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Investigating the performance of potato tuber in terms of nitrogen and phosphorus consumption in Jiroft

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Abstract
Potato is one of the most important crops in the world. This plant is in the third place after rice and wheat in terms of consumption in the world, for this reason this plant is considered as one of the plants that protect food security. Low soil fertility is the most important limitation for potato production. Farmers should deal with this problem by using mineral fertilizers that improve soil productivity. Using the right amount of NP fertilizer is the main factor in potato production. A field experiment was conducted in the main cropping season of 2022 and 2023 to investigate the optimal amount of NP on potato tuber yield in Jiroft region. The treatments including four levels of nitrogen (0, 46, 92, 138 kg/ha) and three levels of phosphorus (0, 46, 69 kg/ha) were factorially combined in a randomized complete block design with three replications. The results of the study showed that the use of 92 kg of nitrogen per hectare is recommended in Jiroft. Even if P application does not affect potato tuber yield, 23 kg/ha of P fertilizer should be applied to maintain soil fertility.

Keywords: Nitrogen, phosphorus, potato

Introduction

Potato (Solanum tuberosum L) is a product of major economic importance in the world and the number one grain-free food product. It contains practically all the essential dietary substances such as carbohydrates, essential nutrients, protein, vitamins and minerals. Although potato productivity can reach up to 50 tons per hectare (Ansari *et al.*, 2012), its productivity in Jiroft is very low, which is 25 tons per hectare. There are many complex reasons for this real low potato yield in the country. Soil fertility, lack of quality seeds, unbalanced mineral nutrition, insufficient consumption of fertilizers, pests and diseases, irregularity in water supply and traditional irrigation programs are the main reasons for reducing potato productivity. Providing the optimal amount of nitrogen encourages root growth and absorption of other nutrients. A sufficient amount of phosphorus nutrient also improves some aspects of plant physiology, including the basic processes of photosynthesis, root growth, especially the growth of lateral roots and fibrous roots (Jalali *et al*., 2014). Various research findings showed that the combined application of NP fertilizer has a significant effect on potato yield. The application of 165 kg of nitrogen per hectare and 60 kg of P2O5 per hectare had the highest salable yield (35

tons per hectare) in Jiroft (Zahedi *et al*., 2023). Similarly, the highest marketable yield (36.1 t/ha) was obtained by applying 165 kg N/ha and 135 kg P2O5/ha. By increasing the amount of nitrogen and phosphorus fertilizers, the yield has increased by 88%. In the studied area, the information about the amount of fertilizer for potato production and other agricultural methods for maximum tuber yield is limited. For this reason, it is very important to determine the optimal phosphorus and nitrogen fertilizer for potato production to increase with relevant recommendations that can optimize potato tuber performance. Therefore, this study was conducted in order to determine the reaction of phosphorus and nitrogen levels on yield and yield components of potato in Jiroft in the south of the country.

Materials and methods

Description of the study area

This experiment was conducted in the 2022-2023 cropping season in Jiroft region in the southeast of Iran. This city is located at 28°12'N to 29°13'N and 57°15'W to 57° 17'W (Fig. 1), 192 km southeast of Kerman (province capital) and is 960 meters above sea level. Jiroft has a pleasant climate and fertile agricultural lands, which has been able to be one of the best in the country in terms of producing high-quality agricultural products that meet the needs of the people's market in terms of variety and mass production. Agricultural products in all seasons of the year (Jaafari, 2019).

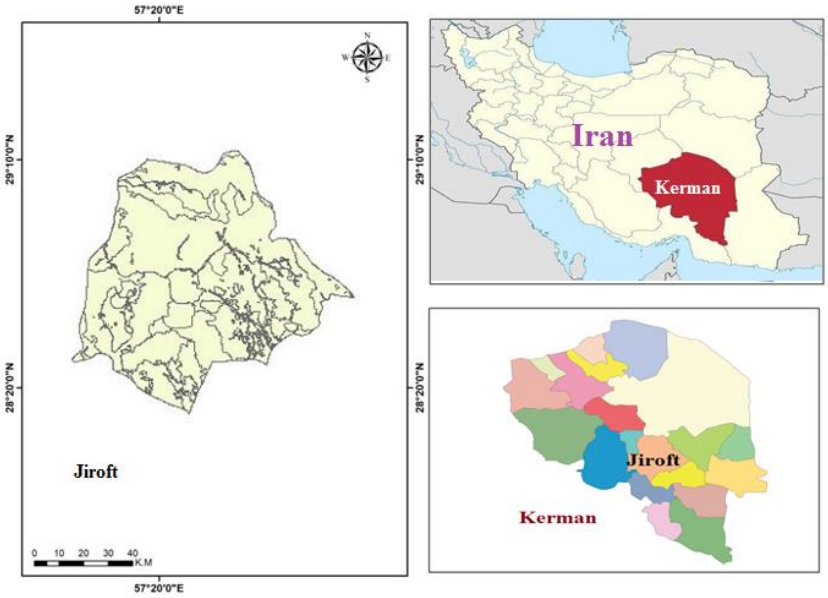

Fig. 1 *Geographical location of Jiroft*

Experimental design and treatments

The experiment was conducted as factorial RCBD with three replications. Three levels of phosphorus were used with four levels of nitrogen. P2O5 levels (0, 46 and 69) and nitrogen levels (0, 46, 92 and 138) were in kg/ha. Jalani potato variety was

used as an experimental product. The area of the gross plot was 2.8 m × 2.4 m and the net plot was 2.4 × 1.4 m. A distance of 1 meter between plots and 1.5 meters between blocks was used. The distance between the row and the bush was 70 and 30 cm, respectively.

Soil sampling technique and analysis

Before planting, soil samples were randomly collected diagonally from 0 to 20 cm deep. The soil samples were air-dried and passed through a 2 mm sieve for physical and chemical analysis. The soil was analyzed for texture and total soil nitrogen, available phosphorus, pH, OC and CEC. Soil texture was determined by hydrometer method. Total soil nitrogen was analyzed by Kjeldahl method with sulfuric acid.Soil pH was determined from the filtered suspension of 1:2.5 soil/water ratio using a glass electrode connected to a digital pH meter, a potentiometer (FAO, 2008). Organic carbon content was determined by volumetric method (Walkley and Black, 1934). Available soil phosphorus was determined by Olsen's method (Olsen et al; 1954). Exchangeable potassium was extracted by ammonium acetate at pH 7 (Sahalmedhin and Taye, 2000) and determined by an atomic absorption spectrometer. Cation exchange capacity (CEC) of soil was determined using 1N ammonium acetate extraction method (pH 7).

Land preparation and planting

The experimental field was prepared for the normal tillage of the region. It was manually leveled and then divided into blocks and pieces. The blocks were separated by a 1.5 m wide open space where the block pieces were 1 m apart. Each piece consisted of 4 rows with a length of 2.4 meters and a distance of 0.7 meters from each other. Selected seed of the potato variety (Sante) was planted manually at an equal distance between the plant and the row.

Collected data

Days to flowering were recorded when 50% of the plant population of each plot produced flowers. Plant height (cm) was measured from ten randomly selected plants in each plot at full maturity. The number of stems in each mound was recorded as the average number of stems of five mounds per unit area at full maturity. The number of days to maturity The number of days from germination to maturity was recorded when 95% of the plants in each plot were ready to harvest. The number of tubers in each hill was obtained by counting the number of tubers in each hill. Salable tuber yield (tons per hectare) including salable and healthy tubers with size categories greater than 25 unsalable tubers (tons per hectare) unsalable tubers including unhealthy tubers as well as healthy tubers weighing less than 25 grams . Total tuber yield (ton/ha) Total tuber yield was recorded as the sum of marketable and non-marketable tubers.

Statistical analysis

Plant data were recorded based on plots and extrapolated based on hectares. All parameters were determined and calculated from the middle rows. Analysis of variance and comparison of treatment means for different measured parameters were performed using SAS software version 9.0. The average separation for the recorded plant parameters was performed using the least significant difference test (at a significance level of 0.05).

Economic Analysis

Economic analysis was performed using partial budget analysis to find the best treatment that has economic benefits.
The following equations were used:
Gross profit = economic return × price
Net Profit = Gross Profit - Total Cost which is different.
Dominance analysis was used to identify the best treatments from the experiment. Marginal rate of return (MRR) was calculated considering a pair of non-dominant treatments mentioned. MRR indicates the return per unit of investment for various managements tested in this field. After the analysis, the treatments with the highest MRR were recommended to the farmers.
MRR = change in TCV/change in NB
where MRR is the marginal rate of return, NB is the net profit per hectare for each treatment, and TCV is the total variable costs per hectare for each treatment.

Results and Discussion

The results of the soil composite samples for the cropping seasons used in determining the physical and chemical characteristics of the experimental sites are presented in Table 1. The pH value of the soil was in the range of 5.58-5.65, which indicated moderate acidity. According to the classification set by London. (1991), the organic contents of all studied sites were ranked very low. The phosphorus content in the composite surface soil sample of the experimental sites can be evaluated as very high. Soil exchangeable potassium was optimal (Berhanu Debele, 2008). According to Murphy (2007), the cation exchange capacity of the soil was very high.

Table 1 - Physical and chemical characteristics of experimental sites

		Year 1		Year 2	
Soil property	**Unit**	**Site 1**	**Site 2**	**Site 1**	**Site 2**
Total nitrogen	%	0.18	0.25	0.22	0.28
Available P	P/PPM	34.61	33.27	25.29	14.37
pH	H2O	5.6	5.65	5.58	5.58
OC	%	1.87	1.79	2.53	2.46
CEC	Cmol/kg Ammon. Acet.	47.48	42.45	39.57	35.82
Ex.K+	Cmol/kg Ammon. Acet.	0.95	1.12	0.55	0.29
Textural class	%	Clay loam	Clay loam	Clay	Clay

Growth parameters

Days to flowering and maturity

Analysis of variance showed that the application of nitrogen and phosphorus has a significant effect on days to flowering and maturity (Table 2). The application of 138 kg of nitrogen per hectare delayed flowering and maturity by 9 and 14 days, respectively, compared to the control plots. Also, the use of phosphorus when its amount increases from 0 to 69 requires a long time to flower and reach. Zahedi et al. (2023); They found that applying high levels of nitrogen delayed flowering and maturity.

Table 2- Effects of nitrogen and phosphorus fertilizers on potato growth parameters

N kg ha-1	DF	DM	SNH	PH (cm)
0	60.78d	106.33d	5.6b	51.9d
46	65.89c	110.78c	6.8a	63.9c
92	68.22b	115.56b	7.3a	69.7b
138	69.89a	120.67a	7.3a	73.5a
LSD(0.05)	**	**	*	*
P kg ha-1				
0	65.58b	111.25b	6.6	65.3
46	65.67b	113.5a	6.8	64.4
69	67.33a	115.25a	6.9	64.3
LSD(0.05)	**	*	ns	ns
CV (%)	1.31	2.05	20.6	11.6

+ days to 50% flowering (DF), days to maturity (DM), number of stems in the hill (SNH), plant height (PH), least significant difference (LSD) and coefficient of variance (CV)

Bush height

Nitrogen levels, analysis of variance showed that nitrogen application has a significant effect on potato plant height, while phosphorus had no effect. Nitrogen fertilization at the rate of 138 kg of nitrogen per hectare increased the plant height by 22 cm compared to the control.

Number of stems per hill

Nitrogen application significantly affected the number of stems per hill. With the increase of nitrogen consumption from 0 to 138 kg/ha, the number of stems per hill increased from 5.6 to 7.3. The highest (7.3) and the lowest (5.6) number of stems per hill were obtained in the amount of 138 kg of nitrogen per hectare and the control plot, respectively. On the other hand, phosphorus fertilization had no significant effect, but with the increase of phosphorus consumption from 0 to 69 kg/ha, the number of stems per hill increased from 6.6 to 6.9. The lowest number of potato stems from the control plot (N/P 0.0) Obtained.

Return factors

Number of tubers per hill

The results showed that the application of nitrogen and phosphorus fertilizers has a significant effect on the number of tubers in the hill. The highest (13.9) and lowest (10.5) tubers were obtained in the amount of 138 kg of nitrogen per hectare and the control plot, respectively. Different levels of phosphorus consumption also have a significant effect on the potato tuber. The highest (13.5) and lowest (12.2) tubers were recorded as 69 kg per hectare and the control plot, respectively.

Table 3- The effect of nitrogen and phosphorus on the average combined growth and yield of potatoes in Jiroft region during two years

Nitrogen	Av.no. of tuber/hill	Marketable yield	Total yield
(kg ha-1)		(ton ha-1)	(ton ha-1)
0	10.5b	20.3c	22.0c
46	13.0a	27.8b	29.8b
92	13.7a	33.3a	35.6a
138	13.9a	33.7a	36.3a
LSD(0.05)	1.1.	2.8	2.7
P2O5 (kg ha-1)			
0	12.2b	28.7	30.8
46	12.6ab	29	30.9
69	13.5a	28.7	31.2
LSD(0.05)	0.9	ns	ns
CV (%)	18.3	2.4	18.6

The least significant difference (LSD) and coefficient of variance (CV) of marketable yield (Tha^{-1}) of nitrogen levels showed a significant effect on marketable yield.

Marketable yield (Tha^{-1})

Nitrogen levels showed a significant effect on marketable yield (Tha^{-1}) while phosphorus levels were insignificant. A maximum of 36.3 tons per hectare and 31.2 tons per hectare were obtained from the received plots, 138 kg of nitrogen per hectare and 69 kg of phosphorus per hectare, respectively. In the application of nitrogen, 92 kg of nitrogen per hectare and 138 kg of nitrogen per hectare were the highest yield, but it was not statistically significant. By increasing the level of nitrogen, the yield of potatoes increases.

Analysis Partial , Budget

Table 4- Analysis partial , testing budget

Treatment arrangement(P2O5, N) respectively	Marketable yield (ton ha-1)	Adjusted yield (ton ha-1)	fertilizer Application Cost (ETB)	fertilizer Cost (ETB)	Total variable cost (ETB)	Gross benefit (ETB)	Net benefit (ETB)	dominance analysis	MRR
(0,0)	21.1	19	0	0	0	151920	151920		
(46,0)	19.5	17.5	0	1558.5	1558.5	140162	138604	D	
(0,46)	25	22.5	700	1456.6	2156.6	180302	178146		12.2
(69,0)	20.5	18.4	0	2337.8	2337.8	147362	145025	D	
(46,46)	29.5	26.5	700	3015.1	3715.1	212342	208627		19.6
(0,92)	34.3	30.8	900	2913.2	3813.2	246600	242787		348.2
(69,46)	28.8	25.9	700	3794.4	4494.4	207360	202866	D	
(46,92)	33.1	29.8	900	4471.7	5371.7	238262	232891	D	
(0,138)	34.3	30.9	1100	4369.8	5469.8	246902	241433	D	
(69,92)	32.6	29.3	900	5251	6151	234418	228267	D	
-46,138	34.1	30.7	1100	5928.3	7028.3	245398	238369	D	
-69,138	32.8	29.5	1100	6707.6	7807.6	236282	228475	D	

The result of partial budget analysis is shown above (Table 4). Financial profitability is the final criterion for recommending mineral fertilizer rates. A partial budget analysis showed that treatment 8 (92 kg/ha N and 0 P) was economically and biologically profitable as it provided a final yield rate above 100% yield acceptance rate. Therefore, it is recommended to use 98 kg/ha for Jiroft and similar areas to achieve higher yield of potatoes.

Conclusion

According to this finding, the use of nitrogen fertilizer, economic analysis is confirmed with agricultural results in Jiroft region. Therefore, 92 kg of nitrogen per hectare is recommended in the field of agriculture and agroecology. Even if the use of phosphorus fertilizer does not have a significant effect on the yield of potato tuber, in Jiroft region, phosphorus fertilizer of 23 kg per hectare should be used to maintain soil fertility.

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