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Effect of different fertilizer forms on yield and yield components of chickpea varieties

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Abstract

This research was conducted to determine the effects of different fertilizer forms (control, diammonium phosphate, urea, phosphorus and bacteria) on yield and yield components of some chickpea varieties (Gokce, Diyar 95, Aziziye 94 and Taek-Sagel) in Diyarbakir, Turkey, during 2018 and 2019 growing seasons. In the study, plant height, plant biomass, pod weight, seed yield per plant, number of pods and number of seeds per pod, biological yield, grain yield, 100-seed weight and harvest index were evaluated. The effect of fertilizer treatments on chickpea varieties for all traits were significant, except 100-seed weight, and harvest index. Grain yield ranged from 1274 kg ha^{-1} to 1479 kg ha^{-1} among treatments. The control group (1479 kg ha^{-1}), urea (1478 kg ha^{-1}) and diammonium phosphate (1449 kg ha^{-1}) fertilizer treatments had produced more grain yield than bacteria inoculation (1274 kg ha^{-1}) and phosphorus (1332 kg ha^{-1}) treatments.

Keywords: Chickpea, *Cicer arietinum*, Nitrogen, Phosphorus, Bacteria

Introduction

Chickpea is produced in over 40 countries from all continents at the present. However, the most important chickpea producing countries are India, Australia, Myanmar, Egypt, Turkey, Pakistan, Iran, Mexico, Ethiopia and Canada. Chickpea is currently grown on about 14 million hectares worldwide. India and Australia rank the first and second with the shares of 65% and 7.3%, respectively. Average annual production of chickpea is about 14 million tons with 95% of chickpea cultivation and consumption occurring in the developing countries (FAO, 2018). The chickpea area in Turkey is about 514 000 ha with a production of 630 000 tons and an average yield of 1230 kg ha^{-1} (TUIK, 2018). Chickpea acreage and productivity in Turkey increased in last decades. The use of improved cultivars and agronomic techniques by the farmers and government supports had an increasing effect on total chickpea production. Even last four-year data shows that harvested area and production in Turkey increased by 31 and 40%, respectively. Chickpea is less labor-intensive and requires fewer external inputs as compared to cereals. Chickpea is played a significant role in improving soil fertility by fixing the atmospheric nitrogen up to 140 kg ha^{-1} meeting most of the requirement. After harvest, it leaves substantial amount of residual nitrogen for subsequent crops and adds some amount of organic matter to maintain and improve soil health and fertility. Farmers can save fertilizer cost not only for chickpea but also for the subsequent crops.

The total amount of N that was fixed by the plant for growth of chickpea varies between 19 to 24 kg N per hectare in drought season (Carranca et al., 1999) and average estimate is 70 kg per hectare in Australia (Drew et al., 2012). The excess amount of nitrogen given as inorganic nitrogen or fertilizer in the soil causes the amount of biologically fixed nitrogen to decrease (Doughton et al., 1995).

It has been suggested that low levels of fertilizer N (i.e., "starter N") may increase yield. For example, recommendations for Southeast Anatolia region of Turkey indicates "if nitrogen fixation is not optimized due to unfavorable growing conditions (e.g., relatively dry seed bed), chickpea may benefit from low rates of starter N in some years. The generally recommended fertilizer rates for chickpea include 20-30 kg nitro-

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gen (N) and 40–60 kg phosphorus (P) per hectare. Total quantities of N and P should be given as a basal dose in absence of bacterial inoculation. Also, farmers have recently begun to apply excessive fertilization in chickpea and lentil crops mostly at sowing time and rarely during flowering period by spraying. Some researchers reported that foliar spray of 2% urea at flowering has been found beneficial in rainfed crops (Das and Jana, 2015). Although many studies are examining the effect of fertilization on yield in chickpea, there are still doubts about chickpea fertilization among chickpea producers. In this study, we tried to determine the effect of different fertilizer applications on yield and some agronomic traits.

Materials and Methods

This research was conducted in Dicle University Agricultural Faculty, Diyarbakir, Turkey during 2018 and 2019 growing seasons.

Experimental Area

Diyarbakir is located on grid 37.91 °N and 40.2 °E, at an altitude of 640 m above sea level. The general climatic conditions of experimental area were characterized as hot and drought during crop growing season. Average long term precipitation is a little bit lower than 500 mm, and it differently fluctuates between the years. The seasonal rainfall distribution is mainly between November and June. Although unusual, irregular precipitation in June is recorded in recent years. Mean temperature is about 16-20 ºC between January and June. May has an irregular precipitation distribution, but June is usually dry and hot. The relative humidity varies between 60 % and 75% from January to April but decreases to about 20-30% after May. In the first experiment year (2018), total precipitation from February to April was 146.8 mm, and weather was dry, but in May, rainfall was 157.8 mm. Mean temperature (February to May) was 11.9 ºC. Precipitation from February to April was 365.2 mm in the second year (2019), but May was considerably dry with 45.8 mm, and mean temperature (February to May) was 11.35 ºC. Growing season in 2019 was quite cool compared to the preceding growing season (Table 1). The soil analysis indicated that soils were neutral (pH: 7.24), insufficient in organic matter (0.79%) and phosphorus content (13.2 kg ha $^{-1}$) with clay texture.

Table 1. Meteorological data of Diyarbakir for experiment years

Month	Mean temperature (ºC)		Total precipitation (mm)		Moisture (%)	
	2018	2019	2018	2019	2018	2019
January	5.2	3.8	86.6	67.6	77.3	81.7
February	7.6	5.4	86.4	77.4	74.5	77.0
March	12.3	8.2	11.6	135.2	63.2	74.9
April	15.9	11.8	48.8	152.6	53.0	78.4
May	19.4	20.1	157.8	45.8	67.5	58.5
June	26.5	28.3	14.4	1.0	37.9	32.5
July	31.2	30.3	0.0	0.07	24.2	24.8

Experimental Design and Agricultural Practices

The experiment was laid out following a split-plot in completely randomized block design with three replications. Fertilization treatments and cultivars were designed as main and sub factors, respectively. Fertilization treatments included the applications of control, diammonium phosphate, urea, phosphorus and bacteria. Four chickpea varieties (Gokce, Diyar 95, Aziziye 94 and Taek-Sagel) were used. The seeds were sown with inter and intra row space of 40x10 cm, respectively, on 7 February 2018 and 11 February 2019. Before sowing, seeds were inoculated with specific strain of Rhizobium at a rate of 10 g /kg seed as bacteria treatment. Inorganic fertilizers were applied at a rate of 40 kg ha^{-1} nitrogen and 80 kg ha^{-1} phosphorus during sowing in the forms of diammonium phosphate (18 N - 46% P), urea (46% N) and triple superphosphate (46% P_2O_5) depending on the ways of treatment. The crops were irrigated after sowing in 2018 due to early seasonal drought. Weed, disease and pests were controlled first manually and then using chemical spray. Data on plant height, plant biomass, pod weight, seed yield per plant, number of pods and number of seeds per plant, biological yield, seed yield, 100 seed weight and harvest index were recorded at harvest.

Data of two years were analyzed separately and pooled, were subjected to analysis of variance, and means were separated using the Duncan's Multiple Range Test (0.05).

Results and Discussions

In the study the effect of fertilizer treatments on chickpea varieties for plant height, plant biomass, pod weight, plant grain yield, number of pods and seeds per plant, biological yield, grain yield, 100 seed weight and harvest index were evaluated.

The effect of fertilizer treatments on for all traits of chickpea varieties was significant, except for 100 seed weight and harvest index. Plant height ranged from 53.3 cm to 57.9 cm. Control, phosphorus (57.9 cm) and diammonium phosphate (57.6 cm) treatments were higher than urea (58.6 cm) and bacteria (53.3 cm) treatments. Cultivar x treatment interaction indicated that the effect of treatments on Aziziye 94, Taek-Sagel and Diyar 95 cultivars were significant, Gokce was non-significant. Urea (57.5 cm) and phosphorus (58.9 cm) treatments in Taek-Sagel, phosphorus (66.0 cm) and diammonium phosphate (65.0 cm) treatments in Diyar 95 were higher than the other treatments. However, Aziziye 94 had the highest value in control group (62.4 cm). Differences among years for plant height were significant. Plant height in the first experiment year (64.6 cm) was higher than that in the second year (47.5

cm) (Table 2).

The most efficient treatment for plant biomass was phosphorus (21.4 g) and diammonium phosphate (20.3 g) treatments. The highest plant pod weight was obtained from diammonium phosphate (10.5 g). The effect of treatments for plant biomass and plant pod weight on varieties was different, and plant biomass and plant pod weight were significant in Gokce and Diyar 95 varieties, and varieties showed high responses to diammonium phosphate fertilizer treatment.

Seed yield ranged from 9.4 g to 11.3 g plant^{-1}, and yield from all treatments were higher than control (9.4 g). The effect of treatments on plant seed yield among varieties was significant in Gokce, and phosphorus fertilizer treatment was an important treatment in Gokce, but other cultivars were not responsive to fertilizer treatments for the plant seed yield (Table 2).

Table 2. The trait means and significance level of variation sources of chickpea genotypes under changing fertilizer treatments

		Plant height (cm)					Plant biomass (g)				
Treatments	**N and P kg ha^{-1}**	**Taek-Sagel**	**Gokçe**	**Aziziye 94**	**Diyar 95**	**Mean**	**Taek-Sagel**	**Gokçe**	**Aziziye 94**	**Diyar 95**	**Mean**
Control	0 - 0	56.1	52.5	62.4	58.8	57.5	14.9	18.1	20.3	18.2	17.9
Urea	40 - 0	57.5	49.3	51.5	58.6	54.2	16.6	20.3	21.7	19.3	19.5
Phosphorus	0 - 80	58.9	52.5	54.2	66.0	57.9	19.3	22.5	19.0	20.3	20.3
DAP	40 - 80	55.4	49.5	60.3	65.0	57.6	17.3	23.8	20.0	24.6	21.4
Bacteria	0 - 0	51.6	47.7	52.7	61.1	53.3	18.6	18.2	20.4	19.9	19.3
Mean		55.9 **	50.3 **	56.2 ns	61.9 **		17.3 ns	20.6 **	20.3 ns	20.4 **	
1st and 2nd year means			64.6	47.5				22.4	16.8		
Source of variation											
Cultivar		**					**				
Treatments		**					**				
Interaction		**					**				

		Plant pod weight (g)					Plant seed yield (g)				
		Taek-Sagel	**Gokçe**	**Aziziye 94**	**Diyar 95**	**Mean**	**Taek-Sagel**	**Gokçe**	**Aziziye 94**	**Diyar 95**	**Mean**
Control	0 - 0	7.6	7.8	10.3	7.5	8.3	8.3	7.6	10.5	11.5	9.4
Urea	40 - 0	8.6	10.6	9.6	10.2	9.8	9.2	10.5	9.3	12.6	10.4
Phosphorus	0 - 80	10.0	10.1	7.9	9.7	9.4	9.7	12.1	7.5	12.6	10.5
DAP	40 - 80	9.4	11.9	10.8	9.8	10.5	10.1	10.5	10.8	13.9	11.3
Bacteria	0 - 0	8.9	8.2	10.4	7.8	8.8	9.5	8.9	9.8	11.5	10.3
Mean		8.9 ns	9.7 *	9.8 ns	9.0 **		9.3 ns	9.9 **	9.6 ns	12.7 ns	
1st and 2nd year means			8.87	9.83				13.5	7.2		
Source of variation											
Cultivars		**					**				
Treatments		**					**				
Interaction		**					**				

**, * and ns: significant at 1 and 5% level, and not significant, respectively

Number of pods per plant ranged from 17.1 to 20.8, and all treatments had the same effect, except for control. The effect of the treatments on plant pod number among varieties was significant. Pod number of Gokce ranged from 14.7 to 23.4, Diyar 95 ranged from 15.4 to 20.0, and both cultivars highly responsive to nitrogen fertilizer (DAP and urea), but control group had low value for this trait. However, Aziziye 94 had the highest value (20.1) in bacteria inoculation and control group. Number of seeds per plant ranged from 17.0 to 19.3 among treatments, and fertilizer treatments had higher compared to control group. Cultivars x treatment interaction indicated that the effect of treatments was significant in only Gokce, and all fertilizer treatments had higher pod number compared to control in Gokce variety. Differences among years were not significant for both traits (Table 3).

Table 3. The effect of fertilizer treatments on number of pods and seeds plant^{-1} in Chickpea

		Number of pods plant^{-1}					Number of seeds plant^{-1}				
Treatments	**N and P kg ha^{-1}**	**Taek-Sagel**	**Gokçe**	**Aziziye 94**	**Diyar 95**	**Mean**	**Taek-Sagel**	**Gokçe**	**Aziziye 94**	**Diyar 95**	**Mean**
Control	0 - 0	18.1	14.7	20.1	15.4	17.1	19.0	16.5	21.5	11.1	17.0
Urea	40 - 0	18.6	23.4	18.7	20.0	20.2	19.4	22.4	19.9	14.9	19.2
Phosphorus	0 - 80	22.4	19.5	15.8	17.5	18.8	21.3	20.0	15.0	14.7	17.8
DAP	40 - 80	19.4	22.9	21.6	19.4	20.8	19.3	20.1	22.0	15.9	19.3
Bacteria	0 - 0	20.4	18.8	20.1	16.7	19.0	21.1	19.5	20.6	13.1	18.6
Mean		19.8	19.8	19.3	17.8		20.0	19.7	19.8	13.9	
		ns	*	**	**		ns	*	ns	ns	
1st and 2nd year means			20.7	17.6				18.3	18.5		
Source of variation											
Cultivars		**					**				
Treatments		**					*				
Interaction		**					**				

**, * and ns: significant at 1 and 5% level, and not significant, respectively.

Biological yield ranged from 3955 kg to 5281 kg per hectare among the treatments. Diammonium phosphate (5281 kg ha^{-1}) and urea (4859 kg ha^{-1}) fertilizer treatments and control group (4699 kg ha^{-1}) had more yields than that of bacteria inoculation (3955 kg ha^{-1}). Variety x treatment interaction was significant, and Gokce, Aziziye 94 and Diyar 95 cultivars had different responses to fertilizer treatments. Diammonium phosphate fertilizer treatment had positive effect on Diyar 95 (7557 kg ha^{-1}) (Table 4). It is generally accepted that the soil nutrients deficiency and alkaline soil reaction (pH) adversely affect the growth of crops. Organic manures or use of inorganic nitrogen fertilizers at sowing is important to ameliorate organic matter and the uptake potential of nutrient elements (Timsina, 2018).

Grain seed yield ranged from 1274 kg to 1479 kg per hectare among treatments. Control group (1479 kg ha^{-1}), urea (1478 kg ha^{-1}) and diammonium phosphate (1449 kg ha^{-1}) treatments had produced more seed yield than those of bacteria inoculation (1274 kg ha^{-1}) and phosphorus (1332 kg ha^{-1}) treatments. Variety x treatment interaction was significant, Gokce and Aziziye 94 cultivars showed different responses to treatments. The highest grain yield for Aziziye 94 was obtained from control while phosphorus and bacteria treatments yielded the lowest (Table 4). Kanwar (1981) reported that phosphorus-deficient soils gave high responses to phosphorus, as the soils with low bacterial activity gave high responses to nitrogen. It has been reported that low rates of starter N (i.e., 30 kg N ha^{-1}) and P (20 kg P2O5 ha^{-1}) may optimize desi type chickpea grain yield (Walley et al., 2005). Gubbels (1992) reported that high rate of phosphorus did not increase the yield. Phosphorus is a nutrient that is effective in nodulation but variable in yield (Chen., 2006), although legumes generally respond well to phosphorus fertilizers (Shukla, 1964), Saxena (1980) stated that this response is variable in chickpea. The phosphorus requirement of chickpea crop is varying by the growth conditions (Johansen and Sahrawat 1991; Riley, 1994; Islam et al., 2011). Bicer (2014) reported that chickpea cultivars showed low response to P and phosphorus fertilization could not be effective in late sown chickpea. Early sown and irrigation supply can be advisable for effective phosphorus uptake in dry regions.

In fact, seed yield had shown little variation among the treatments, although they were statistically significant. The results might have been due to the climatic conditions of two years of trial. The rate of seedling emergence was higher in 2018 compared with 2019 due to the high temperature and the low precipitation in February 2018. Low temperature and rainfall also delayed the time of first emergence and flowering in 2019, some seeds could not even germinate, and had no effect on the duration of vegetative growth and reproductive growth stages. Finally, high precipitation may have caused the draining of fertilizers in the soil. However, biological yield and seed yield were declined by decreasing the seedling emergence rate and vegetative growth rate such as plant height and plant biomass. Although decreased in the second year, this decrease in seed yield was not as sharp as in biological yield. Short and high-branched plants had sufficient number of pods and seeds (Table 1,4). Fertilizer use is the second important factor after water availability in rainfall dependent agriculture (Umrani, 1995), and fertilization increases deeper penetration of roots and therefore fertilizer treatment cause relatively high water extraction (Hedge, 1986). Fertilizer is vital to increase productivity in drylands farming systems (Kanwar, 1981). In this study, our opinion is that we could have better revealed the effect of fertilizer in dry year of the experiment if we had employed a little higher fertilizer dose.

Table 4. The effect of fertilizer treatments on biological yield and seed yield, 100 seed weight and harvest index in chickpea

		Biological yield (kg ha^{-1})					Seed yield (kg ha^{-1})				
Treatments	**N and P kg ha^{-1}**	**Taek-Sagel**	**Gokçe**	**Aziziye 94**	**Diyar 95**	**Mean**	**Taek-Sagel**	**Gokçe**	**Aziziye 94**	**Diyar 95**	**Mean**
Control	0 - 0	4857	4361	4620	4956	4699	1628	1517	1506	1264	1479
Urea	40 - 0	5132	5026	3536	5743	4859	1616	1378	1393	1235	1478
Phosphorus	0 - 80	5292	4107	4137	4209	4436	1688	1432	872.4	1335	1332
DAP	40 - 80	5265	4545	3758	7557	5281	1553	1804	1088	1351	1449
Bacteria	0 - 0	4463	3998	3319	4039	3955	1570	1290	878.5	1355	1274
Mean		5002	4407	3874	5301		1669	1484	1148	1308	
		ns	**	**	**		ns	**	**	ns	
1st and 2nd year means			6211	3081				1572	1231		
Source of variation											
Cultivars		**					**				
Treatments		**					**				
Interaction		**					**				
		100 seed weight (g)					**Harvest index (%)**				
Treatments		**Taek-Sagel**	**Gokçe**	**Aziziye 94**	**Diyar 95**	**Mean**	**Taek-Sagel**	**Gokçe**	**Aziziye 94**	**Diyar 95**	**Mean**
Control	0 - 0	37.96	39.78	40.96	41.29	40.00	34.50	37.83	36.17	42.50	37.75
Urea	40 - 0	38.10	39.29	41.72	41.57	40.17	37.00	36.17	29.83	35.67	34.66
Phosphorus	0 - 80	38.47	39.72	41.59	42.20	40.49	33.33	32.17	28.33	27.83	30.41
DAP	40 - 80	36.51	39.42	42.26	40.76	39.74	30.67	41.67	32.83	23.50	32.16
Bacteria	0 - 0	39.64	39.28	40.84	40.33	40.02	36.83	35.33	35.50	30.50	34.54
Mean		38.14	39.50	41.47	41.23		34.46	36.63	32.53	32.00	
		ns	ns	ns	ns		ns	ns	ns		
1st and 2nd year means			40.17	39.99				26.13	41.68		
Source of variation											
Cultivars		ns					ns				
Treatments		ns					ns				
Interaction		ns					ns				

** and ns: significant at 1 and 5% level, and not significant, respectively.

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100-seed weight and harvest index were not affected by treatments. It ranged from 38.14 g in Taek-Sagel to 41.47 g in Aziziye 94 (Table 4). The reason for the low effect of applications on 100-seed weight is due to the high inheritance of this character (Toker and Canci, 2003). It has been reported that 100-seed weight is positively affected by dry and rainy conditions, but it has decreased in arid years/conditions. Therefore, the seed weight can be improved with an optimum fertilizer dose. The differences among years were significant for harvest index. In the second year of the experiment, seed yield increased instead of vegetative parts (Table 4).

Differences among the two trial years for plant height, plant biomass, plant seed yield, biological yield, seed yield and harvest index may be due to climatic conditions. In 2018 growth period; February, March and April were quite dry and hot, and the experiment was regularly irrigated by sprinkler irrigation. Irrigation supply water, sunny days and warm weather during the vegetation period and high rainfall in May had a positive effect on plant development. In 2019 growth period; since February, March and April were quite rainy and the cloudy weather, the low temperature delayed the plant growth at the beginning of the growing season. Seed germination and emergence delayed due to low soil temperature, emergence rate and seedling vigor was low and weak. Most of seeds that could not emerge due to low soil temperature, could not survive under the soil. As a result, the number of plants per plots decreased. May 2019 was extremely dry during the generative period, and caused negative effects on plants. In 2019, the vegetative period started late and progressed slowly. Finally, the generative period due to drought delayed the development of the plant.

Fertilizer applications could not be useful for crops in wet trial year, 2019, since it applied in sowing time. Because the rainy year increased the nutrient loss by drainage, therefore fertilizer dose, especially for inorganic nitrogen, must be accurately calculated for rainy areas or seasons. In addition, proper combinations of mineral fertilizer and bacteria inoculation would be better for seed productivity, but only bacteria and only mineral fertilizer applications were not very effective in this trial. Zhang et al. (2016) reported that the combined application of organic manures and mineral fertilizers plays an important role in optimizing soil nutrient pool, increasing crop yields or water use efficiency.

Conclusion

The effect of fertilizer treatments on chickpea varieties for all traits were significant, except for 100-seed weight and harvest index. As a result of this experiment, although nitrogen and phosphorus applications gave high values, the effects of fertilizer application in such wet and rainy years were different for yield and its traits. Long-term experiments are required for monitoring the changes in crop yields and soil fertility since short-term studies cannot reveal these changes. In our region, the effect of fertilizer types and doses on legumes crop should separately be investigated in dry and rainy conditions.

Compliance with Ethical Standards

Conflict of interest

The authors declare that for this article they have no actual, potential or perceived the conflict of interests.

Author contribution

The contribution of the authors is equal. All the authors read and approved the final manuscript. All the authors verify that the Text, Figures, and Tables are original and that they have not been published before.

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