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Growth analysis and yield of chickpea (*Cicer arietinum* L.) in relation to organic and inorganic nitrogen fertilization

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Growth analysis is still the most simple and precise method to evaluate the contribution of different ecological processes in plant development. In order to study the effects of organic and inorganic nitrogen on growth indices and yield components of chickpea (*Cicer arietinum* L.) cv. ILC 482, a spilt plot experiment based on randomized complete block design with four replications was conducted at the Experimental Farm of the Agriculture Faculty, University of Mohaghegh Ardabili, Ardebil, Iran. Experimental factors were comprised of inorganic nitrogen fertilizer at four levels (0, 50, 75 and 100 kg ha^{-1}) in the main plots applied in the urea form, and two levels of inoculation with *Rhizobium* bacteria (with and without inoculation) as sub plots. Application of N and *Rhizobium* inoculation continued to have positive effect on growth indices and yield components of chickpea. Lower levels of nitrogen application and non-inoculated plants showed less growth indices including total dry matter (TDM), leaf area index (LAI), crop growth rate (CGR), relative growth rate (RGR) and net assimilation rate (NAR) while the highest values of these indices were observed at the high levels of nitrogen application and inoculated plants. The highest plant height, number of primary and secondary branches, number of pods per plant and number of grains per plant were obtained from the highest level of nitrogen fertilizer (100 kg urea ha^{-1}) and *Rhizobium* inoculation. Application of 75 and 100 kg urea ha^{-1} showed no significant difference in these traits. Moreover, the highest grain yield was recorded in the inoculated plants that were treated with 75 kg urea ha^{-1}. The results indicated that the application of suitable amounts of nitrogen fertilizer (i. e. between 50 and 75 kg urea ha^{-1}) as a starter can be beneficial in improving growth, development and total yield of inoculated chickpea.

Key words: chickpea, grain yield, growth indices, nitrogen fertilizer, *Rhizobium* inoculation, yield components

INTRODUCTION

Grain legumes are a major source of protein in human and animal nutrition and play a key role in crop rotations in most parts of the world. When grown in rotation with other crops, under certain environmental conditions, they can improve soil fertility and reduce the incidence of weeds, diseases and pests (Chemining wa, Vessey, 2006; Albayrak et al., 2006). Chickpea (*C. arietinum* L.) is the third most widely grown grain legume in the world after bean and soybean. The agronomical importance of chickpea is based on its high protein concentration (approx. 19.3–25.4%) for the human and animal diet, being used more and more as an alternative protein source. Moreover,

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it is also widely used as fodder and green manure (Ali et al., 2004; Togay et al., 2008; Erman et al., 2011; Namvar et al., 2011).

Growth is generally a function of environmental factors (such as temperature and solar radiation) and mineral nutrition, along with genotype and production practices (Alam, Haider, 2006). Growth analysis is one way to verify the crops ecological adaptation to new environments, the competition between species, crops management effects and the identification of the productive capacity of different genotypes. The dynamics of dry matter distribution to various plant organs, their yielding and productivity may be characterized by using various indices of growth analysis (Zajac et al., 2005; Kibe et al., 2006). Growth analysis is still the most simple and precise method to evaluate the contribution of different physiological processes in plant development. It provides a considerable insight into the functioning of a plant as depends on genotype or environment. The purpose of growth analysis is the determination of the increase in dry matter referred to a suitable basis for photosynthetically active tissue, leaf area and amount of leaf protein (Ali et al., 2004; Gupta, Gupta, 2005; Alam, Haider, 2006; Yasari, Patwardhan, 2006).

Nitrogen (N) deficiency is frequently a major limiting factor for high yielding crops all over the world (Salvagiotti et al., 2008; Namvar et al., 2011). The most important role of N in the plant is its presence in the structure of protein and nucleic acids which are the most important building and information substances of every cell. In addition, N is also found in chlorophyll that enables the plant to transfer energy from sunlight by photosynthesis. Thus, the supply of N to the plant will influence the amount of protein, amino acids, protoplasm and chlorophyll formed. Consequently, it influences cell size, leaf area and photosynthetic activity (Kibe et al., 2006; Walley et al., 2005; Alam, Haider, 2006; Caliskan et al., 2008; Salvagiotti et al., 2008). Therefore, adequate supply of N is necessary to achieve high yield potential in crops. In general, N deficiency causes a reduction in growth rate, general chlorosis, often accompanied by early senescence of older leaves, and reduced yield (Caliskan et al., 2008; Erman et al., 2011). Mckenzie and Hill (1995) studied the effects of two levels of N applications (0 and 50 kg N ha^{-1}) on chickpea and reported that the increase of N rate from 0 to 50 kg N ha^{-1} significantly enhanced seed and dry matter yield, harvest index, number of pods per plant and 1 000 seed weight. Walley et al. (2005) investigated chickpea response to starter N (0, 15, 30 and 45 kg N ha^{-1}) and stated that the application of 45 kg N ha^{-1} enhanced seed yield by as much as 221 kg ha^{-1} over control. Alam and Haider (2006) studied the effects of N fertilizer on growth attributes of barley and found that total dry matter (TDM), leaf area index (LAI), crop growth rate (CGR) and net assimilation rate (NAR) increased due to N fertilization. Kibe et al. (2006) in wheat and Yasari and Patwardhan (2006) in rapeseed concluded the same results about these growth indices. Amany (2007) reported that urea foliar application had a significant impact on plant height, number of branches, pods and seeds per plant, 1 000 seed weight, TDM, seed yield and harvest index in chickpea.

Increasing and extending the role of biofertilizers such as *Rhizobium* can reduce the need for chemical fertilizers and decrease adverse environmental effects. Therefore, in the development and implementation of sustainable agriculture techniques, biofertilization has great importance in alleviating environmental pollution and deterioration of nature (Werner, Newton, 2005; Chemining wa, Vessey, 2006; Erman et al., 2011). As legume, chickpea can obtain a significant portion (4–85%) of its N requirement through symbiotic N_2 fixation when grown in association with effective and compatible *Rhizobium* strains (Saini et al., 2004; Rudresh et al., 2005; Togay et al., 2008). Chickpea and *Rhizobium leguminosarum* sub sp. *ciceri* association annually produces up to 176 kg N ha^{-1} depending on cultivar, bacterial strain and environmental factors (Ogutcu et al., 2008). The inoculation of seeds with *Rhizobium* is known to increase nodulation, N uptake, growth and yield parameters of legume crops (Adgo, Schulze, 2002; Reudresh et al., 2005; Sogut, 2006; Erman et al., 2011; Namvar et al., 2011). Ali et al. (2004) indicated that inoculated chickpea plants had the highest values of LAI and TDM. Albayrak et al. (2006) studied the effects of inoculation with *Rh. leguminosarum* on seed yield and yield components of common vetch (*Vicia sativa* L.) and observed that inoculated common vetch cultivars gave higher TDM (8.5%), seed yield (7.6%), straw yield (10.4%), pod length (25.5%), number of seeds per pod (16.2%), number of pods per plant (28.4%), main stem length (3.5%) and 1000 seed weight (5.5%) compared to non-inoculated cultivars. Malik et al. (2006) found that seed inoculation with *Rhizobium* significantly increases plant height, LAI, number of pods per plant, number of seeds per pod, 1 000 seed weight, TDM, seed yield and harvest index in soybean. Togay et al. (2008) reported that inoculation with *Rhizobium* significantly increases the plant height, first pod height, number of branches, pods and seeds per plant, grain and dry matter yield in chickpea. Saini et al. (2004) and Ogutcu et al. (2008) reported the same results in chickpea.

Mineral nutrition is one of the most important factors affecting plant growth and productivity and N is the major nutrient required by crops. Chickpea is usually managed with low fertilizer input, and has shown variable growth pattern and yield response to N application. Moreover, it seems that there is little investigation on combined effects of N fertilization and *Rhizobium* inoculation on growth attributes and yield of some legume crops such as chickpea. Therefore, the present study aimed to assess the *Rhizobium* contribution to plant growth and yield of chickpea under different levels of mineral N fertilizer application.

MATERIALS AND METHODS

Field experiments were conducted at the Experimental Farm of Mohaghegh Ardabili University. The area is located at latitude 38°15' N and longitude 48°15' E at an altitude of 1350 m above the mean sea level. Climatically, the area is in the semi arid temperate zone with cold winter and hot summer. Annual average rainfall is about 400 mm, most of the rainfall is concentrated between winter and spring. The soil is silty loam, with electrical conductivity approx. 2.3 ds m^{-1}, pH approx. 7.9 and organic matter approx. 16.8 g kg^{-1}.

The experimental design was a spilt plot in randomized complete block design with four replications. The main plot treatments consisted of four N fertilizer rates: 0, 50, 75 and 100 kg urea ha^{-1}. Sub plot treatments were two levels of inoculation with *Rhizobium* (inoculated and non-inoculated).

N fertilizer in each level, divided into three equal parts; the first part of the N was broadcasted by hand and incorporated immediately in planting time, the second and third parts were used in 6–8 leaves and flowering stages. Just before planting seeds of inoculation treatments were inoculated with *Rh. legominosarum* bv. *Ciceri* obtained from the Soil and Fertilizer Research Institute, Tehran.

The area was mold board-ploughed and disked before planting. Phosphorus (P) was applied at planting to each plot at 50 kg P ha^{-1} as triple super-phosphate. Seeds of chickpea (*C. arietinum* L.) cv. ILC 482 were hand planted on 14 May in five rows plots, 5 m long with spacing of 0.5 m between rows. Two seeds were sown per hill. The field was immediately irrigated after planting to ensure uniform germination. After germination, the plants were thinned to one seedling per hill to obtain approx. 36 plants per m^{-2}. Weeds were controlled over the growth period by hand hoeing.

Two types of measurements are needed for growth analysis: (i) the plant weight; this is usually the oven dry weight (g) and (ii) the size of the assimilating system; this is usually in terms of leaf area (m^{-2}). In order to estimate these two factors, eight harvests were taken at equal intervals of 10 days. Three plants were selected from each plot in each harvest. The first harvest was taken at 30 days after planting (DAP). LAI was determined using the LI-COR model 3100 LI Area Meter. To obtain the dry matter weight, samples were oven dried at 72 °C till they reached constant weight. The variances trend of TDM, LAI, CGR, relative growth rate and NAR were determined using the below equations (Gupta, Gupta, 2005):

$$TDM = e^{a + bt + ct^2 + dt^3}$$

$$LAI = e^{a + bt + ct^2}$$

$$\text{CGR}=LnTDM / dt = (b + 2ct + 3dt^2) \times e^{(a + bt + ct^2 + dt^3)}$$

$$RGR = b + 2ct + 3dt^2$$

$$\text{NAR} = \text{CGR} / \text{LAI}$$

In these equations, "t" is the intervals of sampling or, in other words, the beginning and the end of the interval sampling and "a", "b" and "c" are the coefficients of equations.

The plants were harvested at maturity on 8 September and yield components, such as plant height, number of primary and secondary branches per plant, number of total pods per plant, number of grains per pod, number of grains per plant and 100-grains weight were recorded on 15 randomly selected plants in each plot. Grain yield was determined by harvesting the middle three rows of each plot.

Statistical Analysis: Analysis of variance was done using SAS computer software package and the mean values were compared with Duncan multiple range test (DMRT) at 0.05 probability level.

RESULTS AND DISCUSSION

1. Growth indices

1.1. Total dry matter (TDM)

The pattern of dry matter production in all levels of N application was almost similar. The results indicated that TDM increased slowly at the early stages of growth and then increased rapidly with the advancement of plant age (Fig. 1). The rapid increase in TDM at the later stages of growth was due to the development of a considerable amount of leaf area compared to early stages (Yasari, Patwardhan, 2006).

The highest values of TDM were observed in the application of 75 kg urea ha^{-1} in inoculated plants while the non-inoculated plants showed

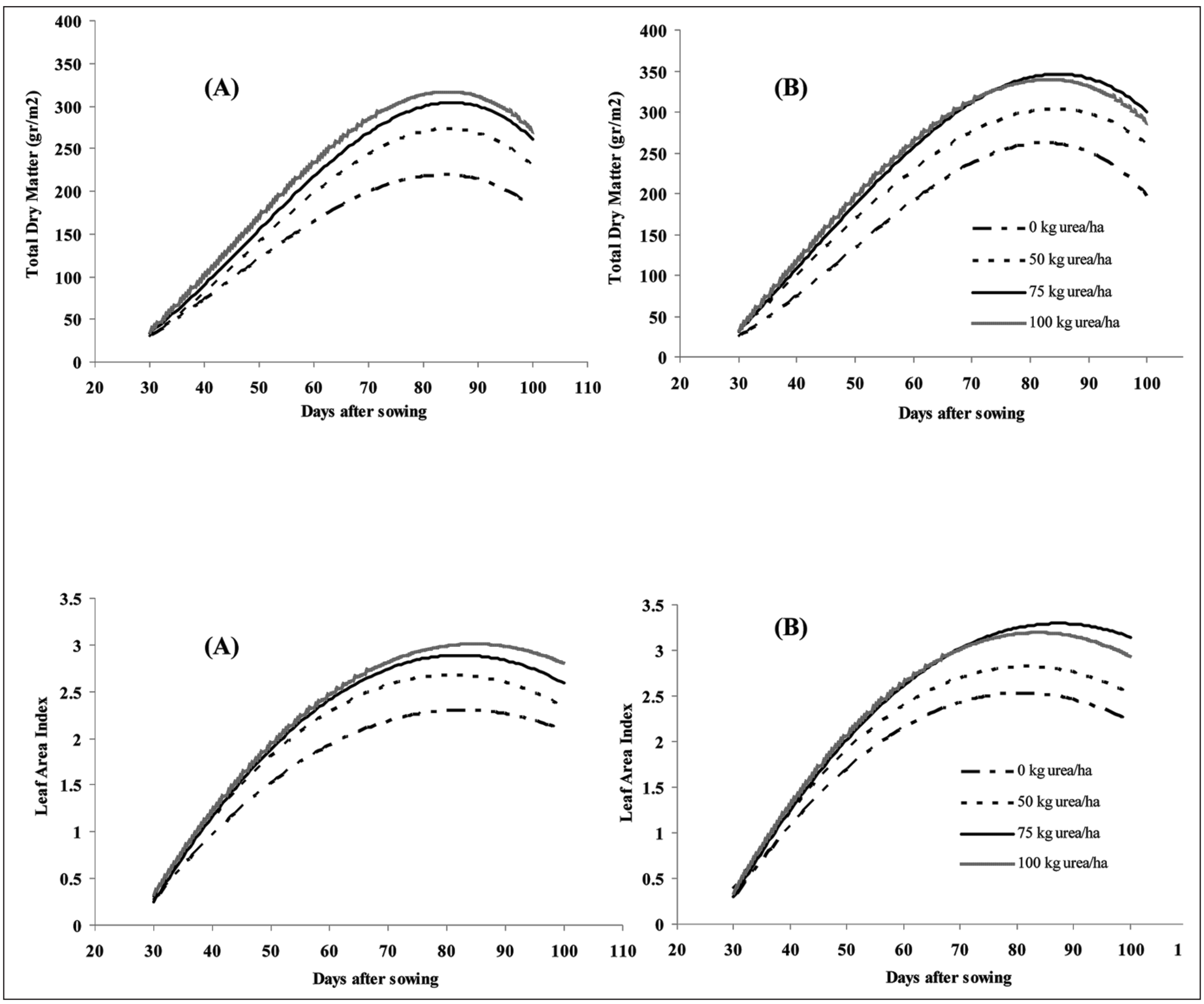

Fig. 1. Influence of different levels of nitrogen application on total dry matter **(TDM)** and leaf area index **(LAI)** in non-inoculated **(A)** and inoculated **(B)** chickpea (*Cicer arietinum* L).

the highest amounts of TDM in the application of 100 kg urea ha^{-1} which may be due to the more positive effects of *Rhizobium* presence in usage of 75 kg urea ha^{-1} rather than the application of 100 kg urea ha^{-1}. The lowest TDM was recorded in non-fertilized plants at both levels of inoculation. Generally, inoculation with *Rhizobium* increased TDM at all levels of N application. Inoculated plants showed about 6.34%, 11.54%, 13.36% and 7.94% higher TDM in application of 0, 50, 75 and 100 kg urea ha^{-1}, respectively, compared to non-inoculated plants at the same rate of N usage (Fig. 1). The same results were reported about the effects of N fertilization (Alam, Haider, 2006; Yasari, Patwardhan, 2006; Chemining wa, Vessey, 2006; Caliskan et al., 2008) and *Rhizobium* inoculation (Ali et al., 2004; Albayrak et al., 2006; Chemining wa, Vessey, 2006; Malik et al., 2006; Ogutcu et al., 2008; Togay et al., 2008; Namvar et al., 2011) on different crops TDM production.

1.2. Leaf area index (LAI)

Effects of N fertilization and *Rhizobium* inoculation on LAI of chickpea have been shown in Fig. 1. We can see that LAI starts from low values, reaches a certain peak and then declines with plant aging. LAI of chickpea also showed the same trend as TDM. LAI increased with the growth of N fertilizer rate. The increasing of LAI was attributed to the rise in leaf number and total leaf area / plant (Alam, Haider, 2006; Kibe et al., 2006; Yasari, Patwardhan, 2006). The maximum values of LAI in inoculated and non-inoculated plants were observed in application of 75 (23.45% increase over control) and 100 kg urea ha^{-1} (20.67% increase over control), respectively. Plants that were treated with 0 kg urea ha^{-1} showed the lowest LAI at both levels of inoculation (Fig. 1). The depletion of LAI at the later stages was possibly due to the senescence and falling of older leaves. Similar results were also reported by Ali et al. (2004), Alam and Haider (2006), Kibe et al. (2006), Yasari and Patwardhan (2006) and Malik et al. (2006). Moreover, *Rhizobium* inoculation enhanced the amount of LAI at all levels of N fertilization (Fig. 1). Generally, inoculated plants showed about 6.36% more LAI than the non-inoculated plants.

1.3. Crop growth rate (CGR)

CGR is regarded as the most meaningful growth function since it represents the net results of photosynthesis, respiration and canopy area interaction (Alam, Haider, 2006). As noted by Gupta and Gupta (2005), CGR is also a representative of the most common agronomic measurements such as yield of dry matter per unit land area. Starting from lower value, CGR reached a certain peak and then declined at the later stages of growth (Fig. 2). In the present investigation, application of 75 and 100 kg urea ha^{-1} showed the highest CGR in inoculated (35.06% increase over control) and non-inoculated (31.33% increase over control) plants, respectively. The lowest CGR was recorded in non-fertilized and non-inoculated plants (Fig. 2). In general, CGR depends mainly on the amount and intensity of intercepted energy and photosynthetic efficiency of the canopy. Higher CGR may be due to higher production of dry matter owing to greater LAI and higher light interception (Zajac et al., 2005; Yasari, Patwardhan, 2006). Moreover, inoculation with *Rhizobium* increased CGR at all levels of N usage. CGR showed approx. 4.00%, 12.94%, 13.68% and 8.85% increase in inoculated plants with application of 0, 50, 75 and 100 kg urea ha^{-1}, respectively, compared to non-inoculated plants at the same rate of N application. These results are in accordance with the findings of Alam and Haider (2006) and Kibe et al. (2006).

1.4. Relative growth rate (RGR)

Irrespective of N fertilizer treatments, RGR was high in the early growth period and showed a decreasing trend as the crop advanced in age (Fig. 2). This may be due to the fact that in the initial stages of the plant growth the ratio between alive and dead tissues is high and almost entire cells of productive organs are activity engaged in vegetative matter production and, consequently, the RGR of plants is high, while with plant aging, the metabolic activity of tissues decreases and hence the tissues cannot contribute to the growth that results in RGR decreasing (Zajac et al., 2005; Alam, Haider, 2006; Kibe et al., 2006). Furthermore, Yasari and Patwardhan (2006) stated that the decreased NAR might reduce the RGR at the later stage. As shown in Fig. 2, RGR enhanced with increasing of the N fertilizer amount. At both levels of inoculation, the highest and the lowest RGR were recorded in maximum (100 kg urea ha^{-1}) and minimum (0 kg urea ha^{-1}) rates of N application, respectively.

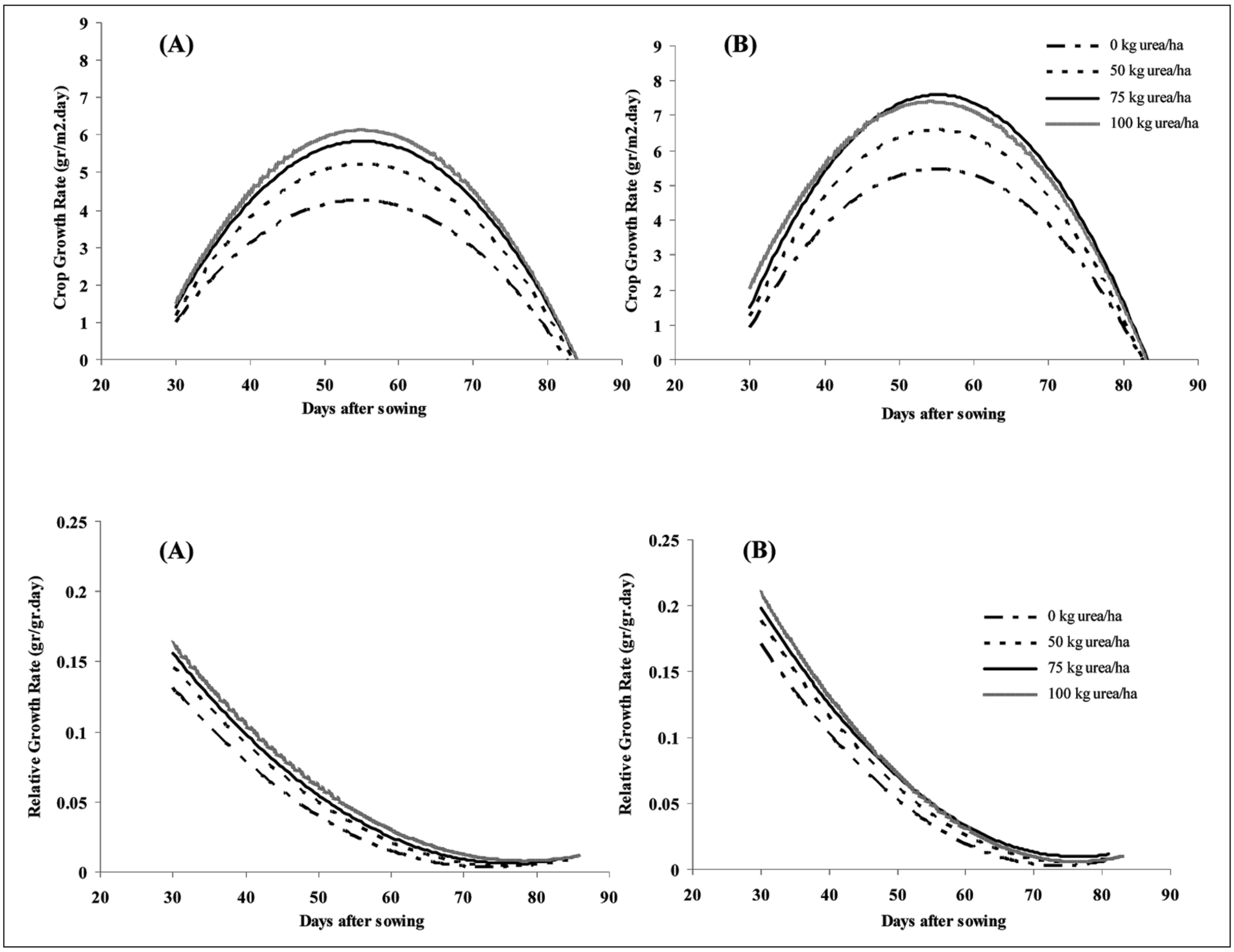

Fig. 2. Influence of different levels of nitrogen application on crop growth rate (CGR) and relative growth rate (RGR) in non-inoculated (**A**) and inoculated (**B**) chickpea (*Cicer arietinum* L.)

Moreover, inoculation with *Rhizobium* bacteria increased RGR at all levels of N fertilization (Fig. 2). These results concur with the observations made by Zajac et al. (2005), Alam and Haider (2006), and Kibe et al. (2006).

1.5. Net assimilation rate (NAR)

Fig. 3 shows that NAR is high at the early vegetative stages and sharply declines as the plant experiences increasing age. When all leaves are exposed to full sunlight NAR remains to be highest. It also remains high when plants are small and there are few leaves to get the maximum sunlight without shading effects. NAR decreases with crop growth due to mutual shading of leaves and reduced photosynthetic efficiency of older leaves (Alam, Haider, 2006; Yasari, Patwardhan, 2006). Usage of 0 and 100 kg urea ha^{-1} showed the lowest and the highest values of NAR, respectively. Moreover, *Rhizobium* inoculation increased plants NAR at all levels of N application (Fig. 3).

2. Yield components

2.1. Plant height (PH)

The plant height was significantly affected by N application, while inoculation with *Rhizobium* showed no significant effects on this trait (Table). The greatest plant height was observed at the maximum rate of N application (100 kg urea ha^{-1}) that did not differ significantly with 75 kg urea ha^{-1}. The minimum plant height was recorded in control. Application of 100 kg urea ha^{-1} increased plant height by 30.9%, compared to control (Table). These results are in line with the findings of Amany (2007) and Caliskan et al. (2008) who reported that

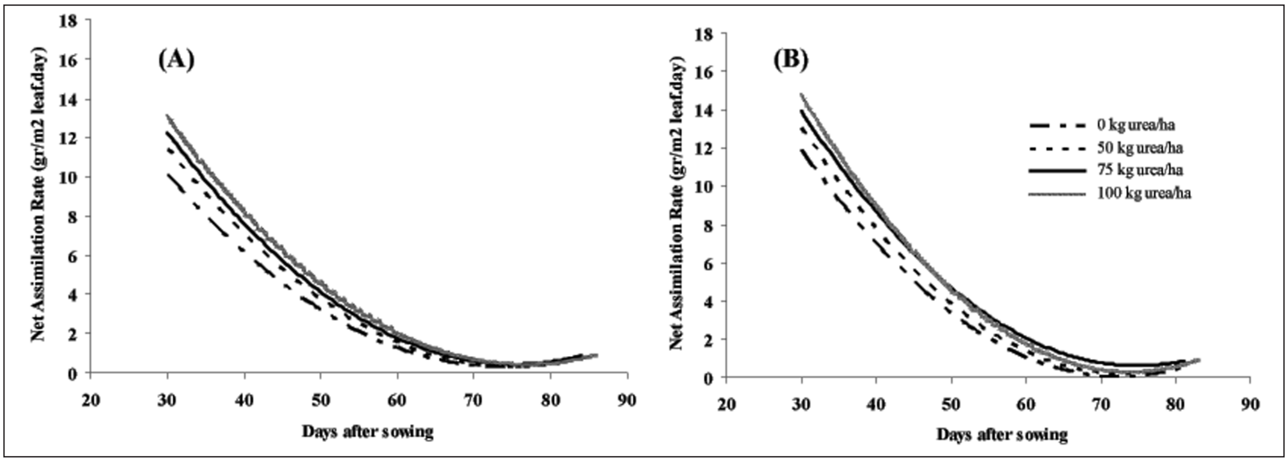

Fig. 3. Influence of different levels of nitrogen application on net assimilation rate **(NAR)** in non-inoculated **(A)** and inoculated **(B)** chickpea (*Cicer arietinum* L.)

Table. **Effects of nitrogen fertilization and *Rhizobium* inoculation on yield and its components in chickpea (*Cicer arietinum* L.)**

Treatments	PH (cm)	NPB (per plant)	NSB (per plant)	NP (per plant)	NG (per pod)	NG (per plant)	100-GW (gr)	GY (kg ha^{-1})
Nitrogen rates (kg urea ha^{-1})								
0	33.47 **c**	1.93 **c**	4.67 **c**	17.85 **c**	1.03 **b**	11.42 **c**	28.47 **a**	911.5 **c**
50	37.43 **b**	2.31 **b**	6.61 **b**	19.42 **b**	1.11 **ab**	14.12 **b**	27.60 **ab**	1207.3 **b**
75	44.37 **a**	2.60 **a**	8.51 a	20.61 **a**	1.18 **a**	16.41 **a**	26.58 **b**	1328.2 **a**
100	45.97 **a**	2.63 **a**	9.35 **a**	21.30 **a**	1.17 **a**	16.63 **a**	26.48 **b**	1413.6 **a**
***Rhizobium* inoculation**								
non	41.25 **a**	2.26 **b**	6.80 **b**	18.97 **b**	1.08 **a**	13.38 **b**	27.21 **a**	1166.5 **b**
with	39.37 **a**	2.47 **a**	7.77 **a**	20.62 **a**	1.15 **a**	15.91 **a**	27.37 **a**	1263.7 **a**
Mean	**40.31**	**2.36**	**7.28**	**19.79**	**1.12**	**14.64**	**27.28**	**1215.15**
Nitrogen	**	**	**	**	ns	**	**	**
***Rhizobium* inoculation**	ns	*	**	**	ns	**	ns	**
Nitrogen × *Rhizobium* inoculation	ns	ns	ns	ns	ns	*	ns	*
CV (%)	**13.63**	**10.30**	**10.96**	**16.29**	**11.02**	**16.10**	**11.23**	**12.34**

PH: Plant Height, NPB: Number of Primary Branches, NSB: Number of Secondary Branches, NP: Number of Pods, NG: Number of Grains, 100-GW: 100-Grains Weight, GY: Grain Yield. Mean values followed by the same letters in each column and treatment showed no significant difference by DMRT (P = 0.05). – *, ** and ns showed significant differences at 0.05, 0.01 probability levels and no significant, respectively

plant height increased with application of N fertilizer. Although variance analysis of data indicated that *Rhizobium* inoculation had no significant effect on plant height of chickpea, the comparisons of means showed that the inoculated plant had more height than non-inoculated plant. Rudresh et al. (2005) also stated that plant height was not significantly affected with *Rhizobium* inoculation.

2.2. Number of primary branches (NPB) and secondary branches (NSB) per plant

Number of primary and secondary branches per plant increased with the increasing of N application rate. Increasing of N fertilizer from 0 to 100 kg urea ha^{-1} enhanced the number of primary and secondary branches per plant by 26.61 and 50.05%, respectively. The lowest and the highest values of these traits were recorded in 0 and 100 kg urea ha^{-1}, respectively (Table). Amany (2007) and Caliskan et al. (2008) reported similar results in chickpea and soybean, respectively.

Moreover, the greatest number of primary and secondary branches per plant was recorded in inoculated plants. Inoculation with *Rhizobium* increased the number of primary and secondary branches by 8.50 and 14.70%, respectively, compared to non-inoculated plants (Table). These results are in agreement with Rudresh et al. (2005) and Togay et al. (2008).

2.3. Number of total pods (NP)

As shown in Table, number of total pods per plant demonstrated significant response to N fertilization and *Rhizobium* inoculation. The highest number of total pods per plant was recorded in 100 kg urea ha^{-1} application that showed no significant difference with those in 75 kg urea ha^{-1}. The least number of this trait was obtained from control. Application of 100 kg urea ha^{-1} increased the number of pods per plant approx. 16.19% compared to control in each plant (Table). Caliskan et al. (2008) investigated the effects of N and iron fertilization on growth and yield of soybean and reported that the number of pods per plant increased with N doses up to 80 kg ha^{-1}, but further increase in N dose (120 kg ha^{-1}) did not show a significant effect on this trait. Similar trends were reported by Mckenzie and Hill (1995) and Amany (2007) in chickpea.

Inoculation with *Rhizobium* bacteria significantly increased the number of total pods per plant (Table). Plants that were inoculated with *Rhizobium* showed about 8.00% more pods per plant than non-inoculated plant. Togay et al. (2008) observed that the number of pods per plant affected statistically significant with *Rhizobium* inoculation in chickpea. These researchers noted that this trait increased from 11.50 pods per plant in non-inoculated plants to 12.35 pods per plant in inoculated plants. Malik et al. (2006) and Albayrak et al. (2006) reported similar results.

2.4. Number of grains per pod and number of grains per plant (NG)

Although variance analysis of data indicated that N fertilization and *Rhizobium* inoculation had no statistically significant effects on number of grains per pod, however, the highest magnitude of this trait was observed in 75 kg urea ha^{-1} application and *Rhizobium* inoculation (Table). In the study on the soybean it was shown that *Rhizobium* inoculation had no significant effect on number of grains per pod (Malik et al. 2006). Non-significant effects of studied treatments on number of grains per pod may be due to more effects of genetic factors in control of this trait than environmental and management factors.

The significant main effect of N fertilization and *Rhizobium* inoculation, and significant N fertilization × *Rhizobium* inoculation interactions (Table) were obtained in chickpea for number of grains per plant. The highest number of grains per plant was recorded in inoculated plants treated with 75 kg urea ha^{-1}. The least value of this trait was obtained from non-inoculated and non-fertilized plants (Fig. 4). Application of 75 kg urea ha^{-1} in inoculated plants increased the number of grains per plant by 40.82% compared to control. The previous studies justified the positive effects of N application (Amany, 2007) and *Rhizobium* inoculation (Togay et al., 2008) on number of grains per plant.

Furthermore, as shown in Fig. 4, inoculation with *Rhizobium* bacteria had the greatest effect on number of grains per plant in 75 kg urea ha^{-1} than other fertilizer levels that may be due to higher effectiveness of *Rhizobium* inoculation at this level compared to other levels of N usage. Inoculation increased the number of grains per plant about 27.87% in 75 kg urea ha^{-1} compared to non-inoculated plants at the same fertilizer level.

2.5. 100-grains weight (100-GW)

100-grains weight was affected only by N fertilization (Table). Increasing of N application rate significantly decreased the weight of 100-grains in chickpea. The highest 100-grains weight was recorded in control while the lowest rate of this trait was obtained from 100 kg urea ha^{-1} (Table). Application of 100 kg urea ha^{-1} decreased 100-grains weight by 7.51% compared to control. The negative correlation between yield and 100-grains weight was reported in some studies (Walley et al., 2005).

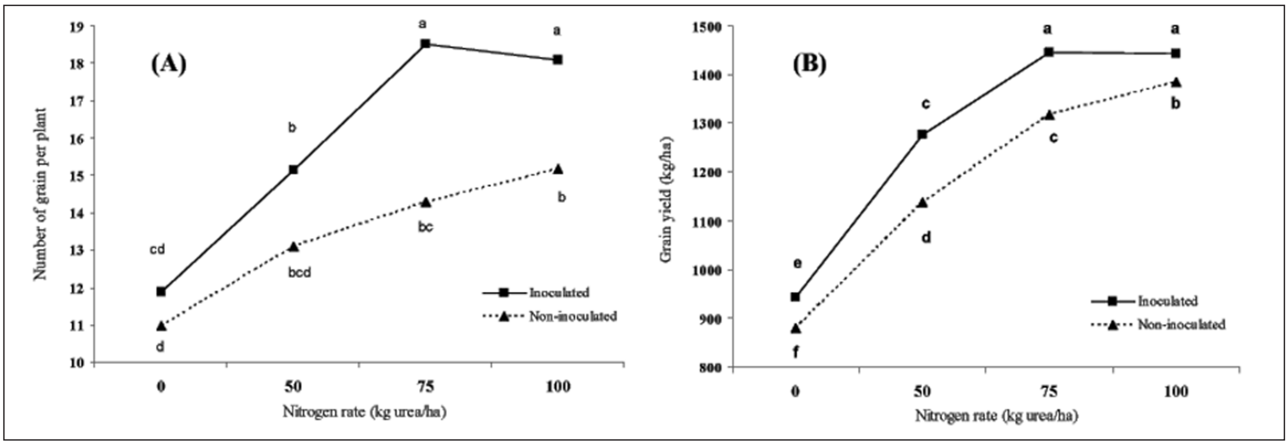

Fig. 4. Effects of different levels of nitrogen application under *Rhizobium* inoculation and non-inoculation on number of grains per plant (A) and grain yield per unit of area (B) in chickpea (*Cicer arietinum* L.). Values with the same letters in each trait are not significantly different (DMRT at 5% level)

3. Grain yield (GY)

The data presented in Table showed that both of the studied experimental factors (N application and *Rhizobium* inoculation) had significant effects on grain yield of chickpea. The highest rate of N fertilizer (100 kg urea ha^{-1}) showed the greatest grain yield, however this rate of N fertilizer was in par with 75 kg urea ha^{-1}. Application of 100 kg urea ha^{-1} increased grain yield by 35.51% compared to the least application of N fertilizer (control). Furthermore, inoculated plants indicated more grain yield than non-inoculated plants. *Rhizobium* inoculation increased grain yield about 7.01% compared to control (Table).

Interaction effects of N fertilization and *Rhizobium* inoculation were found significant in grain yield of chickpea (Table). Grain yield continuously increased with increasing of N application in inoculated and non-inoculated plants. However, grain yield of chickpea increased until 75 kg urea ha^{-1} and further increase in N rate resulted in no significant grain yield increase (Fig. 4). Moreover, grain yield of inoculated plants at all rates of N application was higher than of non-inoculated plants at the same rate of N application (Fig. 4). The highest grain yield was recorded in inoculated plants with 75 kg urea ha^{-1} application. The lowest rate of N application showed the lowest grain yield in non-inoculated plants (Fig. 4). The study of the interactions between N application and inoculation showed that inoculation with *Rhizobium* bacteria had more effects on grain yield in 75 kg urea ha^{-1} than other levels of fertilizer application (Fig. 4).

Other researchers reported the same results about the effects of N application (Walley et al., 2005; Amany, 2007; Caliskan et al., 2008; Salvagiotti et al., 2008; Namvar et al., 2011) and *Rhizobium* inoculation (Rudresh et al., 2005; Chemining wa, Vessey, 2006; Togay et al., 2008; Erman et al., 2011) on grain yield in different legume crops.

N is known to be an essential nutrient for plant growth and development (Kibe et al., 2006; Sogut, 2006; Salvagiotti et al., 2008), it is involved in vital plant functions such as photosynthesis, DNA synthesis, protein formation, respiration and N_2 fixation would directly influence plant growth and development (Werner, Newton, 2005; Caliskan et al., 2008; Erman et al., 2011). The growth parameters such as LAI, TDM and leaf photosynthesis significantly decreased due to unsatisfactory N availability (Malik et al., 2006; Alam, Haider, 2006; Kibe et al., 2006; Chemining wa, Vessey, 2006; Caliskan et al., 2008). The results obtained from this study indicated that usage of N fertilization had positive effects on growth indices and, consequently, on yield and its attributes of chickpea. Adding N increases the production of dry matter in plants (Kibe et al., 2006; Salvagiotti et al., 2008; Erman et al., 2011) which can increase the potential of plant to produce more plant height, branches, pods and seeds that ultimately results in high grain and biological yield. On the other hand, N application and thus uptake increased LAI, CGR, RGR, yield attributes and ultimately total biomass and grain yield. Therefore, with adequate supply of N, the crop produced more leaf area and showed higher growth rates, which consequently resulted in higher biomass and grain yields of crops (Ali et al., 2004; Alam, Haider, 2006; Kibe et al., 2006; Namvar et al., 2011). N fertilization increases TDM for a number of reasons: (i) N can increase the LAI in plants (Malik et al., 2006; Alam, Haider, 2006; Kibe et al., 2006; Caliskan et al., 2008). Higher LAI increased the interception of solar radiation by plants that resulted in higher accumulation in plants (Kibe et al., 2006; Caliskan et al., 2008). (ii) N can increase photosynthesis rate in plants. Increasing photosynthetic rate with N fertilization can be attributed to increasing amount of chlorophyll pigments since N is one of the main components of chlorophyll (Werner, Newton, 2005; Alam, Haider, 2006; Caliskan et al., 2008). In contrast, supplementation of adequate N for crops can increase their growth and development. Hence plants are able to show high growth indices and produce more yield components that result in higher grain yield.

Inoculation of legumes with rhizobia for the purpose of enhancing N_2 fixation and yield in legume crops is possibly the oldest and most common method of voluntary release of microbes into the environment (Werner, Newton, 2005; Ogutcu et al., 2008; Chemining wa, Vessey, 2006). The influence of *Rhizobium* bacteria on promoting legumes growth is documented in some researches (Ali et al., 2004; Saini et al., 2004; Rudresh et al., 2005; Chemining wa, Vessey, 2006; Erman et al., 2011; Namvar et al., 2011). The observed benefits on chickpea by *Rhizobium* inoculation seem to be due to the supply of N to the crop (Chemining wa, Vessey, 2006; Togay et al., 2008). Moreover, growth promoting substances (phytohormones) are produced by these organisms. *Rhizobium* bacteria synthesized phytohormones like auxin as secondary metabolites in inoculated plants. Phytohormones are known to play a key role in plant growth regulation. They promote seed germination, root elongation and stimulation of leaf expansion. In addition, great root development and proliferation of plants in response to *Rhizobium* activities enhance water and nutrient uptake (Werner, Newton, 2005; Erman et al., 2011). These results are in accordance with the works of Mckenzie and Hill (1995), Adgo and Schulze (2002), Rudresh et al. (2005), Malik et al. (2006), Albayrak et al. (2006), Amany (2007), Ogutcu et al. (2008) and Togay et al. (2008). Sogut (2006) stated that supremacy of symbiotic N versus combined N is explained as follows: symbiotic N is already in the organic reduced form and hence more readily available for plant metabolism. In contrast, in the absence of symbiotic N, plant must spend a lot of energy to take up nitrates and reduce them to the level of NH_3. Thus, inoculation resulted in greater dry matter compared to N fertilization.

CONCLUSION

Lower levels of N application and non-inoculated plants were seen to result in less growth indices in chickpea including TDM, LAI, CGR, RGR and NAR. The highest values of these indices were observed at the high levels of N application and inoculated plants. Furthermore, N application and *Rhizobium* inoculation had significant effects on yield and its components. The highest values of plant height, number of primary and secondary branches, number of pods per plant, number of grains per plant and grain yield were obtained from the highest level of N fertilizer (100 kg urea ha^{-1}) and *Rhizobium* inoculation. Application of 75 kg urea ha^{-1} was statistically in par with 100 kg urea ha^{-1} in all of these traits. The results pointed out that some N fertilization (i. e. between 50 and 75 kg urea ha^{-1}) as a starter can be beneficial in improving growth, development and total yield of inoculated chickpea.

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REFERENCES

1. Adgo E., Schulze J. 2002. Nitrogen fixation and assimilation efficiency in Ethiopian and German pea varieties. Plant and Soil. Vol. 239: 291–299.
2. Alam M. Z., Haider S. A. 2006. Growth attributes of barley (*Hordeum Vulgare* L.) cultivars in relation to different doses of nitrogen fertilizer. Journal of Life and Earth Sciences. Vol. 1(2): 77–82.
3. Albayrak S., Sevimay C. S., Tongel O. 2006. Effect of inoculation with *Rhizobium* on seed yield and yield components of common vetch (*Vicia sativa* L.). Turkish Journal of Agriculture and Forestry. Vol. 30: 31–37.

4. Ali H., Khan M. A., Randhawa Sh. A. 2004. Interactive effect of seed inoculation and phosphorus application on growth and yield of chickpea (*Cicer arietinum* L.). International Journal of Agriculture & Biology. Vol. 6(1): 110–112.
5. Amany A. B. 2007. Effect of plant density and urea foliar application on yield and yield components of chickpea (*Cicer arietinum* L.). Research Journal of Agriculture and Biological Sciences. Vol. 3(4): 220–223.
6. Caliskan S., Ozkaya I., Caliskan M. E., Arslan M. 2008. The effect of nitrogen and iron fertilization on growth, yield and fertilizer use efficiency of soybean in Mediterranean type soil. Field Crops Research. Vol. 108: 126–132.
7. Chemining wa G. N., Vessey J. K. 2006. The abundance and efficacy of *Rhizobium leguminosarum* bv. *viciae* in cultivated soils of eastern Canadian prairie. Soil Biology & Biochemistry. Vol. 38: 294–302.
8. Erman M., Demir S., Ocak E., Tufenkci S., Oguz F., Akkopru A. 2011. Effects of *Rhizobium*, arbuscular mycorrhiza and whey applications on some properties in chickpea (*Cicer arietinum* L.) under irrigated and rainfed conditions 1-Yield, yield components, nodulation and AMF colonization. Field Crops Research. Vol. 122(1): 14–24.
9. Gupta N. K., Gupta S. 2005. Plant Physiology. Oxford and IBH Publishing, pp. 580.
10. Kibe A. M., Singh S., Karla N. 2006. Water-nitrogen relationship for wheat growth and productivity in late sown conditions. Agricultural Water Management. Vol. 8(4): 221–228.
11. Malik M. A., Cheema M. A., Khan H. Z. 2006. Growth and yield response of soybean (*Glycine max* L.) to seed inoculation and varying phosphorus levels. Journal of Agricultural Research. Vol. 44(1): 47–53.
12. McKenzie B. A., Hill G. D. 1995. Growth and yield of two chickpea (*Cicer arietinum* L.) varieties in Canterbury, New Zealand. New Zealand Journal of Crop and Horticultural Science. Vol. 23: 467–474.
13. Namvar A., Seyed Sharifi R., Sedghi M., Asghari Zakaria R., Khandan T., Eskandarpour B. 2011. Study on the effects of organic and inorganic nitrogen fertilizer on yield, yield components and nodulation state of chickpea (*Cicer arietinum* L.). Communications in Soil Science and Plant Analysis. Vol. 42(9): 1097–1109.
14. Ogutcu H., Algur O. F., Elkoca E., Kantar. 2008. The determination of symbiotic effectiveness of *Rhizobium* strains isolated from wild chickpea collected from high altitudes in Erzurum. Turkish Journal of Agriculture and Forestry. Vol. 32: 241–248.
15. Rudresh D. L., Shivaprakash M. K., Prasad R. D. 2005. Effect of combined application of *Rhizobium*, phosphate solubilizing bacterium and *Trichoderma* spp. on growth, nutrient uptake and yield of chickpea (*Cicer aritenium* L.). Applied Soil Ecology. Vol. 28: 139–146.
16. Saini V. K., Bhandari S. C., Tarafdar J. C. 2004. Comparison of crop yield, soil microbial C, N and P, N-fixation, nodulation and mycorrhizal infection in inoculated and non-inoculated sorghum and chickpea crops. Field Crops Research. Vol. 89: 39–47.
17. Salvagiotti F., Cassman K. G., Specht J. E., Walters D. T., Weiss A., Dobermann A. 2008. Nitrogen uptake, fixation and response to N in soybeans: A review. Field Crops Research. Vol. 108: 1–13.
18. Sogut T. 2006. *Rhizobium* inoculation improves yield and nitrogen accumulation in soybean (*Glycine max*) cultivars better than fertilizer. New Zealand Journal of Crop and Horticultural Science. Vol. 34: 115–120.
19. Togay N., Togay Y., Cimrin K. M., Turan M. 2008. Effect of *Rhizobium* inoculation, sulfur and phosphorus application on yield, yield components and nutrient uptake in chick pea (*Cicer aretinum* L.). African Journal of Biotechnology. Vol. 7(6): 776–782.
20. Walley F. L., Boahen S. K., Hnatowich G., Stevenson C. 2005. Nitrogen and phosphorus fertility management for desi and kabuli chickpea. Canadian Journal of Plant Science. Vol. 85: 73–79.
21. Werner D., Newton W. E. Nitrogen fixation in agriculture, forestry, ecology and environment. Springer; 2005: 347.
22. Yasari E., Patwardhan A. M. 2006. Physiological analysis of the growth and development of canola (*Brassica napus* L.) under different chemical fertilizer application. Asian Journal of Plant Sciences. Vol. 5(5): 745–752.
23. Zajac T., Grzesiak S., Kulig B., Polacek M. 2005. The estimation of productivity and yield of linseed (*Linum usitatissimum* L.) using the growth analysis. Acta Physiologiae Plantarum. Vol. 27(4A): 549–558.

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SĖJAMOJO AVINŽIRNIO (*CICER ARIETINUM* L.) AUGIMO IR DERLINGUMO PRIKLAUSOMYBĖ NUO ORGANINIO IR NEORGANINIO AZOTO

Santrauka

Augimo analizė yra paprastas ir tikslus būdas, leidžiantis įvertinti įvairių ekologinių veiksnių įtaką augalo vystymuisi. Siekiant ištirti organinio ir neorganinio azoto poveikį sėjamojo avinžirnio (*Cicer arietinum* L.) cv. ILC 482 augimo rodikliams ir derliaus komponentams, Mohaghegh Ardabili universiteto (Iranas) Žemės ūkio fakulteto eksperimentiniame ūkyje buvo atliktas bandymas (keturi pakartojimai, atsitiktinės imtys). Išbandytos tokios karbamido kaip neorganinio azoto normos – 0, 50, 75 ir 100 kg ha^{-1}, taip pat gumbelinės *Rhizobium* bakterijos (inokuliavus ir neinokuliavus). Azotas ir *Rhizobium* inokuliavimas teigiamai veikė sėjamojo avinžirnio augimo ir derlingumo rodiklius. Mažesni azoto kiekiai ir neinokuliuoti augalai lėmė prastesnius augimo rodiklius – sausosios medžiagos kiekį (TDM), lapų ploto indeksą (LAI), augimo greitį (CGR), santykinį augimo greitį (RGR) ir asimiliacijos greitį (NAR). Didžiausios šių rodiklių reikšmės gautos augalus paveikus didelėmis azoto normomis ir inokuliavus *Rhizobium* bakterijomis. Didžiausias augalų aukštis, pirminių ir antrinių šakelių skaičius, ankščių ir grūdų skaičius, tenkantis vienam augalui, buvo gauti paveikus didžiausia azoto trąšų norma – 100 kg karbamido ha^{-1} ir inokuliavus *Rhizobium*. Panaudojus 75 ir 100 kg ha^{-1} karbamido normas, patikimo skirtumo minėtuose požymiuose nepastebėta. Didžiausias grūdų derlius gautas augalus inokuliavus ir patręšus 75 kg ha^{-1} karbamido. Tyrimo rezultatai liudija, kad 50–75 kg ha^{-1} karbamido paspartina netgi inokuliuotų sėjamųjų avinžirnių augimą, vystymąsi ir bendrą produktyvumą.

Raktažodžiai: sėjamasis avinžirnis, grūdų derlius, augimo rodikliai, azoto trąšos, inokuliavimas *Rhizobium*