http://www.pjbs.org

PJBS

ISSN 1028-8880

Pakistan Journal of Biological Sciences

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Pakistan Journal of Biological Sciences 11 (15): 1949-1952, 2008
ISSN 1028-8880

Effects of Different Plant Density and Nitrogen Application Rate on Nitrogen Use Efficiency of Potato Tuber

[1]Sh. Jamaati-e-Somarin, [2]A. Tobeh, [1]M. Hassanzadeh,
[1]M. Saeidi, [2]A. Gholizadeh and [1]R. Zabihi-e-Mahmoodabad
[1]Young Researchers Club, Department of Agronomy, Faculty of Agriculture,
Islamic Azad University, Ardabil Branch, Ardabil, Iran
[2]Department of Agronomy and Plant Breeding, Faculty of Agriculture,
University of Mohaghegh Ardabili, Ardabil, Iran

Abstract: In order to investigate the plant density and nitrogen level on nitrogen use efficiency components (agronomical, physiological, apparent recovery and nitrogen use efficiency), the amount of nitrogen uptake by plant, yield and yield components of potato (*Solanum tuberosum* L.) Agria cultivars' tuber, a factorial experiment based on randomized complete block design was conducted in Ardabil, Iran, in 2006 with three replications. Factors were adjusted for the nitrogen level (0, 80, 160 and 200 kg ha^{-1} net nitrogen) and plant density (5.5, 7.5 and 11 plant m^{-2}). Results showed that with increasing the nitrogen levels and plant densities agronomical nitrogen use efficiency, physiological nitrogen efficiency and nitrogen use efficiency were decreased and apparent recovery nitrogen efficiency was increased. The most nitrogen uptake in plant was observed at the 200 kg ha^{-1} net nitrogen. The most yield and number of tuber per unit area were gained at the 80 and 160 kg ha^{-1} net nitrogen. Increasing the plant density resulted in increasing in the tuber yield per unit area and the rate of nitrogen up to the 160 kg ha^{-1} net nitrogen. So, application of the 80 kg ha^{-1} net nitrogen and plant density of 11 plant m^{-2} is recommended to get highest yield with the most nitrogen use efficiency.

Key words: Nitrogen efficiency, nitrogen uptake, plant density, potato and yield

INTRODUCTION

Potato (*Solanum tuberosum*) is grown and eaten in more countries than any other crop and in the global economy it is the fourth most important crop after the three cereals including maize, rice and wheat (Stephen, 1999). Efficiency has defined as crop production per unit input, which means nutritional efficiency consists in the amount of dry matter production per unit nutrient elements usage or uptake (Hashemidezfooli *et al*., 1998). Haase *et al*. (2007) found that tuber N uptake was significantly influenced by amounts of nitrogen fertilizer. The most nutrient element efficiency is attained while its concentration reaches critical level, because without excessive elements, greatest yield can be gain. Rate of this efficiency decreases at abundance and luxury (poisonous) ranges because with increasing element concentration, yield remains constant or decreases (Hashemidezfooli *et al*., 1998). When plant density increases, since available nitrogen is constant, so, competition to its absorption increases (Koochaki and Mohassel, 2001). Marguerite *et al*. (2006) showed that the mean maximum increase in the total tuber yield, generated by N fertilization against to zero-N treatment, was 34.3% and ranged from 10.5 to 54.7% and in regard to potato, the improvement of N efficiency should be also achieved by splitting N fertilizer applications. Karafyllidis *et al*. (1997) reported that plant density strongly affected yield, both by number and by weight and more tubers and yield per square meter were expected in higher plant densities. Georgakis *et al*. (1997) concluded that by increasing plant density, the tuber yield was increased.

The aim of this research was to evaluate effects of the nitrogen levels and plant densities on the nitrogen efficiency components (agronomical, physiological, apparent recovery and nitrogen use efficiency), the amount of nitrogen uptake by plant, yield and yield components in order to determination of the most suitable density and nitrogen level to get favorite yield with the highest nitrogen use efficiency in year 2006 in Ardabil region, Iran.

Corresponding Author: Shahzad Jamaati-e-Somarin, Young Researchers Club, Department of Agronomy, Faculty of Agriculture, Islamic Azad University, Ardabil Branch, Ardabil, Iran

MATERIALS AND METHODS

In order to investigate the plant density and nitrogen level on the nitrogen use efficiency of potato tuber Agria cultivar a factorial experiment based on randomized complete block design with three replications was conducted in the research Field of University of Mohaghegh Ardabili, Ardabil, Iran, in 2006. First factor was nitrogen level (0, 80, 160 and 200 kg ha^{-1}) and second was plant density (5.5, 7.5 and 11 plant m^{-2}). It 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 and plots contained 6 rows each 3 m. In order to preventing nitrogen effects in adjacent plots (border effects), 1.5 m border was made. Tubers of 60-70 g were sown in 13 May 2006. Sowing depth was 12-13 cm. Last harvest was assigned for yield. Promoting storage capability, 10 days before harvest, aerial parts were removed (Khajehpour, 2004). Sampling was done from 2 m^2 plot area, then, tubers were transferred to the laboratory. Before measurements, tubers were washed along with roots and stolons. Different plant tissues were dried separately for 48 h in 75°C and weighed.

Amount of N absorbed by plant calculated as shown by Hashemidezfooli *et al.* (1998) (Element absorption = element concentration×dry matter). N uptake by plant was measured of sum of its rates in aerial parts and tubers. Also, tuber nitrogen content was calculated by Kjeldahl method. Agronomical, apparent and physiological nitrogen efficiencies were calculated from Hashemidezfooli *et al.* (1998):

$$NAE = [(Y_{f1}-Y_{f0})/N_f]$$
$$PHNE = [(TDM_{f1}-TDM_{f0})/(NU_{f1}-NU_{f0})]$$
$$ARNE\% = [(NU_{f1}-NU_{f0})/N_f]\times 100$$
$$NUE = (PHNE\times ARNE) = kg\ kg^{-1}$$

NAE : Agronomical N efficiency (kg ha^{-1})
Y_{f1} : Tuber yield/plot with N application (kg ha^{-1})
Y_{f0} : Tuber yield/plot without N application (kg ha^{-1})
N_f : N rates (kg ha^{-1}), PHNE: Physiological nitrogen efficiency (kg ha^{-1})
TDM_{f1} : Total plant dry matter with N application (kg ha^{-1})
TDM_{f0} : Total plant dry matter without N application (kg ha^{-1})
Nu_{f1} : N uptake by plant with N application (kg ha^{-1})
Nu_{f0} : N uptake by plant without N application (kg ha^{-1})
ARNE% : Apparent recovery nitrogen efficiency percent, NUE: Nitrogen use efficiency (kg ha^{-1}).

In order to normalize data distribution, yield and efficiency data analysis of variance was done by SAS Software, means of variances were compared through Duncan's multiple range test and graphs were drawn by Excel software. By the way, ANOVA results were not shown.

RESULTS

Agronomical nitrogen use efficiency: Results revealed significant effects of the plant density ($p<0.05$) and nitrogen levels ($p<0.01$) on agronomical nitrogen use efficiency. With the increasing of nitrogen application and plant density, this efficiency was reduced so that, highest (121.19 kg ha^{-1}) and lowest (21.6 kg ha^{-1}) efficiency values were reached at 80 and 200 kg ha^{-1} net nitrogen. Also, in the 5.5 and 11 plant m^{-2}, highest (98.95 kg ha^{-1}) and lowest (43.37 kg ha^{-1}) rates were observed for the efficiency (Table 1).

Apparent recovery nitrogen efficiency: It was found that nitrogen levels ($p<0.05$) and plant density ($p<0.01$) had the significant effects on apparent recovery nitrogen efficiency. As shown in Table 1, at level of 80 kg ha^{-1} net nitrogen, utmost efficiency of 69.28 % was gained. Also, at level of 200 kg ha^{-1} net nitrogen, this rate was 50.25 % which were significant. In regard to plant density, the most efficiency concerned to density of 11 plant m^{-2} about 74.17 % furthermore in density of 7.5 plant m^{-2} this value was 53.94 % which both were significant.

Physiological nitrogen efficiency: Effect of plant density and nitrogen levels ($p<0.05$) on physiological nitrogen efficiency was significant. In this case, with increasing plant density and nitrogen levels, physiological nitrogen efficiency was decreased. In the other words, in 5.5 plant m^{-2}, highest and in 7.5 and 11 plant m^{-2}, jointly lowest efficiency was gained. 80 kg ha^{-1} net nitrogen caused to highest rate whereas, there was no significant difference between 80 and 160 kg ha^{-1} net nitrogen. At 200 kg ha^{-1} net nitrogen, lowest rate was got (Table 1).

Nitrogen use efficiency: Nitrogen levels had the significant effect on nitrogen use efficiency ($p<0.05$) but there was no significant effect of plant density for this parameter. Its increment reduced the efficiency. The highest efficiency value was obtained at the 80 kg ha^{-1} net nitrogen (26.81 kg ha^{-1}) and lowest at the 200 kg ha^{-1} net nitrogen (13.32 kg ha^{-1}) (Table 1). Plant density was not significant for this trait.

Table 1: Effects of plant density and nitrogen levels on measured traits

Treatments		Agronomical nitrogen use efficiency (kg kg^{-1})	Apparent recovery nitrogen efficiency (%)	Physiological nitrogen efficiency (kg kg^{-1})	Nitrogen use efficiency (kg kg^{-1})
Nitrogen fertilizer	0	-	-	-	-
doses (kg ha^{-1})	80	121.19a	69.28a	0.56a	26.81a
	160	71.87b	47.08b	0.54a	23.89ab
	200	21.62c	50.25ab	0.28b	13.32b
Plant density	5.5	98.95a	38.5b	0.68a	25.28a
(plant m^{-2})	7.5	72.37ab	53.94ab	0.39b	18.96a
	11	43.37b	74.17a	0.32b	19.78a

Table 2: Effects of plant density and nitrogen levels on measured traits

Treatments		Nitrogen uptake plant (g m^{-2})	No. of tuber in m^2	Mean tuber weight (g)	Total dry matter yield (kg m^{-2})	Tuber yield/plant (g)	Tuber yield (g m^{-2})
Nitrogen fertilizer	0	1753.8c	63.86b	23.29b	0.9c	257.44c	2024.6b
doses (kg ha^{-1})	80	2308.1b	93.35a	30.21ab	1.17bq	403.96a	2994.1a
	160	2507.2b	100.9a	33.67a	1.29a	420.76a	3174.6a
	200	2759.0a	80.23ab	24.85b	1.12b	318.63b	2457.0b
Plant density	5.5	1851.21c	77.12b	30.55a	0.91c	449.79a	2346.3b
(plant m^{-2})	7.5	2234.42b	81.62ab	27.36ab	1.05b	312.84b	2473.8b
	11	2910.45a	95.0a	26.11ab	1.4a	287.97b	3116.6a

Values with different letter(s) are significantly different at $p<0.05$ and $p<0.01$ levels

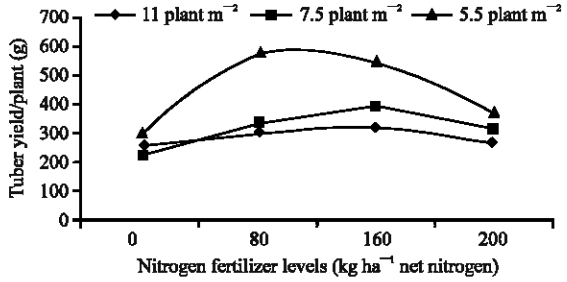

Fig. 1: Tuber yield per plant under interaction effect of nitrogen and plant density levels

Nitrogen uptake by plant: Effects of plant densities and nitrogen levels significantly ($p<0.01$) affected N uptake by plant. The highest and Lowest N uptake values were observed at 200 kg ha^{-1} net nitrogen (2759.0 g m^{-2}) and control treatments (1753.8 g m^{-2}), respectively. For plant density, its highest and lowest values were taken at 11 plant m^{-2} (2910.45 g m^{-2}) and 5.5 plant m^{-2} (1851.21 g m^{-2}), respectively (Table 2).

Yield and yield components: Tuber yield was affected significantly by plant density and nitrogen level ($p<0.01$) and their interactions ($p<0.05$). The higher the plant density, the lower tuber yield per plant occurred (Table 2). However, densities of 7.5 and 11 plant m^{-2} statistically were not found different from each other. Also, in combination of 160 and 80 kg ha^{-1} net nitrogen jointly and density of 5.5 plant m^{-2}, the highest and in combination of 7.5 plant m^{-2} and control, the lowest tuber yield was gained (Fig. 1). With increasing N up to 160 kg ha^{-1}, total plant dry matter, number of tuber/unit area and mean tuber weight/plant were increased and in excessive rates, were decreased. In 7.5 and 11 plant m^{-2} jointly the lowest and in 5.5 plant m^{-2} the highest mean tuber weight per plant was observed, as well. Increase in density led to significant increment in tuber yield and total plant dry matter/unit area.

DISCUSSION

With increasing nitrogen application from 80 kg ha^{-1}, agronomical nitrogen use efficiency and nitrogen use efficiency were decreased. Since in this level of fertilization, the most yield was gained and thereafter, this increase was reductional, so, it could be the reason for decrease of these efficiencies. Hartemink *et al.* (2000) reported that nitrogen use efficiency increases with increased N application for sweet potato. For apparent recovery nitrogen efficiency, it could be said that since highest tuber yield have been gained jointly at 80 and 160 kg ha^{-1} nitrogen, so, it might concluded that values of N uptake at this level (80 kg ha^{-1}) had been much more than next level, per unit fertilizer. There fore, the most efficiency have occurred at this rate and since, utmost N uptake have been made at 200 kg ha^{-1}, so, this efficiency have been improved, as well. Darwish *et al.* (2006) found that decreasing N application of 125 kg ha^{-1}, (against 250, 375 and 500 kg N ha^{-1}) significantly led to higher N recovery. In this study, we found that higher nitrogen levels resulted in lowest physiological nitrogen efficiency. In general, it could be said that with increasing nitrogen fertilizer and plant density, agronomical, physiological and nitrogen use efficiencies were decreased and apparent recovery nitrogen efficiency was increased. As shown in this study, nitrogen application over the 160 kg ha^{-1}, total plant dry matter, number of tuber and mean tuber weight

were decreased. Likely, this is attributable to intra competition of different plant parts to achieve environmental resources such as water, light and nutrient elements and effect of excessive nitrogen to stimulate growth of plant aerial parts and directly, reducing photosynthetic matters transfer to the tubers. Alvin *et al.* (2007) reported that with increasing plant density, yield of potato was increased. On the other hand, increment of plant density, probably is the reason of lack of nutrient elements for each plant or production of more tubers/unit area and reduction of their mean size. In several studies, narrow in-row spacing increased yield (Arsenault and Malone, 1999; Arsenault *et al*., 2001). Beraga and Caeser (1990) found that mean tuber weight was reduced with increasing plant density. Osaki *et al.* (1995) found that used nitrogen, enhances tuber number and their weight, but in case of excessive nitrogen amounts, mean tuber weight decreases.

CONCLUSIONS

According to the results, application of 80 kg ha^{-1} net nitrogen to achieving highest tuber yield along with utmost of agronomical, physiological and nitrogen use efficiencies is recommended in Agria cultivar for Ardabil region (Ardabil, Iran). Noticing mean potato tuber yield in Ardabil region of 28.7 t ha^{-1} and its comparison with yields of 80 and 160 kg ha^{-1} net nitrogen treatments of 29.94 and 31.74 t ha^{-1} (in this study), respectively, it could be said that this range of nitrogen fertilizer is suitable for Ardabil region. Also, density of 11 plant m^{-2} reducing tuber weight and size is suitable for planting purposes but density of 7.5 plant m^{-2} is suitable for eating uses.

ACKNOWLEDGMENTS

This study was supported by the Central Laboratory of Agricultural Faculty, University of Mohaghegh Ardabili, Ardabil, Iran. Valuable experimental support by Aziz Jamaati-e-Somarin is greatly appreciated. This work was extracted from M.Sc. Thesis of Shahzad Jamaati-e-Somarin.

REFERENCES

Alvin, J.B., P.D. Mitchell, M.E. Copas and M.J. Drilias, 2007. Evaluation of the effect of density on potato yield and tuber size distribution. Crop Sci., 47: 2462-2472.

Arsenault, W.J. and J.A. Malone, 1999. Effects of nitrogen fertilization and in-row seed piece spacing on yield of three potato cultivars in Prince Edward Island. Potato Assoc. Am., 76: 227-229.

Arsenault, W.J., D.A. LeBlanc, C. George, C. Tai and P. Boswall, 2001. Effects of nitrogen application and seedpiece spacing on yield and tuber size distribution in eight potato cultivars. The Potato Assoc. Am., 78: 301-309.

Beraga, L. and K. Caeser, 1990. Relationships between numbers of main stems and yield components of potato (*Solanum tuberosum* L. CV. *Erntestolz*) as influenced by different day length. Potato Res., 33: 257-267.

Darwish, T.M., T.W. Atallah, S. Hajhasan and A. Haidar, 2006. Nitrogen and water use efficiency of fertigated processing potato. Agric. Water Manage., 85: 95-104.

Georgakis, D.N., D.I. Karafyllidis, N.I. Stavropoulos, E.X. Nianiou and I.A. Vezyroglou, 1997. Effect of planting density and size of potato seed-minitubers on the size of the produced potato seed tubers. Acta Hort. (ISHS), 462: 935-942.

Haase, T., C. Schuler and J. Heb, 2007. The effect of different N and K sources on tuber nutrient uptake, total and graded yield of potatoes (*Solanum tuberosum* L.) for processing. Eur. J. Agron., 26: 187-197.

Hartemink, A.E., M. Johnston, J.N. O'Sullivan and S. Poloma, 2000. Nitrogen use efficiency of taro and sweet potato in the humid lowlands of Papua New Guinea. Agric. Ecos. Environ., 79: 271-280.

Hashemidezfooli, A., A. Koochaki and M.B. Avval, 1998. Crop Plant Improvement (Translation). 3rd Edn., Jehad Daneshgahi Mashhad Press, Mashad, Iran, ISBN 964-6023-05-3 .

Karafyllidis, D.I., D.N. Georgakis, N.I. Stavropoulos, E.X. Nianiou and I.A. Vezyroglou, 1997. Effect of planting density and size of potato seed-minitubers on their yielding capacity. Acta Hortic. (ISHS), 462: 943-950.

Khajehpour, M., 2004. Production of Industrial Plants. 1st Edn. Jehad-e-Daneshgahi Isfahan Press, Isfahan. Iran, ISBN 961-6122-63-9. .

Koochaki, A. and M.H.R. Mohassel, 2001. Physiology of Crop Plants (Translation). 9th Edn., Jehad Daneshgahi Mashad Press, Mashad, Iran, ISBN 964-6023-92-4 .

Marguerite, O., G. Jean-Pierre and L. Jean-Francois, 2006. Threshold value for chlorophyll meter as decision tool for nitrogen management of potato. Agron. J., 98: 496-506.

Osaki, M., H. Ueda, T. Shinano, H. Matsui and T. Tadano, 1995. Accumulation of carbon and nitrogen compounds in sweet potato plants grown under deficiency of N, P, or K nutrients. Soil Sci. Plant Nutr., 41: 557-566.

Stephen, D.J., 1999. Multiple signaling pathways control tuber induction in potato. Plant Physiol., 119: 1-8.