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Optimizing Planting Density and the Use of Potassium Fertilizers for the Prospect of Enhancing Yield of Field Grown 'CXD_222' Tomatoes

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ABSTRACT

Background: Potassium fertilizer and optimum planting density are important factors for maximizing fruit yield in field grown tomatoes. We conducted a field study to evaluate the effects of planting density and potassium fertilizers on the yield performance of CXD_222 tomatoes.

Materials and Methods: We evaluating the fruit yield of CXD_222 tomatoes in NP + 50 (nitrogen and phosphorus in a 50 x 50 cm planting pattern), NP + 40 (nitrogen and phosphorus in a 40 x 40 cm planting pattern), NPK + 50 (nitrogen, phosphorus, and potassium in a 50 x 50 cm planting pattern), and NPK + 40 (nitrogen, phosphorus, and potassium in a 40 x 40 cm planting pattern).

Findings: Wider spacing (NPK +50 and NP + 50) resulted in significantly heavier fruits per plants and produced more fruits per plants. Narrow spacing; however, produced significantly higher yield per square meter. The effect of potassium fertilizer was obvious in a sense that planting space treatments with potassium fertilizers produced significantly higher yield than the corresponding treatments without the application of potassium fertilizer. The highest yields of 5.2 and 4.75 kg m^{-2} were achieved in NPK + 40, NPK+50 and NP + 40, respectively whereas bigger and more fruits per plants were harvest from NPK + 50 and NP + 50, respectively.

Conclusion: This study indicates that optimizing planting space and the use of potassium fertilizers will significantly enhance fruit yield.

Keyword: Potassium Fertilizer; Planting Density; Yield; CXD_222: Tomatoes

INTRODUCTION

Tomato is the fourth most important fresh-market vegetable after potato, lettuce, and onions. It is rich in nutrients and offers several health benefits including weight loss, healthy skin, regulated blood pressure, diabetes prevention, and a healthy heart. Despite the significant health advantages, tomato was considered poisonous in the U.S around 200 years ago because it is related to the nightshade family (Mariya et al., 2020). Even though over 80% of its population is engaged in agriculture, Afghanistan is not self-sufficient in terms of tomato production; therefore, it relies on neighboring countries especially Pakistan to meet the tomato demand of the people. This is largely due to the long-lasting civil war that has destroyed agricultural infrastructures and research centers (Gulab et. al., 2020).

Several factors including variety, sunlight, temperature, pollinators, water supply, nutrients, and others determine the yield and health benefits of tomatoes (Dorais, 2007). In 2004, It was reported that tomato was cultivated on about 7,940 ha land and produced up to 85,000 tons of harvestable yield in Afghanistan (MAIL, 2012). The Food and Agriculture Organization (FAO) stated that tomatoes accounted for up to 16% of horticulture crops in Afghanistan (GULAB et al., 2020). Because of having a large quantity of water (Gastelum et al., 2011), tomato is very sensitive to several factors and can easily perish (Nasrin et al., 2008). Moreover, poor cultural practices and post-harvest management can cause great losses (Rahman & Hossain, 2005).

Snyder (2007) states that plant density and pruning methods are important practices for achieving higher yield in tomatoes. He recommends a 4-4.3 ft-2 area for each tomato plant so it can grow optimally. Putting this to in-row and between row spacing, his recommended spacing is 13.7-15.7 and 4 ft, respectively. Similarly, field and greenhouse-grown tomatoes have shown different responses to different plant densities. Yield per plant was improved but yield per land was reduced in greenhouse-grown cherry tomato when the plant spacing was increased from 11.8 to 19.7 inches (Charlo et. al., 2007). High yield was achieved in heated greenhouses as the plant density was increased (Saglam and Yazgan, 1995). Although Kemble and colleagues (1994) didn't find any difference between fruit yield at 12 and 30 inches in-row spacing, higher yield in field-grown tomatoes was obtain with smaller in-row spacing (Santos et. al., 2010).

The yield response of tomato to animal manure and chemical fertilizers is well established (Ramyabharathi et al., 2014). Chapagain and Wiesman (200) reported that the use of Potassium (K) increases the growth of tomato plants and thus it results in higher fruit production. Potassium is essential to plant growth in several ways. As a major nutrient, it plays a great role in growth and development, activation of enzymes, energy consumption, photosynthesis, nutrient translocation, and water uptake (Havlin et. al., 2005). A yield enhancement of 35.55% over the control was reported in Ahmad and colleagues (2015) study when they applied a higher dose of 120 kg K2O/ha. Prajapati and Modi (2012) revealed that K improves the quality, disease resistance, and shelf-life of fruits. It was also reported that 375 kg ha of K2O resulted in 27.44% and 101.23% increase of total solids and soluble solids, respectively when compared to the control one (Javaria et. al., 2012).

In a previous study, we tested the seed yield of CXD_222 and Roma_VF in the field condition and found that the CXD_222 produced a significantly higher yield than the Roma_VF. In that study we used 50 x 50 cm planting space and did not use K. As stated in the literature, optimum planting space and K are extremely effective for fruit yield production in tomatoes. We hypothesized that reducing the planting space from 50 x 50 cm to 40 x 40 cm and the application of K fertilizers will improve yield in tomato. Therefore, the objective of the current study was to evaluate the yield potential of CXD_222 tomato variety with two planting densities and K fertilizer.

MATERIALS AND METHOD

Planting materials

A high yielding tomato variety, CXD_222, was chosen for this study. Seeding trays were filled with compost and sandy loam soil. Two seeds per hill were sown in the trays and were kept in a greenhouse in Sarkhroad, Nangarhar, Afghanistan. A 20 g m Urea was also used during seeding to assure the maximum growth rate of the seedling. The seedlings were then thinned to one after the first true leaf expanded. As soon as the seedling expanded the third true leaf, they were transplanted in the field. A randomized complete block design (RCBD) was assigned with two replications. The distance between the two replications was 500 m due to lack of land availability. Each plot was 3 x 12 m long. Two planting density patterns with and without K fertilizer were used in each block which means each block had four plots. Our treatments consisted of NP + 50 (nitrogen and phosphorus in a 50 x 50 cm planting pattern), NP + 40 (nitrogen and phosphorus in a 40 x 40 cm planting pattern), NPK + 50 (nitrogen, phosphorus, and potassium in a 50 x 50 cm planting pattern), and NPK + 40 (nitrogen, phosphorus, and potassium in a 40 x 40 cm planting pattern). An 80:60:150 kg ha-1 ratio of Urea and DAP and K2O was applied. Total DAP and K2O, and half of N were applied during seedbed preparation. The remaining N was applied 30 days after transplanting. To avoid fruit setting close to the ground and have erected stems, with pruned the plants as they grew. Plants were irrigated on a regular basis.

Yield Measurement

We selected ten plants in the center of each plot for measuring yield and yield attributes. The fruit was harvested at the red-ripe maturity stage. Only the marketable tomatoes were used in the final yield measurements. Fruit weight per plant (FWPP) was the total of all fruits harvest from a single plant. Single fruit weight (SFW) was measured as the average weight of a single fruit in each plant. Fruit number per plant (FNPP) was measured as the number of all harvestable fruits per single plant.

Statistical Analysis

We used a two-way analysis of variance (ANOVA), tukey's test of multiple comparisons (Tukey, LSD), and Pearson's correlations test to validate the data. Two-way ANOVA was used between treatments, blocks, and treatment and block interaction. The reason for using a test between blocks and the interaction between block and treatments was due to the distance between two blocks. We used Pandas, Numpy, Scipy, and Pingouin libraries in python programming language and Agricolae package (Mendiburu, 2015) in R statistical language for the tests.

RESULTS

Plants with wider spacing and K applied (NPK + 50) resulted in significantly greater yield per plant which was followed by NP + 50. Total yield per plant was 1063.61 g and 969.25 g for NPK + 50 and NP + 50 treatments, respectively. In dense plants, the total yield per plant was 836.99 g and 760.37 g for NPK + 40 and NP + 40, respectively and the difference was highly significant among all groups. Fig.1 shows the influence of treatment on the yield performance of a single plant.

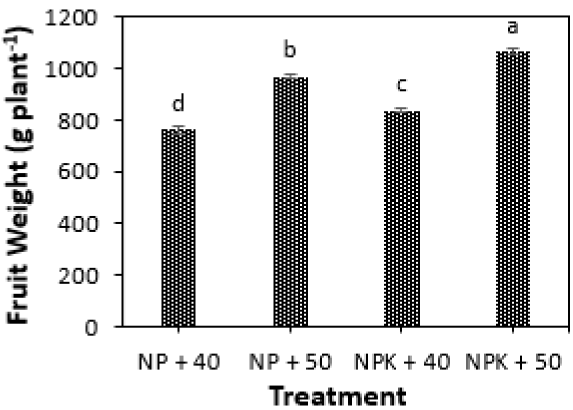

Fig.1. Fruit weight per plant (g). Each data point is the mean of n = 20 observations. Letters on the bar show level of significances.

We observed a similar pattern in fruit number per plant (FNPP) and single fruit weight (SFW). Winder spacing generally produced significantly more fruits per plant. The same thing happened in the case of K fertilizers. Tomatoes with K applied produced significantly more fruits than those without K. NPK +50 produced 10.53 fruits per plant and was followed by NP + 50 by producing 9.83 fruits per plant. In the narrow spacing, NPK + 40 produced significantly more fruits than NP + 40. Fruit number in NPK + 40 and NP + 40 was 8.75 and 8.08, respectively **(Fig. 2).** The weight of single fruit (SFW) also differed between the treatments. Wider spacing produced heavier fruits than narrow spacing. The difference was; however, significant only with K fertilizer treatment (NPK + 50). In narrow spacing, NPK + 40 produced heavier fruits than NP + 40, but the difference was not significant **(Fig. 3).**

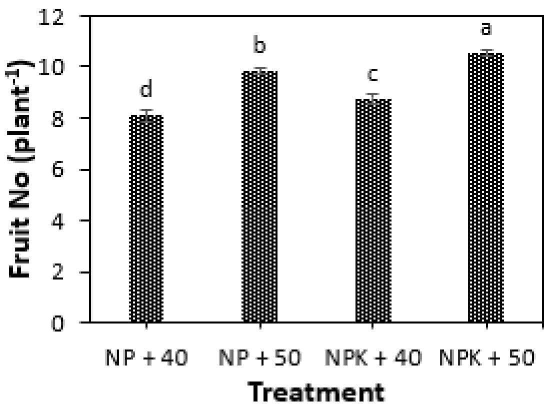

Fig. 2. Average number of fruits/plant (FNP). Each data point is the mean of n = 20 observations. Letters on the bar show level of significance.

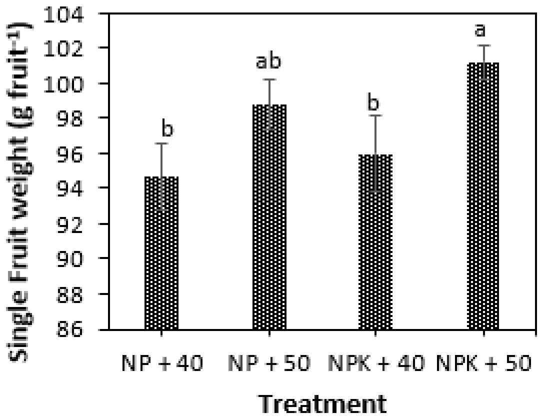

Fig. 3. Single fruit weight (SFW [g]). Each data point is the mean of n = 20 observations. Letters on the bar show level of significance.

As Fig. 4 reveals, the pattern of yield per square meter was the opposite of other measured yield parameters. Narrow spacing produced a significantly higher yield per square meter than the wider spacing. Moreover, yield in plots where K fertilizer was applied was significantly higher than those without K. NPK + 40 produced the highest yield (5.2 kg m-2) in a square meter and was followed by NP + 40 (4.75 kg m-2). In wider planting space, NPK + 50 and NP + 50 yielded 4.25 and 3.87 kg m-2 tomatoes, respectively and the difference was significant.

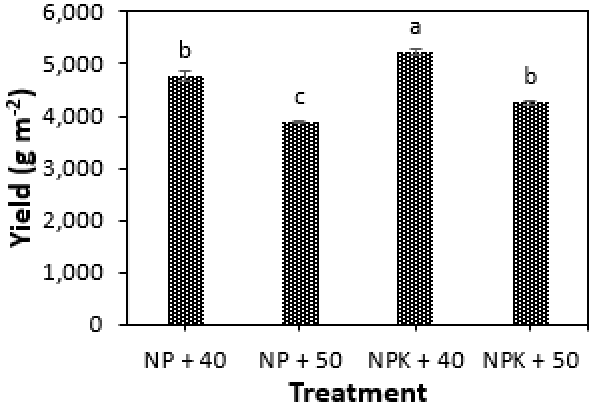

Fig. 4. Average yield/m2 in g. Each data point is the mean of n = 20 observations. Letters on the bar show level of significance.

The difference among treatments, between blocks, and the interaction of blocks and treatments are shown in the following table. A significant difference was observed among the treatments in all four yield parameters. We did not observe any significant difference between blocks and the interaction of blocks and treatments. As stated previously, the reason for the ANOVA test between blocks was to see if the location that was around 500 apart would affect the yield performance or not. Furthermore, the result showed that there is no significant difference among the blocks and treatments (P > 0.05), (Table. 1).

Table 1. Analysis of variance (ANOVA) on yield, single fruit weight, Fruit weight per plant and fruit number per plant

Factor			Yield ($kg\ m^{-2}$)	SFW (g)	FWPP ($g\ plant^{-1}$)	FNPP ($plant^{-1}$)
Mean	Treatment (T)	NPK + 50	4.25	101.2	1064	10.53
		NP + 50	3.88	98.8	969	9.83
		NPK + 40	5.23	96.0	837	8.75
		NP + 40	4.75	94.6	760	8.08
	Block (B)	BLK1	4.54	97.8	910	9.30
		BLK2	4.52	97.5	905	9.30
	ANOVA	T	0.000***	0.002**	0.000***	0.000***
		B	0.44^{ns}	0.76^{ns}	0.33^{ns}	1.00^{ns}
		T X B	0.64^{ns}	0.96^{ns}	0.60^{ns}	0.84^{ns}

SFW = Single Fruit Weight; **FWPP** = Fruit Weight Per Plant; **FNPP** = Fruit No Per Plant
***= $\rho < 0.000$, **$\rho = 0.01$, n.s.= not significant.

Table 2 summarizes the correlation of yield parameters. With increasing planting density, the single fruit weight dropped significantly which could be due to competition for nutrients and other resources. In dense canopies, competition for resources increase, and the imbalance of source and sink might have caused smaller fruit. The same applied in the case of fruit number per plant. Plants with sparse canopy resulted in more fruits per pant and thus the correlation between planting density and FNPP was strongly negative. A very strong correlation between yield per square meter and planting density suggests that yield per unit land area is strongly connected with planting density. Interestingly, the SFW and FNPP have a negative but insignificant correlation. The reason this correlation is not strong enough can be justified using K fertilizer and relatively wider spacing. As can be inferred from the literature, the smallest planting space (40 x 40 cm) we used in our experiment might be relatively wider for achieving further yield increases per unit land area.

Table 2. Coefficient of correlation. Stars indicate the significance and strength of the correlation.

Coefficient of Correlation

	SFW	FWPP	D	FNPP
FWPP	0.41***			
D	-0.38***	-0.91***		
FNPP	-0.06^{ns}	0.88***	-0.80***	
Yield (m^{-2})	-0.28*	-0.60***	0.87***	-0.52***
Yield (ha^{-1})	-0.28*	-0.60***	0.877***	-0.52***

SFW = Single Fruit Weight; **FWPP** = Fruit Weight Per Plant;
FNPP = Fruit No Per Plant; **D** =Planting Density
*** = ρ<0.000, ** = ρ < 0.001, * = ρ < 0.05

DISCUSSION

The effect of planting density and K fertilizers in tomato crop has been explored in many studies. Our study revealed that wider planting space significantly increased fruit weight per plant, fruit number per plant, and single fruit weight. On the contrary, fruit yield per square meter was significantly higher in plants with narrow planting space.

Our results are consistent with the finding of Papadopoulos and Ormrod (1990) who stated that fruit weight per plant decreased while yield per square meter increased with narrow planting space. It can be explained by the smaller interplant and inter-row spacing that causes competition between plants (Fery and Janick, 1970). Since narrow spacing results in sparse canopies, light interception, and CO2 fixation by the lower leaves of a plant increase accordingly which ultimately increases yield per plant (Papadopoulos and Ormrod, 1990). Similarly, yield per plant was improved but yield per land was reduced in greenhouse-grown cherry tomato when the plant spacing was increased from 11.8 to 19.7 inches (Charlo et. al., 2007). High yield was achieved in heated greenhouses as the plant density was increased (Saglam and Yazgan, 1995). Although Kemble and colleagues (1994) didn't find any difference between fruit yield between 12 and 30 inches in-row spacing, higher yield in field-grown tomatoes was obtained with smaller in-row spacing (Santos et. al., 2010).

The yield response of tomato is well established to animal compost and chemical fertilizers. (Ramyabharathi et al., 2014). In this study, we found that K application increased all yield parameters irrespective of planting space. These findings are in alignment with the findings of Chapagain and Wiesman (200) who reported that the use of Potassium (K) increases the growth of tomato plants and thus it results in higher fruit production. A yield enhancement of 35.55% over the control was reported when a higher dose of 120 kg K2O/ha was applied (Ahmad et. al., 2015). The use of K fertilizers increased the size of fruits especially in soil with low to medium fertility (Perkins-Veazie and Robert, 2003). Amjadet l., (2014) reported that the use of K significantly increases fruit diameter which could be attributed to the role of K in enhancing photosynthesis (Havlin et. al., 2005).

Our study suggests that if the fruit size is not of importance, reducing the planting density from 50 x 50 cm to 40 x 40 will significantly increase fruit yield in a unit land area. Using K, on the other hand, will not only improve tomato fruit size, fruit number per plant, and fruit weight per plant, it will also increase the total yield. We found this study as one of the biggest milestones towards increased tomato productivity in Sarkhroad, Nangarhar, Afghanistan.

CONCLUSION

We conducted this study to show the effect of planting density and K fertilizer on the yield and yield attributes of tomato in Nangarhar, Afghanistan. Less dense plants (wider spacing) increase the FNPP, SFW, and FWPP, however, yield per unit land area was not promising. Dense plants (narrow spacing) resulted in reduced FNPP, SFW, FWPP whereas yield per square meter was significantly increased. The application of K fertilizer affected all measured parameters irrespective of planting density, suggesting that if planting space is reduced and K fertilizer applied, the productivity would improve.

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