Australian Journal of Basic and Applied Sciences, 5(11): 1296-1303, 2011
ISSN 1991-8178

Impact of Nitrogen Fertilizer and Foliar Spray of Selenium on Growth, Yield and Chemical Constituents of Potato plants

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Abstract: Two field experiments were carried out in El –Kassasin region, Ismailia Governorate during 2009 and 2010 seasons to study the effect of both nitrogen (N) fertilizer (at 0,150,200 and250 kg N fed^{-1} rates) and selenium (Se) spray (at 0, 20, and 40g fed^{-1}. rates) on the vegetative growth, tuber yield and chemical composition of Potato plants. Results showed that nitrogen application resulted in an increase in the vegetative growth, tuber yield and quality parameters as compared with the untreated plants. Data also demonstrated that selenium application promoted plant growth, tuber yield and quality over the control treatments. The interaction effects between different nitrogen rates and selenium application significantly promoted growth parameters compared with nitrogen and/or Se alone treatments, with respect to all growth and quality characters. Protein, starch, total carbohydrates, N, P and K percentages in shoots and tubers showed similar response to N and Se applications.

Key words: Potato plants - nitrogen – selenium- vegetative growth- yield - quality parameters- NPK content and uptake

INTRODUCTION

In Egypt, Potato (*Solanum tuberosum L.*) is recognized as one of the most important vegetable crops for local consumption and exportation and is know as the fourth most important world crop, after rice, wheat, and maize. It is considered one of the national income resources. Potato is a major source of inexpensive energy; it contains high levels of carbohydrates and amounts of vitamins B, C and minerals. (Spooner and Bamberg, 1994; Struik, and Wiersema1999 Stephen, 1999; Kari Tigoni, 2005 and Muthoni and Nyamongo, 2009).

Both yield and quality of potato are affected by variety, environmental conditions, and cultural practices. Fertilizer application has important effects on the quality and yield of potato (Westermann 2005). Potato is highly responsive to N fertilization and N is usually the most limiting essential nutrient for potato growth, especially on sandy soils **(Errebhi *et al.*, 1998).** Nitrogen supply also plays an important role in the balance between vegetative and reproductive growth for potato (Alva 2004 and White *et al*., 2007). Many previous studies have shown that fertilizer N applications can increase dry matter content, protein content of potato tubers, total and/or marketable tuber yield (Bélanger et al., 2002; Kara 2002 and Zebarth *et al*.,2004; Zelalem *et al*., 2009) also reported similar effects of N doses on dry matter content and specific gravity of potato in Ethiopia 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 (Hashemidezfooli *et al*., 1998). Moreover, N applied in excess to crop requirement results in increased vegetative growth rather than in tuber production, delayed maturity (Love *et al*., 2005) and reduced tuber quality (Zebarth and Rosen 2007) and can result in the need for higher rates of defoliant chemicals before harvest. Haase *et al*., (2007) found that tuber N uptake concentration were significantly influenced by amounts of nitrogen fertilizer Also, nitrogen uptake increases number of tuber, tuber weight, qualitative and quantitative aspects of tuber but, over-usage of nitrogen delays tuber growth and reduces its qualitative and quantities aspects. The role of nutrient elements in plants involves: cell osmotic potential. Marguerite, *et al*., (2006) showed that the mean maximum increase in total tuber yield, generated by nitrogen fertilizer against the zero-N treatment, was 34.3% and ranged from 10.5% to 54.7%. Waddell *et al*. (1999) and Saeidi *et al*. (2009a and 2009b) reported that application of nitrogen, led to increase in tuber yield than control.

Although Se is not considered an essential nutrient for plant growth, it is a vital element for human and animal nutrition (Levander 1986, 1987). Selenium is a constituent of selenoproteins, many of which have important functions, including antioxidant protection, energy metabolism and redox regulation during transcription and gene expression (Combs 2001; Rayman 2002 Fordyce, 2005 Kong *et al.,* D. 2005). Foliar application of selenium was shown to be several times more efficient than application in fertilizers Aspila (2005) but riskier as Se uptake by the crop depends on spraying conditions. Curtin *et al.* (2006) also showed that foliar spray gave a high recovery. However, Lyons *et al.* (2004) found that foliar application to be less efficient than application to soil at planting. Selenium supplementation to plants enhance the production and quality of edible plant products, by increasing antioxidant activity of the plants, as shown in tea leaves of tea Xu *et al*

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(2003) and in rice. Xu and Hu (2004). Spraying plants with selenium (Se) solution may enrich the utilizable plant parts with Se compounds in concentrations of nutritional importance (Germ *et al*., 2007, Ozbolt *et al*., 2008).

It is suggested that interaction with general minerals is one of more important factors due to which trace elements affect the plant's metabolism. Presence of heavy metals may induce deficiency of macronutrients and micronutrients necessary for a proper course of principal life processes (Baranowska-Morek 2003and Barbara Hawrylak-Nowak (2008). Selenium like heavy metals can modify uptake and accumulation of minerals which are important for metabolism (Kopsell *et al.* 2000; Pazurkiewicz-Kocot *et al*. 2003). Moreover, positive influence of selenium on changes in the activity and permeability of the cellular membrane has been found, and this may be one of the earliest symptoms of the influence of selenium on plants (Kinraide 2003).

Therefore the present investigation aimed to study the response of Potato (*Solanum tuberosum L.*) to nitrogen fertilizer and foliar spray of Selenium on the vegetative growth, tuber yield and chemical composition.

MATERIALS AND METHODS

Two field experiments were carried out in El –Kassasin region, Ismailia Governorate during the two growing seasons (2009 and 2010) to study the effect of nitrogen fertilizer and foliar spray of selenium on the vegetative growth, tuber yield and chemical composition of Potato plants. Prior to any practices, a composite soil sample was taken from the soil surface (0-30 cm) of the experimental site, air dried, sieved by 2 mm sieve and analyzed (Table 1). The physical and chemical properties of soil were determined according to Chapman and Pratt (1961) and Cottenie *et al* (1982)

Table 1: some characteristics of the experimental site in two seasons.

	Physical properties				Chemical properties						
	Sand	Silt	Clay	Texture	pH	EC	$CaCO_3$	OM	N	P	K
	%					dSm^{-1}	%		ppm		
1st season	86.3	8.8	4.8	sandy	8.5	1.3	1.9	0.3	22	9	44
2nd season	88.6	7.9	3.4	sandy	8.3	1.1	2.3	0.5	29	12	56

Potato tubers (*Solanum tuberosum, L.*) cv Sponta were sown at the second week of October in both seasons. Potato crop was harvested after 105 days from planting. Treatments were arranged in completely Randomize Blok design (CRBD) with four replications with nitrogen treatments in the main plots and selenium treatments in the sub plots. Farmyard manure (FYM) was applied at rate 30 m fed^{-1}. for soil before planting. Recommended dose of phosphorus fertilizer as superphosphate (15.5% P_2O_5) was fully added to the soil during soil preparation at 50 kg P_2O_5 fed^{-1}. and Potassium fertilizer at 100kg K_2O fed^{-1}. divided into two equal portions were applied during soil preparation, then 45 days after planting, ammonium sulphate fertilizer was applied at the rates of (0,150,200and 250 kg N fed^{-1}) divided into two does at 30 and 60 day after sowing. Selenium was sprayed at a rate of (0, 20, and 40g fed^{-1}) .Three sprays at 3 weeks intervals were used. The first was 45 days after sowing.
The experimental treatments were as follows:

1- Control
2- Ammonium sulphate150kgN fed^{-1}
3- Ammonium sulphate200kgN fed^{-1}
4- Ammonium sulphate250kgN fed^{-1}
5- 20g of Se fed^{-1}
6- Ammonium sulphate 150kgN fed^{-1}+ 20g of Se fed^{-1}
7- Ammonium sulphate 200kgN fed^{-1}+ 20g of Se fed^{-1}
8- Ammonium sulphate 250kgN fed^{-1}+ 20g of Se fed^{-1}
9- 40g of Se fed^{-1}
10- Ammonium sulphate 150kgN fed^{-1}+ 40g of Se fed^{-1}
11- Ammonium sulphate 200kgN fed^{-1}+ 40g of Se fed^{-1}
12- Ammonium sulphate 250kgN fed^{-1}+ 40g of Se fed^{-1}

The following data were recorded:

1- Vegetative growth characters.
Plant height (cm), leaves and shoots number and dry weight of shoots fed^{-1}.
2- Tuber yield measurements.
Tuber diameter and size, tuber average weight and total tuber yield (ten fed^{-1})
Chemical composition

Shoots and tubers contents of nitrogen, phosphorus and potassium were recorded according to the method described by Cottenie *et al* (1982). Specific gravity was determined according to the method described by (Smith, 1975).Tuber total carbohydrates was determined (as glucose) after acid hydrolysis and spectro photometrically measured using phenol sulfuric acid reagent according to Dubois *et al*. (1956). Starch was determined according to the method by (Burton, 1948) Collected data was subjected to statistical analysis of variance according to Snedecor and Cochran (1980).

The combined analysis of the two seasons was calculated according to the method of Steel and Torrie (1980). The physical and chemical properties of the soil were determined according to Chapman and Pratt (1961).

RESULTS AND DISCUSSION

Vegetative Growth and Tuber Yield:

Data in table (2) indicated that application of nitrogen fertilizer at rates of (150, 200 and 250 kg fed^{-1}.) significantly promoted vegetative growth representing the highest values of plant height, leaves number, shoots number, dry shoot yield, tuber size, weight and diameter as well as total tuber yield as compared with the untreated plants in both seasons. These results are in agreement with those obtained by Alva 2004 and White *et al*., 2007, Zelalem *et al*., 2009 and Saeidi *et al*. (2009a and 2009 b) who reported that the increase in nitrogen application amounts up to a definite point, increases growth parameters including tuber but beyond that, reversely decreases them. Over-application of nitrogen may result in a decrease in yield. This may attribute to the fact that in such conditions, vegetative growth of the aerial parts can be increased and hence, prevented transferring of photosynthetically matters into the storage parts (Tubers). Marguerite *et al*. (2006) and Alam *et al*., (2007) revealed that tuber yield per unit area was increased with increasing nitrogen fertilizer up to suitable level.

Data also demonstrated that application of foliar spray with selenium gave an increase in all growth characters as compared with the control which was in agreement with obtained results by Marja Turakainen *et al*., 2004 Germ *et al*., 2007and Ozbolt *et al*., 2008. The highest value was noticed with selenium applied at rate of 20g of Se fed^{-1} as compared with 40g of Se fed^{-1}. The results achieved by Hartikainen *et al.* (2000) could confirm the fact that selenium interaction with plants depends on its concentration. At lower rates, selenium stimulated growth of ryegrass seedlings, while at high doses it acted as pro-oxidant reducing yields and inducing metabolic disturbances Also, Barbara Hawrylak-Nowak (2008) revealed that disturbances of growth and reduction of plant's biomass at the presence of high selenium concentrations in the nutrient solution may have resulted from the disturbance of mineral balance of plants, namely accumulation of large amounts of phosphorus in shoot tissues of maize.

With regard to the interaction between foliar spray of selenium (20 and 40g Se fed^{-1}) and different rates of nitrogen (0,150,200 and 250 kg fed^{-1}), data presented in Table (2) revealed that fertilizers with different nitrogen rates as well as selenium spray at the two levels significantly promoted growth parameters compared with N and/or Se spray alone treatment. Increased yield of Se treated plants suggested that Se may enhance the translocation of photoassimilates for tuber growth, acting as a strong sink for both Se and for carbohydrates. The positive impact of Se on the yield of potato plants could be related to its antioxidative effect in delaying senescence.

Foliar application of selenium at a rate of (20 g Se fed^{-1}) with different nitrogen rates were more effective compared to selenium (40 g Se fed^{-1}) with nitrogen rates. The highest value of this characteristic as affected by nitrogen and/or selenium spray was in agreement with data obtained by Marja Turakainen *et al*., 2004.

Tuber Quality Parameters:

Specific gravity is considered an important quality character particularly for chips and flour making industries. It generally tends to decrease with increasing rate of N fertilizer (Tables 3). The highest specific gravity (1.071) was recorded with application 200 kg N fed^{-1} and the lowest specific gravity (1.062) with application of 250 kg N fed^{-1} in both seasons. These results are in a good harmony with (Westermann *et al.* 1994, Ram and Moha 2004 and Zelalem *et al*., 2009) who mentioned that interaction effect between N fertilizer levels and foliar spray of selenium on specific gravity was significantly increased as compared with nitrogen and/or Se alone. Increasing levels of Nitrogen and foliar spray of selenium (40 g Se fed^{-1}) decreased specific gravity in both seasons.

Data in table (3) showed the contents of potato tubers of nitrogen, protein, starch and total carbohydrates as affected with nitrogen and selenium applications. Data indicated that nitrogen application significantly increased those characters over the control plants in both seasons which was in agreement with obtained results of Yibekal (1998), Waddell, *et al*., (1999) and Kara, (2002).

It is evident that protein content (%) of tubers was significantly increased with increasing nitrogen dose. This significant effect on protein % could be related to the vital role of N in plant that associated directly and indirectly with protein synthesis. Erdoğan *et al*., (2010) found that protein content of tubers was significantly increased with increasing nitrogen dose.

Table 2: Effect of nitrogen fertilizer rates and foliar spray of selenium on vegetative growth and tubers yield of potato plants during two seasons(average of two seasons).

Treatments		Plant height (cm)	Number of		Dry shoot yield Ten/fed	Diameter of tuber (cm)	Size of tuber (cm^3)	Weight of tuber (gm)	Tuber yield Ten/fed
N (kg/fed)	Se (g /fed)		leaves	shoots					
0	0	48.7	12.3	5.4	0.536	4.4	97	84	6.58
	20	52.8	14.1	6.0	0.569	4.8	110	98	7.11
	40	54.1	14.7	6.7	0.571	4.6	105	101	7.54
150	0	67.3	14.7	7.1	0.748	6.3	153	120	9.11
	20	70.2	16.8	7.9	0.773	7.6	158	130	10.04
	40	75.9	18.2	8.4	0.844	7.3	151	127	9.30
200	0	73.1	17.8	8.9	0.853	6.8	162	135	9.81
	20	88.3	22.0	13.5	0.938	8.7	173	148	11.33
	40	84.0	20.3	11.8	0.863	7.5	161	142	10.74
250	0	70.6	16.0	8.3	0.871	5.7	157	125	9.23
	20	80.4	20.3	9.4	0.989	8.1	165	136	10.57
	40	84.3	18.6	11.1	0.883	7.1	158	130	9.41
LSD 0.05									
N		3.82	2.26	0.99	.031	0.52	5.32	5.55	1.31
Se		3.31	1.96	0.86	0.003	0.45	4.61	4.81	N.S
N x Se		6.61	3.93	1.72	0.05	0.91	9.22	9.61	2.27

Concerning the interaction between N rates and foliar spray of selenium, data showed a significant increase in protein content in tubers of potato due to N and Se interaction over the control plants. These results are in agreement with Munshi, *et al.* (1990) who found that application of selenium increased protein content in tubers of potato.

Data also showed that increased application levels of nitrogen, can lead to lower starch content in tubers (Burton 1989and Erdoğan *et al*., 2010). In physiologically older tuber, the amyloplast membrane becomes more permeable due to oxidative damage and thus it is not able to protect starch against enzymatic degradation (Knowles and Knowles 1989). In addition, starch reserves in tubers are mobilized to support sprout growth, which in turn promotes further ageing of tubers (Kumar and Knowles 1993). The previous data revealed that starch was significantly affected by interaction between N rates and foliar spray of selenium which led to an increase of starch comparing with control treatment. These results are in agreement with Marja Turakainen, *et al.* (2004) they found that in young potato plants Se promoted starch accumulation in the upper leaves and later in mature roots. The maximum value was observed with 200 kg N $fed^{-1}$and 20 g Se fed^{-1} (11.50% in protein and 14.00% in starch).

Table 3: effect of nitrogen fertilizer rates and foliar spray of selenium on protein%, starch% and Total carbohydrates% of tubers potato plants during two seasons(average of two seasons).

Treatments		Specific gravity (g/cm^3)	Protein	Starch	Total carbohydrates
N (kg/fed)	Se (g /fed)		%		
0	0	1.045	6.31	6.84	35.14
	20	1.047	8.25	7.23	38.38
	40	1.050	7.81	7.83	38.00
150	0	1.066	9.00	11.02	40.59
	20	1.073	10.69	12.41	43.00
	40	1.070	10.00	11.81	42.44
200	0	1.071	9.44	12.01	44.87
	20	1.081	11.50	14.00	48.98
	40	1.072	11.13	12.21	46.12
250	0	1.062	9.25	10.22	42.30
	20	1.076	10.38	13.01	45.83
	40	1.070	10.00	11.81	44.28
LSD 0.05					
N		N.S	0.44	0.54	2.22
Se		N.S	0.38	0.47	1.92
N x Se		N.S	0.77	0.94	3.85

According to the obtained results, Se application significantly increased total carbohydrates %. This assumption is supported by the recent results of Marja Turakainen, *et al.* (2004) who suggested that Se led to retarded senescence of potato plants as demonstrated by elevated carbohydrate concentration in aged roots and shoots.

Chemical Composition:

Results in Table (4) showed the effect of N application and foliar spray of selenium on protein%, starch% and Total carbohydrates% of tubers potato plants in both two seasons present. Data indicated that all treatments tended to increase nitrogen, phosphorus and potassium content (%) and uptake (kg fed^{-1}) in shoots and tubers of potato as compared with the control treatments in both seasons. Our results cooperate with the findings of Alam, *et al.* 2007, and Erdoğan Öztürk, *et al.* (2010).

Data also showed that applied nitrogen at a rate of 200 kg fed^{-1} without selenium gave significant increase in nitrogen content % and uptake (kg fed^{-1}) of shoots and tubers of potato plants which was in agreement with obtained results of Love, *et al.* 2005 and Haase, *et al.* 2007. From the data recorded in Table(4) , it can be seen that application of nitrogen at a rate of (200 kg fed^{-1}) with selenium at rate of 20 g Se fed^{1} gave high significant increase in N content parallrd to nitrogen applied at a rate of 200 kg fed^{-1} with selenium at rate 40 g Se fed^{-1} in both seasons . These results are in agreement with Mahendra Singh (1979) who found that N concentration was decreased with increasing Se application.

Table 4: effect of nitrogen fertilizer rates and foliar spray of selenium on N, P, and K content (%) and uptake (kg fed-1) of shoots and tubers potato plants during two seasons(average of two seasons).

Treatments		N		P		K		N		P		K	
N (kgfed^{1})	Se (g fed^{-1})	%						Uptake kg fed^{-1}					
		shoots	tubers	shoots	tubers	shoots	tubers	shoots	tubers	shoots	tubers	shoots	tubers
0	0	2.11	1.01	0.25	0.19	2.87	2.07	11.31	66.46	1.34	12.50	15.38	136.21
	20	2.30	1.32	0.33	0.25	3.24	2.22	13.09	93.85	1.88	17.78	18.44	157.84
	40	2.42	1.25	0.40	0.26	3.11	2.15	13.82	94.25	2.28	19.60	17.76	162.11
150	0	2.40	1.44	0.33	0.24	3.10	2.18	17.95	131.18	2.47	21.86	23.19	198.60
	20	2.71	1.71	0.30	0.24	3.51	2.34	20.95	171.68	2.32	24.10	27.13	234.94
	40	2.60	1.60	0.47	0.28	3.33	2.40	21.94	148.80	3.97	26.04	28.11	223.20
200	0	2.57	1.51	0.38	0.28	3.42	2.41	21.92	148.13	3.24	27.47	29.17	236.42
	20	3.01	1.84	0.42	0.28	3.81	2.71	28.23	208.47	3.94	31.72	35.74	307.04
	40	2.89	1.78	0.55	0.31	3.62	2.64	24.94	191.17	4.75	33.29	31.24	283.54
250	0	2.61	1.48	0.32	0.26	3.38	2.20	22.73	136.60	2.79	24.00	29.44	203.06
	20	2.84	1.66	0.38	0.26	3.56	2.44	28.09	175.46	3.76	27.48	35.21	257.91
	40	2.66	1.60	0.44	0.28	3.44	2.20	23.49	150.56	3.89	12.50	30.38	207.02
LSD 0.05													
N		0.21	0.07	N.S	N.S	0.16	0.13	0.87	6.55	0.16	1.04	0.56	21.53
Se		0.18	0.16	N.S	N.S	0.15	0.11	0.76	5.67	0.14	0.91	0.48	18.64
N x Se		0.37	0.13	N.S	N.S	0.22	0.23	1.52	11.34	0.29	1.81	0.97	37.29

Regarding P concentration in shoots and tubers of potato plants treated with selenium and nitrogen fertilizer doses it has been denoted that the phosphorus percentage in shoots and tubers was increased under all treatments compared to the control treatment (Table 4**.** The highest level of P was recorded at 200 kg N fed^{-1}use and 40 g Se fed^{-1} (0.55% in shoots and 0.31 % in tubers).The same trend was observed with P uptake. Phosphorus in dry matter manifested an increasing content and uptake tendency along with an increase in the selenium concentration these results are of agreement with Barbara Hawrylak-Nowak (2008). who recorded increased phosphorus content in plants cultivated at the presence of selenium.

It is evident from the obtained data in Table (4) that potassium content and uptake were slightly increased with increased N applied .Data also indicate that selenium at rate of 20 g Se fed^{-1} more effective on K content than selenium at rate of 40 g Se fed^{-1} . Positive effects of selenium on potassium accumulation were also observed by Pazurkiewicz-Kocot *et al.* (2003), who found that the content of potassium in maize leaves significantly increased when introducing 10 µmol Se dm into the medium, but a contrary dependence was recorded in roots KOPSELL *et al.* (2000) revealed that potassium level in cabbage leaves was linearly increased along with the increase in selenium spray concentration in the medium rose.

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