Malik, K., Naz, S., Mehdi, S., Munir, A., Khan, A., Akbar, S., Andleeb, S., & Zia ur Rehman (2018). Exploring different fertilizer combinations for potato growth and yield in Rawalpindi region of Pakistan. World Journal of Biology and Biotechnology, 3(3), 227-231. DOI: https://doi.org/10.33865/wjb.003.03.0171

(Online) ISSN2522-6754 | 2018 | (Print) ISSN 2522-6746

WORLD JOURNAL OF BIOLOGY AND BIOTECHNOLOGY

Volume: 03 | www.sciplatform.org | Issue: 03

EXPLORING DIFFERENT FERTILIZER COMBINATIONS FOR POTATO GROWTH AND YIELD IN RAWALPINDI REGION OF PAKISTAN

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ABSTRACT

Potato (*Solanum tuberosum* L.) is one of the most important tuber crops produced in Pakistan. Due to its nutritive importance, it ranks as fourth after rice, wheat and maize in the world. However, production of the crop is far below the average due to poor crop stand, soil fertility and water management practices. There is a strong need for improvement in the fair yield of potato through managed production techniques and best soil nutrient combinations. To find out the best combination of fertilizer level of NPK on growth, yield and quality of the potato crop, nine field experiments on potato crop were conducted at Rawalpindi division, Punjab Pakistan for three successive Rabi seasons during 2014-2017. Treatments consisted of four levels of N (244, 300, 356 and 412 Kg N ha^{-1}), P (163, 200, 237 and 275 kg P ha^{-1}) and K (136, 167, 198 and 229 Kg K ha^{-1}) laid out in Randomized Complete Block Design (RCBD) with three replications. Results showed that there was no significant difference of location in terms of yield (T ha^{-1}). However, mean data showed that the fertilizer combinations significantly (<0.05) affected yield and yield components of the potato crop. Among the treatments, NPK level (412, 275 and 229 Kg ha^{-1}) gave maximum (100 tuber m^{-2}), potato yield (3.2 Kg m^{-2}), dry matter (1.3 Kg m^{-2}), while the least number of tuber m^{-2} (63), potato yield m^{-2} (2.02 Kg), dry matter yield m^{-2} (0.9 Kg) were recorded where combination NPK (244, 163and 136 Kg ha^{-1}) were applied. From the results, it can be concluded that farming community can obtain the maximum potato yield by adopting NPK (412, 275, 229) levels of fertilizers.

Key word: Potato, *Solanum tuberosum*, fertilizer, Rawalpindi, Pakistan.

INTRODUCTION

Potato (*Solanum tuberosum* L.) is considered as the world's major economic crop and number one non-grain food commodity (Rykaczewska, 2013). It is categorized as the third most consumed food crop in the world after rice and wheat (Hancock *et al.*, 2014). Potato cultivated area is almost 19.34 million hectares in more than 158 countries globally with an estimated annual production of 364 million tons (FAOSTAT, 2014). It has ability to provide a high yield product per unit input with a shorter crop cycle (mostly < 120 days) in comparison with major cereal crops. Furthermore, potato is enriched with protein and micronutrients while low in fat (Lutaladio and Castaldi, 2009).

The production of potato crop in Pakistan is very low due to several biotic and abiotic factors (Abbas *et al.*, 2012; Abbas *et al.*, 2014; Abbas and Madadi, 2016; Qamar *et al.*, 2016; Urooj *et al.*, 2016) Soil fertility is the key factor that affects yield and quality of potato (Bradfield *et al.*, 2017). Several studies describe relationships between fertilizer applications, leaf nutrient concentrations, potato tuber yield and tuber quality (Adhikari and Sharma, 2004). Lack of optimum nitrogen and phosphorus application rates, there are a number of production problems accounting for low yields of potato in Ethiopia. These constraints include limited supply of high quality seed tubers of potato (Gildemacher *et al.*, 2009) inappropriate agronomic practices and inadequate storage and limited knowledge resulting in poor seed tuber selection (Lung'aho *et al.*, 2007). This situation would become more critical in potato production in view of the fact that the crop is one of the heavy feeders of soil nutrients (Powon, 2005). Growing healthy potatoes for maximum yield and quality requires that all the essential nutrients be supplied at the right rate, the right time and the right place (Bradfield *et al.*, 2017). In Pakistan major area under potato production is suffering from major nutrient deficiency which can be accomplished by addition of mineral fertilizer and proper water management practices (Harris, 1978). Application of N, P and K fertilizer significantly influence the plant height, flowering, total tuber number, total tuber yield and tuber dry matter percentage (Mulubrhan, 2004).

OBJECTIVES

A study was conducted in different districts of Rawalpindi Division for three successive Rabi seasons (2014 to 2017) to explore the best combination of NPK levels for improved yield and quality of potato.

MATERIAL AND METHODS

The experiment was conducted repeatedly at two different locations of two districts of Rawalpindi division during three successive seasons of Rabi 2014-2017 (Fig. 1). The variety used during experiment was Karoda. The tubers were planted about 3 inches deep and 12 inches apart within the rows, leaving about 36 inches of space between the rows. The Complete Block Design (RCBD) with three replications (Table 1). Urea (46%) and SSP (18% P_2O_5) and SOP (50%) were used as a source of nitrogen and phosphorus and potassium.

Time and method of fertilizer application

1. ⅓ N with all P & K at sowing.
2. ⅓ N after one month of germination.

treatments consisted of four levels of N (244, 300, 356 and 412 Kg N ha^{-1}), P (163, 200, 237 and 275 kg P ha^{-1}), and K (136, 167, 198 and 229 kg K ha^{-1}) laid out in Randomized

3. ⅓ N after two months of germination

Observations and data collection

1. Soil analysis of each site (Pre- & post-harvest Table 2).
2. Periodic observations of plant growth and yield attributes (Table 3)

Figure 1: Photographs of experimental sites and potato tuber yield (Taxila potato field = A and potato yield = C, Attock potato field = B and potato yield = D).

Table 1: Detail of NPK fertilizer treatment combinations used for potato crop in the current study.

	Nutrients (kg/ha)		
Tr. No.	**N**	**P_2O_5**	**K_2O**
1	244	163	136
2	300	200	167
3	356	237	198
4	412	275	229

Table 2: Physico-chemical properties of the experimental sites (pre-sowing and post harvest soil analysis).

Pre Sowing Soil Analysis				Post Harvest Soil Analysis							
Parameters studied	**Depth (Inches)**	**Taxila**	**Attock**	**Taxila**				**Attock**			
				T1	**T2**	**T3**	**T4**	**T1**	**T2**	**T3**	**T4**
Organic Matter (%)	0-6	0.45	0.47	0.40	0.43	0.41	0.41	0.47	0.46	0.46	0.47
	06-12	0.42	0.44	0.39	0.41	0.39	0.40	0.45	0.39	0.50	0.46
pH	0-6	7. 54	7.5	7.52	7.51	7.45	7.32	7.48	7.45	7.39	7.25
	06-12	7.50	7.3	7.50	7.51	7.42	7.30	7.40	7.42	7.35	7.22
Electrical conductivity	0-6	1.70	0.96	1.72	1.74	1.75	1.83	1.10	1.12	1.34	1.52
	06-12	1.69	0.95	1.70	1.73	1.73	1.82	0.95	1.10	1.29	1.45
Extractable Potassium (ppm)	0-6	100	76.4	138	155.2	164.9	201	85.3	92.8	100.3	126.9
	06-12	96.50	72.60	135	149.3	163	193.2	79.8	92.3	97.1	120.3
Available Phosphorus (ppm)	0-6	5.5	4.9	6.20	7.1	7.59	7.85	5.47	5.91	6.34	7.62
	06-12	5.3	4.5	7.15	7.02	7.30	7.83	5.20	5.75	6.01	7.44
Texture		Loam									

Table 3. Effect of level of NPK fertilizers on tuber, dry matter and yield of potato at Rawalpindi division, Punjab, Pakistan for three successive Rabi seasons during 2014-2017.

Nutrients (kg/ha)				Results (Average)		
Tr. No.	**N**	**P_2O_5**	**K_2O**	**No. of Tubers (m^{-2})**	**potato yield (kg m^{-2})**	**dry matter (kg m^{-2})**
1	244	163	136	63	2.02	0.9
2	300	200	167	81	2.59	1.08
3	356	237	198	95	2.83	1.27
4	412	275	229	100	3.1	1.3

Data analysis: The data was collected for different yield parameters. For number of tubers were quantifies by using the method previously used by Tekalign, (2005) and tuber yield was estimated by the method proposed by Mohammad *et al.* (2013). Obtained data were subjected to analysis of variance (ANOVA) by using Statistical Analysis System (SAS) version 9.2 statistical software (SAS, 2008). All pairs of treatment means were compared using Least Significant Difference (LSD) test at the 5% level of significance. The correlation analysis was performed to determine simple correlation coefficient between growth and yield components as affected by nitrogen, phosphorus and potassium applications.

RESULTS AND DISCUSSION

Results showed that there was no significant difference of location in terms of yield (t ha-1). However, mean data showed that the fertilizer combinations significantly (<0.05) affected yield and yield components of the crop. The interaction of the highest level of nitrogen, phosphorus and potassium increased total tuber number, tuber yield and maximum dry matter yield.

The maximum total tuber number (100 tuber m^{-2}), was recorded for the combination of 412 Kg N, 275 Kg of P and the 229 Kg K ha^{-1} while the least number of tuber m^{-2} (63), was obtained from the 244 Kg N, 163 Kg of P and the 136 Kg K ha^{-1}, respectively (Figure 2).

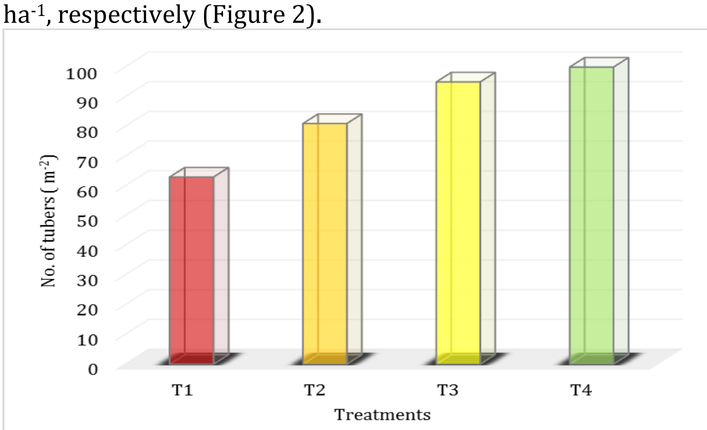

Figure 2: Mean average number of potato tubers (m^{-2}) as influenced by nitrogen, phosphorus and potassium rates.

The increment of total tuber number per hill with increasing nitrogen fertilizer levels could be explained by the maintenance of photosynthetically active leaves for longer duration and the formation of more new leaves than with lower or no nitrogen supply (Millard and Marshall, 1986). Increase in photosynthetic activity and translocation of photosynthesis to the sink might have helped in the initiation of more tubers. As reported in Uganda, nitrogen application to potatoes before tuber initiation increases the number of tubers per plant and mean fresh tuber weight (Kanzikwera *et al.*, 2001).

Phosphorus is relatively immobile in soil (Tisdale and Nelson, 1995) and because of its importance for early crop growth; banded application of phosphorus at planting is recommended (Rosen and Bierman, 2008). Yield response to fertilizer P has received the most attention, but there are also reports that Phosphorus can affect the number of tubers and tuber size distribution. Increases in tuber set with Phosphorus application have been found by (Sanderson *et al.*, 2002).

Potato tuber yield is also known to be influenced by P fertilizers through its effect on the number of tubers produced, the size of the tubers and the time at which maximum yield is obtained (Sharma *et al.*, 2014). They showed that yield response to increasing levels of P fertilizer was generally positive up to a particular level, above which the response became negative. They also noted that excess use of P fertilizers is usually associated with reduced tuber weight by hastening the maturation period and reducing tuber size. Applied P has been found to increase the yield of small and medium size tubers (Hanley *et al.*, 1965).

In agreement with the present finding, Zelalem *et al.* (2009) and Zamil *et al.* (2010) have reported a significant tuber number increment in response to nitrogen fertilizer application. Zamil *et al.* (2010) has also observed the maximum tuber yield when potato plants received 300 and 254 Kg nitrogen per hector. Similarly, Rosen and Bierman (2008) have reported that phosphorus fertilizer treatments significantly increased total number of tubers per hill. They have also noted that application of phosphorus increased the number of tubers set per unit area.

The interaction of nitrogen, phosphorus and potassium was highly significant (P<0.0001) for total tuber yield per hectare. Increasing the rate of nitrogen, phosphorus and potassium consistently increased total tuber yield from 2.02 to 3.2 kg m^{-2}. The highest total tuber yield (3.2 Kg m^{-2}) was recorded for the combined application of 412 Kg N, 275 Kg of P and the 229 kg K ha-1 and the lowest value (2.02 Kg m^{-2}), was obtained from the 244 Kg N, 163 kg of P and the 136 Kg K ha-1 respectively (Figure 3).

Application of nitrogen above 356 Kg N ha^{-1} and phosphorus application above 237 Kg ha^{-1} and 198 Kg K ha^{-1} could be recommended for total tuber yield of potato. Similar to the present finding, an increase in total tuber yield in response to nitrogen fertilization has been reported by several researchers such as Westermann *et al.* (1994); Maier *et al.* (1994) who observed a maximum tuber yield harvest at the

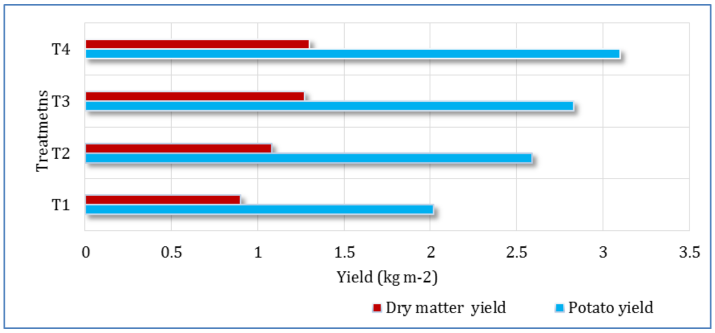

Figure 3: Mean average tuber yield and dry matter yield (kg m^{-2}) of potato as influenced by nitrogen, phosphorus and potassium rates.

rates of 165 Kg N and 3990 Kg P ha^{-1}. Similarly, there is highly significant increases in total tuber yield in response to increased level of nitrogen application (Zelalem *et al.*, 2009). Westermann *et al.* (1994) also noted that increase in the application of nitrogen fertilizer up to a certain level increases yield of potato but since then, it has no effect on the increase in yield. Reduction in yield due to high rate of N application could be explained by a phenomenon that extra nitrogen application often stimulates shoot growth at the expense of tuber initiation and bulking (Kar and Kumar, 2007).

Application of phosphorus also highly significantly increased total tuber yield of potato. In general, different rates nitrogen and phosphorus fertilizer application had yield advantage (Table 1). In line with the present finding, Mulubrhan (2004) have reported that increasing phosphorus application increased total tuber yield.

The interaction of nitrogen, phosphorus and potassium significantly ($P < 0.05$) influenced dry matter content of potato tubers. The highest dry matter percentage (1.3 Kg m^{-2}) of potato tuber was recorded for plots that received the combination of 412 kg ha^{-1} N, 275 Kg ha^{-1} of P and 229 Kg ha^{-1} of potassium, while the lowest value (0.9 Kg m^{-2}) was obtained where combination NPK (244, 163 and 136 kg ha^{-1}) were applied. This could be attributed to delay tuber initiation and maturity due to high rates of nitrogen. As a result, tubers tend to be harvested immature with low dry matter percentages. These results are in agreement with the findings of (Cucci and Lacolla, 2007) who have observed a significant increase in the tuber dry matter percentage with increasing nitrogen and phosphorus levels up to 200 kg N and 50 kg P ha^{-1}.

Correlation analysis: The correlation analysis was performed to determine simple correlation coefficient between growth and yield parameters as affected by N, P and K application. Marketable tuber number was significantly and positively correlated with and total tuber yield ($r = 0.989$). Many yield components contributed to marketable tuber yield increment because marketable tuber yield was found to be strongly and positively associated significantly with dry matter yield ($r = 0.97$), number of tubers ($r = 0.99$). The present finding indicated that yield components and fertilizer applied contributed to total tuber yield increment because total tuber yield was highly and positively correlated with nitrogen ($r = 0.97$), Phosphorus ($r = 0.96$) and Potassium ($r = 0.97$) (Table 4).

Table 4: Correlation analysis on nutrients (kg ha-1), No. of tubers (m-2), potato yield (kg m^{-2}) and dry matter yield of potato (kg m^{-2}).

	N	**P_2O_5**	**K_2O**	**No. of tubers (m^{-2})**	**Potato yield (Kg m^{-2})**	**Dry matter (kg m^{-2})**
N	1					
P_2O_5	0.999978	1				
K_2O	1	0.999978	1			
No. of Tubers (m^{-2})	0.973271	0.971789	0.973271	1		
Potato yield (Kg m^{-2})	0.976896	0.976017	0.976896	0.989472033	1	
Dry matter (kg m^{-2})	0.965301	0.963567	0.965301	0.996815912	0.974931323	1

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Date Published (D-M-Y): 15-12-2018