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Full Length Research Paper

The effect of bacterial inoculation and different nitrogen doses on yield and yield components of some chickpea genotypes (*Cicer arietinum* L.)

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This study was carried out to determine the effect of bacterial inoculation and different nitrogen doses on yield and yield components of some chickpea genotypes in Mustafakemalpaşa province. The research was conducted at Uludag University, Mustafakemalpaşa Vocational School, Application and Training Field Bursa, Turkey in 1999 and 2000. Three genotypes; Local population, Canıtez 87 cultivar and ILC-114 Line were used as the crop material. Five different N dozes (0, 30, 60, 90 and 120 kg ha^{-1}) as ammonium nitrate and bacterial isolate (*Rhizobium ciceri*), supplied from Ankara Soil and Fertilizer Research Institute as the inoculating material were used. The complete randomized blocks design in factorial arrangement with three replications was used in this study. Seed yield, plant height, first pod height, number of pods per plant, number of seeds per plant, harvest index and 1000 seed weight were observed in the study. Data over two years showed that inoculation of seed did a significant effect on yield and some yield components of chickpea. But, nitrogen doses had no significant effect on yield and yield components. According to two years results, Local population gave the highest yield (2149.1 kg ha^{-1}) among chickpea used.

Key words: Chickpea, inoculation, N fertilizer, seed yield.

INTRODUCTION

The chickpea most probably originated in the area of present-day south–eastern Turkey and adjoining Syria. The cultivated chickpea is one of the first grain legumes to be domesticated in the Old World (Van Der Maesen, 1986). Chickpea is an indispensable source of protein and cash, usually grown in developing countries. It has been one of the most important legume crops in Mediterranian Basin and Turkey for human nutrition over thousands of years.

The chickpea was planted in an area of 557800 ha and its production is about 551746 tones, and the average yield is about 990 kg ha^{-1} in Turkey (Anonymous, 2006). This crop is sown on marginal land with poor to medium fertility. Although chickpea yield is higher than the world average, it is generally low in Turkey, due to inadequate agronomic practices and lack of cultivars improved with large yield potential. Production practice is ancient and traditional with no or few inputs.

Inadequate agronomic management significantly causes poor productivity of chickpea. This includes especially Anthracnose disease (*Ascochyta rabiei pass*. Labr.), insufficient fertilizer and bacterial inoculation, late planting, inadequate seed rate, excessive planting depth, non-uniform seed distribution, insufficient weed control, etc.

Chickpea responds positively to inoculation when grown in soils that contain native chickpea rhizobia (Sharma et al., 1983). N_2 fixation in chickpea range from 0 to 176 kg ha^{-1} season^{-1}, depending on method of measurement, cultivar, presence of appropriate rhizobia, and environmental variables (Beck et al., 1991). When native bacteria are less ineffective, less inoculation with selected rhizobium bacteria strain may increase yield and

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Table 1. Mean air temperature and total monthly precipitation in 1999, 2000 and long-term (1928 - 1996).

Month	Long term average			1999			2000		
	Temp. (°C)	Precip. (mm)	Relative humidity	Temp. (°C)	Precip. (mm)	Relative humidity	Temp. (°C)	Precip. (mm)	Relative humidity
March	8.3	68.8	72.2	8.9	63.9	67.5	8.0	96.0	63.4
April	12.9	60.0	70.3	14.5	32.9	62.3	15.0	108.8	71.9
May	17.7	52.4	70.0	19.0	4.5	50.5	17.7	48.9	64.6
June	22.1	30.3	61.4	22.9	74.2	60.4	21.8	16.1	60.6
July	24.5	25.1	59.1	26.1	2.0	56.7	25.5	9.4	51.4
Total	-	236.6	-	-	175.5	-	-	279.2	-
Mean	17.1	-	66.6	18.3	-	59.5	17.6	-	-

N fixation (Beck, 1992).

The use of fertilizer is limited on farmer's fields and inoculation of chickpea is not adopted by the majority of the farmers due to insufficient knowledge about inoculation and doubts about increasing the yield. Inoculation trial must be emphasized not only for the benefits of chickpea inoculation, but also for the combination of that practice with N fertilization in order to obtain maximum yields.

This study was conducted in order to analyze the effect of different dozes of nitrogen and rhizobium inoculation on some yield components in chickpea plant grown in slightly alkaline soil. The aim of this study is to determine the effects of bacterial inoculation and different nitrogen doses on yield and yield components of some chickpea genotypes.

MATERIAL AND METHODS

Field trials were carried out in Mustafakemalpaşa, Bursa located in Southern Marmara Region of Turkey, with average 713 mm rainfall and 14.4°C mean monthly temperature, based on long-term average (Table 1). The soil structure has a clay loam with alluvial characteristics. It contains 0.1% total nitrogen, 41 kg ha^{-1} phosphorus, 770 kg ha^{-1} exchangeable potassium and 3.0% organic matter. The soils were slightly alkaline reactions (pH = 7.2 - 7.4). The average monthly air temperature during the growing period in the experimental years (respectively 18.3 - 17.6°C) was higher than climatic data of long-term period (17.1°C). Total amount of precipitation during the growing period in both years were different (respectively 175.5 - 279.2 mm) average of long-term period (236.6 mm).

The experiments were designed in a randomized complete block design with three replications in each year. Plantings were made on 10^{th} March 1999 and 26^{th} March 2000. The plot size was 4.0 x 1.8 m. Each plot had four rows. The inter and intra row spacing were 45 and 5 cm respectively. Plot size was 7.2 m^2 at harvest time. Each block had two rows at the beginning and at the end of the block for protection which were removed before harvest.

A popular local genotype named Yerli, Canıtez 87 cultivar and ILC-114 Line, five nitrogen doses (0, 30, 60, 90 and 120 kg ha^{-1}) as ammonium nitrate and conditions with and without bacteria (*Rhizobium ciceri*) were investigated as experimental factors. Bacteria were supplied from Soil and Fertilizer Research Institute in Ankara, Turkey. The *R. ciceri* bacteria were inoculated on the surface of seeds (100 kg seed, 1 kg inoculate) just before sowing. 60 kg of phosphorus per hectare (Triple Super Phosphate, 46% P_2O_5) were applied prior to sowing and the doses of ammonium nitrate were added to plots after emerging. No pesticide was used at sowing to seed and soil. Plots were harvested by hand in July and threshed with hand to determine seed yield and other seed traits.

Hand hoeing control was done twice (at vegetative stage and the beginning of the flowering) by hand every year. Weed control was done with hand when necessary. Plots were harvested by hand in July to determine seed yield and yield components.

Plant height (cm), first pod height (cm), number of pods per plant, number of seeds per plant, harvest index and 1000 seed weight (g), were measured on ten randomly selected plants from all plots at each year. The seed yield was measured after mature plants were threshed from four rows each 4 m in length and harvested. An analysis of variance was made for each trait combined over years.

The data were analyzed as a randomized complete block design. All the data were subjected to analyses of variance for each trait using MSTAT-C (version 2.1, Michigan State University, 1991). Results of ANOVA for single experiments were combined over years. The significance of the genotypes, locations and years were determined at the 0.05 and 0.01 probability levels using appropriate F-values. For multiple corporations of means, the F-protected least significant difference (LSD) was calculated at the 0.05 probability level according to Steel and Torrie (1980).

RESULTS AND DISCUSSION

Table 2 shows the result of analysis of variance (ANOVA) considering the combined data of two years. Grain yield (Seed yield per unit area), first pod height, the number of pod per plant and the number of seed per plant were significantly affected by rhizobium inoculation. The number of pod per plant, the number of seed per plant and yield per unit area increased with rhizobium inoculation. Nitrogen doses had no significant effect on any measured components. Significant differences were found between cultivars at 1% level in terms of the plant height, first pod height, 1000 seed weight, and seed yield per unit area. Effect of years was found significant at 1% probability level, for seed yield per unit area and all characteristics.

Year x bacteria inoculation interaction was found significant at 1% probability level for first pod height. In addition, year x cultivar interactions were significant in plant height and seed yield per unit area at 5% probability level.

Table 2. Combined data over two years .

Source of variation	D.F.	Plant height	The first pod height	Pod number/ plant	Seed number/ plant	Harvest Index	1000 seed weight	Seed yield
Years (Y)	2	17385.34**	10065.09**	1261.93**	429.36**	1.322698**	13190.7**	77273.2**
Bact. (B)	1	68.45	180.00 **	228.04 **	278.76**	0.02521	551.3	3638.7 *
Cult. (C)	2	422.07 **	435.72 **	13.68	27.62	0.01774	52737.3**	10734.2**
Nit. (N)	4	10.65	25.31	12.68	17.56	0.02325	326.2	737.3
YXB	2	6.05	131.76 **	122.68	104.68	0.02520	123.3	280.0
YXC	4	164.36*	26.87	63.69	53.29	0.01825	59.6	3034.8 *
YXN	8	20.82	16.52	14.83	52.18	0.02179	42.4	473.3
BXC	2	5.0	2.02	73.34	79.21	0.3487	141.9	118.8
BXN	4	3.46	5.24	14.07	15.41	0.2238	34.0	752.8
YXN	8	16.29	12.11	29.35	19.27	0.2596	167.4	514.2
YXBXC	4	11.40	3.04	32.49	20.96	0.2316	93.5	379.5
YXBXN	8	11.90	2.80	52.22	55.19	0.2577	26.9	424.3
YXCXN	16	10.30	14.84	40.50	50.46	0.2710	19.5	405.7
BXCXN	8	20.93	17.34	42.32	22.86	0.2232	95.4	381.0
YXBXCXN	16	23.33	13.58	25.42	41.00	0.2562	19.8	345.2
Exper.error	178	34.66	17.31	33.26	39.66	0.02004	199.0	870.5

Table 3. The mean values of two years in terms of yield and yield components.

Parameter	Factor	Plant height	The first pod height	Pod number/ plant	Seed number/ plant	Harvest index	1000 seed weight	Seed yield/ kg ha^{-1}
Bacteria	B1	56.300	32.067 a	23.438 b	24.921 b	0.42	482.73	1999.0 b
	B2	55.067	30.067 b	25.689 a	27.410 a	0.39	479.23	2088.9 a
L.S.D.			1.228	1.228	1.703			8.711
Cultivar	C1	58.683 a	34.167 a	25.113	26.890	0.42	497.98 a	2149.5 a
	C2	54.717 b	29.283 b	24.255	25.545	0.40	498.22 a	2088.7 a
	C3	53.650 b	29.750 b	24.322	26.062	0.39	446.75 b	1893.5 b
L.S.D		2.129	1.504				5.101	10.67
Nitrogen	No	56.306	31.333	24.581	26.600	0.41	482.82	2079.0
	N_3	55.778	29.861	25.150	26.933	0.40	485.19	2105.0
	N_6	56.056	32.167	24.597	26.097	0.45	480.44	2019.0
	N_9	55.306	30.806	24.900	26.103	0.39	478.08	2007.0
	N_{12}	54.972	31.167	23.589	25.089	0.38	478.42	2008.0
Year	Y1	45.856 b	23.589 b	27.211 a	27.710 a	0.49 a	489.54 a	2251.1 a
	Y2	65.511 a	38.544 a	21.916 b	24.621 b	0.32 b	472.42 b	1836.7 b
L.S.D.		1.738	1.228	1.228	1.703	0.04180	4.165	8.711

B1 and B2: Non Inoculated and inoculated bacteria.
C1, C2 and C3: Local population, Canıtez-87 and ILC-114, respectively.
N_0, N_3, N_6, N_9, and N_{12}: 0, 30, 60, 90 and 120 kg ha^{-1} N application, respectively.
Y1 and Y2: First and second year.

Table 3 shows the average values and groupings belonging to characters investigated. Mean values were discussed and evaluated separately for each character.

Plant height

The applications of bacteria and nitrogen had no statistically significant effect on the plant height. It was found in a similar study (Kaçar at al., 2004, 2005) that there was no difference between bacterial inoculations in plant height. Togay et al. (2008) and Çakır (2005) reported that the applications of rhizobium bacteria had a positive effect on plant height; Meral et al. (1998), Karadavut and Özdemir (2001), Akçin and Işık (1995) and Vadavia et al.

(1991) reported that applications of bacteria and nitrogen increased the plant height. Özdemir and Engin (1991) reported that if the soil had enough nitrogen, the N application was not effective on plant height. Sharma et al. (1983) reported that the effect of fertilizer was positive on plant height.

The plant height was differently affected across the years (Table 3). Plants were taller in 2000 (65.5 cm) compared to 1999 (45.9 cm). More rainfall was recorded in April the vegetative period of plants. It was likely that plant height was affected positively and therefore lodging in plants was an important problem because of more rainfall in 2000.

The effects of cultivars were statistically significant at 1% probability level on the plant height. While maximum plant height was recorded on popular local genotype named Yerli (58.7 cm), Canıtez-87 cultivar and ILC-114 line had shorter plant height (54.7 and 53.7 cm, respectively). The plant height was differently affected across the years (Table 3).

First pod height

Popular local genotype named Yerli, which had the highest plant height, also gave the highest first pod height (34.2 cm), while Canıtez-87 cultivar (29.3 cm) and ILC-114 genotype (29.8 cm) had less first pod height. Local genotype Yerli is appropriate for mechanical harvest. Inoculation bacteria were statistically significant on the first pod height. Inoculation decreases the first pod height non inoculated plots (32.1 cm) had more first pod height than inoculated plots (30.1 cm). Contrary, Togay et al. (2008) reported that inoculation of bacteria increased first pod height. Karadavut and Özdemir (2001) reported that inoculation of bacteria did not affect first pod height.

Nitrogen doses did not affect first pod height either. First pod height was higher in 2000 (38.5 cm), when compared with 1999 (23.6 cm). Especially in April, the vegetative growth period, the plants had more rainfall (109 mm) in 2000. It was likely that more rainfall positively affected the plant height and first pod height in 2000.

The number of pod per plant

The effect of bacteria inoculation was found significantly on the number of pod per plant. The number of pods per plant was higher in plots with bacteria inoculation (25.7) than those without bacteria inoculation (23.5). Yağmur and Engin (2004) explained that inoculation of bacteria did not affect the number of pod per plant. However, in close agreement with our finding, Meral et al. (1998), Togay (2008), Muhammet and Naimat (1987), Çakır (2005) reported that inoculation of bacteria increased the number of pods per plant. On the other hand, the number of pods per plant were higher in 1999 (27.2) than 2000 (21.9).

In April and May months, the vegetative period, plants had more rainfall in 2000. It was likely that the plants had more vegetative parts, but fewer numbers of pods per plant because of more rainfall in those months. The effects of cultivars and nitrogen applications were not statistically significant on the number of pods per plant. El Hadi and Elcheikh (1999), Karadavut and Özdemir (2001), explained that both inoculation of bacteria and application of nitrogen increased the number of pod per plant.

The number of seed per plant

The effect of bacteria inoculation was found significant on the number of seed per plant. The number of seed per plant was higher in plots with bacteria inoculation (27.4) than those without bacteria plots (24.9). Similar results have also been reported by Akdağ and Şehirali (1995), Kaçar et al. (2004), Çakır (2005) and Hernandez and Hill (1983).

The effects of cultivars and nitrogen doses were not statistically significant on the number of seed per plant. Similarly, Kaçar et al. (2004) reported that increasing nitrogen doses did not affect the number of seed per plant, furthermore as nitrogen doses increase, the number of seeds per plant decreased. However, Akdağ and Şehirali (1995) reported that inoculation of bacteria and increasing nitrogen doses had positive effect on the number of seeds per plant.

Effect of years occurred differently on the seed numbers per plant. The number of seeds were higher in 1999 (27.7) than 2000 (24.6), as well.

In April and May, the vegetative period, the plants had more rainfall in 2000. It was likely that because of more rainfall in these months the plants had more vegetative parts, and had fewer numbers of seed per plant. Excessive rainfall in April and May, vegetative period of plants, increased the plants vegetative period and vegetative parts in 2000. It was likely that more rainfall affected negatively the pollination and insemination; therefore it resulted in fewer numbers of pods per plant and the number of seeds per plant.

Harvest index

The effects of cultivars, applications of bacteria and nitrogen were not statistically significant on the harvest index. Also, some researchers previously reported that inoculation of bacteria did not affect the harvest index (Meral et al., 1998). However, Çakır (2005) explained that inoculation of bacteria increased the harvest index to a small extent. The harvest index was differently affected across the years. Harvest index was higher in 1999 (49.0%) than in 2000 (32.0%).

In April and May, the vegetative period, the plants had more rainfall in 2000. It was likely that more rainfall increased plant height. Because of increasing plant height, lodging in plants increased in 2000. The lodging decreased in harvest index.

Mean values of harvest index were higher in plots without bacteria (42%) than those with bacteria (39%). Increasing nitrogen doses (N_9 and N_{12}) decreased harvest index values (38 and 38%, respectively). N_0, N_3, and N_9 nitrogen dozes gave higher harvest index (41, 40 and 45%, respectively).

1000 seed weight

The applications of bacteria and nitrogen did not statistically have significant effect on the 1000 seed weight. Some researchers reported that inoculation of bacteria and nitrogen applications did not affect the 1000 seed weight (Karadavut and Özdemir, 2001; Meral et al., 1998; Harnandez and Hill, 1983; Akçin and Işık, 1995; Pekşen and Gülümser, 1996; Kaçar et al. 2004; Kaçar et al. 2005; Çakır, 2005).

The effects of cultivars were statistically significant at 1% probability level on the 1000 seed weight. While maximum 1000 seed weight was obtained from Canıtez-87 cultivar (498.2 g) and popular local genotype Yerli (497.9 g), ILC-114 line had fewer 1000 seed weight (446.8 g).

The effect of years was also significant at 1% probability level on 1000 seed weight. 1000 seed weight was higher in 1999 (489.5 g), than in 2000 (472.4 g).

Seed yield per unit area

The effects of cultivars, bacteria inoculation and years on seed yield were found significant according to the combined data of the two years. Differences between cultivars were determined significantly at 1% probability level. The highest yield was obtained from local variety Yerli (2150.0 kg ha^{-1}), and Canıtez-87 cultivar (2089.0 kg ha^{-1}), whereas ILC-114 Line (1894.0 kg ha^{-1}) gave lower yield. Inoculation of bacteria increased seed yield. Seed yield per unit area was higher in plots with bacteria inoculation (2089.0 kg ha^{-1}), than those without bacteria (1999.0 kg ha^{-1}). Similarly, Tokay et al. (2008), Kantar et al. (2003), El Hadi and Eisheilch (1999), Hernandez and Hill (1983), Meral et al. (1998), İbrahim and Salih (1983), Rai and Singh (1980), Gürbüzer (1980), Karuç et al.1993, Akçin and Işık (1995), Başaran (2000), Çakır (2005), Erdoğan and Özdemir (1998), Karadavut and Özdemir (2001), Akdağ and Şehirali (1995), Ersin (1984) reported that rhizobium inoculation positively affected the seed yield, whereas, Kaçar et al. (2005) and Beck et al. (1991) reported that inoculation of bacteria affected yield negatively. Pekşen and Gülümser (1996) reported that three different rhizobia strains did not have any different effects on the seed yield of native rhizobium strain. Karadoğan et al. (1999) reported that the areas on which cicer have not been sown for long years because of less effective bacteria strain, inoculation will be useful when sowing cicer. Chemical composition of field and the population of rhizobium bacteria strains in the environment must be taken in to consideration. The highest yield was obtained in 1999 (2251.0 kg ha^{-1}), and the lowest yield was obtained in 2000 (1837.0 kg ha^{-1}). It was likely that more rainfall positively effected the vegetative period and vegetative parts of plant but negatively the pollination and insemi-nation, so it resulted in fewer seed yield. Year x cultivar interaction was significantly at %5 probability level.

Although the effect of nitrogen application was not significant, seed yield per unit area was relatively more at N_3 and N_o nitrogen dozes (2105 and 2075 kg ha^{-1}, respectively) than the other N doses. The lowest seed yield per unit area were N_{12}, N_9, and N_6 nitrogen dozes which were the highest nitrogen dozes (2008.0, 2007.0, 2019.0 kg ha^{-1} respectively). N_{12}, N_9, N_6 which were the highest nitrogen dozes, decreased seed yield per unit area compared to N_o and N_3 nitrogen dozes. Similarly Şehirali (1988) reported that 60 - 100 kg ha^{-1} N application, a high doze, affected negatively seed yield every time. Nevertheless, Meral et al. (1998), Pekşen and Gülümser (1996), reported that N application increased seed yield .On the other hand, Kaçar et al. (2004), reported that N applications didn't affect on seed yield. Singh (1987), reported that because the response of cicer to fertilizer was less, producing the cultivar which had positive response to fertilizer will be useful, in order to increase yield .

Conclusion

It is rather difficult to determine to which extend the inoculation material affected the nitrogen fixation when the inoculation treatments were carried out under field condition, (Cebel and Altuntaş, 1992) since nodule formation and nitrogen fixation are greatly affected by environmental factors (Azkan, 2002).

According to the results, producing cicer in these conditions, before sowing cicer seed, the seeds must be inoculated with effective rhizobium bacteria and the application of high dosage nitrogen must be avoided.

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