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Evaluation of Tuber Size and Nitrogen Fertilizer on Nitrogen Uptake and Nitrate Accumulation in Potato Tuber

[1]M. Saeidi, [2]A. Tobeh, [3]Y. Raei, [4]A. Roohi, [1]Sh. Jamaati-e-Somarin and [1]M. Hassanzadeh
[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, Mohaghegh Ardabili University, Ardabil, Iran
[3]Department of Agronomy and Plant Breeding, Faculty of Agriculture, Tabriz University, Tabriz, Iran
[4]Department of Agronomy and Plant Breeding, Faculty of Agriculture, Urmia University, Urmia, Iran

Abstract: In order to investigate tuber size and nitrogen fertilizer on nitrogen uptake and nitrate accumulation in potato tuber cultivar Agria, a factorial experiment based on randomized complete block design with three replications was carried out in Ardabil, Iran, in 2006. Factors were nitrogen fertilizer level (0, 80, 160 and 200 kg ha^{-1} net nitrogen) and tuber size (<40 = small, 40-80 = medium and >80 = large, g). Results showed that the most tuber yield, No. of tuber per plant, mean tuber weight and tuber dry weight were resulted at medium tuber size. Also, the most tuber yield, mean tuber weight, tuber dry weight and tuber nitrogen percent were observed at 160 kg ha^{-1} nitrogen. The most nitrogen taken up in tuber and aerial parts and nitrate accumulation in fresh and dry weight was gained at 200 kg ha^{-1} nitrogen and medium size. The most important result from this study was that nitrogen application over the favorite values, resulted in reduction of crop production along with increasing nitrate accumulation in tubers. So, nitrogen value of 160 kg ha^{-1} and medium tuber size to get the highest yield and suitable planting and eating usages are recommended, respectively.

Key words: Tuber size, yield, nitrate accumulation, nitrogen uptake, potato

INTRODUCTION

Potato (*Solanum tuberosum* L.) is an annual plant farm *Solanum* genus, Solanaceae family including 200 cultivars from which 8 cultivars are agronomical (Khajehpour, 2004). It belongs to cool and temperate zones with altitude of 2000 m (Koocheki *et al*., 1993). Potato tuber is a part of stem which have adapted for storage of matters and reproduction of plant. In other words, it comprises of transformed stem whose lateral buds have been gathered together named eyes (Khajehpour, 2004; Beukema and Zaag, 1990). Tuber size may be stated as tuber diameter or weight. In most cases, it is shown as tuber weight (Beukema and Zaag, 1990). Nitrogen is one of the most important elements for plants and its great effete is on quality and quantity of crop. The best results can be obtained while so- 60% of nitrogen applies at planting date and the rest, after tubering. Uppermost values may be determined using soil and petiole nitrogen content tests (Evanylo, 1990). Schulz *et al*. (1998) reported that larger mini tubers, significantly produce more tubers. Jenkins and Nelson (1992) found that nitrogen increased number of large tubers per plant and this way, increased the yield of each

Corresponding Author: Mohammad Hassanzadeh, Young Researchers Club, Department of Agronomy, Faculty of Agriculture, Islamic Azad University, Ardabil Branch, Ardabil, Iran

plant. Application of sufficient values of nitrogen in early season, results in expanding leaf area and increasing plant capacity for photosynthesis (Khalghani *et al*., 1997). Vander Zaag *et al*. (1990) reported that while nitrogen application reached to 185 kg ha^{-1}, the highest tuber yield was gained and mean tuber weight was higher than those of other nitrogen rates. If nitrogen values excesses the favorite level, both mean tuber weight and No. of tuber, are decreased (Kleinhenz and Bennet, 1992). Nitrogen deficit in early season can reduce tuber yield reducing tubering (Joern and Vitash, 1995). Potato is a nitrate accumulator plant. Inappropriate rates of nitrogen causes to accumulation of this element highly in crops which usually don't accumulate it. Carter and Bosma (1974) measured the most tuber nitrate content at the highest nitrogen application rate. Saffigna and Keeney (1977) showed that with increasing nitrogen concentration at root zone, total nitrogen content in plant tissues was increased and also shown that nitrate levels in plant correlated with the available nitrogen for plant. Non- mineral fertilizers in comparison with mineral ones, release nitrogen gradually for plant nutrition but the other types, do this very rapidly and lead to increase of plant nitrate concentration. The aim of this study was evaluating the rate of nitrogen uptake and accumulation in potato tuber under different tuber sizes and nitrogen levels and was determining the best values of mentioned factors in order to obtaining high yields with the lowest nitrate accumulation of tuber.

MATERIALS AND METHODS

In order to evaluation of tuber size and nitrogen fertilizer on nitrogen uptake and nitrate accumulation in potato tuber Agria cultivar, a factorial experiment based on randomized complete block design was carried out with three replications in Ardabil, Iran, in 2006. First factor was nitrogen level (0, 80, 160 and 200 kg ha^{-1} net nitrogen) and second was tuber size (<40 = small, 40-80 = medium and >80 = large, g). Nitrogen was of urea source and applied in two stages, planting date and earthling up stage. Based on soil test from depth of 0-30 cm, Total Saturated Electrical Conductivity (TSEC) was 3.68 mmhos cm^{-1}, soil pH was 8.09, total nitrogen was 0.56% and soil texture was loamy sand. Rows were spaced 60 cm. Plots were included six rows each 3 m. In order to preventing nitrogen effects in adjacent plots, they were placed 1.5 m distance. 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 stools. Different plant tissues were dried separately for 48 h in 75°C and weighed. Nitrate accumulation of tuber was calculated by sulfosalicylic acid method using spectrophotometer device (Cecile, France). Calculation of nitrogen uptake rate was made according to the Hashemidezfooli *et al*. (1998):

$$NEU = DM \times EC$$

Where:
NEU = Nutrient Element Uptake
DM = Dry Matter
EC = Element Concentration

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

Results showed that main effect of nitrogen except for No. of tuber, was significant on other measured traits ($p<0.01$). Main effect of tuber size, except for nitrogen uptake per plant and nitrate accumulation as fresh and dry weight of tuber, was significant on other measured traits ($p<0.01$). Also,

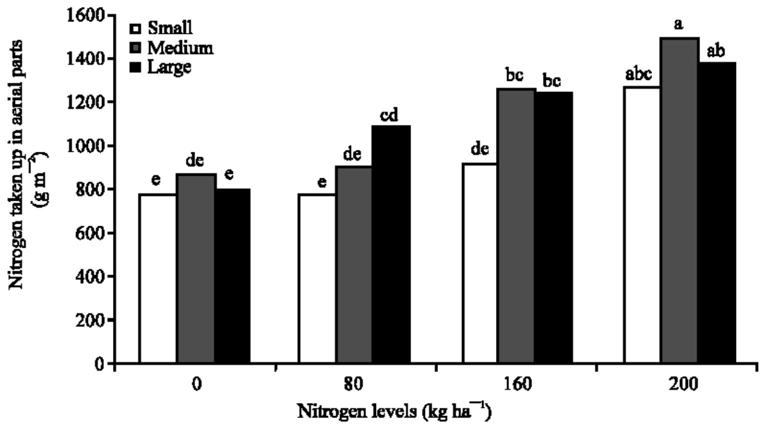

Fig. 1: Mean nitrogen taken up in aerial parts affected by tuber size and nitrogen levels

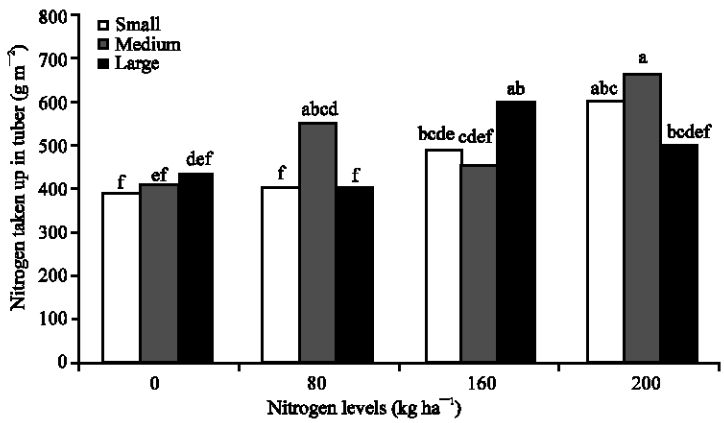

Fig. 2: Mean nitrogen taken up in tuber affected by tuber size and nitrogen levels

Table 1: Mean comparisons of nitrogen levels and tuber sizes on measured traits

Treatments	Nitrogen content of aerial parts (%)	Nitrogen content of tuber (%)	Nitrogen taken up in aerial parts ($g\ m^{-2}$)	Nitrogen taken up in tuber ($g\ m^{-2}$)	Total nitrogen taken up in plant ($g\ m^{-2}$)	Nitrate accumulation in tuber dry weight (ppm)	Nitrate accumulation in tuber fresh weight (ppm)	No. of tuber per plant	Tuber dry weight per plant (g)	Mean tuber weight (g)	Tuber yield ($kg\ m^{-2}$)
Tuber size											
Small	2.71ab	2.04ab	932.47b	491.38a	1423.85b	285.51a	98.41a	7.50b	35.75b	39.46a	2.25b
Medium	2.80a	2.08a	1120.94a	528.66a	1649.60a	292.58a	91.09a	9.50a	37.91ab	45.86a	2.64a
Large	2.57b	1.85b	1119.31a	496.68a	1615.99a	293.66a	102.94a	10.50a	40.11a	47.27a	2.87a
Nitrogen fertilizer levels ($kg\ ha^{-1}$)											
0	2.57b	1.84c	810.26b	409.28b	1219.5b	257.65c	63.85c	8.55a	33.20c	26.68c	1.67d
80	2.61b	1.86bc	915.64b	453.90b	1368.54b	287.09b	90.90b	8.88a	36.50b	51.39ab	2.50b
160	2.73ab	2.18a	1209.15a	557.80a	1766.94a	289.92b	97.39b	9.69a	43.41a	55.17a	3.29a
200	2.86a	2.07ab	1295.25a	602.31a	1897.56a	307.65a	137.76a	9.55a	38.39b	43.70b	2.89c

*Numbers with same letter(s) in each column, have no significant differences to each other

interaction effect of tuber size×nitrogen rate was significant ($p<0.01$) on traits other than nitrogen percent of tuber and aerial parts, nitrogen uptake by whole plant and No. of tuber.

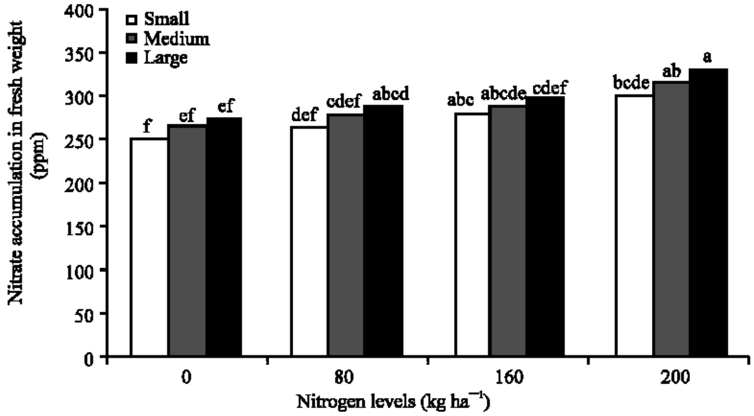

Fig. 3: Mean nitrate accumulation in fresh weight affected by tuber size and nitrogen levels

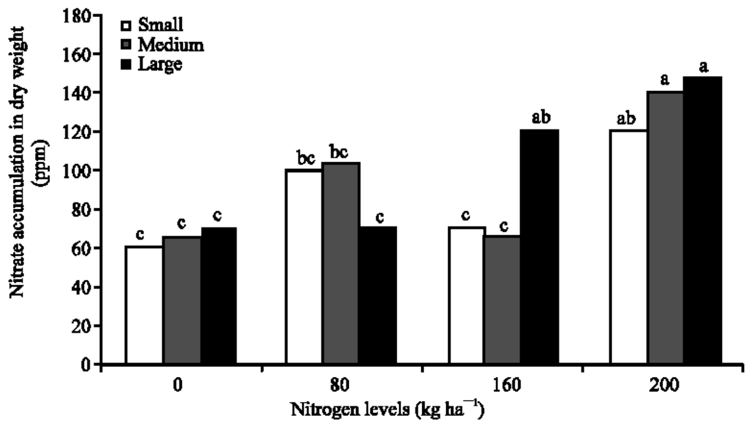

Fig. 4: Mean nitrate accumulation in dry weight affected by tuber size and nitrogen levels

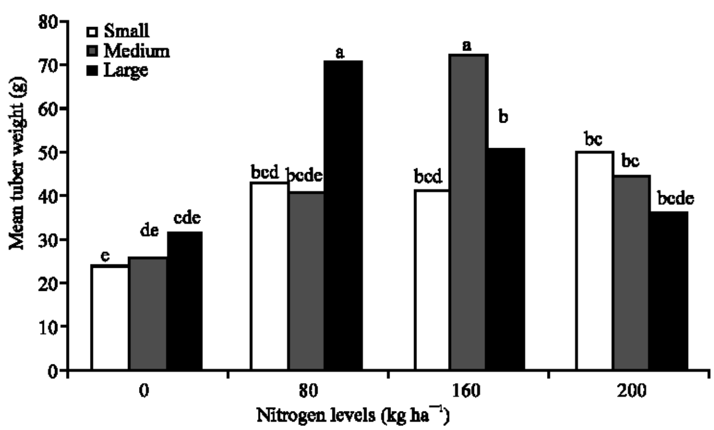

Fig. 5: Mean tuber weight affected by tuber size and nitrogen levels

Nitrogen Uptake and Nitrogen Percent

Medium tuber size significantly had the most nitrogen percent in tuber and aerial parts than other sizes. With increasing nitrogen level, nitrogen percent significantly increased as well, so, the most rates in aerial parts belonged to 200 kg ha^{-1} nitrogen and in tuber, belonged to 160 kg ha^{-1} nitrogen (Table 1).

Medium size significantly had the most nitrogen absorption in aerial parts and whole plant than other sizes. With increasing nitrogen usage, nitrogen absorption in aerial parts tuber and whole plant was increased. Among the nitrogen levels, 200 kg ha^{-1} nitrogen led to the most value (Table 1). Evaluating interaction effect (Fig. 1, 2) it can be realized that the most significant effect belongs to medium size×200 kg ha^{-1} nitrogen. So, it can be concluded that with increasing absorbed nitrogen not only the increase of yield was not achieved, but also it was reduced of course, nitrogen uptake up to 160 kg ha^{-1} increased yield but more values decreased it. Probably this may as a result of inability of plant to use more rates of applied nitrogen and hence, changing nitrogen to nitrate and consequently more nitrate accumulation in plant and as will be described later. Westermann *et al*. (1988) reported that while nitrogen utilization was done at stage of tuber growth, nitrogen utilization was done at stage of tuber growth, nitrogen firstly accumulated in stem and leaves but at the maturity stage of tuber, found that with increasing nitrogen, its uptake by tuber was increased and the most value was obtained at 200 kg ha^{-1} nitrogen.

Nitrate Accumulation

With increasing nitrogen from zero to the last level, nitrate content in tuber dry and fresh weight significantly was increased and reached to the digest rate.

Same results have been obtained by Joern and Vitosh (1995) as well. In 200 kg ha^{-1} nitrogen×large tuber size, the most nitrate accumulation was observed (Fig. 3, 4). In all nitrogen levels, Agria cultivar has accumulated fewer nitrates in fresh and dry weight of tuber. Also, it is clear that application of excessive values of nitrogen, in addition to reducing yield, increased nitrate accumulation.

Yield and Yield Components

Results showed that the large and medium tuber sizes jointly caused the most number, dry weight and yield of tuber (Table 1). Wurr *et al*. (1992) and Lommen (1995) reported that with increasing the weight of planted tuber, number of produced tubers per plant was increased. Schulz *et al*. (1998) realized that the larger planted tubers significantly produced more tubers Marknielson and Weller

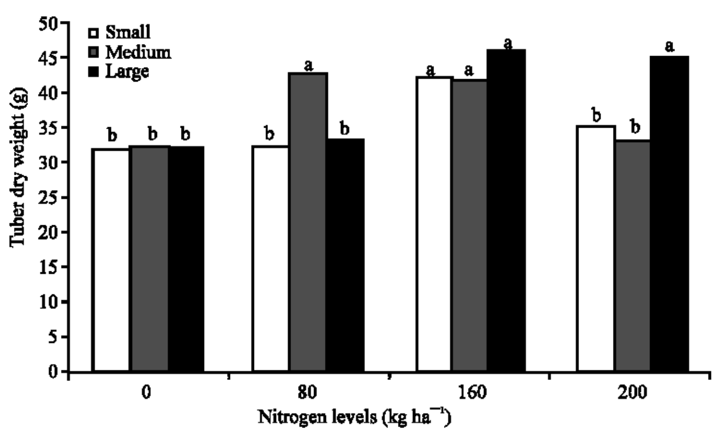

Fig. 6: Mean tuber dry weight affected by tuber size and nitrogen levels

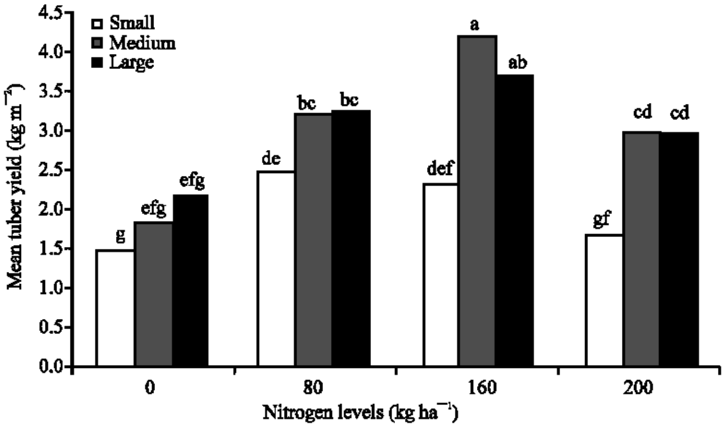

Fig. 7: Mean tuber yield affected by tuber size and nitrogen levels

(1989) reported that in increase on stem No., tuber No. and tuber yield Beraga and Caeser (1990) and Kleinhenz and Bennet (1992) indicated that nitrogen affecting on large tuber No. increased yield. With application of nitrogen up to 160 kg ha^{-1}, dry weight, mean weight and tuber yield was increased and then, was decreased (Table 1). This may attributed to over expanding of aerial parts as a result of improper nitrogen values application (over the 160 kg ha^{-1} nitrogen) and consequently, increase of intra-competition of plant to gain environmental sources such as water and minerals which caused the significant decrease in yield and yield components at 200 kg ha^{-1} nitrogen. It seems that over-usage of nitrogen may highly expand the stems and leaves, thus, tubering is delayed and so, yield reduction and low tuber quality is occurred.

Medium tuber size×160 kg ha^{-1} nitrogen was led to the most dry weight, mean weight and tuber yield (Fig. 5, 6, 7). Lommen (1995) reported that with increasing tuber size, tuber dry weight was increased, as well.

Mollerhagen (1993) and Osaki *et al*. (1995) confirm these results. Applied nitrogen less affects No. of tuber but its most effect is on tuber size (Struik *et al*., 1990). But if nitrogen rates pass the favorite values, both mean tuber weight and No. of tuber were decreased (Kleinhenz and Bennet, 1992). Lommen (1995) reported that small tubers caused lower yields large tubers resulted higher yields.

CONCLUSIONS

It observed that the most nitrate content in dry and fresh weight of tuber was obtained at 200 kg ha^{-1} nitrogen×large tuber size and the highest tuber yield was achieved at 160 kg ha^{-1} nitrogen×medium tuber size. Nitrate accumulation at 160 kg ha^{-1} nitrogen was measured of 298.03 mg kg^{-1} tuber dry weight and 128.43 mg kg^{-1} tuber fresh weight. In this level, nitrate content in fresh and dry weight of tuber, was lower than critical level so, application of 160 kg ha^{-1} nitrogen, to obtain the most tuber yield and the least nitrate accumulation for Agria cultivar in Ardabil, Iran, is recommended. Referring to mean tuber yield in Ardabil region of 28.7 t ha^{-1} and its comparison with the yield resulted in this study, it can be said that this recommendation, is beneficial. Also, it is suitable for edible and planting usages.

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