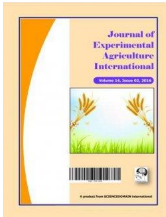

Journal of Experimental Agriculture International

28(5): 1-9, 2018; Article no.JEAI.20206
ISSN: 2457-0591
(Past name: American Journal of Experimental Agriculture, Past ISSN: 2231-0606)

Effect of Nitrogen and Potassium Levels on the Potatoes Growth in the Chott Mariem Region of Tunisia

Wissem Hamdi[1*], Rihab Beji[2], Sarra Ouertatani[3] and Azaiez Gharbi[3]

[1]High Institute of Agronomy, Sousse University, Chott Meriem 4042, Sousse, Tunisia.
[2]Faculty of Sciences of Monastir, Monastir University, Tunisia.
[3]Soil Sciences Laboratory, Higher School of Agriculture of Kef (ESAK) / BP 138 Barnoussa, Kef 7100, Tunisia.

Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JEAI/2018/20206
Editor(s):
(1) Dr. Mirza Hasanuzzaman, Assistant Professor, Department of Agronomy, Sher-e-Bangla Agricultural University, Bangladesh.
Reviewers:
(1) Shelley Gupta, India.
(2) Rezzoug Waffa, Ibn Khaldoun University, Algeria.
Complete Peer review History: http://www.sciencedomain.org/review-history/27429

Original Research Article

Received 16 July 2015
Accepted 29 December 2015
Published 27 November 2018

ABSTRACT

An experiment was conducted at the experimental station of Higher Institute of Agronomy, Chott Mariem, Sousse (Tunisia) to investigate the effect of similar levels of nitrogen and potassium on potato growth (*Spunta* variety). Four similar levels of nitrogen (N) and potassium (K) (0, 50, 80 and 120 kg ha^{-1}) were randomized complete block design with four replications. Data collected on growth and yield parameters were analyzed using SPSS.20 computer software. Nitrogen (N) and potassium (K) levels showed significant effect on mostly growth and yield parameters. It can be show that N and K application at the level of 120 kg ha^{-1} significantly affected plant height (59.16 cm), number of leaves plant^{-1} (294), number of branches plant^{-1} (14.66), fruits plant^{-1} (20.96), and leaf area (422.66) index. Additionally the maximum of dry matter (13.83%), tuber size (79 mm), tuber yield (22.193) and tuber weight (203.66 g) were recorded with 120 kg ha^{-1}. From this study, it can be concluded that the higher levels of nitrogen (N) and potassium (K) (120 kgha^{-1}) can be used for optimum production of potato variety Spunta in the study area.

**Corresponding author: E-mail: wissemhemdi@yahoo.fr;*

Keywords: Potatoes; nitrogen (N); potassium (K); growth; yield; Tunisia.

1. INTRODUCTION

Nitrogen (N) and potassium (K) were typically the most limiting factor for growth and production crop. The nitrogen was uptake by plant on nitrate (NO_3^{-}) and ammonium (NH_4^{+}) forms. Also plants absorb K in its ionic form K^{+}. Simret [1] reported that N and K are deficient in most soils and thus application of these fertilizers has significantly increased yield of the crop. The accumulation of N and K in the edible parts of crops is directly related to the type of N and K fertilizer used as well as the soil properties [2]. Crops have different responses to N and K rates. But for most plants, a combination of N and K is preferred over application of a sole source of either form and the optimal N/K ratio varies with the crop [4]. Also, some plants are large consumers of N and K such a potato (*Solanum tuberosum* L.). Nitrogen (N) is essential for maintaining higher growth, quality of tuber and more dry matter production [5] and K is responsible for translocation of carbohydrates and increased resistance to withstand drought and frost stresses. Although the response of N and K on potato growth has been studied and the inconsistent recommendations have been reported by several groups at different location. Al-Moshileh et al. [6] observed a significantly increase in potato production and leaves NK content due to fertilization. Nebret [7] reported an increasing in the average of fresh tuber weight with N level (0-25 kg/h) increase and a decline in tuber specific gravity. Al-Moshileh et al. [6] indicated that increasing K application levels significantly augmented plant height, leaf area, chlorophyll, specific gravity, and marketable tubers yield of potato. El-Tohamy et al. [8] observed that K treatments (0, 96, 192, and 288 kg K/ha) significantly increased four potato varieties yield. By cons Banu et al. [9] with increasing K rate from 225 to 450 kg/ha reported that yield was not affected with K levels. Adane et al. [10] don't showed a significantly effect on tuber dry matter, whereas exceeding the K level was occasionally reducing the dry matter. According to Prasad [11], application of 150/66 kg ha^{-1} of N/K under rain-fed condition resulted in a yield advantage of 32% over the unfertilized control. Singh et al. [12] found that the optimum fertilizer levels for potatoes were 87 kg N ha^{-1} and 46 kg of K ha^{-1} on clay soil. According to Anabousi et al. [13], the application of 165 kg of N and 90 kg of K ha^{-1} is needed for optimum potato production on vertisols. Sharmila et al. [14] found in their study conducted on response of potato to different fertilizer levels under rain fed highland situation and 207 kg N ha^{-1} and 90 kg K ha^{-1} gave optimum tuber yield. Boyd et al. [15] found that the optimum fertilizer rates for potatoes were 87 kg of N and 46 kg of K ha^{-1} on clay soil. In semi arid region of Tunisia low soil fertility is one of the most important constraints limiting potato production and hence accelerated intensification is required for suitable potato production. For this raison optimization fertilizer application is an important issue for sustainable agriculture because it can reduce the negative effects of farming on the surrounding environment. Furthermore, there is little research regarding the response potato growth to N and K application. Our objective was therefore to determine the influences of different rates of N and K on potato growth.

2. MATERIALS AND METHODS

2.1 Site Description

The experiments were conducted from September to December in the research station of the Agronomic Height Institute of Chott-Mariem (35° 54' N 10° 36' E), Sousse, Tunisia. The topography is irregular dominated by a string of folds generally oriented NE-SW (N045). The climate is semi-arid with an annual precipitation varied between 150 and 550 mm. Annual temperatures varied between 10 to 19°C in winter and 22 to 39°C in summer. The soils in Sousse are generally deep, well drained with low to moderate status.

2.2 Experimental Treatments

Spunta potato variety obtained was used for this experiment. It is one of the potential potato cultivars. It is being cultivated widely and has been required by farmers due to its high yielding, better cooking ability and relatively resistance to late blight compared to local and other improved potato varieties growing in the area. Four similar levels of nitrogen and potassium (0, 50, 80 and 120kg/ha) were combined in 4x4 factorial arrangements in randomized complete block design with three replications. A distance of 1 m was maintained between the plots within a block and 1 m distance was maintained between blocks and 75 cm row spacing was uniformly used and medium sized and well sprouted potato tubers were planted. The half rate of N and K was applied after two weeks of planting and the remaining half of N and K was applied 45 days after planting. Nitrate ammonium fertilizers were used as sources of nitrogen and nitrate potassium were used as source of potassium. All management practices, such as weeding, insect pest and diseases control were applied as per the general recommendations for potato.

2.3 Soils Analysis

Soil samples were collected annually from the 0 to 20 cm depth layer before the fertilizer application, air dried, and sieved to pass through a 2 mm screen for soil physical and chemical analysis. The soil sample was analyzed for soil texture, pH, organic carbon, total N, extractable P, exchangeable levels of Ca, Mg, Na and K, and cation exchange capacity. Soil texture was determined by the pipette method. Soil pH was determined potentiometrically in 1:2 soil/distilled water suspensions after shaking. Soil organic matter was measured using the walkley and black method. The Kjeldahl method was used to determine the soil total nitrogen (N_{tot}). A total P (P_{tot}) was determined using Olsen's method. Exchangeable K was determined using a flame photometer. Exchangeable Ca and Mg were determined using anatomic absorption spectrophotometer.

2.4 Plant Analysis

In the context to determine leaf and tuber nutriment concentration, leaf samples were taken from the fourth leaf from the growing point of 10 randomly chosen plants per plot. For tuber analysis, five tubers were randomly selected at harvest from each treatment per block and taken as the representative sample. The leaf area index was determined by a plumb-bob method. The dry matter of tuber, tuber weight and tubers size were determined from 15 randomly selected plants in each treatment during harvesting. All samples of leaf and tubers were oven-dried at 104°C for 2 h and then washed with water and dried with filter paper. Samples of leaf and tuber were mixed with 1 ml of 30% trichloroacetic acid and 50 ml of distilled water, and then triturated in a blender until a homogeneous mass was achieved. The homogeneous mass was centrifuged at 2000 r/min for 15 min, and then 5 ml of the supernatant was placed to a 100 ml volumetric flask and the volume completed with distilled water. The nitrogen (N) was determined using the Kjeldahl method. The phosphorus (P) was analyzed by the molybdenum blue method and the potassium (K) was determined by flame photometry. Finally the calcium (Ca) and magnesium (Mg) contents were determined by atomic absorption spectrophotometer.

2.5 Statistical Analysis

Data were analyzed using mixed model procedures (SPSS.20) and subjected to the combined analysis of variance. For comparing average values, Student test was used when F test was significant at the level of ($P \leq 0.05$).

3. RESULTS

3.1 Soil Physicochemical Characteristic

Table 1 shows the result of the physical and chemical analysis of the soil studied. The soil was sandy loam and slightly alkalizes. The values 90, 66 and 160 ($kgha^{-1}$) of total nitrogen (N), available phosphorus (P), and exchangeable potassium (K) of the experimental soil were below the critical values of the semi arid soil of Tunisia; this may be due to low soil organic matter (0.8%). The weakly soil contents for the major nutrients indicating the necessity for improvement of potato growth.

3.2 NK Uptake by Sheets and Tubers

Fertilizer N and K (0, 50, 80 and 120 kg ha^{-1}) treatments revealed significant interaction effects in respect of N and K uptake by sheets and tuber (Table 2). It can be seen that the maximum uptake of N and K by sheets and tubers was recorded from 120 ($kgha^{-1}$) fertilized level and most the fertilizer treatments significantly statistically differed from one another. NK uptake by sheets and tubers increased significantly with increase in their sheets of application and mostly it is due to increase in availability of nutrients in the soil. Highest uptake of N and K ($kg.ha^{-1}$) was due to better crop growth and higher NK concentration in plant resulted in high tuber yield which ultimately resulted into higher NK uptake by leaves and tubers [16]. Among the fertilizer treatments, application of 120 ($kgha^{-1}$) of the recommended dose gave the highest NK uptake. The nutrient uptake by tubers was found closely linked with productivity and their higher concentration in plant [17]. It is due to increase in availability of nutrients in the soil. Moreover it can be seen that the leaves part of the potato plant is higher in NK than in the tubers due to the tubers' low rate of transpiration as NK moves passively throughout the plant in the xylem as a result of the transpiration pull [18]. Sheets NK was increased by low humidity and high air temperature both of which result in higher transpiration. Studies by Bose et al. [19] showed that tuber NK varies with variety and season but had no relationship to soil availability of nutrients. Application of NK to the main root system does not increase tuber NK since water and nutrients will be transported to the leaves [20]. Tubers have less transpiration rates than the sheets and hence cannot compete effectively for NK applied to the main root system. Bose et al. [19] showed that the accumulation of NK in tubers varied among cultivars and seasons, and concluded that different cultivars have different NK uptake thresholds due to their genetic makeup implying that improvement of tuber NK can be done through plant breeding.

3.3 Effect of N and K Levels on Growth Parameters

3.3.1 Plant height

The effect of N and K fertilization on potato plant height is indicated in Table (3). It was clear that plant height significantly increased with of N and K levels. For this it can be seen that the mean plant height increased from the minimum (46) cm in control to 53.2; 56.51 and 59.16 cm with increasing N and K levels to 0, 50, 80 and 120 kg ha^{-1}respectively. This can be attributed to the enhanced the availability of nutrients to the crop increased, which may have resulted in increased photosynthetic efficiency of the plant. Plant height is a function of genetic as well as environmental conditions. Increased metabolic activities of the plant with increase in fertilizer N and K dose have been reported by Etemad [21]. Similar report of increase in all evaluated vegetative traits on application of N and K rates of 150 kg ha^{-1} was given by Vaezzadeh [22]. Nitrogen and potassium play a significant role in the production of stem and axillary branches [21]. In addition N and K fertilizer increased potato leaf area, which increases the amount of solar radiation intercepted and consequently increases plant height and dry matter production of different plant parts [9]. The obtained results were in agreement with those reported by Al-Moshileh et al. [6].

3.3.2 Number of sheets $plant^{-1}$

The number of leaves $plant^{-1}$ affected by N and K levels but was non-significant (*$P \leq 0.05$*). The highest level of N and K (120 kg N ha^{-1}) resulted in the maximum number leaves $plant^{-1}$ (26.21) as compared to the minimum (18.86) in control (Table 3). As nitrogen and potassium were an essential part of chlorophyll, helps in protein synthesis. Increase in leaves $plant^{-1}$ may be due to sufficient amount of N and K provided an ideal environment and balanced nutrition to plants, which increased number of sheets. Sheets have direct relation with number of branches. Plants having more branches gave more sheets and vice versa. The results are to some extent in agreement with the findings of Simret [1] who obtained maximum number of sheets $plant^{-1}$ with increasing nitrogen and potassium application.

3.3.3 Number of branches $plant^{-1}$

The number of branches $plant^{-1}$ were significantly ($P \leq 0.05$) affected by nitrogen and potassium effect. The maximum number of branches $plant^{-1}$ (14.66) were recorded from the highest N dose (120 kg ha^{-1}) , followed nitrogen applied 80 kg ha^{-1} (13.91), while the lowest (10.53) was recorded in control treatment (Table 3). Nitrogen and potassium have a significant effect on number of branches $plant^{-1}$ as it activates

Table 1. Soil physicochemical proprieties

	Chemical proprieties ($mgkg^{-1}$)						Physical proprieties (%)		
pH	OM (%)	N	P	K	Mg	Ca	Clay	Sand	loam
8.2	0.8	90	66	160	50	110	23	62	15

Table 2. Levels of N and K in sheets and tubers

Treatments ($kgha^{-1}$)	N-Sheet (%)	K- Sheet (%)	N-tuber (%)	K-tuber (%)
0	3.09^{a}	1.1^{a}	0.96^{a}	0.35^{a}
50	3.2^{b}	1.3^{a}	1.18^{c}	0.46^{b}
80	3.48^{c}	1.3^{a}	1.51^{b}	0.46^{b}
120	3.82^{c}	1.4^{a}	2.06^{b}	0.468^{b}

vegetative growth. These results agree with the findings of Simret [1]. Similarly, a linear increase in the number of branches plant^{-1} with increase in nitrogen and potassium levels was also noticed by Boyd et al. [15]. They conclude that branches plant^{-1} increasing with increasing nitrogen and potassium levels.

3.3.4 Number of fruits plant^{-1}

The number of fruit plant^{-1} were significantly ($P \leq 0.05$) affected by nitrogen and potassium (Table 3). The mean analysis shows that maximum numbers of fruits plant^{-1} (20.96) were recorded when nitrogen was applied 120 kgha^{-1}, followed by 80 kgN ha^{-1} (19.96) and minimum (16.21) was recorded from control plots. The highest number of fruits plant^{-1} might be due to vigor of plant and more number of leaves plant^{-1}. The results are in agreement with those of Boyd et al. [15], who reported that the number of fruit plant^{-1} increased with increasing nitrogen and potassium application.

3.3.5 Leaf area index

The maximum leaf area index (422.66) were recorded from the highest N and K levels (120 kg ha^{-1}) , followed N and K applied 80 kg ha^{-1} (367.6), while the lowest (296.66) was recorded in control treatment (Table 3). The result of this study indicates that the leaf area index was influenced by N and K fertilizer dose. This result is similar with those of El-Tohamy et al. [8] who sated that leaf area index can vary widely according to growing conditions. Al-Moshileh et al. [6] also reported that, tuber formation is the result of leaf photosynthesis. Moreover El-Tohamy et al. [8] found that young and fully expanded leaves led to better tuberization in potatoes than the very young or very old leaves with less leaf area index.

3.4 Effect of N and K Levels on Yield Parameters

3.4.1 Dry matter

With application of 120 kg ha^{-1} the highest root dry weight (13.83%) was obtained compared to the control treatment with the lowest root dry weight of 9.5% (Table 4). The result of the current investigation is in conformity with the finding of Zare et al. [23] who concluded that N and K fertilization significantly influenced dry matter of potato. The concentration of N and K levels fertilizer can increase the N and K uptake and this increase has a positive effect on chlorophyll concentration, photosynthetic rate, sheets expansion, total number of sheets and dry matter accumulation. Santamaria [24] indicate that N and K fertilizer play an important role in canopy development especially on the dry matter. In similar manner Petropoulos [25] reported that good supply of N and K to the plant stimulates root growth and development as well as uptake of other nutrients.

3.4.2 Tuber number

The maximum tuber number (22.193) were recorded from the highest N dose (120 kg ha^{-1}), while the lowest (12.97) was recorded in control treatment (Table 4). It can show that the increasing the application of N and K increased total tuber number. This can be attributed to increased vegetative growth of the potato plant. The current result is in consistent with the work of the researcher of Tamme [26] who had reported that an increase in N and K and application increases tuber number.

Table 3. Plant growth parameters

Treatments (kgha^{-1})	Plant height (cm)	Number of branches plant^{-1}	Number of sheets plant^{-1}	Number of fruits plant^{-1}	Leaf area index
0	46 ^{a}	10.53 ^{a}	18.86 ^{a}	16.21^{a}	296.66 ^{a}
50	53.2 ^{b}	12 ^{b}	23.98 ^{a}	18.23 ^{a}	338^{b}
80	56.51 ^{b}	13.91 ^{b}	25.56 ^{a}	19.96^{b}	367.6^{b}
120	59.16 ^{c}	14.66 ^{c}	26.21 ^{a}	20.96^{b}	422.66^{c}

Table 4. Plant yield parameters

Treatments (kgha^{-1})	Dry matter (%)	Tuber size (cm)	Tuber number	Tuber weight (g)
0	9.5 ^{b}	62.7 ^{a}	12.97 ^{a}	97.66 ^{a}
50	11.63^{c}	68 ^{a}	18.28 ^{b}	120.66 ^{a}
80	13.26 ^{a}	71.66 ^{b}	20.913 ^{c}	193.33 ^{b}
120	13.83 ^{b}	79 ^{b}	22.193 ^{c}	203.66 ^{b}

Table 5. Correlation matrix of growth and yield related traits in potatoes

	Leaf area	Num fruits	Num leaves	Num branche	Plant height	Dry matter	Tuber size	tuber num	Tuber weight	N sheet	K sheet	N tuber	K tuber
Leaf area	1	-,715	-,980	-,386	,995*	-,897	,998*	-1	-,153	,859	-,506	,960	-,868
Num fruits		1	,562	,921	,642	,950	-,755	,735	,801	-,256	-,241	-,490	,273
Num leaves			1	,196	,995*	,793*	-,967	,974*	-,045	-,943	,667	-,996*	,949
Num branche				1	,293	,754	-,440	,414	,971	,140	-,600	-,112	-,123
Plant height					1	,849	-,987	,992*	,054	-,906	,589	-,983	,913
Dry matter						1	-,922	,910	,573	-,546	,074	-,738	,560
Tuber size							1	-1	-,211	,828*	-,454	,942	-,837
Tuber num								1	,182	-,844	,480*	-,951	,853
Tuber weight									1	,374	-,775	,130	-,358
N sheet										1	-,876	,968	-1
K sheet											1	-,728	,868*
N tuber												1	-,972
K tuber													1

3.4.3 Tuber size

The increasing of the levels of N and K application from 0-120 kg N ha^{-1} increased tuber size from 62.7 mm to79 mm (Table 4). For this result it can be suggested that size tuber increases at higher N and K rate because N and K can trigger the vegetative growth development. The increase of tuber size in applied N and K was associated with decrease in the number of tubers due to increase in the weight of individual tubers. This result is in line with the finding of Lobell [28] who confirmed that application of nitrogen specially increased the number of tubers produced in a study conducted for three consecutive years.

3.4.4 Tuber weight

Increasing the application rates of N and K from 0 to 120 kg ha^{-1} increased total tuber yield from 97.66 g to 203.66 g (Table 4). For this result it can concluded that the application of N and K levels can influence the tuber weight and it may be due to the positive interaction and complementary effect between N and K in affecting and increasing the tuber weight of potato in the study area. This result is in agree with the finding of Tamme [26] who reported that application of nitrogen and potassium increased the total tuber weight. On other hand Santamaria [26] revealed that it is possibly that no yield increases with N and K doses application were observed on soils considered low in N and K but Davenport and Bentley (2001) showed that the yield increases were observed on soil considered to have adequate or high soil test N and K. Moreover Petropoulos [25] indicate that they are other factors, such as growing season conditions, irrigation, variety and soil pH, may also impact the potential for yield responses to K doses application

3.4.5 Matrix correlate

Result on Table 5 showed the correlation matrix of yield and heights potatoes-contributing traits in. It revealed that there were significant positive correlations between plant heights $plant^{-1}$ and number of leaves $plant^{-1}$ (0,995*), leaf area $plant^{-1}$ (0,995*) and number of tuber number $plant^{-1}$ (0,992*). It also showed that the number of leaves was positively correlated with the dry matter (0,793*) and tuber number (0,974*). Tuber number had a positive significant association with N-Sheet (0.828*). Additionally, Tuber size correlated positively with K-Sheet (0. 480*) while K-sheet correlated positively with K-tuber (0.868*).

4. DISCUSSION AND CONCLUSION

The results of this study showed that different doses of N and K have different significant effects on plant growth and production in 5% probability. It is reported that plant growth increases as a result of increased of N and K doses from 0 to 120. This result is in agree with the finding of Jha et al. [28] who reported that plants growth parameters increased as a result of increased nitrogen and potassium fertilizer usage. The growth parameters increased with of N and K fertilizer consumption so it causes increased photosynthesis and, consequently, increased growth. However increased of N and K had no significant effect on increased of N and K content of sheets and tubers and, in general despite its properties plant growth. Moreover, nitrogen effect on 5% level was significant on increased potato yield parameters. The results of this study indicate that the higher yield obtained with application of higher dose of nitrogen and potassium doses would have helped in increase in tuberization as well as increased duration of tuber bulking which would have resulted in higher production. Moreover, it can be suggested that the increasing nitrogen and potassium application, number of stolon, number of tuber and consequently yield were increased. By cons others studies show that the higher application of N and K fertilizer produced more tubers size because most of the nitrogen may have been lost due to de-nitrification, leaching and volatilization and therefore making them unavailable during the critical stages of plant growth [17,27]. Santamaria [24] indicated that applying total nitrogen once increases nitrogen losses through leaching and hence producing small tubers. The high mobility of nitrogenous fertilizers means that it is subjected to high losses from the plant system Zare [23]. By cons Vaezzadeh et al. [22] indicate that excessive nitrogen application promotes excessive vegetative growth at the expense of reproduction that subsequently has a negative effect on tuber formation.

In conclusion, the result of this study showed that different nitrogen and potassium levels have sound and promising impact on growth and 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 area of Chott Mariem region and farmers can benefit more by using

120 kg ha^{-1} of nitrogen in combination with 120 kg ha^{-1}potassium.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Simret B. Influence of inorganic nitrogen and potassium fertilizers on seed tuber yield and size distribution of potato (*Solanum tuberosum* L.). An. M. Sc Thesis Presented to the School of Graduate Studies of Haramaya University, Ethiopia. 2010;65.
2. Dhital A, Prasad S, Phil A, Choi H. Effect of leaf age, leaf area, plant growth regulator and genotypes on the production of potato mini tubers. Biotechnology Journal. 2009;26:67 87.
3. Allison MF, Flowler JH, Allen EJ. Response of Potato (*Solanum tuberosum*. L) to Potassium Fertilizers. The Journal of Agricultural Sciences. 2001; 136:407-426.
4. Lung'aho C, Lemaga M, Nyongesa P. Gildermacher P, Kinyale P. Commercial seed potato production in eastern and central Africa. Kenya Agricultural Institute. 2007;140.
5. Karam R, Lahoud R. Masaad C, Stephan Y. Yield and tuber quality of potassium treated potato under optimum irrigation conditions. Acta Hort. 2005;(ISHS)684: 103-108.
6. Al-Moshileh AM, Errbhi MA, Motawei M. Effect of various potassium and nitrogen rates and splitting methods on potato under sandy and arid environment conditions. Emir. J. Aric. Sci. 2005;17(1): 1-9.
7. Nebret T. The effect of Nitrogen and Sulfer on yield and yield component of common bean in Eastern Ethiopia. Unpublished M.Sc. Thesis presented to the school of graduate studies of Haramaya University. 2011;13.
8. El-Tohamy W. Ghoname S, Abou H. Improvement of pepper growth and productivity in sandy soil by different fertilization treatments under protected cultivation. Applied Science Research Journal. 2006;2:8-12.
9. Banu S, Thiyagarajan TM, Malarvizhi P. Effect of graded levels of fertilizers on quality aspects of potato. Potato J. 2007; 34(3–4):242–44.
10. Adane H, Meuwissen A, Tesfaye W. Lommen AO, Lansink A. Tsegaye, Struik PC. Analysis of seed potato systems in Ethiopia. American Potato Research Journal. 2010;87:537-552.
11. Prasad S, Chetty A. Nitrate-N determination in leafy vegetables: Study of the effects of cooking and freezing. Food Chem. 2008;106:772–780.
12. Singh SK, Lal SS. Effect of potassium nutrition on potato yield, quality and nutrient use efficiency under varied levels of nitrogen application. Potato J. 2012; 39(2):155–65.
13. Anabousi OAN, Hattar BI, Sawwan MA. Effect of rate and source of nitrogen on growth, yield and quality of potato. Dirasat Agric Sci. 1997;24(2):242–59.
14. Sharmila B, Malarvizi T, Thiyagarajan B. Effect of nitrogen, potassium and magnesium on tuber yield grade and quality of potato Cv. Kufri Giriraj.18th World Congress of Soil Science, 2006; July 9-15, Philadelphia, Pennsylvania, U S A.
15. Boyd NS, Gordon S, Martin R. Relationship between leaf area index and ground cover in potato under different management conditions. Potato Research. 2002;45(2/4):117-129.
16. Mousavi F, Faeznia HF, Ommati F. Different amounts of water and nitrogen fertilizer effects on potato's quantitative and qualitative properties. A Collection of 11st Conference of Iranian National Committee for Irrigation and Drainage, 2001;273-295.
17. Wang Z, Zong ZQ, Li S, Chen, B. Nitrate accumulation in vegetables and its residual in vegetable fields. Environ. Sci. 2002;23: 79–83.
18. Pandey SK, Kumar P, Singh BP, Singh SV, Kumar D. Effect of nitrogen rate on growth, yield, economics and crisps quality of Indian potato processing cultivars. Potato Res. 2007;50(2):143–55.
19. Bose US, Bisen A and Nayak S. Effect of different levels of nitrogen and potassium on growth and yield of potato (*Solanum tuberosum* L.). Green Farming. 2008;2(1): 6–17.
20. Griffin TS. Nitrogen availability. In Nitrogen in Agricultural Systems; Schepers, J., Raun, W.R., Eds.; SSSA Inc. and ASA Inc.: Madison, WI, USA. 2008;613–646.

21. Etemad B, Sarajuoghi M. Study of the effect of different levels and application timing of nitrogen fertilizer on yield and number of potato tuber. Annals of Biological Res. 2012;3(3):1385–87.
22. Vaezzadeh M, Naderidarbaghshahi M. The effect of various nitrogen fertilizer amounts on yield and nitrate accumulation in tubers of two potato cultivars in cold regions of Isfahan (Iran). Int J Agri Crop Sci. 2012; 4(22):1688–91.
23. Zare F Abadi, Kouchaki AA, Alimoradi L. Study of remaining nitrogen, phosphorus and potassium changes in soil in response to frequencies and typical agricultural and biological systems. Modern Ways for Plant Nutrition 1st edition (Sana publication, Tehran, Iran). 2004;103-116.
24. Santamaria P. Nitrate in vegetables: Toxicity, content, intake and EC regulation. J. Sci. Food Agr. 2006;86:10–17.
25. Petropoulos SA, Olympios CM, Passam HC. The effect of nitrogen fertilization on plant growth and the nitrate content of leaves and roots of parsley in the Mediterranean region. Sci. Hortic. 2008; 118:255–259.
26. Tamme T, Reinik M, Roasto M. Nitrates and nitrites in vegetables: Occurrence and health risks. In Bioactive Foods Promoting Health: Fruits and Vegetables; Watson, R.R., Preedy, V.R, Eds.; Academic Press: Salt Lake City, UT, USA. 2009;307–321.
27. Lobell DB. The cost of uncertainty for nitrogen fertilizer management: A sensitivity analysis. Field Crop. Res. 2007; 100:210–217.
28. Jha KK, Jha AK, Deepshikha, Bedia HT. Quality of potato (*Solanum tuberosum* L.) tubers as affected by varieties and NPK levels. Int J Tropical Agric. 2008;26(1–2): 271–72.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history/27429