under weed control and weed infested conditions.
Different letters indicate a significant difference at $p \leq 0.05$ (Duncan test)

3.7 HECTOLITER MASS

According to the results of variance analysis (Table 3), the hectoliter mass was affected by fertilization, cultivar, and weeding. The interaction effects of the treatments were not significant for this trait (Table 3). The application of different sources of nitrogen improved hectoliter mass in the chickpea. Among the various fertilizer treatments, the highest (0.770 g cm^{-3}) and lowest (0.757 g cm^{-3}) hectoliter mass were achieved in the integration of *Rhizobium* + 50 % chemical fertilizer and without fertilization (control), respectively (Figure 14). These results are in agreement with the findings of Kordi and Ghanbari (2019). They reported that differ-

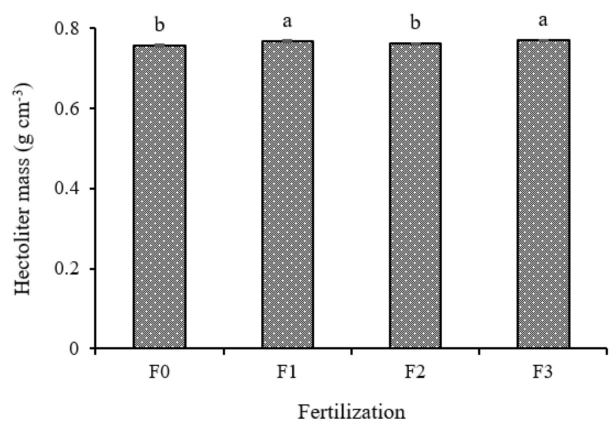

Figure 14: Hectoliter mass of chickpea under different nitrogen sources.
F0, F1, F2, F3: Control, bio-fertilizer, 100 % chemical fertilizer, and bio-fertilizer + 50 % chemical fertilizer, respectively.Different letters indicate a significant difference at $p \leq 0.05$ (Duncan test)

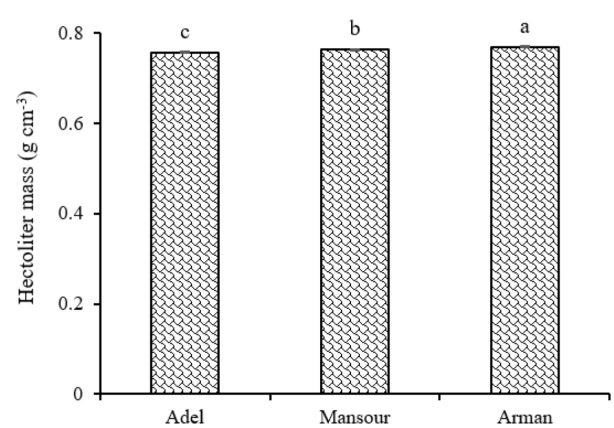

Figure 15: Hectoliter mass of different chickpea cultivars.
Different letters indicate a significant difference at $p \leq 0.05$ (Duncan test)

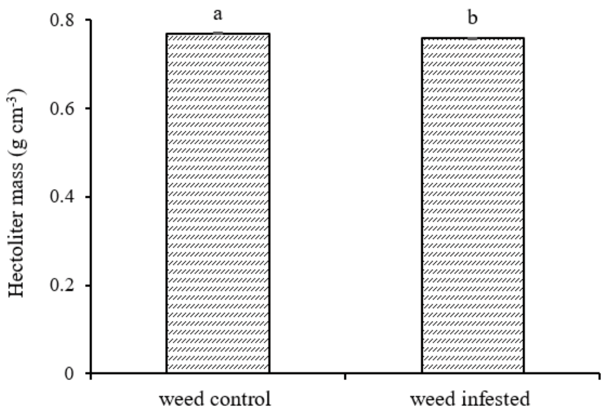

Figure 16: Hectoliter mass of chickpea under weed control and weed infested conditions.
Different letters indicate a significant difference at $p \leq 0.05$ (Duncan test)

ent sources of nitrogen resulted in changes in the hectoliter mass of maize, and the highest and the lowest hectoliter mass appeared in the integration of bio-fertilizer + 75 % chemical fertilizer and without fertilization (control), respectively. Evaluation of different chickpea cultivars in terms of hectoliter mass showed that the maximum (0.770 g cm^{-3}) and minimum (0.758 g cm^{-3}) hectoliter mass were related to the Arman and Adel cultivars, respectively (Figure 15). The mean comparisons indicated that under weed control conditions, the hectoliter mass of chickpea was higher than that in weed infested treatment (Figure 16). The reduction of hectoliter mass under weed infested treatment can be due to the decreased traits such as 100-grain mass, leaf area, and photosynthetic pigments, which finally reduces assimilates production.

3.8 GRAIN PROTEIN CONTENT

The results showed that the simple effects of fertilizer, cultivar, and weeding were significant on grain protein content. The interaction effects of fertilizer × weeding and cultivar × weeding were also significant for this trait (Table 3). Integration of *Rhizobium* + 50 % chemical fertilizer had the highest grain protein content under weed control and weed infested conditions. However, maximum grain protein content was obtained by applying *Rhizobium* + 50 % chemical fertilizer under weed control conditions (Figure 17). The grain protein content is used as one of the most important parameters for measuring grain quality. Nitrogen is an integral part of the protein and has a vital role in the quality of crops due to its involvement in the synthesis of amino acids and proteins (Caliskan et al., 2008). Nitrogen deficiency is one of the limiting factors of yield in most of the crops (Liu et al., 2015). Adding nitrogen in any form (as a chemical fertilizer or bio-fertilizer) increases the grain protein content of crops. It has been reported that inoculation and nitrogen fertilization has resulted in a significant increase in grain protein content of chickpea (El-Hadi and Elsheikh, 1999). Kordi and Ghanbari (2019) reported that the highest and the lowest protein contents in maize grain were achieved from the integration of bio-fertilizer + 75 % chemical fertilizer and

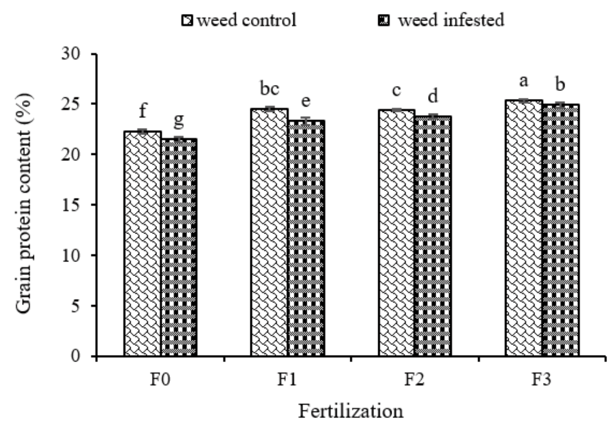

Figure 17: Grain protein content of chickpea under different nitrogen sources and weed control and weed infested conditions.
F0, F1, F2, F3: Control, bio-fertilizer, 100 % chemical fertilizer, and bio-fertilizer + 50 % chemical fertilizer, respectively.
Different letters indicate a significant difference at $p \leq 0.05$ (Duncan test)

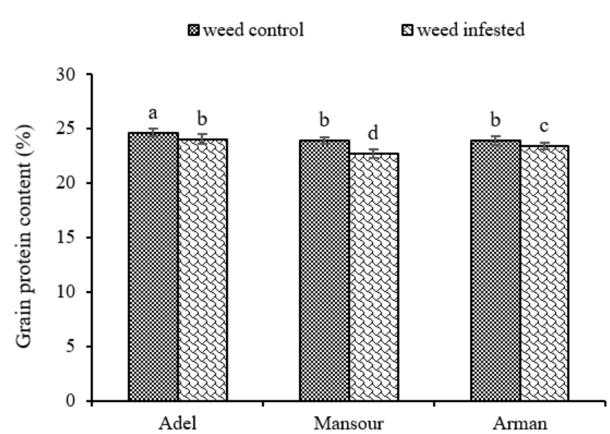

Figure 18: Grain protein content of chickpea cultivars under weed control and weed infested conditions.
Different letters indicate a significant difference at $p \leq 0.05$ (Duncan test)

without fertilization (control), respectively. Nitrogen-fixing bacteria activity increases the nitrogen fertilizer recovery by providing a part of the required nitrogen during the growing season and reducing the nitrogen loss within the soil (Jalilian et al., 2012). It is reported that *Rhizobium* has facilitated the uptake of nutrients in chickpea through the development of the root system (Rudresh et al., 2005).

The result of mean comparisons indicated that the Adel cultivar had higher grain protein content compared to the other studied cultivars in both weed control and weed infested conditions. The highest (24.6 %) and the lowest (22.7 %) grain proteins were achieved from the Adel cultivar under weed control conditions and the Mansour cultivar under weed infested treatment, respectively (Figure 18). The higher competitive ability of weeds compared to chickpea under weed infested treatment led to a significant reduction of available nitrogen and finally decreased the amount of protein in plants. Tanveer et al. (2015) reported that the grain protein content of chickpea decreased with increasing weed density.

4 CONCLUSIONS

The results obtained from this research clearly indicated that the application of nitrogen fertilizer, especially *Rhizobium* + 50 % chemical fertilizer, improved all the investigated parameters compared to the control treatment (without fertilizer). Thus, the integration of *Rhizobium* + 50% chemical fertilizer can be used as the most appropriate treatment for reducing the extensive use of chemical fertilizers in agriculture and paving the way for sustainable agricultures. Hand weeding had a positive and significant effect on yield, yield components, and some qualitative traits of chickpea cultivars. According to the results of this research, the Arman cultivar has priority over other cultivars for the grain yield under the climate conditions of Khorramabad.

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