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Evaluation the effects of multiple doses of phosphorus and nitrogen on potato tuber performance (Solanumtuberosum L.) in Jiroft-Iran

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Abstract : An experiment was conducted in Jiroft, South-East of Iran in order to investigate the effect of different doses of nitrogen and phosphorus on yield and yield components of potato. Four levels of nitrogen (0, 55, 110, 165 kg/ha) and four levels of phosphorus (0, 20, 40, 60 kg/ha) were combined in a 4x4 factorial design in a randomized complete block design with three replications. Collected data on growth and yield parameters were analyzed using SAS 9.2 software. The application of 165 kg of nitrogen per hectare significantly increased 6 days to flowering, 13 days to physiological maturity, aboveground biomass 36%, belowground biomass 29.79%, total tuber yield 60.33%, number of marketable tuber increased by 56.36.The percentage and number of the total tuber is 31.7% and the average tuber weight is 22.43%. However, N did not affect days to emergence, number of unmarketable tubers. The application of phosphorus increased the days to flowering by 3 days, the biomass on the ground and underground by 8.78 and 61.4%, respectively, and the number of salable tubers by 19.72%. The interaction effect of 165 kg of nitrogen and 60 kg of phosphorus increased the salable tuber yield (36 tons/ha) by 122% compared to the control (16.2 tons/ha). The results of this study confirmed that potato yield and yield components are affected by nitrogen and phosphorus rates. From this study, it can beconcluded that higher amounts of nitrogen (165 kg/ha) and phosphorus (60 kg/ha) can be used for optimal production, of Sante potato variety in Jiroft.

Keywords:Growth Parameters;Nitrogen; Phosphorous; Sante potato variety; Yield Parameters.

I. INTRODUCTION

Potato (Solanumtuberosum L.) is a starchy food, a tuber of the solanacaea plant and a root vegetable native to Africa. Wild potato species can be found from the southern United States to southern Chile. It was first believed that the potato was known to Native Americans, but genetic studies have traced the origin of the potato to what is now southern Peru and northwestern Bolivia. In the second half of the 16th century, it was introduced to Europe from the American continent by the Spanish, and in 1812, it was introduced to Iran by Sir John Malcolm (Foroghi,2018). For many years in Iran, potato production was limited to only homesteads, as a garden crop. World annual production of potato is about 360 million metric tons with area coverage of 18,651,838 ha. In Asia total production of potato is about 197,769,527 tons with total area coverage of 1,765,617 ha. In Iran total production is around 4474886 tons on area coverage of 69784 ha. It is one of the major world food crops in its ability to produce high food per unit area per unit time (FAOSTAT,2020). Iran is endowed with suitable climatic and edaphic conditions for potato production. However, land acreage under potato production is estimated to be only about 69,784 ha and the national average yield is about 8.2 t /ha, which is very low as compared to the world's average production of 17.67 t /ha (FAOSTAT, 2020). Potato requires a variety of plant nutrients for growth and development. Nitrogen, phosphorus and potassium are the most important among the elements that are essential to potato. Fertility of most Iran soils has already declined due to continuous cropping, abandoning of fallowing, reduced use of manure and crop rotation. The use of animal manure and crop residues for fuel and erosion coupled with low inherent fertility are among the main causes for decreasing soil fertility (Khadim et al., 2016). In Iran, national yield and variety trials data over several locations on different crop species clearly indicated that soil nutrient stress is the most significant factor controlling crop yield (Alizadeh et al., 2008). Farmers should tackle this problem through the application of both organic and inorganic fertilizes, which amend the soil environment. Nutrient and soil fertility management is also becoming more accepted by development and extension programs in Agricultural Research and Education Organization and most importantly, by smallholder farmers (Ghafarinejad, 2016). It has been reported that nitrogen and phosphorus are deficient in most Iran soils and thus application of these fertilizers has significantly increased yield of the crop (Rejali et al., 2013). Nitrogen and phosphorus fertilizers application have shown good yield responses, for different crops across different locations indicating low nitrogen and phosphorus status of the soils (Ansari et al., 2013). This situation would become more critical in potato production in view of the fact that the potato crop one of the heavy feeders of plant nutrients (Falah Qalhari et al, 2015).Soils in Southeast of Iran are low in soil organic matter, Cation Exchange Capacity and are high in acidity.

The low level of soil organic matter combined with poor land coverage have resulted in poor soil structure, limited rooting depth and susceptibility to accelerated erosion (Koj et al, 2012). Without considering the fertility status of the soil and the type of crop cultivar, blanket national recommendation of 165 kg urea and 195 kg Diammonium phosphate(DAP) per hectare is being used in Jiroft since there is limited information on soil fertility studies for potato production in the area .Fertilizer practices in the region have been mainly based on the experience of other regions. Therefore, investigating the response of potato for nitrogen and phosphorus fertilizers under this specific agro-ecology is required to come up with relevant nitrogen and phosphorus recommendation for Jiroft Southeast of Iran.

II. RESEARCH METHODOLOGY

***2.1.Description of the study area*:** The experiment was conducted in the Jiroft region of southeastern Iran during the 2023/2024 crop season. This city is located at 57°, 44°, 15° east longitude and 28°, 40°, 15° north latitude, 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 the field of producing high-quality agricultural products, which responds to the market demand of the people in terms of variety and mass production of agricultural products in all seasons of the year (Jafari, 2021).

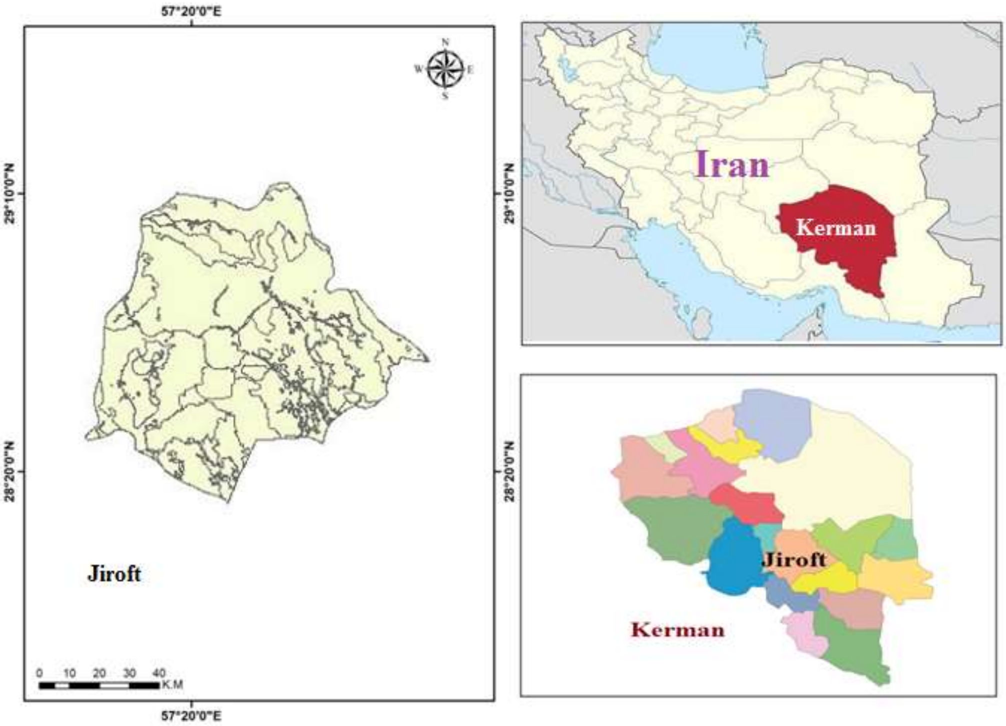

***Fig. 1** Geographical location of Jiroft*

***2.2.Design and Procedures*:** For this experiment, the Sante potato variety obtained from the Center for Research and Education of Agriculture and Natural Resources in the South of Kerman Province was used. It is one of the potential potato cultivars for Jiroft region in the southeast. This plant is widely cultivated and due to its high yield potential, consumer preference, greater adaptability, better cooking ability and relative resistance to late blight compared to local varieties and other improved potatoes grown in the region, has been accepted by farmers. Four levels of nitrogen 0, 55, 110 and 165 kg and four levels of phosphorus 0, 20, 40 and 60 kg/ha were combined in the form of a 4x4 factorial design in the form of a randomized complete block design with three replications. All management measures, such as weeding, insect and pest control, and diseases were applied according to general recommendations for potato (Gebremedhin et al., 2008). The experimental farm was divided into three blocks, each block containing 16 plots, and an area of 9 square meters (length 3 meters by width 3 meters) was used. The distance between the plots in the block was 0.75 m and the distance between the blocks was 1 m, and the distance between the rows was 75 cm uniformly, and medium-sized and germinated potato tubers were planted. The total amount of phosphorus and half of the amount of nitrogen at the time of planting and half of the remaining nitrogen were used 45 days after planting. Urea (46% nitrogen) and triple superphosphate, TSP (46% P2O5) fertilizers were used as nitrogen and phosphorus sources.

***2.3.Data collection and analysis*:** Data collected on growth parameters such as days to 50% flowering and maturity, plant heights, shoot and root dry weight and yield parameters such as total and marketable tuber number, total and marketable tuber yields (t/ha) and average tuber weight were checked for normality and subjected to analysis of variance using SAS Version 9.2 statistical software. Treatment means were compared using LSD value at 5% significant level (Soltani, 2012).

III.RESULTS AND DISCUSSION

***3.1. Effect of nitrogen and phosphorus rates on growth parameters*:** The effect of both nitrogen and phosphorous rates were found highly significant ($p<0.001$) on all growth parameters studied including days to 50% maturity, shoot and root dry weight except days to 50% flowering which was highly significantly ($p<0.01$) affected by rates of nitrogen and significantly ($p<0.05$) affected by rates of phosphorus.

***3.2.Days to 50% flowering*:** Application of 165 kg N /ha delayed the time required to reach 50% flowering by 7 days (Fig. 2). This is because high N levels promoted excessive vegetative growth and delayed flowering. This result in coherent with the findings of Lauer (1986), who reported excessive vegetative growth and delayed flowering due to high nitrogen levels.

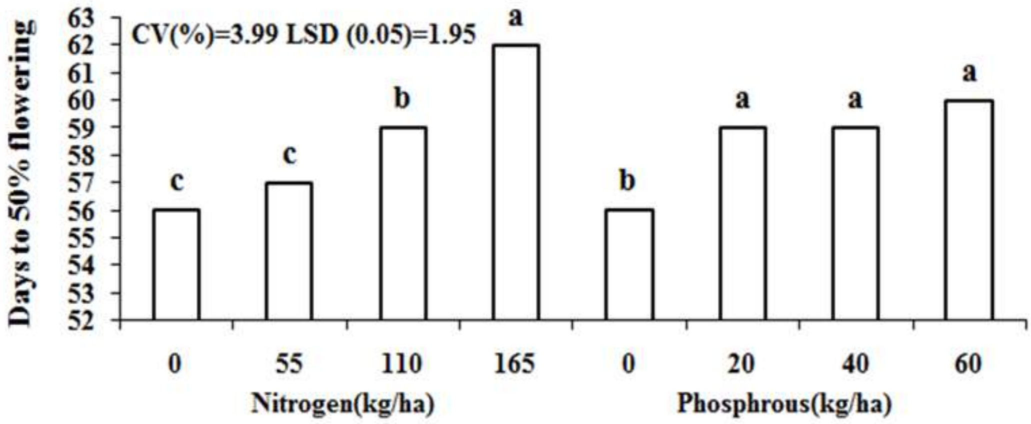

Fig. 2 Means for number of days to 50% flowering of potato as influenced by nitrogen and phosphorus rates. Means for number of days to 50% flowering of potato followed by different letters differ significantly at $p<0.05$ as established by LSD test

Similarly increased phosphorus application from 0-60 kg P /ha prolonged the days to 50% flowering by 3 days from 56-59 (Fig.2). This result is in agreement with the findings of Harris (1978) and Mulubrhan (2004) who confirmed that phosphorus application had been found to prolong days required to 50% flowering.

***3.3.Days to 50% maturity*:** Increasing the application rate of nitrogen from zero to 165 kg N /ha delayed days to 50% maturity from 99-112 by 13 days (14%) (Fig. 3). This is due to the fact that increased level of nitrogen increased the leaf area which in turn increased the amount of solar radiation intercepted and consequently, increased days to physiological maturity.

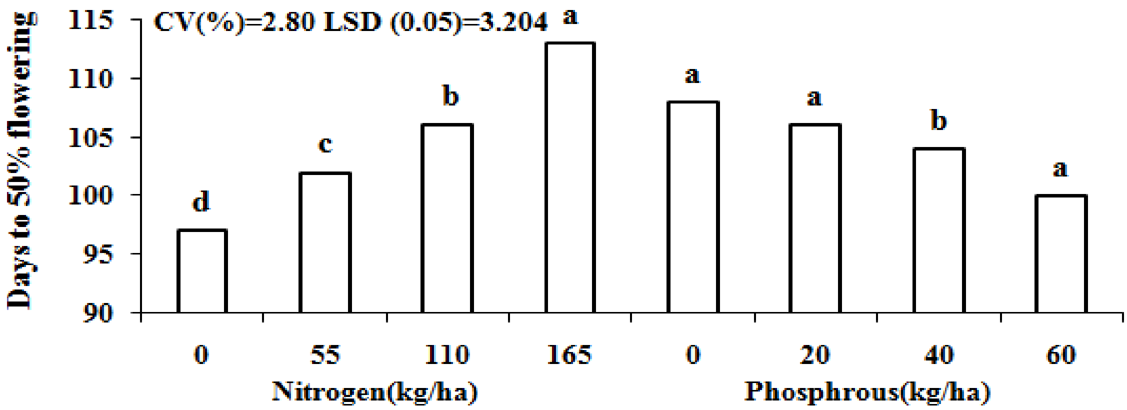

Fig. 3 Means for number of days to 50% maturity of potato as influenced by nitrogen and phosphorus rates. Means for number of days to 50% maturity of potato followed by different letters differ significantly at $p<0.05$ as established by LSD test

Therefore, a crop with more nitrogen will mature later in the season than a crop with less nitrogen because later growth is related to excessive haulm development whereas early tuber growth to less abundant haulm growth On the other hand, increased rate of phosphorus application reduced the days to 50% maturity (Fig. 3). This might be due to the role of phosphorus in accelerating the physiological maturity of potato.

***3.4.Shoot dry weight*:** Application of 165 kg N/ha increased shoot dry weight from 52.75-72.25 by 19.5 g per hill. This increase in shoot dry weight is 37% as compared to control treatment (Table 1, 2).

Table 1 Effect of nitrogen and phosphorus rates on shoot and root dry weight of potato

Treatments	Shoot dry weight(g/hill)	Root dry weight(g/hill)
Nitrogen(kg/ha)		
0	52.75^{d}	8.90^{c}
55	58.33^{c}	9.97^{bc}
110	65.00^{b}	11.43^{ba}
165	72.25^{a}	11.56^{a}
Phosphorus(kg/ha)		
0	59.67^{b}	7.59^{c}
20	61.25^{ba}	10.37^{b}
40	63.00^{ba}	11.70^{a}
60	64.92^{a}	12.21^{a}
LSD(p<0.05)	2.785	1.541
CV(%)	5.370	17.640

Means followed by different letters per column differ significantly at $p<0.05$ as established by LSD test

Table 2 Mean squares for potato growth parameters and harvest

Source of variation	df	Mean squares				
		DF	DM	pH	SDW	RDW
Block	2	2.79	20.27	06.90	8031.06	171.37
Nitrogen	3	95.82**	384.7**	496.27**	837.91**	19.48**
Phosphorus	3	30.37*	158.3**	201.09*	61.36**	51.88**
Nitrogen×Phosphorus	9	02.79^{ns}	15.33^{ns}	21.37*	02.90^{ns}	01.08^{ns}
Error		05.47	03.36	02.83	11.16	03.41
SE±		02.34	03.36	01.37	03.34	01.84
CV		04.00	03.20	04.48	05.37	17.64

SDW: Shoot dry weight, RDW: Root dry weight, DM: Dry weight, *Significant,**Highly significant, ns: Non significant, Df: Degree of freedom

This is due to the fact that, increased concentration of nitrogen fertilizer can increase the nitrogen uptake and this increase has a positive effect on chlorophyll concentration, photosynthetic rate, leaf expansion, total number of leaves and dry matter accumulation. Consequently nitrogen fertilizer plays an important role in canopy development especially on the shoot dry matter. As the rate of phosphorus application increased from 0-60 kg P/ha, the shoot dry weight of potato increased from 59.67-64.91 g per hill and the increased application rate of phosphorus increased shoot biomass by 8.78 (Table 1,2). The researchers concluded that nitrogen and phosphorus fertilization significantly affects the dry weight of potato shoot.

***3.5.Root dry weight*:** With application of 165 kg N /ha the highest root dry weight (11.56 g /hill) was obtained compared to the control treatment with the lowest root dry weight of 8.90 g /hill (Table1,2). This could be due to the effect of nitrogen that stimulated the growth and development of roots. In similar manner FAO (2000) reported that good supply of nitrogen to the plant stimulates root growth and development as well as uptake of other nutrients. Regarding phosphorus the maximum root dry weight (12.2 g /hill) was registered from plants that were fertilized with phosphorus at rate of 60 kg P/ha and this value was statistically at par with the application of 40 kg P/ha but the lowest root dry weight (7.58 g /hill) was recorded from plots that received no phosphorus application.

This might be application of higher rate of phosphorus enhanced the development of roots particularly lateral and fibrous rootlets. Similarly Brady and Weil (2002) reported that P is required in large quantities in young cells, such as root tips, where metabolism is high and cell division and development of root is rapid. The result of the experiment showed that the higher level of nitrogen and phosphorus fertilizer significantly affects the dry weight of potato roots.

***3.6.Effect of nitrogen and phosphorus rates on yield parameters*:** The effect of both nitrogen and phosphorous rate was found highly significant ($p<0.001$) on yield parameters such as marketable tuber number and total tuber yield and significant ($p<0.05$) on average tuber weight except total tuber number which was highly significantly ($p<0.01$) affected by rate of nitrogen and significantly ($p<0.05$) affected by rate of phosphorus (Table 3, 4).

Table 3 Effect of nitrogen and phosphorus rates on total and marketable tuber number, total tuber yield and average tuber weight of potato

Treatments	Total tuber No./hill	Marketable tuber No./hill	Total tuber yield (t/ha)	Average tuber weight (g/hill)
Nitrogen(kg/ha)				
0	9.77^{d}	5.68^{c}	23.75^{d}	54.58^{c}
55	10.70^{c}	6.80^{b}	30.17^{c}	63.00^{b}
110	11.20^{b}	7.13^{b}	34.64^{b}	67.54^{ab}
165	12.19^{a}	8.88^{a}	38.08^{a}	70.23^{a}
Phosphorus(kg/ha)				
0	10.67^{c}	6.44^{b}	27.10^{c}	56.8^{c}
20	10.82^{bc}	6.58^{b}	28.83^{c}	59.68^{c}
40	11.15^{ab}	7.76^{a}	33.11^{b}	65.93^{b}
60	11.55^{a}	7.71^{a}	37.56^{a}	72.85^{a}
LSD(5%)	0.456	0.523	1.270	5.499
CV(%)	4.95	8.80	10.32	10.33

Means followed by different letters per column differ significantly at $p<0.05$ as established by LSD test

Table 4 Mean squares for potato yield parameters

		Mean squares				
Source of variation	**Df**	**Marketable tuber No./hill**	**Total tuber No./hill**	**Marketable tuber yield (t/ha)**	**Total tuber yield (t/ha)**	**Average tuber weight (g/hill)**
Block	2	1.00	0.92	7.86	0.05	29.31
Nitrogen	3	21.15**	13.17**	334.54**	459.51**	571.44**
Phosphorus	3	6.03**	1.80*	291.62**	264.29**	609.69**
Nitrogen×Phosphorus	9	0.46^{nc}	0.37^{nc}	15.84*	20.11^{nc}	52.62^{nc}
Error	30	0.4	0.3	6.16	10.69	43.50
SE±		0.63	0.54	2.48	3.27	6.59
CV(%)		8.80	4.95	9.66	10.33	10.33

*Significant, **Highly significant, ns: Non significant, Df: Degree of freedom

***3.7.Total tuber number*:** Increasing the application of nitrogen increased total tuber number per hill from 9.78-12.2 (Table3,4). This can be attributed to increased vegetative growth of the potato plant. The current result is in consistent with the work of some researchers (Herlihy and Carroll, 1969; Hanley *et al*., 1965; Mahmoodabad *et al*.,2010) who had reported that an increase in nitrogen application increases tuber number. In the present study, raising the rate of applied nitrogen from 0-165 kg /ha increased total tuber number by 31.7%. Similarly, increasing the level of applied phosphorus significantly increased total tuber number per hill from 10.68-11.55 (Table 3,4). According to Sparrow *et al.* (1992), the application of phosphorus increased the number of potato tubers set per unit. Application of phosphorus from 0-60 kg P/ha increases total tuber number by 8.19% as compared to control.

***3.8. Marketable tuber number*:** Marketable tuber number increased with increased rate of nitrogen. Hence, increasing rate of nitrogen application from 0-165 kg N/ha increased marketable tuber number from 5.68-8.85/hill without affecting the unmarketable tuber number (Table 3). This could be probably due to the fact that marketable tuber number increases at higher nitrogen rate because nitrogen can trigger the vegetative growth development.

The increase in number of marketable tuber with increase in applied nitrogen was associated with decrease in the number of the small size tubers due to increase in the weight of individual tubers. This result is in line with the finding of Hanley *et al.* (1965) who confirmed that application of nitrogen increased the number of tubers produced per hill in a study conducted for three consecutive years. Application of nitrogen from 0-165 kg N /ha increased marketable tuber number by 56.36%. Similarly, increasing the level of applied phosphorus also increased marketable tuber number per hill from 6.44-7.76. However, there was no apparent difference between application of 40 and 60 kg P /ha (Table 3).

***3.9.Total tuber yield*:** Increasing the application rates of nitrogen resulted in increasing the total tuber yield from 23.75 to 38 t /ha (Table3). While, the highest yield was obtained at 165 kg N /ha but the lowest yield was obtained at zero nitrogen application. Increasing the application rates of nitrogen from 0 to 165 kg N /ha increased total tuber yield by 60.33%. Similar to the effect of increased nitrogen, increasing phosphorus application rate from 0-60 kg P /ha increased the total tuber yield from 27.1 to 37.6 t /ha. The highest total tuber yield (37.6 t /ha) was obtained at phosphorus application of 60 kg P/ha but the lowest yield (27.1 t/ha) was obtained at no phosphorus application (control treatment). This value is statistically similar with the application of 20 kg of phosphorus. Application of phosphorus from 0-60 kg P /ha increased total tuber yield by 38.6% as compared to the control treatment. Phosphorus application also increased significantly total tuber yield the increase in total tuber yield by phosphorus application was not sharp (Table 3). This show there is opportunity for additional gain in tuber yield through further application of more N and P fertilizers above 165 kg N /ha and 60 kg P /ha, respectively.

***3.10. Marketable tuber yield*:** The highest marketable tuber yield (35 t/ha) was recorded at 165 kg /ha nitrogen in combination with phosphorus at 60 kg /ha but the lowest marketable tuber yield (16.2 t/ha) was obtained from the combination of zero levels of nitrogen and phosphorus. Nitrogen showed significant differences in marketable tuber yield under the same phosphorus level (Fig.4), indicating that the effect of different levels of phosphorus on marketable tuber yield is dependent on the levels of nitrogen. This may be due to the positive interaction and complementary effect between nitrogen and phosphorus in affecting and increasing the marketable tuber yield of potato in the study area.

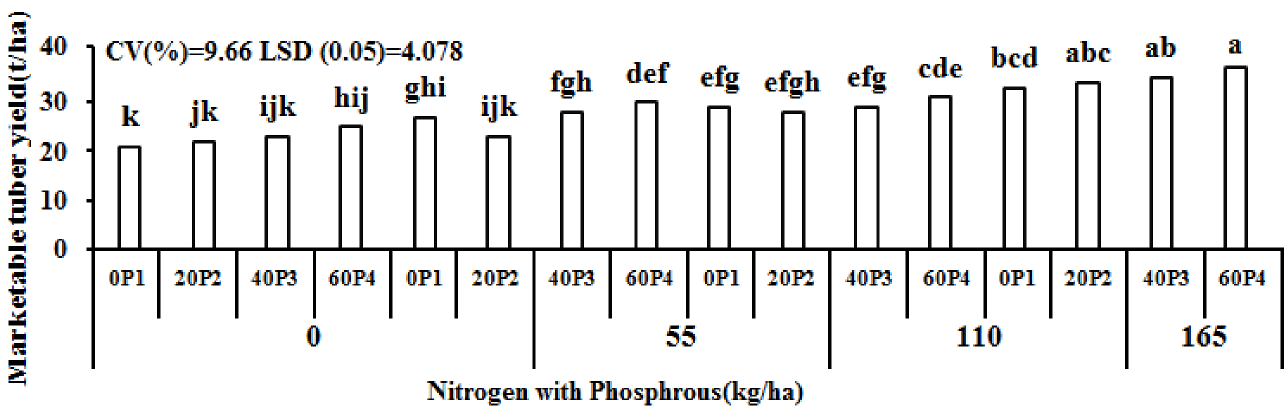

Fig. 4 Means for marketable tuber yield of potato per hectare as influenced by the interaction between nitrogen and phosphorus rates. Means for marketable tuber yield followed by different letters differ significantly at p<0.05 as established by LSD test

Similarly FAO (2000) reported without phosphorus application, nitrogen efficiency declined thereby indicating interaction between these nutrients.

3.11. Average tuber weight: The highest average weight of tubers (70.23 g) was found in the treatment that received 165 kg N /ha and this value was statistically similar with application of 110 kg N/ha and the lowest average weight of tubers (54.47 g) was obtained in the treatments that received no nitrogen (Table3). Increased application rate of nitrogen from 0-165 kg N/ha increased average tuber weight by 22.43% as compared to the control. Likewise increasing application of phosphorus increased average tuber weight and showed a consistent increasing trend with increasing dose of phosphorus fertilizer rate. Increasing the phosphorus application rate from 0 to 60 kg P/ha increased the average tuber weight by 22.49% as compared with the control.

IV.Conclusions

Several factors limiting crop yields have been reported by many workers and the current investigation showed that the effect of both nitrogen and phosphorous rates were found highly significant on all growth parameters studied including days to 50% maturity, shoot and root dry weight except days to 50% flowering which was highly significantly affected by rates of nitrogen and significantly affected by rates of phosphorus. The longest days to 50% flowering was achieved with the application of (165 kg N/ha), which had a similar effect with application of (60 kg P /ha). Similarly delay in maturity from treatments of plants with 165 kg N /ha while, with phosphorus the delay in maturity of plants was due to absence of phosphorus application (0 kg /ha). The highest shoot and root dry weight of potato was obtained at 165 kg /ha nitrogen and 60 kg /ha of phosphors. The effect of both nitrogen and phosphorous rate was found highly significant on yield parameters such as marketable tuber number and total tuber yield and significant on average tuber weight except total tuber number which was highly significantly affected by rate of nitrogen and significantly affected by rate of phosphorus. Considering of the yield of potato, the highest marketable tuber yield was obtained from the combined application of (165 kg N /ha) with (60 kg P /ha). In conclusion, the result of this study showed that different nitrogen and phosphorus rates and their interaction have sound and promising impact on growth and marketable tuber yield of potato. Therefore, on the basis of the results of the present study, it is indicative that potato can grow well in the Jiroft area and farmers can benefit more by using 165 kg /ha of nitrogen in combination with 60 kg /ha phosphors.

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Declaration of Conflict

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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