Journal of Soil Sciences and Agricultural Engineering

Journal homepage: www.jssae.mans.edu.eg
Available online at: www.jssae.journals.ekb.eg

Production of Potato Yield and Quality under Inorganic Fertilization and *Azotobacter.*

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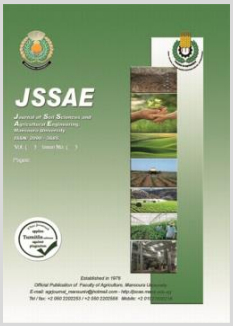

ABSTRACT

A field trial was carried out during season of 2017-2018 in a Randomized Complete Block Design having eight treatment combinations *i.e.*, control, *Azotopacter*, 50% of recommended doses from NPK fertilizers, 50% of recommended doses from NPK fertilizers plus *Azotopacter*, 75% of recommended doses from NPK fertilizers, 75% of recommended doses from NPK fertilizers plus *Azotopacter*, 100% of recommended doses from NPK fertilizers and 100% of recommended doses from NPK fertilizers plus *Azotopacter*. The findings illustrated that the potato plants performance was significantly influenced due to all studied treatments. Among all treatments, 75% of recommended doses from NPK fertilizers plus *Azotopacter* was the superior treatment with respect to overall plant growth criteria as well as yield and its components, chemical content and great quality traits of potato tubers. Regarding the nutrients availability in soil after harvest, the highest mean values of N, P and K were obtained from soil of corresponding plants, which represent control treatment.

Keyword: inorganic fertilization, *Azotobacter*, quality and potato plant

INTRODUCTION

Potato (*Solanum tuberosum* L.) is considered high yielding so it needs higher quantities of nitrogen fertilizers compared to other crops. Pandey *et al.,* 2006) reported that a normal potato crop yielding is 30 Mg ha^{-1} , where it removes about 100 kg N ha^{-1} from soil. It can supports the diversification food program due to their tubers contain carbohydrates (16.0%), protein (1.9 %), fibers(2.5 %) and fat (0.1%) (Gunadi, 2009).

The high total cost and shortage of chemical fertilizers in peak periods leads to make crop production uneconomical especially for small farmers. Thus, it is necessary to improve a suitable strategy for integrated supply of nutrient elements using a combination of synthetic fertilizers and bio-fertilizers. Utilizing nitrogen-fixing microbes will cause reduce the dependence on urea fertilizer, therefore will help in curtailing over-dependence on synthetic N fertilizers alone for N supply to potato. Nitrogen is one of the major nutrients required for potato cultivation along with phosphorus and potassium (Antanaitis *et al*., 2000 and Westermann 2005).

Potato plants are significantly responsive to nitrogen fertilizers, where this element is usually the most limiting macro essential nutrient for its growth. Also, in potato cultivation, N element plays a vital role in the balance among both vegetative and reproductive growth. Many previous research works have shown that N fertilizer additions led to increasing quality parameters of potato i.e., dry matter and protein contents as well as potato yield (Zebarth *et al.,* 2004; White *et al.,* 2007 and Zelalem *et al.,* 2009).

Biofertilizers *e.g., Azotobacter....* etc contain either live or latent microorganisms capable of mobilizing many nutrients e.g., N, P, K, Si....etc through biological processes from unavailable form to available form (Gaur, 2010), where this approach helps in maintaining the soil fertility (Kannaiyan, 2002). This type of fertilizers improves the availability of soil nutrients to plants grown. *Azotobacter* is considered a nitrogenous bio-fertilizer and it is free-living bacteria that colonize near the root region and increase the available nitrogen content in the soil through N fixation, converting N2 OF atmospheric into the ammonium form available to plants as mentioned by Bade *et al.,* (2017). *Azotobacter* has been known as the cheapest bio-fertilizer causing better crop production in developing countries such as Egypt.

The objectives of this paper was to investigate the impact of combinations of chemical and bio- fertilizers on potato plants and determine the optimum and safe dose of fertilizers to be applied for potatoes production.

MATERIALS AND METHODS

A field trial was executed in a Randomized Complete Block Design having eight treatment combinations *i.e.*, T_1: control, T_2: *Azotopacter*, T_3: 50% of recommended doses from NPK fertilizers, T_4: 50% of recommended doses from NPK fertilizers plus *Azotopacter*, T_5: 75% of recommended doses from NPK fertilizers, T_6: 75% of recommended doses from NPK fertilizers plus *Azotopacter*, T_7: 100% of recommended doses from NPK fertilizers and T_8: 100% of recommended doses from NPK fertilizers plus *Azotopacter* at the experimental farm affiliate to faculty of agricultural, El-Mansoura University, Egypt during 2017/2018. The soil of the experimental site was clay loam in nature with pH value of 8.03 (1:2.5 soil: water), EC value of 0.92 dsm^{-1}, low in organic matter content of 1.76%, available N with (61.2 ppm), low in available P with (6.67 ppm) and adequate in available K with 173.1 ppm at the start of experiment.

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DOI: 10.21608/jssae.2021.200992

Pieces of tubers (Cv. Sponta) were fertilized with *Azotobacter* at rate of 2.0g 10.0 g^{-1} of Pieces of tubers. Cultivation process was done on the 1st week of November at 25 cm apart among each other on one only side of ridges (4.0 m long and 70.0 cm wide, where the plot contain 4 ridges with total area of 10.5 m^2. While ammonium sulfate (20.5 % N) was added at rate of 120 kg fed^{-1}, super phosphate (15 % P_2O_5) 75 kg fed^{-1} and potassium sulfate (48 % K_2O) 96 kg fed^{-1}, where full dose of super phosphate was added before planting, while both N and K were added in two equal doses; the first was done after 15 days from potato planting and the second was added two weeks later.

Five plant samples were randomly taken from each plot at two stages to determine the following criteria;

After 70 days from sowing, fresh and dry weights of potato plant foliage, plant height, No. of leaves $plant^{-1}$, chlorophyll (according to Sadasivam and Manickam, (1996), N, P and K contents were determined.

At full maturity stage (125 days from sowing); total tuber yield, fresh weight of tuber, No. of tubers $plant^{-1}$, tuber weight and tuber day matter as well as chemical constituents in tubers *i.e.*, N, P and k % according to Mertens, (2005a & b) and Agrilasa, (2002).

Quality parameters of fresh tubers i.e. crude protein (%), total carbohydrates (%), starch (%), TSS (%) according to Sadasivam and Manickam, (1996), while NO2-N, NO_3-N contents were measured according to Singh (1988). V.C was determined according to Mazumdas and majumdas (2003).

At harvest stage also soil samples were taken from each plot and available N, P and K were measured according to Reeuwijk, (2002).

According to Gomez and Gomez, (1984), statistically analyzed of obtained data were implement through CoSTATE Computer Software.

RESULTS AND DISSECTION

The present research work has been executed to study the appropriate chemical nutrient management in the presence *Azotobacter* as bio-fertilization for enhancing growth performance, yield, chemical constituents and quality traits of potato. The obtained findings obtained in the present studies are tabled as follows.

1.Vegetative growth parameters of potato.

Data presented in Table (1) indicate the effect of chemical fertilization and *Azotobacter* in single way and its interaction at different rates of NPK fertilization comparing with control on growth traits [*i.e.* plant length, No. of leaves, fresh and dry weight] of potato plant foliage at period of 70 days from cultivation.

Table (1) shows that the average values of all studied parameters for potato fertilized with the different rates of NPK fertilization and *Azotobacter* in single form were less than that obtained for the interaction effect compared to the control that gave the lowest values. The differences among these values were significant for all aforementioned traits. Treatment **T_6** (75% NPK + AZ) showed maximum values vegetative growth under investigation. The percentages of increase over the control treatment with **T_6** were 37.89 % for plant height, 37.12 % for No. of leaves, 37.08 % for fresh weight and 37.72 % for dry weight.

This clearly indicated that higher levels of NPK helped in cell elongation of the stem as a result of the development of cell as well as due to both rapid cell elongation and division in the meristematic area of potato plants, also, This may be attributed to the vital role of N in potato plants., where it is important for forming nuclic acids proteins and co-enzymes (Singh *et al.*, (2010). on the other hand, phosphorus also possess a vital role in N_2 fixation as well as it leads to enhance modulation of plant and improve photosynthesis (Kołodziejczyk, 2014 and Baddour, 2014), while potassium element activates many enzymes and plays a vital role in controlling stomatal guard cells of leaves in addition to its ability in enhancing photosynthesis is (Singh *et al.*, 2017). Also, it can be said that *Azotobacter* might help in the production of growth-regulating materials which proved for raising potato plant growth (Baddour, 2014; Singh *et al.*, 2017 and Sriom *et al.*, 2017).

Table 1. Effect of chemical fertilization, *Azotobacter* and its interaction on vegetative growth of potato plant after 70 days.

Treatments	Plant height, cm	No of leaves /plant	FW plant, g/plant	DW plant, g/plant
Control (T1)	58.78h	32.59g	185.37h	46.02h
AZ (T2)	61.87g	34.21f	195.14g	48.25g
50% NPK (T3)	65.05f	36.28e	204.64f	50.87f
50% NPK +AZ (T4)	74.74c	41.25c	233.81c	58.19c
75% NPK (T5)	68.49e	37.68d	215.40e	53.96e
75% NPK + AZ (T6)	81.05a	44.69a	254.12a	63.38a
100% NPK (T7)	72.12d	40.12c	224.64d	55.99d
100% NPK + AZ (T8)	77.39b	42.87b	244.61b	61.00b
LSD at 5%	1.87	1.22	4.74	0.84

2.Yield and its components of potato.

Total yield of potato (ton fed^{-1}) and its components [fresh weight of tuber (g $plant^{-1}$), No. of tubers $plant^{-1}$, tuber weight (g) and dry matter (%)] as affected by different rates of NPK fertilization and *Azotobacter* in single way and its interaction comparing with control are presented in Table (2).

Table (2) shows that using 100% NPK was superior treatment for conferring the highest values of all the above mentioned characteristics followed by 75% NPK and lately 50% NPK. For example, the values of tubers fresh weights were 575.37, 544.30 and 523.98 (g $plant^{-1}$) for the treatments of 100, 75 and 50% NPK, respectively. The same trend was recorded for the other yield traits. Comparing with the control treatment (without addition of studied fertilizers), the values of tubers yield and its components of potato plants fertilized with any of the studied chemical fertilization in single form at different rates were more than that obtained for the control treatment(without addition of studied fertilizers) and such effect was significant for all parameters. All treatments significantly affected all parameters except average tuber weight/ g had no significant effect. The highest mean values of all parameters of tubers yield and its components compared to the control and other treatments recorded with using treatment T6 (75% NPK + AZ) which were 646.44, 5.72, 15.63 and 16.58 for fresh weight of tubers (g $plant^{-1}$), No. of tubers $plant^{-1}$, dry matter of tubers (%) and total yield (ton fed^{-1}), respectively.

Table 2. Effect of chemical fertilization, *Azotobacter* and its interaction on yield and its components of potato plant.

Treatments	Total tuber yield , ton/fed	FW tuber, g/plant	No. of tuber /plant	Average weight, g	DM tuber, %
Control	12.00h	473.77h	4.14h	114.39a	11.40h
AZ	12.75g	494.45g	4.42g	111.96b	12.07g
50% NPK	13.33f	523.98f	4.59f	114.22a	12.64f
50% NPK +AZ	15.28c	598.66c	5.28c	113.31ab	14.41c
75% NPK	13.95e	544.30e	4.83e	112.74ab	13.17e
75% NPK + AZ	16.58a	646.44a	5.72a	112.95ab	15.63a
100% NPK	14.73d	575.37d	5.09d	113.12ab	13.77d
100% NPK + AZ	15.89b	623.83b	5.52b	113.11ab	15.03b
LSD at 5%	0.37	12.17	0.14	n.s	0.30

This might be attributed to that the synthetic fertilizers are more available and solubility for potato plant absorption. Moreover, increasing the rates of NPK in the rooting area led to founding increases in its absorption by potato plants, therefore raising the ability of plant roots to absorb more macronutrients in plant tissues. many investigators confirmed that increasing the application of NPK fertilizers enhanced the yield of potato plants as reported by Singh *et al.,* (2010); Kołodziejczyk, (2014); Baddour, (2014) and Singh *et al.,* (2017).

3.Chemical constituents of potato.

Potato plant foliage (70 days from sowing):

The comparison among the investigated combined treatments of chemical fertilization and bio fertilization in form *Azotobecer* as shown in Table (3) has been reflected as significant differences among the values of chemical traits in leaves of potato *i.e.*, chlorophyll ,N, P and K after 70 days from planting.

Table 3. Effect of chemical fertilization, *Azotobacter* and its interaction on chlorophyll (a, b & a+b), N, P and K concentrations in the leaves of potato plant after 70 days from sowing.

Treatments	Chlorophyll a (mg g^{-1} leaves) F.W	Chlorophyll b (mg g^{-1} leaves) F.W	Total chlorophyll (mg g^{-1} leaves) F.W	N% leaves	P% leaves	K% leaves
Control	0.588h	0.412g	0.999h	2.03h	0.150	2.40h
AZ	0.598g	0.422f	1.020g	2.14g	0.163	2.50g
50% NPK	0.609f	0.429f	1.039f	2.25f	0.175	2.63f
50% NPK +AZ	0.642c	0.457c	1.099c	2.57c	0.210	2.99c
75% NPK	0.620e	0.438e	1.058e	2.35e	0.187	2.75e
75% NPK + AZ	0.664a	0.477a	1.142a	2.79a	0.234	3.20a
100% NPK	0.632d	0.448d	1.080d	2.48d	0.199	2.88d
100% NPK + AZ	0.653b	0.466b	1.119b	2.68b	0.224	3.10b
LSD at 5%	0.009	0.008	0.015	0.07	0.007	0.07

Regarding the effect of different rates of NPK fertilization and *Azotobecter*, data in Table (3) revealed that individual application of NPK fertilization significantly increased the values of studied chemical traits in leaves of potato *i.e.*, chlorophyll ,N, P and K after 70 days from planting compared to the control treatment. On other words; the highest values (1.080, 2.48, 0.199 and 2.88 for total chlorophyll, N, P and K, respectively were realized for 100% NPK fertilization, while the lowest one (0.999, 2.03, 0.150 and 2.40) for such trait were obtained from the control plants. With adding *Azotobecter* to the chemical fertilization, the parameters were increased compared with the single forms or control. All treatments under investigation were significantly affected all parameters. The highest mean values were recorded with using T6 (75 % NPK+ AZ).

Nutrients contents of potato tubers (at harvesting stage)

Nutritional elements of potato tubers; nitrogen, phosphorus and potassium concentrations as affected by the treatments under investigations are presented in Table (4). These Results demonstrated that; adding of different rates of NPK fertilization in single form significantly increased the mean values of all nutritional elements over those obtained for the control treatment. With using Azotobacter as bio-fertilization in combination with different rates of NPK fertilization, the mean values of N, P and K concentration increased significantly comparing with the other treatments. The highest mean values of N, P and K concentration of potato tubers after investigation were realized with using treatment of T6 (75% NPK%+Az).

Table 4. Effect of chemical fertilization, *Azotobacter* and its interaction on N, P and K concentrations in the tuber of potato plant after harvesting.

Treatments	N, %	P, %	K,%
Control	1.18g	0.099h	2.63h
AZ	1.27f	0.110g	2.76g
50% NPK	1.39e	0.124f	2.85f
50% NPK +AZ	1.70c	0.157c	3.16c
75% NPK	1.50d	0.133e	2.97e
75% NPK + AZ	1.94a	0.184a	3.41a
100% NPK	1.54d	0.144d	3.08d
100% NPK + AZ	1.84b	0.169b	3.30b
LSD at 5%	0.07	0.006	0.06

Results of this investigation showed that; under mineral fertilization (control), most of soil nitrogen will be in form of nitrate and plants may absorb great quantity of nitrogen due to its assimilation capacity; the difference between N-absorption and assimilation may be great and the utilized nitrogen will be stored as nitrate in potato. This finding was close conformity with results of Mohammadi *et al.,* (2013); Salehi *et al.,* (2014); Baddour, (2014); Singh *et al.,* (2017).

These improving impacts of bio fertilization might be due to the essential role of N-fixing bacteria in secreting chelating materials such as organic acids that are so important for solubilization of both macro and micronutrients from the organic fertilizers. Similar results have been reported by Baddour, (2014) and Singh *et al.,* (2017).

Quality parameters of potato tubers.

Quality parameters of potato tubers in expression of total carbohydrates, starch (%), T. sugar%, vitamin C (mg

100g $^{-1}$), TSS% and crude protein in addition NO_3-N; (mg kg $^{-1}$) and NO_2-N;(mg kg $^{-1}$) are shown in Table (5). Obtained data indicated that, all the aforementioned characteristics were significantly increased as a result of using all treatments under investigation compared to control. Within levels of NPK fertilization; the highest values (26.31, 20.33, 2.98, 19.85, 56.70, 1.41, 6.55 and 8.87 for total carbohydrates, starch (%), T.sugar%, vitamin C (mg 100g $^{-1}$), NO_3-N;(mg kg $^{-1}$) and NO_2-N;(mg kg $^{-1}$) as well as TSS% and crude protein were recorded for the treatment of 100% NPK. On the contrary of this trend, sharply increases were recorded in the values of all studied parameters in potato tubers due to an addition of the *Azotobecter* to all rates of NPK than those obtained from the control treatment and single forms of chemical fertilization. The highest mean values of all studied traits were realized with using T6 (75% NPK + AZ).

Our results are in harmony with the obtained those by Baddour (2010) who reported that solely soil addition of NPK-fertilizers at a rate of 75% of the recommended dose was superior for raising the values of Acidity, V.C and TSS in tomato plants over the control treatment. Also, the increased activity of the *Azotobecter* might have resulted in the release of more amounts of auxins gibberellins and cytokinins that led to accelerating the physiological process e.g., synthesis of carbohydrate and protein and consequently improving quality. This result was confirmed with Baddour, (2010; 2014); Singh *et al*., (2017) and Sriom *et al.,* (2017).

Table 5. Effect of chemical fertilization, *Azotobacter* and its interaction on quality in tuber of potato plant.

Treatments	T.carbohy-dreates %	Starch %	T. Sugar%	V.C, mg/100g	NO_3-N, ppm FW	NO_2-N, ppm FW	TSS %	Protein %
Control	23.83f	18.11g	2.08h	18.50h	42.27h	0.82e	5.95g	6.80g
AZ	24.38f	18.72fg	2.32g	18.87g	39.77g	0.69f	6.06g	7.32f
50% NPK	25.21e	19.22ef	2.53f	19.17f	51.40f	1.19b	6.22f	7.97e
50% NPK +AZ	26.96bc	20.92bc	3.24c	20.23c	44.57c	0.88e	6.71c	9.79c
75% NPK	25.73de	19.72de	2.77e	19.52e	53.90e	1.27b	6.37e	8.61d
75% NPK + AZ	28.24a	22.03a	3.64a	20.87a	46.87a	0.98d	7.05a	11.14a
100% NPK	26.31cd	20.33cd	2.98d	19.85d	56.70d	1.41a	6.55d	8.87d
100% NPK + AZ	27.55b	21.34ab	3.44b	20.56b	49.13b	1.09c	6.87b	10.56b
LSD at 5%	0.68	0.72	0.18	0.22	1.39	0.09	0.11	0.38

4.Available concentrations of N, P and K in soil after harvesting.

Concentrations of available macronutrients i.e., N, P and K, found in the experimental soil after cropping with potato plants are presented in Table (6).

Data of Table (6) showed that the concentrations of N, P and Kin the soil after cropping were generally slightly increased over that obtained from this soil before harvesting; as illustrated in materials. This result might be due to the impact of potato roots activity which affected greatly on the value of soil pH thus increasing the availability of these elements. Also, the values of available elements were significantly affected due to the addition of all treatments under investigation; which already contained moderately amount of these elements and recorded the highest values for the treatment of T3 (50% NPK), while the lowest one was attained from the treatment of T7 (100% NPK). On the other hand, the average values of available N, P and K in soil treated with N, P and K fertilizers and *Azotobacter* have been recorded a lower amounts of these elements more than that obtained from the treatments, of chemical fertilization alone. On the other hand, the highest mean values of available N, P and K concentration in soil after cropping potato plant were recorded with control treatment.

Table 6. Effect of chemical fertilization, *Azotobacter* and its interaction on available N, P and K in the soil after cropping potato plant.

Treatments	Available N, mg kg^{-1}	Available P, mg kg^{-1}	Available K, mg kg^{-1}
Control	87.55a	13.22a	162.00a
AZ	82.72b	11.98b	152.83b
50% NPK	80.48bc	11.20c	148.07b
50% NPK +AZ	74.68d	9.33de	126.37e
75% NPK	78.64c	10.73c	140.60c
75% NPK + AZ	68.25e	8.06f	112.23g
100% NPK	74.52d	9.90d	132.83d
100% NPK + AZ	70.24e	8.73ef	119.77f
LSD at 5%	3.93	0.76	4.91

Increased availabilities of N, P, and K maybe also as a result of changes in nutrient turnover rates of soil due to altered ecosystem attributes. Soil nutrient turnover rate consists of weathering, chemical complexation, decomposition, mineralization, adsorption or nutrient absorption by crops and organisms of soil (Marrs, 1993). our results agree with those of Kamble and Kathmale, 2015) who found that the highest available nitrogen and phosphorus were recorded with the addition of 125 % of the recommended dose of NPK to onion plants, where this treatment appeared to be better for improving soil fertility..

CONCLUSION

It can fairly be concluded on the basis of above findings that the application of 75% NPK fertilization from recommended dose mixed with *Azotobacter* as source of N-bio fertilization is quite effective to promote growth performance of potato as well as its yield and quality. It increased tuber size and yield per fedden, along with better quality of tubers.

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انتاجية محصول البطاطس وجودته تحت ظروف التسميد المعدني والأزوتوباكتر

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أجريت تجربه حقليه خلال موسم النمو 2017-2018 بالمزرعه الخاصه لكليه الزراعه جامعه المنصوره. صممت التجربه كقطاعات كامله العشوائيه كررت ثلاث مرات لثمتنى معاملات متداخله وهى كنترول، أزوتوباكتر، 50% من الموصي به تسميد كيماوي، 50%+ ازوتوباكتر، 75% من الموصي به تسميد كيماوي،75% + أزوتوباكتر، 100% من الموصي به أزوتوباكتر، 100%+ أزوتوباكتر. أوضحت نتائج البحث تحت الدراسه أن محصول البطاطس تأثر معنويا بجميع إضافات المعدلات المختلفه من التسميد الكيماوى في وجود الازوتوباكتر. من خلال جميع المعاملات وجد ان معامله 75% من الموصي به تسميد كيماوي في وجود الازوتوباكتر تعتبر افضل المعاملات في الحصول على اعلى صفات لمعدل النمو، المحصول ومكوناته، التركيب الكيماوى، وافضل صفات جوده لدرنات البطاطس. أما بالنسبه لمحتوى التربه من العناصر فسجلت اعلى القيم مع النباتات الغير معامله.