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Responses of potato (*Solanum tuberosum* L.) varieties to NPK fertilization on tuber yield in the Southeast of Kazakhstan

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Abstract

In this study, field experiment was conducted to assess the effect of different doses of NPK on tuber yield on the potato (*Solanum tuberosum* L.) varieties such as Inovator, Gala, Aladin and Tyanshansky in foothill zone of the southeast of Kazakhstan. Five different combinations of NPK with control were studied. Results revealed that the fertilizer application increased the total tuber yield, the longest plant, number of main stem, number of leaves plant and average tuber number on the potato significantly over control. The highest tuber yield was obtained when 25% more than the recommended fertilizer dose with manure was applied at all potato varieties. Aladin potato variety significantly yielded higher than the other varieties tested at the same time in this experiment.

Keywords: Potato, fertilization, manure, tuber yield, potato varieties.

Introduction

Potatoes are an important crop in the Central Asian Republics (Loebenstein and Manadilova, 2003). They are the second most important crop in Kazakhstan, after wheat, grown on about 205.000 ha. In Kazakhstan, the largest potato grower in the Central Asian Republics, yields average 19,5 tons ha-1 which is very low in comparison to other potato producing countries like 50.4 tha-1 in New Zealand, 49.7 tha-1 in USA and 33.5 tha-1 in the Turkey in 2018. (Potatopro, 2020). Potatoes in Kazakhstan are planted in April-May, depending on the region and weather and harvested in September- October.

Fertility is one of the controllable major factors that affect the yield and quality of potatoes (Dubetz and Bole, 1975). Supply of nutrients plays an important role in growth and yield. Nitrogen is an essential constituent of protein and chlorophyll, where phosphorus fertilization contributes to early crop development and tuberization and enhances tuber maturation, whereas potassium influences both yield and tuber quality and also enhances plant resistance to withstand stress against drought and frost (Nizamuddin et al., 2003). In order to obtain good yield, modern varieties of different crops require relatively high quantity of fertilizer compared to the traditional cultivars (McArthur and McCord, 2017). However, the economic condition of Kazakhstan farmers often does not support them to use required quantity of fertilizers due to its high cost. On the other hand, the organic matter content of most of the soils of Kazakhstan is very low (<2.5%) as compared to desired (3% and above) levels (Takata et al., 2007; Causarano et al., 2011). Therefore, it becomes an immense need to formulate an optimum fertilizer recommendation that would produce satisfactory yields and would maintain soil health to ensure sustainable crop production. One of the alternatives to economize the use of chemical fertilizer is to incorporate farmyard manure in combination with chemical NPK fertilizers (Black and White, 1973; Zhang, 2009; Li et al., 2017). Bandyopadhyay et al.

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(2010) showed that mixed use of farmyard manure (cow dung) and chemical fertilizer improved soil organic carbon content compared to the use of chemical fertilizer (NPK) alone.

Different potato varieties (improved, imported or local) characterized by diverse forms, plant height and skin colour are found in Kazakhstan. In recent years, many foreign varieties of potatoes have been imported to Kazakhstan. However, these varieties are not yet fully adapted to the conditions of Kazakhstan. Therefore, the issues of adaptability of foreign highly productive potato varieties to the conditions of the irrigated zone of Kazakhstan are relevant and are of scientific and practical interest. Foreign potato varieties are highly intensive, i.e. the formation of high yields requires the use of very high rates of mineral fertilizers and the repeated use of pesticides against pests, diseases and weeds. In this aspect, it is important to study the responsiveness of different potato varieties to fertilization and determine their most optimal rates. The objective of this study was to determine the influence of applying different levels of NPK fertilizer on tuber yield on the potato (*Solanum tuberosum* L.) varieties in foothill zone of 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" (merger of two institutions (fruit growing and vegetable growing)), foothill zone of the southeast of Kazakhstan (43°09'32.8"N 76°26'57.3"E) during the growing season 2019 with a view to finding out the suitable variety as well as determining the optimum dose of fertilizer of potato. 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 250 – 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 50 m^2 (6 m x 8.3m). The sources of fertilizers used were ammonium nitrate 34.5% N, double superphosphate 46%P_2O_5 and potassium sulphate 56% K_2O. 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. Four potato varieties (Inovator (Netherlands), Gala (Germany), Aladin (Netherlands) and Tyanshansky (Kazakhstan)) were combined with four fertilizer treatments. The trial was implemented on May (17th) and harvested on September (27th) 2019. Trial was well protected against insects and weeds during the season.

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

Treatments	Nutrient Rate (kg ha^{-1})			Manure
	N	P	K	(t/ha)
T1 = Absolute control	0	0	0	0
T2 = Recommended fertilizer dose (for 30 t ha^{-1} yield)	150	90	120	0
T3 = 25% more than the recommended fertilizer dose	190	110	150	0
T4 = 50% more than the recommended fertilizer dose	225	135	180	0
T5= 25% more than the recommended fertilizer dose with manure (40 t ha^{-1})	190	110	150	40

Variables evaluated

Total tuber yield (t ha^{-1}): Total tuber yield was calculated as the sum of the weights of marketable and unmarketable tubers from the net plot area and transformed to ton per hectare.

Number of leaves per plant: The number of leaves per plant were determined by counting the number from ten plants (hills) in each plot before the start of tuber formation and averaged.

Number of main stem/hill: Data on Number of main stem/hill was recorded as the average stem number counted from ten hills per plot at 50% flowering. Only stems that had directly grown from the mother tuber

and acted as an independent plant above the soil were considered as main stems. Stems branching from other stems above the soil were not considered as main stems.

Average tuber number/hill: Average tuber number/hill was recorded at harvest as the actual number of tubers collected from 20 middle row plants in each plot and calculated as an average tuber number.

Statistical analysis was performed using analysis of variance and LSD test using the SPSS package program.

Results and Discussion

The total tuber yields of potato are presented in Table 2 for the performance of potato varieties. In foothill zone of the southeast of Kazakhstan, significant differences between the four varieties tested were detected in 2019. Aladin potato variety significantly yielded higher than the other three varieties tested at the same time in experimental site. The tuber yield and means of the growth traits of potato varieties differed significantly due to NPK fertilization (Table 2). At all potato varieties, Application of NPK fertilization significantly ($P< 0.05$) influenced the total tuber yield (TTY), the longest plant (PLH), Number of main stem (NMS), Number of leaves plant (NLP) and Average tuber number (ATN) compared to untreated (control) plants. Similar results were obtained by Gunarto et al. (1985), Yousaf et al. (1999), Magnusson (2002) and Li et al. (2019) 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). The yield of potatoes is a function of the number of tubers produced and the average weight per tuber. Besides yield, tuber size distribution and specific gravity are also important to the producer and the processor. N promotes cell elongation and vegetative growth whereas P is involved in root cell division and thus root growth. Adhikari and Rana (2017) reported that K was also important in cell division. Kołodziejczyk (2014) showed that N fertilizer increased the number of tubers set and allowed them to develop rapidly. Rosen and Bierman (2008) and Daoui et al (2014) reported a similar response from P. Nizamuddin et al. (2003) and Manolov et al. (2006) reported that K fertilizer increased the number of tubers as well as tuber size.

Table 2. Tuber yield and yield contributing characters of potato (*Solanum tuberosum* L.) varieties

Treatments	Traits				
	TTY	PLH	NMS	NLP	ATN
Variety Tyanshansky					
T1	22,3a	54a	4,8a	97a	9,5a
T2	26,0b	67b	5,3b	116b	11,6b
T3	31,1c	70c	5,5b	123c	12,9c
T4	35,2d	75d	5,5b	128d	14,0d
T5	36,4d	78e	6,0c	134e	14,7e
Mean	30,2	68,8	5,4	119,6	12,5
Variety Aladin					
T1	24,5a	60a	5,4 a	105a	12,4a
T2	28,4b	72b	5,7b	120b	15,7b
T3	33,5c	77c	6,0c	131c	16,5b
T4	37,9d	80d	6,2d	136d	17,9c
T5	40,8e	84e	6,3d	145e	18,4c
Mean	33,0	74,6	5,9	127,4	16,2
Variety Gala					
T1	21,4a	48a	4,5a	94a	9,2a
T2	25,7b	56b	4,7b	109b	10,8b
T3	30,5c	61c	5,0c	122c	13,1c
T4	34,4d	66d	5,3d	130d	13,6c
T5	35,3d	70e	5,5d	132d	14,2d
Mean	29,5	60,2	5,0	117,4	12,2
Variety Inovator					
T1	23,2a	57a	5,0a	102a	11,0a
T2	27,2b	68b	5,4b	114b	13,5b
T3	31,8c	72c	5,6b	128c	16,4c
T4	35,6d	79d	6,0c	139d	17,1d
T5	38,4e	82e	6,1c	143e	17,5d
Mean	31,2	71,6	5,6	125,2	15,1

TTY: Total tuber yield (t ha^{-1}), PLH: Plant height, cm; NMS: Number of main stem; NLP: Number of leaves per plant, ATN: Average tuber number

TTY, PLH, NMS, NPL and ATN were recorded from 25% more than the recommended fertilizer dose with manure (T5) based on average yield goal and it was statistically similar to all potato (*Solanum tuberosum* L.) varieties (Table 2). A similar study by Black and White (1973) showed that barnyard manure (9.7 t ha^{-1}) combined with chemical fertilizer resulted in high increase in total soil N. Moreover, it is believed that potato is more stable under combined organic and inorganic fertilization treatment compared with inorganic fertilization alone. The application of manure and chemical fertilizers in this experiment promoted yield response compared to mineral fertilized. Furthermore, the crop yield is also promoted with this fertilization treatment. This finding is in agreement with that one of Zhang (2009). That a combination of chemical fertilization and organic nutrient source gave maize higher yield than when applied separately. A similar study by Bandyopadhyay et al. (2010) found that manure application with chemical fertilizer causes higher yield in soybean, available nutrients and soil organic matter compared with those found under mineral fertilizer treatment.

Conclusion

It can be concluded that integrated use of organic manure and recommended dose of NPK fertilizers resulted in significant improvement in tuber yields of potato and quality despite being an active practice in nutrient management. Organic manure used with NPK fertilizers can maintain tuber yields of potato and meet the nutrient requirements to grow. Using organic manure from castoff and applying it in an intensive cropping system can be considered as an essential measure to decrease the potential risk of water pollution caused by castoff. In sustainable agriculture, the integrated use of organic manure and NPK fertilizers is necessary to create a healthy soil environment in the long run. This method produces a significant yield of crops compared to the application of organic manure or NPK fertilizers alone. Hence, combining the use of organic manure with NPK fertilizers is the right approach to sustainable agriculture.

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