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Effects of Nitrogen Fertilizer and Plant Density on NPK Uptake by Potato Tuber

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Abstract: In order to evaluate nitrogen fertilizer and plant density effects on NPK uptake by potato tuber cultivar Agria, a factorial experiment based on randomized complete block design was conducted with three replications in 2006, Ardabil, Iran. Factors were nitrogen levels (0, 80, 160 and 200 kg ha^{-1} net nitrogen) and plant densities (5.5, 7.5 and 11 plant m^{-2}). Results showed that the highest nitrogen percent of tuber and mean tuber weight was achieved using 80 kg ha^{-1} along with 5.5 plant m^{-2}. The highest phosphorus and copper uptake by tuber was observed at 80 kg ha^{-1} nitrogen and density of 7.5 plant m^{-2}. With increasing nitrogen application up to 200 kg ha^{-1} and densities of 7.5 and 11 plant m^{-2}, the highest uptake of calcium and potassium was done, respectively. With increasing nitrogen level up to 80 kg ha^{-1} and increase in density, number and yield of tuber per unit area was increased and at 80 kg ha^{-1} nitrogen level (equal to 160 kg ha^{-1} nitrogen) and 11 plant m^{-2}, the highest number and yield of tuber was achieved. So, treatment of 80 kg ha^{-1} nitrogen and 11 plant m^{-2} in order to gain tubers having high edible quality and high yield along with the lowest nitrate pollution (in the soil and under-ground water) is recommended.

Key words: Plant density · Nitrogen fertilizer · Potato and NPK

INTRODUCTION

Potato *(Solanom tuberosum* L.) is classified as tuber crops which has important impact on human feeding and in terms of high yield per unit area, energy content and produced protein, is superior to wheat and rice [1]. The role of nutrient elements in plants involves: cell osmotic potential controlling, cell constructive component, PH adjustment, cell membrane penetrability adjustment and catalytic imbibitions activity [2]. Over-application of nitrogen, results in decrease in PH, base saturation and lack of calcium, magnesium and potassium. Also, this can lead to increase in potassium to calcium ratio [3]. As we know, potato, like other plants, needs all the elements to growth naturally but in soils without trace elements deficit, potato tuber yield, associates with the presence of elements N-P-K and its requirement to the two later elements is much more than nitrogen and there are various evidences indicating impact of potassium and phosphorous on physiological aspects of potato [3], but on account of accumulation of available calcium and phosphorous in the majority of soils, fields receiving advised amounts of the mentioned elements, generally, do not response to the excessive values of calcium and phosphorous so, nitrogen is a most limiting element for potato plant [4]. The rate of applied nitrogen fertilizers is a key factor in soil fertility management, as its over-usage can delay plant maturity and directs dry matter storage into aerial parts rather than tubers [5]. Sowing density in potato, affects some important aspects of plant such as yield [6]. Increase in plant density, leads to decrease in mean tuber weight, increase in yield and number of tuber per unit area [7-9]. Belanger *et al.* [10] found that application of appropriate amounts of nitrogen (80 kg ha^{-1}) resulted in more favorable effects than higher rates. Waddell *et al.* [11] and Saeidi *et al.* [12, 13] reported that application of nitrogen, led to increase in tuber yield than control. This rate has been obtained 34.3% by Marguerite *et al.* [14].

Since, over-application of nitrogen in potato cultivation results in decrease in tuber quality, exposure of human healthy to the risk as well as environmental

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pollutions, the objective of this work was to investigate nitrogen amounts and plant densities on NPK content of tuber and determine the best nitrogen rates to get the highest yield and quality of potato tuber along with the lowest environmental pollution.

MATERIALS AND METHODS

In order to investigate the plant density and nitrogen fertilizer on NPK uptake and some other traits of potato tuber, Agria cultivar, a factorial experiment based on randomized complete block design with three replications was conducted at the research field of University of Mohaghegh Ardabili, Ardabil, Iran, with longitude of 48°15' and latitude of 38°15' in 2006. Ardebil region has very cold winters, rainy spring, dry and warm summers and with mean precipitation of 400 mm yearly. First factor was nitrogen levels (0, 80, 160 and 200 kg ha^{-1}) and second was plant densities (5.5, 7.5 and 11 plant m^{-2}). Nitrogen was given as urea form at 2 stages namely, planting date and date of earthing up. According to soil analysis results, total nitrogen content was 0.56% and soil texture was sandy-loam. Rows were spaced 60 cm to each other and plots contained 6 rows each 3 meters. In order to prevent nitrogen effects in adjacent plots (border effects), 1.5 meter border was made. Tubers of 60-70 grams were sown on 13 May 2006. Sowing depth was 12-13 cm. The last harvest was assigned to yield. To promote storage capability, ten days prior to harvest, aerial parts were removed [1]. Sampling was done from 2 m^2 plot area, then, tubers were transferred to the laboratory. Before measurements were done, tubers were washed along with roots and stolons. Different plant tissues were dried separately for 48 hours at 75°C and weighed. In order to calculate total nitrogen percent of tuber, Kjeldahl method was used. After tubers were dried and turned into ash at 500°C, different elements were measured. Calcium via titration, phosphorous using spectrophotometer, potassium using flame photometer and copper using atomic absorption devices were calculated. Results were analyzed by SAS software, mean comparisons were done via Duncan's multiple range test and graphs were drawn by Excel software.

RESULTS AND DISCUSSION

Nitrogen and Calcium Percent of Tuber: Nitrogen ($P < 0.05$) and calcium ($P < 0.01$) percent were significantly affected by plant density × nitrogen level interaction effect. While 160 kg ha^{-1} nitrogen along with the 5.5 plant m^{-2} treatments was employed, the highest nitrogen percent of tuber was obtained. In contrast, treatments of 200 and 0 kg ha^{-1} nitrogen as well as 5.5 plant m^{-2}, led to the lowest one (Table 2). Since, at 200 kg ha^{-1} nitrogen application, the highest amounts of this element have been spent to increase the growth of leaves and stems rather than tubers so, yield has decreased. But in treatment of 160 kg ha^{-1} nitrogen, the highest yield has been gained. This shows that tubers have more used nitrogen and hence, nitrogen percent of tuber has been more than other treatments. Increase in applied nitrogen has led to increase in calcium percent of tuber so that, at 200 kg ha^{-1} nitrogen along with the 7.5 plant m^{-2}, the highest rate was observed but, in treatment of 80 kg ha^{-1} nitrogen as well as 5.5 plant m^{-2}, the lowest value was obtained (Table 2). Koochaki and Sarmadnia [12] have reported the same results, as well.

Phosphorous and Potassium Percent of Tuber: Phosphorous content of tuber was affected ($P < 0.05$) by nitrogen and interaction effect of plant density × nitrogen level ($P < 0.01$). With increasing nitrogen rates

Table 1: Simple effects of plant density and Nitrogen level on measured traits

Treatments		Tuber N (%)	Tuber Ca (%)	Tuber P (%)	Tuber K (%)	Tuber Cu (ppm)	Mean tuber weight (g $plant^{-1}$)	Number of tuber (m^2)	Tuber yield (g m^{-2})
Nitrogen fertilizer level (kg ha^{-1})	0	1.25^{a*}	1.33^{a}	0.26^{ab}	2.09^{b}	9.6^{c}	23.29^{b}	63.86^{b}	2024.6^{b}
	80	1.3^{a}	1.37^{a}	0.32^{a}	2.31^{a}	15.15^{a}	30.21^{ab}	93.35^{a}	2994.1^{a}
	160	1.3^{a}	1.55^{a}	0.25^{b}	2.25^{a}	11.15^{b}	33.67^{a}	100.9^{a}	3174.6^{a}
	200	1.27^{a}	1.55^{a}	0.23^{b}	2.32^{a}	9.02^{c}	24.85^{b}	80.23^{ab}	2457.0^{b}
Plant density (plant m^{-2})	5.5	1.3^{a}	1.53^{a}	0.26^{a}	2.15^{b}	9.13^{b}	30.55^{a}	77.12^{b}	2346.3^{b}
	7.5	1.28^{a}	1.53^{a}	0.26^{a}	2.25^{a}	11.89^{a}	27.36^{ab}	81.62^{ab}	2473.8^{b}
	11	1.27^{a}	1.3^{a}	0.28^{a}	2.32^{a}	12.67^{a}	26.11^{ab}	95.00^{a}	3167.6^{a}

*Numbers with the same letters in each column, have no significant differences to each other

Table 2: Interaction effects of plant density and Nitrogen level on measured traits

Interactions effects	Tuber protein (%)	Tuber Ca (%)	Tuber P (%)	Tuber K (%)	Tuber Cu (ppm)
Control × 5.5 plant m^{-2}	7.43^{c*}	1.46^{bc}	0.34^{b}	2.30^{abc}	11.57^{d}
Control × 7.5 plant m^{-2}	8.07^{abc}	1.46^{bc}	0.17^{d}	1.74^{d}	9.44^{ef}
Control × 11 plant m^{-2}	7.96^{bc}	1.06^{c}	0.27^{bcd}	2.23bc	7.78^{fg}
80 kg ha^{-1}× 5.5 plant m^{-2}	8.77^{ab}	1.86^{ab}	0.23^{bcd}	2.19c	10.39^{de}
80 kg ha^{-1} × 7.5 plant m^{-2}	8.1^{abc}	1.2^{bc}	0.46^{a}	2.38^{a}b	21.17^{a}
80 kg ha^{-1} × 11 plant m^{-2}	8.05^{abc}	1.06^{c}	0.29^{bcd}	2.35^{abc}	13.91^{c}
160 kg ha^{-1} × 5.5 plant m^{-2}	9.00^{a}	1.6^{abc}	0.23^{bcd}	2.199bc	7.07^{g}
160 kg ha^{-1}× 7.5 plant m^{-2}	$7.9b^{c}$	1.2^{bc}	0.21^{cd}	2.28^{abc}	9.44^{ef}
160 kg ha^{-1}× 11 plant m^{-2}	7.78^{bc}	1.86^{ab}	0.3bc	2.27^{abc}	16.94^{b}
200 kg ha^{-1} × 5.5 plant m^{-2}	7.75^{c}	1.2^{bc}	0.23^{bcd}	2.33^{abc}	7.5^{fg}
200 kg ha^{-1} × 7.5 plant m^{-2}	7.96^{bc}	2.26^{a}	0.19^{cd}	2.19c	7.5^{fg}
200 kg ha^{-1}× 11 plant m^{-2}	8.07^{abc}	1.2^{bc}	0.26^{bcd}	2.44a	12.05^{d}

*Numbers with the same letters in each column, have no significant differences to each other

(over the 80 kg ha^{-1}), phosphorous content of tuber was decreased. As shown in results, the highest phosphorous content was achieved in 80 kg ha^{-1} nitrogen treatment and the lowest rate was obtained at levels of 160 and 200 kg ha^{-1} nitrogen (Table 1). Also, it was observed that by application of 80 kg ha^{-1} nitrogen in density of 7.5 plant m^{-2}, the highest value of phosphorous was resulted. In contrast, the lowest ones were achieved by application of 0, 160 and 200 kg ha^{-1} nitrogen at 7.5 plant m^{-2} level (Table 2). Clearly it was observed that with increasing nitrogen usage, phosphorous content was decreased so that, at the first level of nitrogen, the highest rate of phosphorous was taken up. Increase in nitrogen application had more significant impact on potassium percent of tuber than control. As shown in Table 1, at the control level, the lowest rate of this trait was obtained but at the other three levels, the highest values were resulted. In terms of plant density, it can be said that densities of 7.5 and 11 plant m^{-2} resulted in the highest amount of potassium content but density of 5.5 plant m^{-2} led to lowest one. According to the interaction effects (Table2), same to the simple effects, treatment done as 200 kg ha^{-1} nitrogen × 11 plant m^{-2} density caused the highest rate of this trait but other treatment, 0 kg ha^{-1} nitrogen × 5.5 plant m^{-2}, resulted in the lowest rate. Mahmoodi and Hakimian, [13] found that increase in nitrogen application, leads to increase in potassium content of tuber. This finding is in accordance with our results on this element.

Copper Percent of Tuber: Amount of this element was affected by effects of nitrogen fertilizer, plant density and interaction effect of nitrogen level × plant density ($P < 0.01$). Over-application of this element (over the 80 kg ha^{-1}) led to decrease in copper content of tuber and its highest and lowest rates was observed at 80 kg ha^{-1} and 200 kg ha^{-1} (equal to control) nitrogen, respectively. Also, increase in plant density, led to increase in this element so that, the highest values were achieved in densities of 11 and 7.5 plant m^{-2} but the lowest one was obtained in density of 5.5 plant m^{-2} (Table 1). In terms of interaction effect, the highest copper percent of tuber was resulted in treatment of 80 kg ha^{-1} nitrogen × 7.5 plant m^{-2} density while, the lowest value was observed in 160 kg ha^{-1} nitrogen × 5.5 plant m^{-2} density (Table 2).

Mean Tuber Weight: Effect of nitrogen ($P<0.01$) and plant density ($P<0.01$) was significant on mean tuber weight. With increasing nitrogen up to definite point, this trait was increased so that, the highest value was obtained by application of 160 kg ha^{-1} nitrogen. Meanwhile, control and 200 kg ha^{-1} rates had significant effect on mean tuber weight. Also, it was seen that the lowest mean tuber weight was achieved at 7.5 and 11 plant m^{-2} and the highest one was achieved at 5.5 plant m^{-2} (Table 1). Increase in density probably causes the increase in competition between and within plants and hence, leads to decrease in availability of nutrients to each plant and consequently, results in decline of mean tuber weight [16]. It seems that except for the competition, potato plant assigns more stored maters into the stems and leaves rather than tubers under high vegetative status. Applied nitrogen less affects number of tuber but more affects tuber size and increases it and directly increases mean tuber weight but in case of excessive rates of nitrogen, mean tuber weight is decreased [3].

Number of Tuber: Number of tuber per unit area for nitrogen level and plant density was significant ($P<0.05$). As shown in table 1, nitrogen level up to definite point had the incremental effect on this trait and then, led to decrease in it. Khajehpour [1] approved increase in number of tuber with increasing nitrogen fertilizer. According to the Table 1, increase in plant density resulted in increase in number of tuber so that; densities of 7.5 and 11 plant m^{-2} jointly were at highest value and 5.5 plant m^{-2} placed afterwards. Increase in number of tuber occurred as a result of increase in number of stolon and increase in density, Increasing stolons, eventually increased tuber yield. It is obvious that with increasing plant number, number of stems grown from the planted tubers and consequently, number of produced tubers per stem, is increased. Thus, increase in plant density leads to increase in produced tubers [1].

Tuber Yield: Effect of plant density and nitrogen level was significant ($P<0.01$) on tuber yield. Results showed that increase in nitrogen rates up to favorite point led to increase in tuber yield per unit area. This result has been reported by many other researchers [17, 9]. The highest values of this trait affected by nitrogen were obtained at 80 and 160 kg ha^{-1} nitrogen and the lowest one was belonged to control. With increasing nitrogen application, number of stolons, number of tubers and consequently, yield were increased. This may attributable to the fact that in such conditions, vegetative growth of the aerial parts can increase and hence, inhibit transferring photosynthetically matters into the storage parts (tubers). Marguerite *et al.* [14] and Alam *et al.* [18] revealed that tuber yield per unit area was increased with increasing nitrogen fertilizer up to suitable level. Also, increase in density led to significant increase in tuber yield so that, the most and the least tuber yield was achieved at 11 plant m^{-2} and at 5.5 and 7.5 plant m^{-2}, respectively (Table 1). According to the Arsenault *et al.* [19], in high densities, number of tuber and yield of potato is increased. As we know, this crop needs to earthing up to produce remarkable tuber yields so, in higher densities, lower distances are provided for tubers and hence, smaller tubers can be produced. But generally, tuber yield per unit area was increased as a result of more produced tubers.

CONCLUSION

Generally, it can be said that since majority of traits such as phosphorus, potassium and cupper content of tuber had the highest values at the level of 80 kg ha^{-1} nitrogen and levels of 80 and 160 kg ha^{-1} nitrogen were in the same group in terms of producing yield, number of tuber and mean tuber weight and also, increase in plant density caused the highest amounts of potassium, cupper and tuber yield so, application of 80 kg ha^{-1} nitrogen along with the density of 11 plant m^{-2} in order to gain the highest tuber yield having the most suitable edible quality per unit area in addition to decrease in environmental pollutions and costs, is recommended for this cultivar.

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