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Growth, Yield and Nutrient Concentration of Potato Plants Grown under Organic and Conventional Fertilizer Systems

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Abstract: This study was conducted to evaluate whether organic fertilization alone or with bio-fertilization could replace mineral fertilization in potato production with no adverse effect on quantity or quality of potato tubers. Two field experiments were conducted at Maba Farm, Cairo - Alexandria Desert Road during the summer seasons of 2009 and 2010 in Egypt on a sandy soil under sprinkler irrigation to compare effect of organic and biofertilizers with a conventional program on growth, productivity and nutrient concentration in leaves of potato (*Solanum tuberosum* L.), cv. Sante. The experiment included the treatments: 1) recommended conventional fertilization, full dose of mineral NPK + 11.9 Mt•ha^{-1} of compost (control); 2) 23.8 Mt•ha of compost; 3) 23.8 Mt•ha^{-1} of compost + bio-fertilizer + rock phosphate (at 357 kg ha^{-1}) + feldspar (at 1547 kg ha^{-1}) ; 4) 11.9 Mt•ha^{-1} of compost + bio-fertilizer (1.2 x 109 CFU ml^{-1}) + rock phosphate + feldspar; 5) 50% mineral fertilizer + 23.8 Mt•ha^{-1} of compost; 6) 50% mineral fertilizer + 23.8 Mt•ha^{-1} of compost + bio-fertilizer + rock phosphate + feldspar; 7) 50% mineral fertilizer + 11.9 Mt•ha^{-1} of compost + bio-fertilizer + rock phosphate + feldspar; and 8) 35.7 Mt•ha^{-1} of compost. There were increases in plant height, haulm fresh weight, number of main stems, leaves content of phosphorus and potassium and total and marketable yields of potato plants from plots treated with 35.7 Mt•ha^{-1} of compost at 90 days after planting, compared to the control. Use of organic fertilizers in Egypt is limited by the threshold of allowable nitrogen level but the results indicated that organic production of potato using 23.8 Mt•ha^{-1} of compost could be an alternative to conventional production without significant reduction in yield and quality.

Key words: Solanum tuberosum · Bacillus megaterium · Bacillus cereus · Compost · Rock phosphate · Vesicular · Arbuscular mycorrhiza

INTRODUCTION

In Egypt, potato (*Solanum tuberosum* L.) is cultivated in the summer, fall and winter seasons. The tremendous use of chemicals in agricultural production has deposited toxic chemicals in water and food, especially in fresh vegetables. As a result, there is a demand for chemical free foods product.

Many farmers and scientists in the world are becoming increasingly aware of the importance of organic production. Challenges for organic production are management of nutrients, diseases and insects [1]. Organic fertilizers, such as compost, provide slow release of nutrients in soil [2, 3]. Yields of crops grown in organic and conventional production systems can be the same [4, 5]. However, use of organic fertilizers is limited by the threshold of nitrogen level. Bio-fertilizer from microorganisms can replace chemical fertilizers to increase crop production. In principle, bio-fertilizers are less expensive and more environmental-friendly than chemical fertilizers. The benefits of using bio-fertilizer, beside their role in reducing chemical fertilizers, are well known [6]. They can be involved in uptake of plant nutrients, such as phosphorus, nitrogen and potassium beside enhancement of tolerance to attack by soil pathogens and improvement of soil stability [7-13]. They also have beneficial effects on plant growth and can increase yield in compared to un-inoculated control [8-11, 14-19]. Bio-fertilizer reduced nitrate and nitrite contents of potato tubers due to use of mycrrohiyzal

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fungi and *Azospirillum* [11-20]. Bio-fertilizer (phosphate and potassium solubilizing bacteria) did not affect starch content of potato tubers [9].

This study was undertaken to determine if potato could be grown organically with no adverse effect on quantity or quality, as compared with conventional production and measure to what extent the bio-fertilizer can replace organic and mineral fertilization in potato production.

MATERIALS AND METHODS

The investigation was carried out at Maba Farm, Cairo and Alexandria Desert Rod, Egypt, during the summer seasons of 2009 and 2010 using cv. Sante. Treatments were arranged in a randomized complete bloke design with 4 replicates.

A soil sample was collected from the experimental field at the beginning of the experiment and physical and chemical properties were determined. The soil fertility prior to the experiment was: O.M. = 0.13%, mineral N = 15.12 mg•kg^{-1}, P = 7.20 mg•kg^{-1}and K = 74.85 mg•kg^{-1}. The sandy soil was comprised of 58.63% coarse sand, 37.23% fine sand, 2.07% silt and 2.07% clay.

Soil salt was leached for 5 days before planting using center pivot irrigation. After partial drying, the soil was prepared with a chisel plow. The field was divided into 1.8 m wide strips. For each treatment two (1.8 m) strips were divided into 50 m long sections. Total plot area was 180 m^2 (3.6 m × 50 m) to which treatment materials were broadcast applied using spreaders (Kuhn Fertilizer Spreader, MDS model, UK; MDS Rauch Fertilizer Spreader, model 10.1/11.1/12.1, Holland). The treatment materials were incorporated into the soil using a rotavator (Grimme, model GF 90-4, Holland).

Potato seed pieces were cut (approximately 35 g pieces) and cured in a dark storage at 12°C for 7 days. All seed pieces were treated with the Bio-health (contains *Trichoderma* sp.+*Bacillus subtilis*) at a rate of 150 ml/100 l of water in an effort to mitigate soil-borne diseases. Seed pieces were mechanically planted on 26 January 2009 and 6 February 2010 using a four-row-planter (Grimme GL 34E) with 25 cm between hills and 90 cm between rows in all plots; plots were 50 m × 3.6 m with 4 rows on 0.90 m centers.

The experiment consisted of the treatments: 1) recommended conventional fertilization, full dose of mineral NPK+11.9 Mt•ha^{-1} of compost (control); 2) 23.8 Mt•ha^{-1} of compost; 3) 23.8 Mt•ha^{-1} of compost+ bio-fertilizer + rock phosphate + feldspar; 4) 11.9 Mt•ha^{-1} of compost+ bio-fertilizer + rock phosphate + feldspar; 5) 50% mineral fertilizers + 23.8 Mt•ha^{-1} of compost; 6) 50% mineral fertilizers + 23.8 Mt•ha^{-1} of compost+ bio-fertilizer + rock phosphate + feldspar; 7) 50% mineral fertilizers + 11.9 Mt•ha^{-1} of compost + bio-fertilizer + rock phosphate + feldspar; and 8) 35.7 Mt•ha^{-1} of compost.

Mineral fertilizers were applied at a rate of 285.6+178.5+357 kg•ha^{1} of N-P_2O_5-K_2O, respectively, applied in 2 equal splits at soil preparation and 6 weeks after planting. The bacterial nitrogen fixers *Azosperllium brasilense* and *Azotobacter chroocooum*; the P-dissolving bacterium *Bacillus megaterium*, vesicular- arbuscular mycorrhiza (VAM) and the K-dissolving bacterium *Bacillus cereus*, were applied just after planting and three, six and nine weeks after planting at a concentration of 1.2×10^9 CFU•mL^{-1}. In addition, rock phosphates (22.8% P_2O_5) at 357 kg•ha^{-1}+feldspar (10.6% KO_2) at 1547 kg•ha^{-1} were applied during soil preparation. The micro-organisms were obtained from existing isolates in the Laboratory of Microbiology, Faculty of Agriculture, Cairo University.

Application of compost was in 2 equal doses, during land preparation and 45 days after planting. The content of the compost was analyzed (Table 1).

Table 1: Analysis of compost.

Characters	Value	Characters	Value
O.C. %	36.1	Zn (ppm)	28
O.M. %	65	Fe (ppm)	1025
C/N ratio	1:16	Mn (ppm)	115
pH	8.5	Cu (ppm)	180
E.C.(ds•m^{-1})	4.3	Ash %	9
Total nitrogen %	1.5	Nematodes present	No
N (ammonium) ppm	460	Humidity %	26
N (nitrate) ppm	120	Weight of m^3 (kg)	500
Total phosphorous %	0.5	Weeds seed present	No
Total potassium %	1.26	Parasites	No
Sodium chloride %	1.31	Zn (ppm)	28

All amounts of synthetic phosphorus and potassium were applied manually during soil preparation in the form of superphosphate (15%) and potassium sulfate (48%). The nitrogen, as ammonium sulfate (20.5%), was divided into 2 equal splits, applied during soil preparation and 6 weeks after planting. The micro-organisms were applied in the form of a liquid suspension using a knapsack pesticide applicator, just after planting and at 3, 6 and 9 weeks after planting.

Biological control for aphids was with a predator, lacewings and for potato tuber moth a parasitoid, *Trichogramma* spp. The latter was used 4 times, every 10 days, starting 40 days after planting. All treatments were also supplied the bio-fungicide; Biocit (SIRIAC, Marsala, Italy), every 10 days, starting 60 days after planting, as a foliage treatment, using a tractor sprayer (Puma), at 480 l•ha^{-1}, in an attempt to control potato foliage diseases. Spray irrigation, with a center pivot, was used.

Fifteen plants were randomly sampled from the inner 2 rows of plots at 75 and 90 days after planting (DAP) to determine development of vegetative growth and mineral concentration in potato plants. Plant height, number of stems per plant, haulm fresh weight and chlorophyll content of leaves (using SPAD apparatus) were determined. To determine plant productivity; number of tubers per plant, weight of marketable tuber, number of marketable tubers/plant, average weight of marketable tubers and number of unmarketable tubers/plant were recorded. Tubers were considered as marketable when diameters were >30 mm and unmarketable when diameters were <30 mm.

A sample of 100 gram fresh weight of leaves from each plot sample was collected, 75 days after planting, to determine nitrogen, phosphorus and potassium percentages in leaves. Samples were dried at 70°C and grounded using stainless steel equipments. From each sample, 0.2 g was digested using 5 cm^3 from the mixture of sulfuric (H_2SO_4) and perchloric ($HClO_4$) acids (1:1) as described by Peterburgski [21] to determine N and P concentrations. Total nitrogen was determined by micro-Kjeldahl method as explained by Hesse [22]. Total phosphorus was determined colorimetrically at wavelength 680 nm using spectrophotometer (Hitachi, U-1000) as described by Cottenie *et al*. [23]. Total potassium was determined by using Gallen Kamp flame photometer as mentioned by Cottenie *et al*. [23].

Data over the 2 years were pooled for analysis. The two seasons were statistically homogenized. Significant differences among treatments means were separated using LSD at 0.05 using M-Stat (ver. 4).

RESULTS AND DISCUSSION

The effect of organic and bio-fertilizers on vegetative growth characteristics of potato plants at 75 days from planting is varied (Table 2). Plant height and haulm fresh weight were greater in plots received 35.7 Mt•ha^{-1} compost compared to all other treatments, including the control. Plots treated with 50% mineral fertilizers + 23.8 Mt•ha^{-1} compost had the highest number of main stems per plant followed by 35.7 Mt•ha^{-1} compost as compared to all other treatments.

The effect of organic and bio-fertilizers on vegetative growth characteristics of potato plants at 90 days from planting is shown in Table 3. Generally, plots treated with compost at 35.7 Mt•ha^{-1} had increased plant height, haulm fresh weight and number of main stems per plant, as compared with the control. The improvement in plant growth traits due to 35.7 Mt•ha^{-1} at 90 days after planting compared to mineral fertilization was likely due to effect of organic matter in improving vegetative growth due to improvement of soil structure, although amounts of N, P and K were similar in both treatments. The present results agree with those of Abou-Hussein [24] who used the organic fertilizer in the form of compost at a rate of 35.7 Mt•ha^{-1} under similar conditions but with higher mineral NPK. The increase may be attributed to improved soil characters and increased organic matter and nutrients at 5 years after the start of the experiment. Abou-Zeid and Bakry [10] found that chicken manure at 35.7 Mt•ha^{-1} (216 kg•ha^{-1} N), in sandy soil, increased plant height, leaf number/plant, branches number/plant and shoot dry matter compared to mineral NPK fertilizers alone, which may be attributed to low rates of mineral fertilizers used (215-85-215 NPK kg•ha^{-1}).

Generally, bio-fertilizer treatments produced weaker plant growth than organic fertilizer at 35.7 Mt•ha^{-1}. The present results agree with those obtained by Abou El-Hassin *et al*. [25] who reported that using compost at 144 m^3•ha^{-1}, with sandy soil, gave taller plants, more main stems/plant and higher foliage fresh and dry weights compared to compost at 96 m^3•ha^{-1} + bio-fertilizer consisting of extract of chicken manure + soil yeast + *Pseudomonas aeruginosa* + *B. megterium.*

Adding bio-fertilizer to compost, or 50%, mineral fertilizers in the present study did not improve vegetative growth compared to the same treatments without bio-fertilizer. This indicates that the micro-organisms also have a nutrition requirement that needs to be considered when adding compost as the primary nutrient source. Inoculants using *B. megaterium* var.

Table 2: Effect of organic and bio-fertilizers on plant height, haulm fresh weight, number of stems per plant and chlorophyll content of potato plants after 75 days from planting, combined data of 2009 and 2010 seasons.

Treatment (ha)	Plant height (cm)	Haulm fresh weight (g)	Number of stems/plant	Chlorophyll (SPAD)
MF + 11.9 Mt compost (control)	43.50	167.3	4.37	44.64
23.8 Mt compost	42.25	165.4	3.75	44.53
23.8 Mt compost + BF	40.75	186.4	3.75	43.42
11.9 Mt compost + BF	43.75	118.5	4.25	43.30
50% MF+23.8 Mt compost	43.63	195.6	6.00	44.64
50% MF+23.8 Mt compost + BF	47.63	215.4	3.25	46.46
50% MF+11.9 Mt compost + BF	51.00	133.5	3.12	41.17
35.7 Mt compost	57.88	225.3	5.00	43.09
L.S.D. at 5%	5.41	49.63	1.16	4.14

MF = Mineral fertilizer (285.6 kg N + 178. 5 kg P_2O_5 + 357 K_2O ha^{-1}); BF= *Azosperllium brasilence*, *Azotobacter chroocooum*, *Bacillus megaterium*, VAM, *Bacillus cereus*, rock phosphates (22.8 % P_2O_5) at 357 kg ha^{-1} + Feldspar (10.6 % KO_2) at 1547 kg ha^{-1}.

Table 3: Effect of organic and bio-fertilizers on plant height, haulm fresh weight, number of stems per plant and chlorophyll content of potato plants after 90 days from planting, combined data of 2009 and 2010 seasons.

Treatment (ha)	Plant height (cm)	Haulm fresh weight (g)	Number of stems/plant	Chlorophyll (SPAD)
MF + 11.9 Mt compost (control)	42.88	339.10	4.68	35.42
23.8 Mt compost	44.75	302.50	3.18	36.00
23.8 Mt compost + BF	40.88	237.90	3.93	34.38
11.9 Mt compost + BF	41.5	352.50	3.93	41.81
50% MF+23.8 Mt compost	46.5	362.30	5.34	40.78
50% MF+23.8 Mt compost + BF	44.38	324.90	3.93	42.42
50% MF+11.9 Mt compost + BF	46.75	348.40	2.81	36.94
35.7 Mt compost	51.25	568.50	6.00	41.39
L.S.D. at 5%	6.47	133.10	0.82	NS

MF = Mineral fertilizer (285.6 kg N + 178. 5 kg P_2O_5 + 357 K_2O ha^{-1}); BF= *Azosperllium brasilence*, *Azotobacter chroocooum*, *Bacillus megaterium*, VAM, *Bacillus cereus*, rock phosphates (22.8 % P_2O_5) at 357 kg ha-1 + Feldspar (10.6 % KO_2) at 1547 kg ha^{-1}.

phosphoricum did not show the same efficiency in soils in the United States [26]. Undoubtedly, the efficiency of the inoculation varies with soil type, cultivar and other parameters. The P content of the soil is probably a crucial factor in determining effectiveness of the product [26].

The present study confirmed the specificity of the relationship of the nitrogen-fixing bacteria, phosphate dissolving bacteria and mycorrhizal isolates to the host potato cultivar used. Their efficacy with other potato cultivars needs further study. The bio-fertilizers are mostly crop specific and dependent on the compatibility of the microorganisms with the crop for delivering maximum utility [6]. The competitiveness of the efficient microorganism in natural environments will depend upon its ability to survive and multiply in soil. In general, population size, or density of the artificially introduced microorganisms, declines rapidly upon introduction in soils [27]. The survival of the inoculant strain depends upon various factors [28 - 30]. High soil salinity, high soil N and low pH can depress N fixation rate. Phosphorus can stimulate N fixation rate. Association with other species has been shown to influence N fixation rate. Bacterial symbionts may increase N fixation rate. Released N is utilized by surrounding organisms, including vascular plants, fungi, actinomycetes and bacteria [31].

No differences were occurred between the control and any organic treatment regarding chlorophyll content, although plots treated with 50% mineral fertilizers + 23.8 Mt•ha^{-1} compost+ bio-fertilizer had the highest chlorophyll content (Table 2). Chlorophyll content at 90 days from planting did not also differ between the control and treatments (Table 3).

Number of tubers per plant, weight of marketable tubers, average weight of marketable tuber and number of unmarketable tubers were varied among treatments (Table 4). The 35.7 Mt•ha^{-1} had higher values than those received the control at 75 days from planting. Plots that received 35.7 Mt•ha^{-1} compost did not differ from those receiving the control in number of marketable tubers per plant at 75 days from planting. Plots that received 11.9 Mt•ha^{-1} compost+ bio-fertilizer had the lowest number of marketable tubers per plant. Plots treated with

Table 4: Effect of organic and bio fertilizers on plant productivity after 75 days from planting (combined data of 2009 and 2010 seasons).

Treatment (ha)	No. of tubers/plant	No. of marketable tubers/plant	Weight of marketable tubers (g/plant)	Average weight of marketable tuber (g)	No. of unmarketable tubers
MF + 11.9 Mt compost (control)	18.00	10.75	366.30	31.74	7.25
23.8 Mt compost	16.63	9.87	394.80	40.08	6.75
23.8 Mt compost + BF	15.13	8.75	352.90	40.96	6.37
11.9 Mt compost + BF	13.63	8.00	345.90	42.81	5.62
50% MF+23.8 Mt compost	16.88	9.50	408.90	43.56	7.37
50% MF+23.8 Mt compost + BF	15.50	8.37	415.90	47.74	7.12
50% MF+11.9 Mt compost + BF	15.38	9.37	416.80	43.74	6.12
35.7 Mt compost	21.50	11.13	539.00	49.89	10.75
L.S.D. at 5%	2.91	1.67	96.72	7.93	2.09

MF = Mineral fertilizer (285.6 kg N + 178. 5 kg P_2O_5 + 357 K_2O ha^{-1}); BF= *Azosperllium brasilence*, *Azotobacter chroocooum, Bacillus megaterium*, VAM, *Bacillus cereus*, rock phosphates (22.8 % P_2O_5) at
357 kg ha^{-1} + Feldspar (10.6 % KO_2) at 1547 kg ha^{-1}

Table 5: Effect of organic and bio fertilizers on plant productivity after 90 days from planting (combined data of 2009 and 2010 seasons).

Treatment (ha)	No. of tubers/plant	No. of marketable tubers/plant	Weight of marketable tubers (g/plant)	Average weight of marketable tuber (g)	No. of unmarketable tubers
MF + 11.9 Mt compost (control)	17.50	11.63	664.80	55.58	5.87
23.8 Mt compost	16.88	10.13	663.30	67.65	6.75
23.8 Mt compost + BF	15.50	10.75	694.40	62.00	4.75
11.9 Mt compost + BF	12.50	8.50	516.80	59.25	4.25
50% MF+23.8 Mt compost	17.38	10.75	784.40	72.38	6.62
50% MF+23.8 Mt compost + BF	16.75	12.00	822.30	66.38	5.62
50% MF+11.9 Mt compost + BF	14.50	11.50	635.50	55.88	3.00
35.7 Mt compost	21.00	14.25	788.30	57.34	7.00
L.S.D. at 5%	2.56	2.2	185.8	11.31	1.62

MF = Mineral fertilizer (285.6 kg N + 178. 5 kg P_2O_5 + 357 K_2O ha^{-1}); BF= *Azosperllium brasilence, Azotobacter chroocooum, Bacillus megaterium,* VAM, *Bacillus cereus*, rock phosphates (22.8 % P_2O_5) at
357 kg ha^{-1} + Feldspar (10.6 % KO_2) at 1547 kg ha^{-1}

Table 6: Effect of organic and bio-fertilizers on the percentage of NPK in leaves after 75 after from planting (combined data of 2009 and 2010)

Treatment (ha)	N %	P %	K %
MF + 11.9 Mt compost (control)	4.85	0.8	5.97
23.8 Mt compost	4.55	0.87	5.64
23.8 Mt compost + BF	4.68	0.82	5.68
11.9 Mt compost + BF	4.57	0.73	5.06
50% MF+23.8 Mt compost	4.97	0.90	6.29
50% MF+23.8 Mt compost + BF	4.79	1.00	6.45
50% MF+11.9 Mt compost + BF	4.35	0.68	4.56
35.7 Mt compost	4.85	1.24	6.78
L.S.D. at 5%	0.4	0.27	0.65

MF = Mineral fertilizer (285.6 kg N + 178. 5 kg P_2O_5 + 357 K_2O ha^{-1}); BF= *Azosperllium brasilence, Azotobacter chroocooum, Bacillus megaterium*, VAM, *Bacillus cereus*, rock phosphates (22.8 % P_2O_5) at 357 kg ha^{-1} + Feldspar (10.6 % KO_2) at 1547 kg ha^{-1}

35.7 Mt•ha^{-1} compost had higher weights of marketable tubers per plant compared to the other treatments. The lowest average weight of marketable tuber was in control plots.

The effect of organic and bio-fertilizer on plant productivity of potato plants at 90 days from planting is presented in Table 5. Plots received 35.7 Mt•ha^{-1} compost had the highest total number of tubers per plant and number of marketable tubers per plant.

Treatment with 50% mineral fertilizers + 23.8 Mt•ha^{-1} compost had the highest average weight of marketable tuber. The highest weight of marketable tubers was with use of 50% mineral fertilizers+23.8 Mt•ha^{-1} compost+ bio-fertilizer. Compost at 23.8 Mt•ha^{-1} was not different from the control for number and weight of marketable tubers per plant. Use of 23.8 Mt•ha^{-1} of compost produced higher average marketable tuber weight than the control. Yield of crops grown in organic and conventional production systems was the same in other previous studies [4, 5]. Other findings reported decreases in plant productivity owing to use organic compared to mineral fertilizer. The reduction in plant productivity after use of organic fertilizers was attributed to decreased average tuber weight or lower number of tubers per plant compared to mineral fertilizer [24, 32, 33, 10]. The contradiction in results may be due to using high amounts of mineral fertilizer in the other studies, using low rates of organic fertilizer or compost in sandy soil [32,33,24].

Use of mineral fertilizer or compost fertilization at 35.7 Mt•ha^{-1} produced higher tubers yield per plant than application of compost at a rate of 11.9 Mt•ha^{-1}+ bio-fertilizer. Such results were attributed to the higher number of tubers per plant and average tuber weight in plots received high amount of compost (35.7 Mt•ha^{-1}) or conventional fertilization as compared with received compost at a rate of 11.9 Mt•ha^{-1}+ bio-fertilizer. Similar results were reported by Abou-Hussein *et al*. [25] who investigated effects of cattle manure + suspensions of bio-fertilizer consisting of soil yeast (*Candida tropicals*), *Pseudomonas aeruginosa* and phosphate solubliizing bacteria (*B. megatherium* var. *phosphaticum*) to sandy soil on potato yield and they found lower total tuber yield per plant than using the recommended mineral fertilizer.

For number of unmarketable tubers, plots received 23.8 Mt•ha^{-1} compost+ bio-fertilizer, 11.9 Mt•ha^{-1} compost+ bio-fertilizer or 50% mineral fertilizer+11.9 Mt•ha^{-1} compost+ bio-fertilizer had fewer number of small tubers as compared to the control.

Effect of compost and bio-fertilizer on NPK concentrations in potato shoots at 75 days after planting is presented in Table 6. Plots received 11.9 Mt•ha^{-1} compost+ bio-fertilizer alone or +50% mineral fertilizer had the lowest NPK concentrations in potato shoots. No differences in N concentration occurred between the control and other treatments, except the 50% mineral fertilizer+11.9 Mt•ha^{-1} compost+ bio-fertilizer, which had reduced N concentration compared to the control. Plots treated with 35.7 Mt•ha^{-1} compost had increased P concentration compared to the control. The lowest P concentration was in plots received 50% mineral fertilizer+11.9 Mt•ha^{-1} compost+ bio-fertilizer of 11.9 Mt•ha^{-1} compost+ bio-fertilizer.

Plots received 50% mineral fertilizer+11.9 Mt•ha^{-1} compost + bio-fertilizer had lower K shoot concentration compared with all other treatments. Plots received 11.9 Mt•ha^{-1} compost+ bio-fertilizer had a shoot K that was not different compared to 23.8 Mt•ha^{-1} compost alone or + bio-fertilizer. These results disagree with those found under sandy soil conditions by Abou-Hussein *et al*. [34] using cattle manure where there was no effect on percent N, P and K in leaves, compared with a lower rate of cattle manure plus mineral fertilizers. Similarly, Abou-Hussein [24] applied a low level of compost to potato plants grown in sandy soil and found no effect on percent of N and P in leaves compared with using higher rates of compost. Warman *et al*. [35] reported no differences in a moderately fertile Pugwash sandy loam in N, P and K in potato shoot tissue due compost or a combination of compost mineral fertilizer.

CONCLUSION

Use of organic fertilizers in Egypt is limited by the threshold of allowable nitrogen level (170 kg•ha^{-1}•yr^{-1} of N). Organic production of potato with 23.8 Mt•ha^{-1} of compost could be an alternative to conventional production without reduction in yield and quality.

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