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Fertilization Effects on Potato Yield and Quality

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ABSTRACT

At Agricultural Research Station Farm, Giza Governorate, Egypt, two field experiments were carried out during two successive winter seasons of 2013/2014 and 2014/2015 to study the effect of nitrogen (0, 90, 120 and 150 kg fed^{-1}.), potassium (0, 72 and 96 kg K_2O fed^{-1}) fertilizer rates and foliar application of boron in sthe form of H_3BO_3 (0 and 100 ppm) as well as their interactions on potato yield and its quality (*Solanum tuberosum* L.) cv. Spunta cultivar. A split-split-plot system in a randomized complete blocks design with three replicates was used in this respect. The obtained results indicated that significant increase in no. of tubers/plant, average tuber weight (g) and tuber yield was observed with 150 kg N fed^{-1} over control. Increase in tuber yield with 96 kg K_2O fed^{-1} was statistically significant compared to other treatments. The quality parameters like dry matter, specific gravity, total carbohydrate, reducing sugar and starch contents were improved with both nitrogen and K application. Spraying potato plants with boron at a rate of 100 ppm significantly increased yield and its components as well as quality of tubers. Interaction treatments among different rates of nitrogen, potassium fertilization and boron foliar application were significant on potato yield and quality. In general, the best interaction treatment among different rates of nitrogen, potassium fertilization and foliar application of boron was fertilization with 150 kg N fed^{-1} in the form of ammonium sulphate, 96 kg K_2O fed^{-1} in the form potassium sulphate and foliar application of boron to improve both yield and quality of potato crop as compared with other treatments.

Keywords: boron foliar application, nitrogen, potato plants, potassium fertilization, yield and its components.

INTRODUCTION

Potato (Solanum tuberosum L.) is one of the most important food crops as a member of the family solanaceae all over the world including Egypt. It ranks the first export and the second vegetable crop in energy. Potato require huge amounts of N and P fertilizers for optimum growth, production and tuber quality (Al-Mosbileh and Errebi, 2004).

Nitrogen supply plays a paramount part in the balance between vegetative and its reproductive for potato (Alva 2004). Suitable nitrogen administration is one of the most important agent required to obtain high yields with superior potatoes quality. An adequate early season N supply is remarkable to support vegetative growth, but too much soil N later in the season will repress tuber initiation, decrease yields, and reduce the specific gravity in some cultivars. A lot of previous studies have shown that application of nitrogen fertilization can increase total and/or marketable tuber yield (Kara 2002; Zebarth *et al.* 2004 and Zelalem *et al.* 2009).

Potassium is one of fundamental element required for plant growth and production. It is labeled as a macronutrient as nitrogen and phosphorus. It has a function vital part in photosynthesis, carbohydrate transport, formation of protein, ionic balance control, water use activation and regulation of plant stomata of plant enzymes (Munson *et al.*, 1985). According to Abd El-Aal *et al.* (2008) studied the addition of K at 90 units/fed and resulted in the best values of plant growth, average number of shoots, leaves number as well as fresh and dry weight and gave heaviest tuber yield as well as number and size of tuber per plant and raised, the concentration of the nutrient elemental in tubers yield tissues.

Boron is one of mineral nutrients that are wanted for natural plant growth. The substance of B for growth and evolution of higher plants has been earlier confirmed (Marschner, 1995). The boron main functions relate to development and cell wall strength, fruit and seed development, cell division, hormone development and sugar transport. Some boron functions connected with those of N, P, K and Ca in plant. The most suitable boron functions in plants are thought to be its structural role in cell wall development; and inhibition of specific metabolism pathways or stimulation.

The objective of the present study is to evaluate the effect of different levels of nitrogen and potassium fertilizer and foliar application of boron as well as their interactions on yield and quality of potato plants (Solanum tuberosum L.) cv. Spunta.

MATERIALS AND METHODS

Two field workout were managment to study the effect of nitrogen, potassium fertilizer rates and foliar application of boron as well as their interactions on yield and its components of potato plants (Solanum tuberosum L.) cv. Spunta cultivar. The experiment were carried out during the two successive winter seasons 2013/2014 and 2014/2015. Representative soil surface sample (0-30 cm) was taken from the experimental location before planting and prepared to define some chemical and physical properties according to Page *et al.*, (1982) and Klute (1986) as shown in Table (1). The experimental layout was a randomized complete blocks design in a split-split-plot system with three replications. Nitrogen fertilizer levels were arranged as the main plots, potassium fertilization treatments were assigned at random in sub-plots, whereas the boron treatments were allocated in the sub-sub–plots. The experimental unit area was 10.5m2 (1/400fed.). The treatments were as follows:

Ammonium sulphate (20.5%N) as a form of nitrogen fertilizer, potassium sulphate (48% K_2O) as a form of potassium fertilizer, were applied at three equal applications; after 30, 45 and 60 days from planting. A seasonal total of 72 Kg P_2O_5 fed^{-1}, as calcium superphosphate (15.5% P_2O_5), was broadcasted during soil preparation. Boron was applied as foliar spray added three times; 45, 60 and 75 days after planting in the rate of 400L/fed.

Potato tubers (*Solanum tubersum* L.); cv. sponta were used in this study. Seeds were planted on the first week of November 2013 and 2014, respectively.

Measurements

Tuber yield:

Tuber number/plant, average tuber weight (g), and total yield/plant (g) were measured by counting and weighing tubers of 10 plants. Total tuber yield (ton/fed) was calculated from tuber yield per plant.

Table 1. Physical and chemical properties of the experimental soil (Average of two years)

Soil properties		Value
Particle size distribution %	Coarse sand	5.8
	Fine sand	9.0
	Silt	38.3
	Clay	46.9
	Textural class	Clay
	Chemical analysis	
EC (dSm^{-1})(soil past extract)		2.60
pH(1:2.5, soil suspension)		8.09
Organic matter (%)		1.7
Total CaCO3 (%)		2.8
Soluble anions (meq/L)	$CO_3^{=}$	-
	HCO_3^-	2.91
	Cl^-	15.1
	$SO_4^{=}$	7.99
Soluble cations (meq/L)	Ca^{++}	9.21
	Mg^{++}	2.84
	Na^+	11.9
	K^+	2.05
Available macronutrients (mg/kg soil)	N	40.8
	P	10.7
	K	386.6
Available Micronutrients (mg/kg soil)	Fe	3.74
	Mn	1.94
	Zn	0.88
	B	0.14

Factor A: Nitrogen fertilizer (4 levels) N_0 - Control (No nitrogen)
N_1 - 90 kg N fed^{-1} N_2 - 120 kg N fed^{-1} N_3 - 150 kg N fed^{-1}
Factor B: Potassium fertilizer (3 levels)
K_0 - Control (No potassium) K_1 - 72 kg K_2O fed^{-1}
K_2 - 96 kg K_2O fed^{-1}
Factor C: Born as foliar application (2 levels)
B_0- Control (No Born) B_1-100 $mgkg^{-1}$ in the from H_3BO_3

Tuber quality characteristics:

Quality parameters analyzed included starch, reducing sugars, specific gravity, total carbohydrate and dry matter content. Total carbohydrates were determined by using a colorimetric method as described by Dubois *et al.* (1956). Total dry matter was determined by oven drying at 70°C to constant mass. As for reducing sugar described by Naguib (1964).

Tuber dry matter: To determine, tuber dry matter percent, five tubers representing all size categories of the variety, were chopped into small 1-2 cm cubes, mixed thoroughly, and two sub-samples each weighing200 g were weighed. The exact weight of each sub-sample was determined and recorded as fresh weight. Each sub-sample was placed in a paper bag and put in an oven drying at 70°C until constant dry weight was attained after checking the weight at intervals. Each sub- sample was immediately weighed and recorded as dry weight. Then, per cent dry matter content for each sub-sample was calculated [(International Potato Centre (CIP)] (2006). The dry matter percentage was calculated according to Williams and Woodbury, (1968).

Dry matter % = (weight of sample after drying (g))/ (intial weight of sample (g) X 100.

Specific Gravity (SG): 10 tubers were sampled per plot from the first category to determine the specific gravity using the method of weight in water (Ww) and weight in air (Wa). The SG was calculated by Talburt and Smith (1975). [SG = Wa/ (Wa - Ww)].

Percentage of starch content in tuber was determined according to A.O.A.C (1995).

Statistically analyzed of all data were according to the technique of analysis variance (ANOVA). Also, the least significant difference (L.S.D) method was used to compare the deference between the means of treatment values to the methods described by Gomez and Gomez, (1984). All statistical analyses were outright using analysis of variance technique by means of CoSTATE Computer Software.

RESULTS AND DISCUSSION

I. Tuber yield and its attributes number of tuber $plant^{-1}$

Effect of nitrogen rates on number of tuber $plant^{-1}$

The variation in the number of tuber $plant^{-1}$ was highly significant due to the effect of nitrogen rates. The maximum number of tuber $plant^{-1}$ (11.00) was recorded at 150 kg/fed of nitrogen and the lower number (3.67) was obtained from the control treatment (Table 2). Increasing in tuber number was observed in response to N could be attributed to an increase in stolon number through its effect on gibberellins biosynthesis in the potato plant (Alemayehu *et al.,* 2015). Nitrogen is one of the main element which has direct part in vital roles in chlorophyll synthesis and growth processes especially the vegetative growth parameters of plants. In agreement with the present finding, a significant increment in tuber number in response to nitrogen application was reported by Jafari-Jood *et al.,* (2013).

Effect of potassium rates on tubers number $plant^{-1}$

Regarding the effect of potassium fertilization levels, the obtained results showed that increasing potassium fertilization level from 0.0 up to 96 kg K_2O/fed significantly increased the number of tuber plant-^{1}. The highest average tuber numbers per plant was described at 96 kg K_2O/fed and lowest at K_0. Potassium is an important element for all plants and has a major effect upon growth and yield of potatoes as well as the general health and vigor of the crop (Abd El-Latif *et al.,* 2011). It is also involved in enzymes activation significant to utilization of energy, synthesis of starch, metabolism of N, and respiration. These enzymes are numerous in the meristematic tissue at the growing points (like sprouting tuber eyes) where cells are dividing and primary tissues are formed (Havlin *et al.,* 2005).

Effect of boron on number of tubers $plant^{-1}$

Table (2) illustrates that applied of boron significantly increased number of $tubers.plant^{-1}$ compared to control. Application of boron and in this experiment significantly improved growth parameters of potato plants as compared with control plants. These results could be attributed to the effective role of boron in controlling various enzymes activities and photosynthetic pigments formation, consequently affecting plant growth. The finding was also supported by Bari *et al.* (2001).

Influence of nitrogen and potassium rates on number of tuber $plant^{-1}$

It is apparent from data in (Table 2) that different nitrogen and potassium rates influenced significantly on number of tubers.plant-^{1}. Application of 150 kg/fed of nitrogen along with 96 kg K_2O/fed significantly increased the number of tuber $plant^{-1}$ and these interaction treatments found significantly superior to rest of combination treatments regarding number of tuber $plant^{-1}$. The increase in number of tuber plant-^{1} supplemented with nitrogen fertilizer may be due to the availability of mineral nitrogen to potato plant root, which ultimately resulted in better root growth and increased mineral absorption that lead to increase number of tuber plant^{-1}and this in turn increased total yield. This might be due to positive response shown by yield characters to potassium could be directly linked by well development of photosynthetic and increased physiological activities leading to more assimilates and improved the translocation accumulation of sugars in development of tubers this was reported by Moniruzzamman *et al*., (2013).

Table 2. Effect of levels of nitrogen and potassium levels with or without boron and their interactions on number of tuber plant^{-1}, average tubers weight (g) and tuber yield (ton fed. $^{-1}$). (Average of two years)

Treatments		No of tubers /plant			Average tuber weight (g)			Yield tuber (ton/fed)		
N-levels kg/fed	K-levels kg/fed	- B	+ B	Mean	- B	+ B	Mean	- B	+ B	Mean
N_0	K_0	3.67	4.00	3.83	97.33	107.67	102.50	4.57	5.05	4.81
	K_1	4.33	4.67	4.50	113.17	121.00	117.08	5.49	5.81	5.65
	K_2	5.00	5.33	5.17	127.00	132.00	129.50	6.70	6.91	6.81
	mean	4.33	4.67	4.50	112.50	120.22	116.36	5.59	5.92	5.76
N_1	K_0	5.67	6.00	5.83	138.67	144.00	141.33	7.58	8.33	7.95
	K_1	6.33	6.67	6.50	153.33	159.00	156.17	8.84	9.17	9.00
	K_2	7.33	7.67	7.50	165.67	169.00	167.33	9.74	10.92	10.33
	mean	6.44	6.78	6.61	152.56	157.33	154.94	8.72	9.47	9.09
N_2	K_0	8.00	8.67	8.33	174.00	177.33	175.67	11.67	12.40	12.04
	K_1	9.00	9.67	9.33	180.00	186.33	183.17	12.79	13.07	12.93
	K_2	10.00	11.33	10.67	191.67	193.33	192.50	13.58	13.91	13.75
	mean	9.00	9.89	9.44	181.89	185.67	183.78	12.68	13.13	12.90
N_3	K_0	11.00	12.00	11.50	197.33	202.33	199.83	14.03	14.58	14.30
	K_1	12.67	13.00	12.83	213.00	223.33	218.17	15.35	16.58	15.96
	K_2	13.67	14.00	13.83	226.67	230.00	228.33	17.21	17.78	17.50
	mean	12.44	13.00	12.72	212.33	218.56	215.44	15.53	16.31	15.92
Average K levels	K_0	7.08	7.67	7.38	151.83	157.83	154.83	9.46	10.09	9.78
	K_1	8.08	8.50	8.29	164.88	172.42	168.65	10.62	11.16	10.89
	K_2	9.00	9.58	9.29	177.75	181.08	179.42	11.81	12.38	12.09
	mean	8.06	8.58	8.32	164.82	170.44	167.63	10.63	11.21	10.92
LSD at 5%	N (A)		0.65			18.33			0.62	
	K (B)		0.64			12.47			0.5	
	Boron (C)		0.42			10.3			0.53	
	A x B		1.29			24.94			0.99	
	A x C		0.83			21.37			1.06	
	B x C		0.72			n.s.			0.92	
	A x B x C		1.45			27.02			1.84	

Effect of interaction between nitrogen and Boron on number of tuber plant^{-1}

The interaction of the two factors clarifies that all plants responded positively and significantly to boron application with the highest significant effect recorded with nitrogen (Table 2) and Fig. (1). Treatment N_{150} plus B produced the maximum number of tubers plant^{-1} (12.00).The lowest number of f tuber plant^{-1} (3.67) was obtained from N_0B_0. These results could be attributed to the effective role of boron in controlling various enzymes activities and photosynthetic pigments formation, consequently affecting plant growth. Moreover, interaction between application of nitrogen and boron amended the growth traits of potato plants over those realized with addition of nitrogen alone. This result may be return to synergistic effects of nitrogen and boron, on other words joint application of these nutrients can be more active in plant growth stimulating than their single application.

Effect of interaction between potassium and Boron on number of tuber plant^{-1}

The interaction between potassium levels and boron revealed that the highest effect was recorded with the highest levels of potassium and sprayed with100ppm of boron (Fig. 2). Many researchers have proven the disturbance of many physiological process due to boron limitation (Tariq and Mott, 2007).

Influence of nitrogen, potassium rates and Boron on number of tubers plant^{-1}

Number of tubers plant^{-1}as shown by Fig. (3) was significantly affected by the interaction effect of nitrogen, potassium rates and boron. Where all interaction treatments significantly increased the average number of tubers.plant^{-1} compared to control.

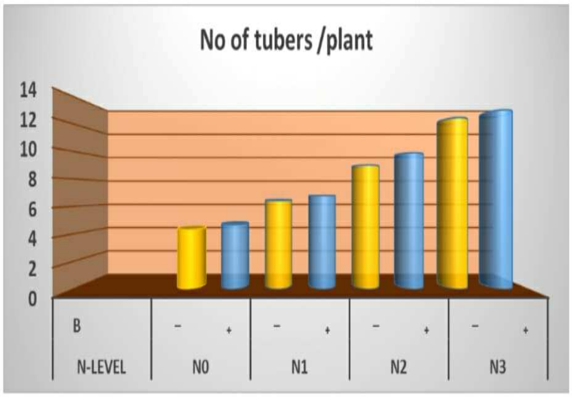

Fig. 1. interaction effect between nitrogen and Boron on number of tuber plant^{-1}

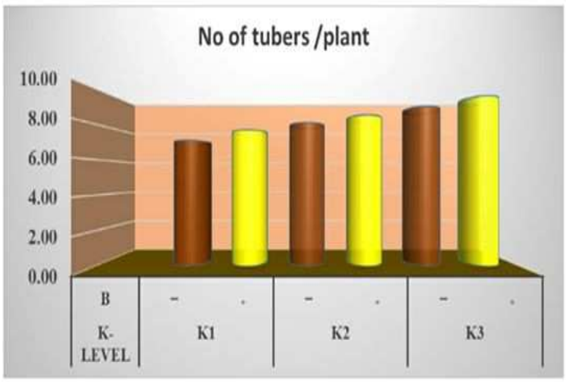

Fig. 2. interaction effect between potassium and Boron on number of tuber plant^{-1}

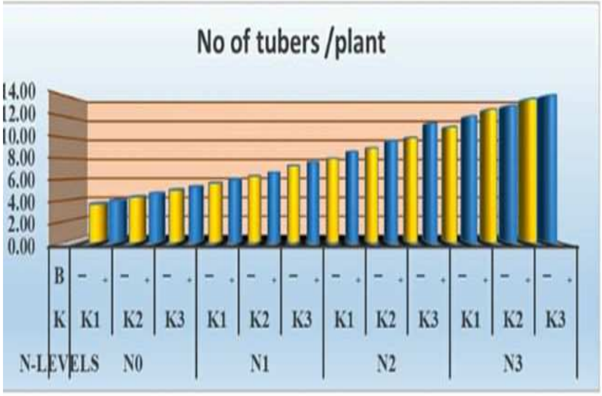

Fig. 3. Influence of nitrogen, potassium rates and Boron on number of tubers.plant^{-1}

2 Average fresh tuber weight (g)

Effect of nitrogen rates on average fresh tuber weight (g)

All applied nitrogen treatments increased significantly average fresh tuber weight (g) compared to control with superiority to the application rate of150 kg N fed^{-1} (Table2). The stimulatory effects of N on average of tuber weight might be attributed to the effect of N on plant growth which, in return improve the production of more photosynthesis required for tuber development and formation. These results agreed to a great extent with those reported by (Patricia and Bansal, 1999).

Effect of potassium rates on average fresh tuber weight (g)

The effect of potassium fertilizer rates had highly significantly effect on average tuber weight, as the K fertilizer rate increased the average tuber weight increased (Table 2) .The significance of potassium application was observed between fertilizer rates and the control and among the rates. The highest average tuber weight (177.75 g) was obtained at rate of 96 Kg K_2O/fed., whereas the lowest average tuber weight (97.33g) was obtained at the control (Table 2). In line to this study, Jenkins and Mahmoud (2003) reported that the average tuber weight was generally much greater when all the three nutrients were supplied at a higher level. In addition, Panique *et al.* (1997) reported that significant increase was happened in the average tuber weight in response to the application of potassium. The increase in average tuber weight of tubers in response to the increased supply of fertilizer nutrients could be related to more more foliage, leaf area, luxuriant growth and higher supply of photosynthesis which may have induced formation of bigger tubers, thereby resulting in higher yields (Patricia and Bansal, 1999).

Effect of boron on average fresh tuber weight (g)

Data in Table (2) indicated that average fresh tuber weight was better with spraying the plants with boron. These result of increase might be due to the suitable role of the used boron in photosynthesis activation, pigments formation and carbohydrates assimilation transfer to the tuber which represent economic part of plant (Marschner, 1995).

Influence of nitrogen and potassium rates on fresh tuber weight

Average fresh tuber weight as shown in (Table 2) responded to the interaction between nitrogen and potassium levels. The interaction effect showed that all treatments were significantly higher than control. The favorable effect of mineral nitrogen fertilizer on fresh tuber weight could be explained through the great role of these fertilizers in enhancing plant growth rate, which exert direct effect on the yield and its components. These results are in harmony with those obtained by Ashour *et al.,* (1997) and Brar (2006).

Influence of nitrogen and boron on Average fresh tuber weight (g)

Data in Table (2) and Fig. (4) indicated that average weight of tuber was significantly increased with application nitrogen and boron. There were positive and significant differences among the different levels of nitrogen and foliar application of boron in respect to average weight of tuber. Average weight of tuber was significantly affected by different levels of nitrogen (Table 2). Plant receiving N at the rate of 150 kg fed-1 produced significantly higher weight of tuber (197.33g) while the lowest weight of tuber (97.33g) was recorded in control treatment. Absence of boron (B0) gave the lowest weight of tuber (97.33g) while 100ppm boron gave the highest weight of tuber (107.67g). The combined effect of N and B on weight of tuber of potato was significant. The highest average weight of tuber (202.33g) was obtained with the application of N3B. On the contrary the lowest average weight of tuber (97.33) was obtained from N0B0. Improvement of growth parameters and increasing of dry matter accumulation in various plants through nitrogen and boron application has earlier been reported by Bari *et al.* (2001).

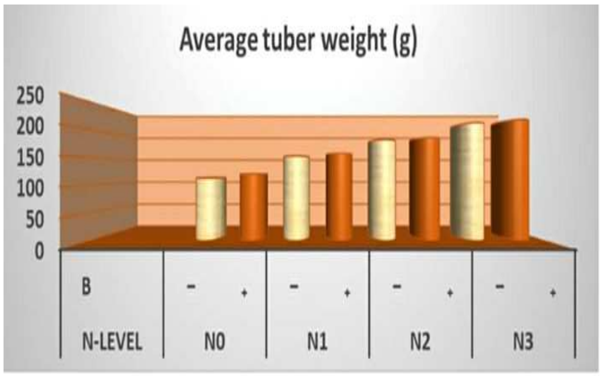

Fig. 4. Interaction effect of nitrogen and boron on Average fresh tuber weight (g)

Influence of potassium and boron on Average fresh tuber weight (g)

The combined effect of potassium and boron on average fresh tuber weight of potato was not significant (Table 2).

Influence of nitrogen, potassium and boron on fresh tuber weight (g)

Different treatment combinations of nitrogen, potassium and boron had significant effect on average fresh tuber weight as shown in Table (2) and Fig. (5). The highest average fresh tuber weight (230.00 g) was recorded in N150 K96 plus boron treatment, which was highly significant compared to other treatments while the lowest average fresh tuber weight (97.33g) was found by the control treatment. These increases may be due to potassium role in physiological processes inside the plant as photosynthesis; increasing enzyme activity (K is required as Co-factor for different enzymes, it also helps to maintain electro neutrality in plant cells), improving synthesis of protein, carbohydrates and fats, translocation of sugars and enabling their ability to resist pests and diseases (Dkhil *et al.* 2011). Also, foliar spray of potato with boron led to significant increases in average fresh tuber weight as compared with the control.

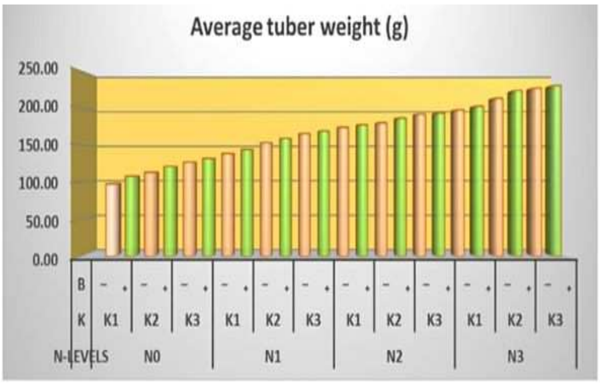

Fig. 5. Interaction effect of nitrogen, potassium and boron on Average fresh tuber weight (g).

3 Tuber yields

Effect of nitrogen rates on Tuber yields

Increasing the application rates of nitrogen resulted in increasing the total tuber yield from 4.57 to 14.03 ton fed^{-1} (Table 2) and Fig. (6). The highest yield was obtained at 150 kg N fed^{-1} and lowest tuber yield was recorded in N_0 (4.57 t fed^{-1}). This effect might be due to application of higher dose of nitrogen which would have helped in increasing growth and higher supply of photosynthesis that may led to increase the tuber weight, tuber diameter and number of tubers. Similar results were also observed by (Sanjana *et al.*, 2014 and Alfred *et al.*, 2000). Our result are agree with those Mulubrhan (2004) and Zelalem *et al.,* (2009).

Effect of potassium rates on tuber yields

The effect of different levels of potassium on tuber yields was significant (Table 2). Tuber yields gradually increased with increasing levels of potassium up to 96 Kg K2O/fed treatment. The highest tuber yields (11.81 t fed-1) was obtained with the application of 96 Kg K2O/fed., which was statistically different from other treatments. The lowest tuber yields (4.57 t fed-1) was produced by control treatment. It was observed that the application of potassium up to 96 Kg K2O/fed increased tuber yields that is in harmony with this study, Eremeev *et al.* (2009) and Eleiwa *et al*., (2012). The role of K in increasing the yield and its components might be attributed to its function in plants which includes energy metabolism and enzyme activation that increase exchange rate and nitrogen activity as well as enhance carbohydrates movement from shoots to storage organs. Potassium application enhanced the stomata resistance coupled with reduced transpiration rate and increased relative water content, thus, may improve water storage capacity of the cells and providing favorable conditions for better yields (Umar and Bansal 1995). They found that application of potassium increased CO2 assimilation and photosynthetic rate. Application of potassium increased photosynthesis that increase nutrient translocation from the upper parts of plant to be accumulated in the tubers.

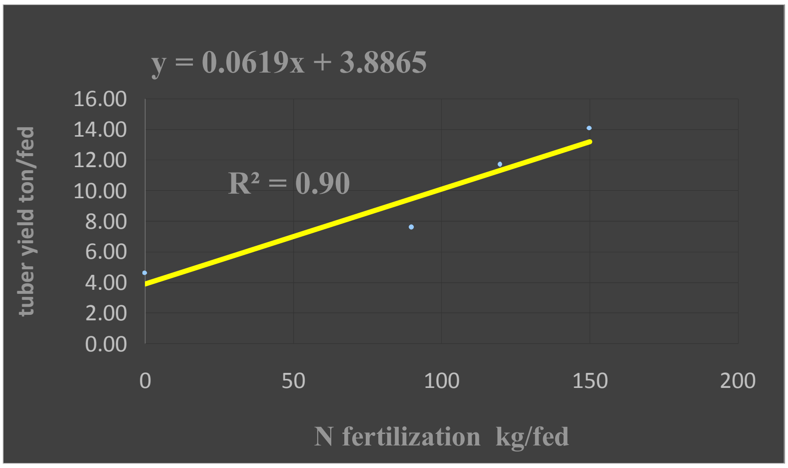

Fig. 6. Effect of N rates on tuber yield ton /fed

Effect of boron on tuber yields

Potato tuber yield as shown by Table (2) was significantly affected by the treatments where boron treatment significantly increased that parameter compared to control. These increases might be due to the suitable role of the used boron in pigments formation, photosynthesis activation and carbohydrates assimilation diverted to the tuber which represent economic part of plant (Marschner, 1995).

Effect of interaction between nitrogen and Potassium rates on tuber yields

The combined effect of nitrogen and potassium on tuber yield of potato was significant (Table 2). The highest tuber yield of potato (17.21 fed-1) was recorded in N150K96 treatment, which was statistically different from other treatment combinations. The second highest tuber yield of potato (15.35t fed-1) was found in N150 K72 treatment combination, which was also significantly different from other treatments. The lowest tuber yield of potato (4.57 t fed-1) was noted in control treatment where neither N nor K was added. Potassium along with nitrogen plays a major role in growth and yield as they are involved in assimilation, transportation and storage at the time of photosynthesis and the effect of N and K interaction in potato yield was reported by Susan Johan *et al*., (2013). The increase in yield and size of tuber could not only by the effect of K fertilizer but also its combination with N was reported by Pushpalatha *et al*., (2017).

Effect of interaction between nitrogen and Boron on Tuber yields

With regard to the interaction between foliar spray of boron and different rates of nitrogen (0, 90,120 and 150 kg fed-1), data presented in Table (2) revealed that the combined effect of N and B on tuber yields was significantly increased. The highest tuber yield of potato (14.58t/fed) was recorded in N150 plus B treatment. The lowest tuber yield of potato (4.57t fed-1) was noted in control treatment where neither N nor B was added. This positive effect of boron application may be attributed to boron role in cell wall synthesis, cell division, cell development and auxin metabolism (Mengle and Kirkby 1978).

Effect of interaction between potassium and Boron on Tuber yields

With regard to the interaction between foliar spray of boron and different rates of potassium (0, 72 and 96 kg K2O fed- 1), data presented in Table (2) revealed that fertilization with different potassium rates as well as boron spray significantly promoted tuber yields and its components compared to potassium or boron spray alone treatment. The positive effect of potassium, boron and its combination treatments on potato tuber yield and its components could be interpreted by multiple physiological functions of both elements. Potassium has a crucial role in the energy status of the plant, translocation and storage of assimilates and maintenance of tissue water relations (Marschner, 1995). The ability of potassium to improve potato tuber yield and its components was reported by Kumar *et al*., (2007). Also, it has roles in cell elongation and nucleic acid synthesis (Shelp, 1993).

Effect of interaction among nitrogen, potassium and Boron on Tuber yields

The interaction effect of nitrogen, potassium and boron was significant on tuber yields. Tuber yield was significantly increased with increasing levels of N up to level (150 kg fed-1). Application of 150 kg N fed-1 produced the highest tuber yield (14.03 t.fed-1) which was significantly different from other treatments of nitrogen (Table 2). The lowest tuber yield (4.57t fed-1) was obtained in control treatment. The combined effect of nitrogen, potassium and boron on tuber yield was significantly influenced. The highest tuber yield (17.78 t fed-1) was recorded in N3K2 plus B treatment, which was statistically different from other treatment combination. The lowest tuber yield (4.57 t fed-1) was noted in control treatment where neither of them (N, K and B) was added.

II. Quality parameters of potato tubers

1 Effect of nitrogen on specific gravity, starch, and dry matter percentage

Data presented in Table (3) clearly that the price of potato tubers is usually determined based on a combination of yield and tuber quality factors such as tuber specific gravity, starch, and dry matter percentage. In this study, specific gravity, starch and dry matter contents increased with N application rates. There was a positive and significant difference among the different levels of nitrogen in respect to starch, specific gravity, and dry matter content. Specific gravity increased with increasing levels of nitrogen up to higher level. The highest specific gravity (1.086 gcm-3) was produced with 150 kg N/fed and the lowest specific gravity (1.041 g cm-3) was found in control treatment. The effect of N on starch was influenced significantly (Table 3) while the highest starch content (15.73%) was recorded from the treatment of 150 kg N/fed and the lowest starch content (13.31%) was found in control treatment. Also, the increasing in dry matter content recorded with the application of N up to 150 kg N/fed which was from 18.42 to 23.88% in potato.

2 Effect of potassium on specific gravity, starch and dry matter percentage

The specific gravity as a quality measure related to the dry matter contents was positively affected by K fertilization Table (3). The dry matter was higher in potato harvest from the plots treated with 96 kg K2O fed- 1 than those of control. A large increase in tuber starch was recorded with 96 kg K2O fed−1. Specific gravity values ranged from 1.069 g cm-3 to 1.088 g cm-3. The applied K improved starch synthesis as it is involved in the activation of the enzyme called starch synthase, responsible for starch synthesis. It is the most suitable efficient cation stimulating the activity of this enzyme that catalyzes the incorporation of glucose into long-chain starch molecules (Mengel and Kirkby, 1978).

3 Effect of boron on specific gravity, starch and dry matter percentage

Data in Table (3) showed that values of all specific gravity, dry matter and starch content in tubers increased significantly with foliar application of boron. The highest dry matter (24.90 %) was recorded in T24 compared to control (18.42 %). Similar results were also reported by Bari *et al*. (2001) and Dissoky and Khader, (2013). The enhanced dry matter production may be attributed to greater accumulation of photosynthesis products by vegetative parts. These effects of boron foliar spray on the previous parameters of potato quality may be referred to the role of boron on sugar transport to parts of storage (tubers), also to its role in synthesis of proteins and regulation of carbohydrate metabolism. These results are in accordance with that obtained by Bari *et al*. (2001) and El-Banna and Abd El-Salsm (2005).

4 Effect of interaction between nitrogen and potassium rates on specific gravity, starch and dry matter percentage

The interaction between nitrogen and potassium fertilization did not significant influenced on specific gravity and dry matter percentage of tuber except for starch was significantly Table (3). The highest specific gravity, starch and dry matter percentage of tuber were obtained at the treatment combination of 150 kg N fed- 1 with high potassium rate of 96 kg K2O fed- 1 and the lowest at control.

5 Effect of interaction between N-levels and boron on specific gravity, starch and dry matter percentage

Data in Table (3) clearly showed that specific gravity and dry matter percentage by potato tubers were not significantly affected by the interaction between N-levels and boron except for starch content in tubers which was significant.

6 The interaction effect between potassium rates and boron on specific gravity, starch and dry matter percentage

Data in Table (3) clearly demonstrated that combined influence of K-levels and boron showed the highest significant value of starch (17.56%) comparing with control (13.31%). Whereas, specific gravity and dry matter were improved by K and B combination but these increases were not significant. The positive effect of K and B combination treatment on starch could be interpreted by multiple physiological functions of both elements. The ability of K to improve dry matter and specific gravity was reported by Kumar *et al*., (2007). K treatments could have an important role in promoting photosynthesis and increasing transport its products to the tubers, and to enhance their conversion into starch, protein and vitamins (Mengel and Kirkby, 1978). Boron increased the rate of photosynthesis by affecting photophosphorylation process inside chloroplasts and shift the hormonal balance in leaves and tubers especially IAA which is important for tuber growth after the onset of tuberization (Puzina, 2004).

7 Effect of interaction among nitrogen, potassium rates and boron on specific gravity, starch and dry matter percentage

Data in Table (3) showed that there is no significant effect in all aforementioned traits as affected by the interaction among the three tested factors except for starch percentage in tuber which was significantly.

Table 3. Effect of levels of nitrogen, potassium with or without boron and their interactions on specific gravity, starch, and dry matter percentage (Average of two years)

Treatments		Specific gravity of tuber (gcm^{-3})			Starch (%)			Tuber dry matter (%)		
N-levels kg/fed	K-levels kg/fed	- B	+ B	Mean	- B	+ B	Mean	- B	+ B	Mean
N_0	K_0	1.041	1.053	1.047	13.31	13.37	13.34	18.42	18.57	18.49
	K_1	1.060	1.065	1.063	15.47	15.65	15.56	18.81	19.39	19.10
	K_2	1.070	1.076	1.073	16.08	16.32	16.20	19.41	19.57	19.49
	mean	1.057	1.065	1.061	14.95	15.11	15.03	18.88	19.18	19.03
N_1	K_0	1.067	1.075	1.071	13.65	14.59	14.12	19.60	19.82	19.71
	K_1	1.079	1.086	1.082	16.27	16.38	16.33	19.86	19.94	19.90
	K_2	1.089	1.094	1.092	16.52	16.60	16.56	20.55	20.63	20.59
	mean	1.078	1.085	1.082	15.48	15.86	15.67	20.00	20.13	20.07
N_2	K_0	1.081	1.086	1.083	15.21	15.82	15.52	22.79	23.00	22.90
	K_1	1.089	1.094	1.092	16.73	17.50	17.12	23.16	23.29	23.23
	K_2	1.096	1.098	1.097	18.10	18.48	18.29	23.53	23.65	23.59
	mean	1.089	1.093	1.091	16.68	17.27	16.98	23.16	23.32	23.24
N_3	K_0	1.086	1.089	1.088	15.73	15.93	15.83	23.88	24.10	23.99
	K_1	1.095	1.097	1.096	17.15	17.75	17.45	24.30	24.50	24.40
	K_2	1.098	1.099	1.099	18.30	18.82	18.56	24.72	24.90	24.81
	mean	1.093	1.095	1.094	17.06	17.50	17.28	24.30	24.50	24.40
Average K levels	K_0	1.069	1.076	1.072	14.48	14.93	14.71	21.17	21.37	21.27
	K_1	1.081	1.085	1.083	16.41	16.82	16.62	21.53	21.78	21.66
	K_2	1.088	1.092	1.090	17.25	17.56	17.41	22.05	22.19	22.12
	mean	1.079	1.084	1.082	16.05	16.44	16.25	21.59	21.78	21.68
LSD at 5%	N (A)		0.005			0.82			0.57	
	K (B)		0.004			0.56			0.36	
	Boron (C)		0.004			0.44			0.24	
	A x B		NS			1.11			NS	
	A x C		NS			0.87			NS	
	B x C		NS			0.76			NS	
	A x B x C		NS			0.95			NS	

8 Effect of nitrogen on the content of carbohydrate %, reducing sugar content (%) and carbohydrate yield / fed

Data in Table (4) showed that the quality parameters of potato tubers like carbohydrate, reducing sugar content (%) and carbohydrate yield fed^{-1} were significantly affected by addition of N rates. The highest contents of carbohydrate(26.47%), reducing sugar content (2.333%) and carbohydrate yield fed^{-1} (886.40 Kg/fed) were obtained at 150 kg N/fed while the lowest contents of carbohydrate (21.43%), reducing sugar content (1.763%) and carbohydrate yield / fed(180.39 Kg/fed) in potato tubers were recorded with the control. The favorable effect of higher N dose on potato tubers quality might be due to that N increases photosynthetic pigments content and photosynthesis rate, which in turn increased the amount of metabolites synthesized and consequently resulted in higher dry matter accumulation in tubers. Similar results reported by Saeedi, (2007).

9 Effect of potassium on the content of carbohydrate %, reducing sugar content (%) and carbohydrate yield / fed

Data in Table (4) showed that the quality parameters of potato tubers like carbohydrate, reducing sugar content (%) and carbohydrate yield / fed. were significantly affected by addition of K rates. Potassium (K) plays a significant role in quality as well as yield attributes of potato such as content of carbohydrate, reducing sugar content (%) and carbohydrate yield fed-1. Its application activates number of enzymes involved in photosynthesis, carbohydrate metabolism and proteins synthesis and assists in the translocation of carbohydrates from leaves to tubers (Patricia and Bansal, 1999) .The higher yield quality in case of adding of potassium may be also related to the role of potassium in translocation of produced photosynthetic assimilates and its accumulation in storage tubers and in turn increase the tuber weight, which consequently affect positively yield quality. Similar results reported by Bansal and Trehan (2011).

10 Effect of boron on the carbohydrate content, reducing sugar content and carbohydrate yield / fed

As regard to the effect of boron foliar spray on the content of carbohydrate, reducing sugar content and carbohydrate yield / fed in the potato tubers, data in Table (4) indicate that boron foliar spray application caused the highest significant increase in the content of carbohydrate, reducing sugar content and carbohydrate yield / fed in the tubers compared with the untreated control. Boron nutrition regulates water absorption and carbohydrate metabolism (Haque *et al.* 2011). In the plant, boron plays a major role in the translocation and production of sugars. In the presence of boron, simple organic sugars (Glucose 1-P) will form carbohydrates and complex sugar molecules. In the absence of boron these simple sugars will form phenols (Quinone phenols), which will accumulate, attract insects and increase disease pressure. When boron is deficient in tissue cambial cells cease to divide but cell elongation continues in growing zones, and as a result phloem and xylem cells are displaced from their original position so it will leads to inactivation of vascular tissue. Inactivation of phloem cells leads to a failure of translocation of carbohydrates and sugars to tubers and fruits.

11 Effect of interaction between nitrogen and potassium rates on the content of carbohydrate, reducing sugar content and carbohydrate yield / fed

Regarding to the effect of nitrogen and potassium rates on the content of carbohydrate, reducing sugar content and carbohydrate yield / fed, data in Table (4) indicate that the nitrogen combined with potassium rates are significant on carbohydrate, reducing sugar content and carbohydrate yield / fed of tuber. Nitrogen rates positively influenced the carbohydrate, reducing sugar content and carbohydrate yield / fed. The addition of 96 Kg K2O /fed. significantly enhanced the carbohydrate, reducing sugar content and carbohydrate yield / fed. Accurate application of nitrogen and potassium fertilizers can stimulate carbohydrate and biomass of potato which considered as a significant factor in industrial usage and food. Potassium is required for efficient transformation of solar energy into chemical energy that could increase carbohydrate content (Taize and Ziger, 2000).

12 Effect of interaction between N-levels and boron on the content of carbohydrate, reducing sugar content and carbohydrate yield / fed

As regard to the interaction effects between N-levels and foliar application of boron on the content of carbohydrate, reducing sugar and carbohydrate yield / fed in potato tuber, the data presented in Table (4) revealed that total carbohydrate, reducing sugar (%) and carbohydrate yield / fed were high with the application of 150 kg N fed-1 plus spraying the plants with boron than control. Since, it significantly increased content of carbohydrate, reducing sugar and carbohydrate yield / fed in potato tuber from 21.43 %, 1.763% and 180.39 kg/fed to 27.48 %, 2.417 % and 965.70 kg/fed, respectively.

Table 4. Effect of levels of nitrogen, potassium with or without boron and their interactions on the content of carbohydrate %, reducing sugar content (%) and carbohydrate yield / fed (Average of two years)

Treatments		Total carbohydrate (%)			Reducing sugars (%)			Total carbohydrate yield		
N-levels kg/fed	K-levels kg/fed	- B	+ B	Mean	- B	+ B	Mean	- B	+ B	Mean
N_0	K_0	21.43	22.13	21.78	1.763	1.790	1.777	180.39	207.53	193.96
	K_1	24.20	24.87	24.54	1.867	2.000	1.934	249.86	280.19	265.02
	K_2	29.30	31.10	30.20	2.483	2.590	2.537	381.04	420.63	400.84
	Mean	24.98	26.03	25.51	2.038	2.127	2.083	270.43	302.78	286.61
N_1	K_0	24.87	25.43	25.15	1.947	2.290	2.119	369.34	419.64	394.49
	K_1	27.75	28.00	27.88	2.663	2.707	2.685	486.92	512.07	499.49
	K_2	29.70	32.33	31.02	2.997	3.133	3.065	594.36	728.06	661.21
	mean	27.44	28.59	28.02	2.536	2.710	2.623	483.54	553.26	518.40
N_2	K_0	25.85	26.83	26.34	2.010	2.253	2.132	687.61	765.49	726.55
	K_1	28.17	29.87	29.02	2.760	2.810	2.785	834.44	909.27	871.86
	K_2	32.60	34.57	33.59	3.217	3.253	3.235	1041.54	1137.31	1089.42
	mean	28.87	30.42	29.65	2.662	2.772	2.717	854.53	937.36	895.94
N_3	K_0	26.47	27.48	26.98	2.333	2.417	2.375	886.40	965.70	926.05
	K_1	28.57	29.90	29.24	2.837	2.923	2.880	1065.32	1214.57	1139.94
	K_2	35.23	37.80	36.52	3.687	3.980	3.834	1498.94	1673.49	1586.21
	mean	30.09	31.73	30.91	2.952	3.107	3.030	1150.22	1284.59	1217.40
Average K levels	K_0	24.66	25.47	25.07	2.013	2.188	2.101	530.93	589.59	560.26
	K_1	27.17	28.16	27.67	2.532	2.610	2.571	659.14	729.02	694.08
	K_2	31.71	33.95	32.83	3.096	3.239	3.168	878.97	989.87	934.42
	mean	27.85	29.19	28.52	2.547	2.679	2.613	689.68	769.50	729.59
LSD at 5%	N (A)		1.58			0.25			58.78	
	K (B)		1.74			0.18			41.79	
	Boron (C)		1.075			0.21			43.81	
	A x B		3.48			0.37			83.59	
	A x C		0.24			0.43			87.63	
	B x C		1.86			0.37			75.87	
	A x B x C		3.72			0.74			151.77	

13 Effect of interaction between potassium rates and boron on the content of carbohydrate, reducing sugar content and carbohydrate yield / fed

K fertilizers plus boron foliar application also increased total carbohydrate, reducing sugar percentage and carbohydrate yield / fed. The highest amounts of content of carbohydrate, reducing sugar content and carbohydrate yield were obtained with the application of 96Kg K2O /fed and 100ppm boron. Michael and Beringer (1980) reported that K+ stimulates the formation of rising storage (sink) capacity through higher photosynthesis. Some enzymes are activates by potassium and plays a role in water balancing in plants. It is also important for some carbohydrate transformations. The boron beneficial effect on stimulating cell division, translocation and building of sugar, water and Mg uptake and the biosynthesis of IAA (Nijjar, 1985) could explain the present results.

14 Effect of interaction among nitrogen, potassium rates and boron on the content of carbohydrate %, reducing sugar content (%) and carbohydrate yield / fed

Data in Table (4) found a significant effect in all aforementioned traits by the interaction among the three tested factors. Potassium and boron have overlapping roles in plant physiology and hence, they are synergistic. Boron and potassium are also involved in some aspects as fruiting processes and flowering, cell division, pollen germination, nitrogen metabolism, carbohydrate metabolism, hormone movement, active salt absorption and action, water and the relations water metabolism in plants. Both of them turn in acting as a buffer and necessary in the maintenance of conducting tissues and to exert a regulatory effect on other elements. It has been showing that an optimal level of boron increases potassium permeability in the cell membrane Mengel, and Kirkby, (1978).

CONCLUSION

The positive perspective of this study emphasized the importance of nitrogen and potassium fertilization for potato plants. It is obvious that yield and its components of the potato variety spunta can be improved with the application of N and K fertilizers. Hence, application of 150 kg N fed^{-1} in the form of ammonium sulphate and 96 kg K_2O /fed in the form potassium sulphate is found to be the appropriate rates for optimum productivity of potato plants in clay soil. From the present study, it was clear that both nitrogen and potassium plus boron fertilization had created a significant impact on growth and yield of potato plants and its quality. 150 kg N fed^{-1} and 96 kg K_2O /fed plus boron foliar application showed the best performance on yield of potato plants and its quality.

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أثر التسميد على محصول البطاطس وجودتها

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أجريت تجربة حقلية فى مزرعة محطة البحوث الزراعية بالجيزة خلال موسمين متتاليين 2014/2013، 2015/2014 لدراسة تأثيرإضافة مستويات مختلفة من النيتروجين (كنترول،90،120،150 كجم /فدان) والبوتاسيوم (كنترول، 72،96 كجم K_2O / فدان) والرش بالبورون (بدون رش- مع الرش 100 جزء /مليون) وايضا التفاعل بينهما على كل من المحصول ومكوناته وصفات الجودة لدرنات البطاطس صنف سبونتا حيث استخدم التصميم الاحصائى للقطع المنشقة مرتين فى ثلاث مكررات. تشير النتائج أن هناك زيادة معنوية لصفتى عدد الدرنات / نبات ، متوسط وزن الدرنة(جم) والمحصول الكلى (طن/فدان) عند المعدل العالى من النيتروجين والبوتاسيوم مقارنة بالكنترول. كذلك صفات الجودة للدرنات والتى تشمل الكثافة النوعية- المادة الجافة-النشا –الكربوهيدرات –السكريات الذائبة ، جميعها تأثرت بالزيادة المعنوية نتيجة لزيادة مستويات النيتروجين والبوتاسيوم وسجلت أعلى القياسات عند المعدل العالى من النيتروجين والبوتاسيوم . أظهر الرش بالبورون حدوث زيادة معنوية على جميع صفات المحصول وجودته مقارنة بالكنترول .كذلك أظهرالتفاعل بين التسميد النيتروجينى والبوتاسي مع الرش بالبورون إلى زيادة معنوية على صفات المحصول وجودته. خلصت الدراسة بأنه يمكن الحصول على أعلى محصول وصفات جودة للدرنات بإضافة 150 كجم نيتروجين/فدان + 96 كجم K_2O /فدان ورش النباتات بالبورون بتركيز 100 مليجرام / لترتحت ظروف التربة الطينية .