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Yield and yield components of five tomato varieties (*Solanum lycopersicum*) as influenced by chemical NPK fertilizer applications under chestnut soil conditions

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Abstract

The tomato is an important fruit, both fresh and processed, for human nutrition worldwide, and plays a significant role in agriculture. Especially in the intensive agricultural system where chemical fertilizers are used, little is known the impact of chemical NPK fertilizer applications on the yield of tomato under chestnut soil conditions. The objective of this study was to investigate the effects of four types of NPK fertilizer applications ($N_{120}P_{90}K_{60}$, $N_{150}P_{120}K_{90}$, $N_{180}P_{150}K_{120}$, $N_{210}P_{180}K_{150}$) on the yield and yield parameters of 5 different tomato varieties (Ogonyok 777, Barin, Hybrid Shuruk, Hybrid SC-2121 and Hybrid Falcon) under chestnut soil conditions in in the Southeast of Kazakhstan. According to field experiment results, there were significant differences among the treatments in relation to yield and yield parameters (plant height, number of stems, number of leaves, and number of fetus after planting) of tomato varieties. In foothill zone of the southeast of Kazakhstan, Hybrid Shuruk and Hybrid SC-2121 tomato varieties significantly yielded higher than the other three varieties tested at the same time under chestnut soil conditions. And also, it was determined that the best outputs tended to be obtained with $N_{210}P_{180}K_{150}$ fertilizer dose.

Keywords: Tomato, tomato varieties, NPK fertilizer, chestnut soil, fertilization.

Introduction

Fertilizers, which are indispensable and the most important material input in modern agricultural production (Chen et al., 2018; Li et al., 2019a), have played a vital role in improving the yield and quality of crops (Mahajan and Singh, 2006; Rajput and Patel, 2006; Hebbar et al., 2014). To date, numerous studies have explored the effects of fertilizer application rate on crop growth, yield, and quality (Mahajan and Singh, 2006; Castellanos et al., 2012; Bilalis et al., 2018). For example, Du et al. (2019) determined that the yield of tomato increased with a rising fertilizer application rate up to a point.

Tomato is one of the most important vegetables worldwide. As it is a relatively short duration crop and gives a high yield, it is economically attractive and the area under cultivation is increasing daily (Kalbani et al., 2016). Yields of field tomatoes usually range between 40 and 100 t ha^{-1} depending on the location, growing season, the cultivar used and crop management practices (Heuvelink and Dorais, 2005). The main reasons for differences in yield in fields tomato crops are well known. Ecological conditions such as soil types, cultivated tomatoes varieties, climate conditions, and fertilizer and pesticide applications are important factors in determining tomato yield and quality (Huat et al., 2013; Bilalis et al., 2018; Ouansafi et al., 2019; Litskas et al., 2019). However, fewer studies have focused on field-grown tomato crops for fresh

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consumption and those that did were mostly conducted in temperate regions in developed countries (Clark et al., 1999; Scholberg et al., 2000). Few studies have dealt with the factors that affect the production of field-grown tomatoes in chestnut soils. And also, little is known about the impact of chemical NPK fertilizer applications on yield of different tomato varieties (*Solanum lycopersicum*) under chestnut soil conditions. Chestnut soils a soil type occurring in arid steppes. The soils cover large areas of Turkey, Mongolia, northern China, the United States, and Kazakhstan (Saparov, 2014; Yertayeva et al., 2018; 2019). The climate in the chestnut soil zone is continental and arid. The genetic and zonal properties of chestnut soils include deficient drainage, a shortage of productive moisture, alkalinity, and soil heterogeneity. The parent material consists chiefly of calcareous deposits with a predominance of loess like loams, calcareous sandy loams, loesses, calcareous sands, sandy loams, and alluvium. Chestnut soils contain carbonates and, in most cases, gypsum in the lower part of the profile. The presence of readily soluble salts causes the alkalinity of chestnut soils.

The aim of our experiment was to investigate chemical NPK fertilizer applications for five tomato varieties (*Solanum lycopersicum*) on chestnut soil conditions in the Southeast of Kazakhstan.

Material and Methods

Description of the Study Sites

The experiment was conducted at the Regional Branch "Kainar" of the LLP "Kazakh Research Institute of Fruit and Vegetable Growing" which is located in the foothill zone of the southeast of Kazakhstan (43°09'32.8"N 76°26'57.3"E) North Slope of Zailiyskiy Alatau Mountains (Altitude: 1000-1050 m) during the growing season 2019-2020 with a view to finding out the Watermelon expo as well as determining the optimum dose of fertilizer of tomato. The locations of the evaluations were characterized by the continental climate (large daily and annual fluctuations in air temperature, characterized by cold winters and long hot summers), the air temperature reaches minimum values in January (-32,-35^{0}C), and maximum values in July (37-43^{0}C). The warm period lasts 240-275 days, the frost-free period is 140-170 days and an annual amount of precipitation is 350-600 mm.

The soil belongs to the general soil type of dark chestnut. The land was medium high with loamy. Before conducting the experiment, the soil sample was analyzed from Kazakh National Agrarian Research University. The soil was characteristically slightly alkaline (pH 7.3-7.4), soil organic matter 2.9-3.0% (moderate), total N 0.18-0.20% (high), available P_2O_5 35-40 mg kg^{-1} (moderate), available K_2O 360-390 mg kg^{-1} (low), cation exchange capacity 20-21 me 100g^{-1} soil, bulk density 1.1-1.2 gr cm^3, field capacity 26.6%.

Treatments and Experimental Design

The experiment was performed using a completely randomized block design with four replications. The experimental unit was 35 m^2 (3,5 m x 10 m). The sources of fertilizers used were urea 46% N, triple superphosphate 44% P_2O_5 and potassium sulphate 50% K2O. The experimental field was prepared in accordance with a standard practice used by RB Kainar of LLP Kazakh Research Institute of Fruit and Vegetable Growing. The land was disk ploughed, harrowed, and leveled with a tractor. Then ridging was done by hand. Fertilizer was applied using grain drill. Other agronomic practices and data collection were conducted based on the recommendations of Kazakh Research Institute of Fruit and Vegetable Growing. Five tomato varieties (Ogonyok 777 (Kazakhstan), Barin (Russia), Hybrid Shuruk (Netherlands), Hybrid SC-2121 (Turkey) and Hybrid Falcon (Turkey)) were combined with four fertilizer treatments. The transplanting was made on 25 May 2019 for field experiment. The tomato field was irrigated at the interval of five to six days depending on the prevailing weather conditions throughout the crop cycle, and harvesting was carried out from the third decade of August to the second decade of September. Trial was well protected against insects and weeds during the season. Full dose of given phosphorus and potassium fertilizer treatment was added at the time of transplanting and Urea was applied in three equal splits, 1/3 at transplanting and 1/3 at 20 days after transplanting, and the remaining 1/3rd was applied 40 days after transplanting. Both urea and phosphate fertilizers were placed alongside the ridge in the plating rows about 5 cm away from the transplanted to ensure that there would be no direct contact with the soil particles below the plant and to reduce fixation and N leaching.

Table 1. Treatment description and nutrient rates used in the field experiment

Treatments	Nutrient Rate (kg ha^{-1})		
	N	P	K
T1 = Absolute control	0	0	0
T2 = $N_{120}P_{90}K_{60}$	120	90	60
T3 = $N_{150}P_{120}K_{90}$ (recommended fertilizer dose)	150	120	90
T4 = $N_{180}P_{150}K_{120}$	180	150	120
T5= $N_{210}P_{180}K_{150}$	210	180	150

Data on growth and canopy characteristics such as plant height, number of stem, number of leaves, and number of fetus were measured from 10 randomly selected plants per plot. Yield of tomato at harvest were measured from sample fruits using digital balance and total yield (tons/ha) were assessed.

Results and Discussion

Effect of different levels of NPK fertilizers on yield parameters and yield of five tomato varieties was evaluated (Table 2). According to the Table 2, there was a significant difference between controls of each variety on yield of tomato, plant height, number of stems, number of leaves, and number of fetus after planting. In foothill zone of the southeast of Kazakhstan, Hybrid Shuruk (Netherlands) and Hybrid SC-2121 (Turkey) tomato varieties significantly yielded higher than the other three varieties tested at the same time in experimental site. The yield of tomato and yield parameters of tomato varieties differed significantly due to NPK fertilization (Table 2). At all potato varieties, Application of NPK fertilization significantly influenced the tomato yield, plant height, number of stems, number of leaves, number of fetus compared to untreated (control) plants. The best outputs tended to be obtained with $N_{210}P_{180}K_{150}$ (T5). Similar results were obtained by Gunarto et al. (1985), Yousaf et al. (1999), Magnusson (2002) and Li et al. (2019b) on several vegetable crops. Numerous studies have reported that inorganic NPK fertilizer increased growth in some species by enhancing nitrogen, phosphorus and potassium uptake (Shehu, 2014; Gülser et al., 2019).

Table 2. Effect of different NPK fertilizer doses on different vegetative parameters and yield of five tomato varieties

Treatments	Tomato plant height, depth,cm	Number of stems plant^{-1}	Number of leaves plant^{-1}	Number of fetus plant^{-1}	Total tomato yield, t ha^{-1}
Variety Ogonyok 777 (Kazakhstan).					
T1 = Control	40.7	3.5	17.6	10.2	27.1
T2 = $N_{120}P_{90}K_{60}$	45.2	3.8	20.3	11.4	30.1
T3 = $N_{150}P_{120}K_{90}$	48.3	4.0	21.7	12.5	32.2
T4 = $N_{180}P_{150}K_{120}$	56.0	4.0	23.5	12.8	36.4
T5 = $N_{210}P_{180}K_{150}$	61.4	4.1	24.2	13.6	40.0
Variety Barin (Russia)					
T1 = Control	39.5	3.4	18.0	8.5	26.7
T2 = $N_{120}P_{90}K_{60}$	42.5	3.5	20.1	9.0	29.4
T3 = $N_{150}P_{120}K_{90}$	44.7	3.8	20.2	9.1	34.2
T4 = $N_{180}P_{150}K_{120}$	50.2	3.9	21.4	11.4	37.3
T5 = $N_{210}P_{180}K_{150}$	53.8	3.9	22.6	12.7	40.5
Hybrid Shuruk (Netherlands)					
T1 = Control	45.3	3.0	16.8	9.0	28.5
T2 = $N_{120}P_{90}K_{60}$	50.5	3.1	18.4	9.5	32.6
T3 = $N_{150}P_{120}K_{90}$	53.6	3.0	19.3	9.6	37.7
T4 = $N_{180}P_{150}K_{120}$	58.4	3.2	22.5	10.7	41.2
T5 = $N_{210}P_{180}K_{150}$	62.7	3.4	25.0	11.8	45.5
Hybrid SC-2121 (Turkey)					
T1 = Control	38.6	3.2	19.2	7.8	30.2
T2 = $N_{120}P_{90}K_{60}$	42.1	3.7	23.0	8.6	33.4
T3 = $N_{150}P_{120}K_{90}$	43.6	3.9	24.1	8.9	36.5
T4 = $N_{180}P_{150}K_{120}$	47.8	3.8	25.6	9.4	40.6
T5 = $N_{210}P_{180}K_{150}$	50.2	4.0	26.7	10.3	44.6
Hybrid Falcon (Turkey)					
T1 = Control	41.0	3.0	17.4	8.1	27.0
T2 = $N_{120}P_{90}K_{60}$	44.3	3.2	18.4	8.7	30.3
T3 = $N_{150}P_{120}K_{90}$	45.7	3.3	19.0	9.0	32.5
T4 = $N_{180}P_{150}K_{120}$	50.4	3.5	21.7	9.8	38.0
T5 = $N_{210}P_{180}K_{150}$	53.5	3.7	23.8	10.5	42.7

Plant nutrition is one of the most important factors that increase plant production. Nitrogen (N) is the most recognized in plant for its presence in the structure of the protein molecule. Accordingly, N plays an important role in synthesis of the plant constituents through the action of different enzymes. Phosphorus (P) is required in large quantities in young cells, such as shoots and root tips, where metabolism is high and cell division is rapid. P aids in root development, flower initiation, seed and fruit development. P_2O_5 has been shown to reduce disease incidence in some plants and has been found to improve the quality of certain crops. Potassium (K) is an important macronutrient and the most abundant cation in higher plants. K has been the target of some researchers mainly because it is essential for enzyme activation (Wiedenhoeft, 2006;

Maynard and Hochmuth, 2007; Barker and Pilbeam, 2007). As per the previous results vegetative characteristics of all five varieties were increased with increase in NPK levels.

Results indicated that integrated supply of plant nutrients through chemical NPK fertilizer, played a significant role in sustaining soil fertility and crop productivity in terms of vegetative and reproductive growth. Several researchers have demonstrated the beneficial effect of combined use of chemical fertilizers to mitigate the deficiency of many secondary and micronutrients in fields that continuously received only N, P and K fertilizers for a few years, without any micronutrient. Also it is evident that the excessive use of synthetic agrochemicals in crop production and in soil fertility management causes detrimental effect on plant growth, make residue toxicity and environmental pollution. Yields of field tomatoes usually range between 40 and 100 t ha^{-1} (Heuvelink and Dorais, 2005). In this study, the fruit yield of tomato ranged from 27 t ha^{-1} to 45.5 t ha^{-1}, with an average of 35 t ha^{-1} (Table 2). The average fruit yield in this study area was higher than the 69 t ha^{-1} in the whole Turkey, 59 t ha^{-1} in China, and 61 t ha^{-1} in Japan. The reason for these significant differences was the climate, field management and soil types.

Conclusion

Five tomato varieties (Ogonyok 777 (Kazakhstan), Barin (Russia), Hybrid Shuruk (Netherlands), Hybrid SC-2121 (Turkey) and Hybrid Falcon (Turkey)) and five treatments (Control, $N_{120}P_{90}K_{60}$, $N_{150}P_{120}K_{90}$, $N_{180}P_{150}K_{120}$ and $N_{210}P_{180}K_{150}$) were used to investigate effects on yield and yield parameters of tomato under chestnut soil conditions in the Southeast of Kazakhstan. It was evident that increased levels of NPK levels resulted higher growth performance in all five tomato varieties than control. The T5 treatment ($N_{210}P_{180}K_{150}$) had a greater tomato yield than the other treatments [control without any nutrient supply (T1), and recommended fertilizer dose' treatment (T3, $N_{150}P_{120}K_{90}$]. This means that the typical NPK fertilization in this area (chestnut soil conditions in the Southeast of Kazakhstan) is not adequate. In general, Hybrid Shuruk (Netherlands) and Hybrid SC-2121 (Turkey) tomato varieties significantly yielded higher than the other three varieties tested at the same time in chestnut soil condition in Southeast of Kazakhstan.

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