PRODUCING POTATO VIA NATURAL, ORGANIC AND BIO AMENDMENTS

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Abstract

Field experiment was performed to evaluate whether using compost and natural rocks of phosphate and potassium with bio fertilizers could replace mineral fertilizers in potato production. The experiment was conducted at Giza Agriculture Research Station, Egypt. The potato tubers (Lady Rosetta and Lady Balfour cultivars) were planted during the third week of January 2016 and 2017 seasons. Individual or combined treatments of rock phosphate with phosphate dissolving bacteria (*Bacillus megaterium*) and feldspar with K releasing bacteria (*Bacillus circulans*) were applied in presence either mineral N or compost with N fixing bacteria (*Azotobacter chroococcum* + *Azospirillium brasilense*). The effects of these treatments on growth characteristics and yield component of potato were compared with recommended dose of NPK as mineral fertilizers. The results mentioned that Lady Balfour cultivar was significantly better in most vegetative traits and yield component than Lady Rosetta. All individual or combined treatments of rock phosphate and feldspar with mineral N did not show any significant differences in growth and yield characteristics compared to mineral NPK. All treatments of rock phosphate and feldspar with compost reduced the growth and yield characteristics compared to mineral NPK. The lowest reductions in yield were obtained by compost + rock phosphate and feldspar treatment. In general, rock phosphate and feldspar with phosphate dissolving bacteria and K releasing bacteria could be an alternative to mineral PK for similar yield and quality of potatoes as well as obtain the highest net return. Compost with N fixing bacteria could be a substitute for mineral N to produce a slightly lower yield of potatoes but it's distinguished by high quality and healthy.

Keywords: Potato, compost, rock phosphate, feldspar, bio fertilizer, mineral fertilizer alternatives.

INTRODUCTION

Potato (*Solanum tuberosum L.*) is one of the most important agricultural crops for world food production after cereal crops, planted with 19,098,328 hectares and produced 381,682,144 tons (FAO 2014). Potato is one of the most important members of solanaceous vegetables in Egypt grown for either local consumption or exportation, it's total cultivated area is about 437386 feddans (feddan = 0.42 hectare), produced about 4955445 tons (Ministry of Agriculture and Land Reclamation, 2015). The export of potatoes was 650 thousand tons at a value of 241 million US$ (General Authority for the Control of Exports and Imports, 2015).

Generally, potato crop requires a huge amount of nitrogen, phosphorus and potassium fertilizer for high productivity and quality. The high prices of chemical fertilizers are currently a major burden for potato farmers and countries that subsidize these fertilizers (Labib *et al.,* 2012). The mineral fertilizers of N, P and K are rapidly lost by either evaporation or leaching in drainage water. The problem does not only stop at losing huge amounts of fertilizers, but it extends to other dangerous environmental pollution (Lee and Song, 2007; Shehata *et al.,* 2014). Slow release forms of N, P and K nutrients include organic nitrogen such as compost, natural minerals of phosphorus and potassium such as rock phosphate and feldspar respectively, these materials are released at a slower rate throughout the season, and thus the plants become able to uptake its most requirements of nutrients throughout the season without lose by leaching. (Abdel–Mouty and El-Greadly, 2008). Organic production of potato using suitable amount of compost could be a substitute to traditional production without decreasing productivity and quality (El-Sayed *et al.,* 2014), with low nitrate content and better storage ability (El-Sayed *et al.,* 2015). Compost, rock phosphate, feldspar and biofertilizers could be an alternative to mineral fertilizer for potato production (Shehata *et al.,* 2014). Other studies reported decreases in plant productivity owing to use organic fertilizer compared to mineral fertilizer (Abou-zeid *et al.,* 2011). Using organic fertilizers for potato production led to produce potatoes with higher content of dry matter and starch than mineral fertilizers. (Abdel-Salam and Shams, 2012). Likewise, decreases in nitrate (Mohammadi *et al.,* 2013; El-Sayed *et al.,* 2015). Utilization of biofertilizers included N fixing bacteria, phosphate dissolving bacteria and K releasing bacteria with application of rocks (rock phosphate and feldspar) in soil improve NPK uptake and the yield parameters of plants (Shaaban *et al.,* 2015). Biofertilizer proved to be very effective in increasing potato quality by reducing nitrate content (Shehata *et al.,* 2014). This study aims to investigate the effect of non-chemical fertilizers using compost and natural rocks of P and K with adding bio fertilizers on the productivity and quality of potato crop.

MATERIALS AND METHODS

The field experiment was carried out on potato at Giza Agriculture Research Station, Giza Governorate, Egypt, during the summer seasons of 2016 and 2017.

Plant Material

Potato tubers (Lady Rosetta and Lady Balfour cultivars) were sown on 20 and 18 of January in the first and second seasons, respectively.

Soil Properties

The tubers were planted in clay soil and were irrigated using surface irrigation system. The soil was analyzed according to FAO (1980) and its physical and chemical properties were presented in Table 1.

Table 1. Physical and chemical properties of the experimental soil

Sand %	Silt %	Clay %	Texture	pH	EC dS/m	Cations meq/l				Anions meq/l			
						Ca^{++}	Mg^{++}	K^{+}	Na^{+}	$Co_3^{=}$	HCO_3^{-}	Cl^{-}	$SO_4^{=}$
23.9	36.6	39.5	Clay loam	7.59	2.45	5.20	2.80	0.80	10.35	-	0.76	16.23	1.80

The Experimental Layout

The experiment soil was ploughed and divided into ridges (70 cm width). The tubers were sown at a distance of 20 cm on one side of ridge.

The Experimental Treatments

1- Mineral fertilizers of NPK (MNPK) as a control
2- Mineral fertilizers of NP + feldspar with K releasing bacteria (MNP + F & KRB)
3- Mineral fertilizers of NK + rock phosphate with P dissolving bacteria (MNP + RP & PDB)
4- Mineral fertilizers of N + rock phosphate with P dissolving bacteria + feldspar with K releasing bacteria (MN + RP & PDB + F & KRB)
5- Compost (C) with N fixing bacteria + MPK (C & NFB + MPK)
6- C & NFB + MP + F & KRB
7- C & NFB + MK + RP & PDB
8- C & NFB + RP & PDB + F & KRB

Experimental Design

The experiments were arranged in split plot design with using three replicates. The potato cultivars were adapted in the main plots and the fertilizer treatments were randomized in the sub plots. The plot area was 10.5 m^2 (3 m length and 3.5 m width). Each plot included 5 ridges.

Quantities of application

The mineral fertilizers of NPK were applied as follow 150 kg N/fed as 448 kg ammonium nitrate (33.5% N), 60 kg P_2O_5/fed as 387 kg calcium super phosphate (15.5% P_2O_5) and 96 kg K_2O/fed as 200 kg potassium sulphate (48% K_2O). The quantity of compost was calculated based on nitrogen recommended dose in clay soil (150 kg/feddan); that was 16.5 tons/feddan as dry weight. Analyses of the used compost were analyzed according to FAO (1980) and showed in Table 2. Rock phosphate (20% P_2O_5) and feldspar (10% K_2O) were applied at rate 300 and 960 kg/fed on respectively. Nitrogen fixing bacteria was used as mixture of *Azotobacter chroococcum* and *Azospirillium brasilense*. Phosphate dissolving bacteria and potassium releasing bacteria were used as single strains of *Bacillus megaterium* and *Bacillus circulans* on respectively.

Table 2. Analyses of the used compost

pH 1:10	EC 1:10 dS/m	O.C (%)	O.M (%)	C/N Ratio	N	P_2O_5	K_2O	$N\text{-}NH_4$	$N\text{-}NO_3$
					(%)			ppm	
7.12	3.69	17.15	28.13	18.84	0.91	0.71	1.20	302.00	76.00

Time and Method Application

All quantities of calcium super phosphate, compost, rock phosphate and feldspar were added as one dose during soil preparation, whereas ammonium nitrate and potassium sulphate were added at two equal portions after 30 and 50 days from sowing. All bio fertilizers were supplemented to the soil surface beside plants at rate 5 L/fed after 20 and 40 days from sowing by using liquid cultures (1ml contains 10^8cell) according to Mashhoor *et al.* (2002).

Data Recorded

Growth characteristics and nutritional status

After 75 days from sowing, six plants were randomly sampled from the inner 3 rows of each plot to determine parameters of vegetative growth and nutritional status. Fresh weight of shoot, plant height, numbers of stems and leaves per plant were measured. Also, chlorophyll reading was recorded in the third upper leaf by using Minolta Chlorophyll Meter Spad 501. Nutrient content (NPK) in potato plants were determined in dry matter of the third upper leaf according to Cottenie *et al.* (1982). Total nitrogen, phosphorus and potassium were determined by Micro Kjeldahl, Spectrophotometer and Flame photometer on respectively according to FAO (1980).

Yield component and quality properties

Potato tubers were harvested at maturity stage after 110 and 120 days from sowing for Lady Rosetta and Lady Balfour cultivars respectively. Five plants from each experimental unit were randomly chosen to measure weight and number of tubers per plant. Total yield/fed. was calculated from plot yield. Potato tubers were graded to three sizes small (2.5-5 cm), medium (5.0-6.5 cm) and large (>6.5 cm) according to Adams and Hide (1981) and the percentage of each size per meter square were calculated. Ten tubers from each replicate were randomly sampled to determine specific gravity and dry matter in tubers. Total soluble solids (TSS) in tubers were measured by using Digital Refractometer. Percentage of starch and carbohydrate were determined according to AOAC (2005). As well as nitrate content of tubers was determined using Cardy Nitrate Meter Model HORIBA, Spectrum Technologies, Inc., as described by Al-Moshileh *et al.* (2004).

Economic evaluate

Economic evaluate was performed by estimate the net return of studied treatments. Cost of cultivation was calculated as sum costs of land preparation, irrigation, fertilization, pest management, transportation, land rent, seeding price and

other expenses based on local charges for all cultivars and treatments (Table 3). Gross return was obtained as the sum price of the total yield at harvesting time on the basis of local field price. Net return was calculated by subtracting total cost of cultivation from gross return.

Table 3. Total cost cultivation of two potato cultivars as mean for both seasons (2016 and 2017)

Items	Cost (L.E./fed.)	Fertilizer treatments	Fertilizer cost (L.E./fed.)	Production cost (L.E./fed.)	Total cost (L.E./fed.)	
					Rosseta	Balfour
Seeding	7500					
Soil preparation	600					
Irrigation	400	MNPK	3447	15100	18547	18547
Weeding	600	MNP + F	2715	15100	17815	17815
Pest control	1000	MNK + RP	3284	15100	18384	18384
Harvesting	600	MN + RP + F	2552	15100	17652	17652
Transportation	400	C + MPK	5503	15100	20603	20603
Other expenses	1000	C + MP + F	4771	15100	19871	19871
Rent	3000	C + RP + MK	5340	15100	20440	20440
Production cost	15100	C + RP + F	4608	15100	19708	19708

MNPK = mineral NPK
C = compost + N fixing bacteria
F = feldspar + K releasing bacteria
RP = rock phosphate + P dissolving bacteria

Statistical analysis

Data of both seasons were arranged and statistically analyzed according to Snedecor and Cochran (1980) with SAS software, version 2004. Treatment means were compared at significance level 0.05 using Tukey test**.**

RESULTS AND DISCUSSION

Vegetative growth

Vegetative growth parameters, i.e. chlorophyll reading in leaves, shoot fresh weight, stem number, plant height and leaf number/plant for two cultivars of potato under different fertilizers were presented in Tables 4 and 5. Data indicated that cv. Lady Balfour showed a significant superiority in all vegetable growth characteristics except chlorophyll reading of leaves and stem number/plant. No significant differences were observed between the two cultivars in stem number/plant. While, Lady Rosetta excelled in chlorophyll reading of leaves. Differences between cultivars might be related to genetic factors which resulted from genetic makeup relations for the cultivars as reported by Zelelew *et al.* (2016).

Effect of different fertilizers on vegetative growth of potato plants, the results revealed that all mineral nitrogen treatments with the addition of PK in the form of minerals or rocks increased the vegetative growth characteristics of plants compared with compost treatments except for the number of stems, which showed no significant differences among all fertilizer treatments. No significant differences were found among all mineral nitrogen treatments, with addition of PK in the form of minerals or

rocks. All compost treatments, with adding PK in the form of minerals or rocks, showed no significant differences among them in all vegetable growth characteristics. These results were similar in both seasons. This superiority in mineral nitrogen treatments in vegetative growth properties over compost treatments, might be attributed to the plants obtain nitrogen from mineral fertilizer more easily than organic fertilizer. Nitrogen has an important role in the formation of chlorophyll and growth hormones into plant, which reflect positive effect on vegetative growth These results are compatible with that obtained by Abou-Hussein 2005 and El-Sayed *et al.* (2014).

Table 4. Effect of treatments on vegetative growth characteristics of two potato cultivars during 2016 and 2017 seasons

Fertilizer treatments	First season						Second season					
	Cultivars											
	Rosetta		Balfour		Mean		Rosetta		Balfour		Mean	
	Chlorophyll reading (SPAD)											
MNPK	43.89	ab	40.78	bc	42.33	A	51.34	a	46.62	bcd	48.98	A
MNP + F	44.89	a	40.78	bc	42.83	A	52.34	a	46.62	bcd	49.48	A
MNK + RP	44.56	a	41.00	bc	42.78	A	52.01	a	46.84	b	49.42	A
MN + RP + F	45.22	a	41.89	abc	43.56	A	52.67	a	47.73	b	50.20	A
C + MPK	40.11	cd	38.67	cd	39.39	B	45.76	bcd	43.14	def	44.45	B
C + MP + F	40.67	cd	37.11	d	38.89	B	44.54	b-f	41.58	f	43.06	B
C + RP + MK	39.33	cd	37.22	d	38.28	B	44.98	b-e	41.69	ef	43.34	B
C + RP + F	40.67	bc	39.00	cd	39.84	B	46.32	bcd	43.47	c-f	44.90	B
Mean	42.42	A	39.56	B			48.74	A	44.71	B		
	Shoot fresh weight (g)											
MNPK	183.67	cde	287.67	a	235.67	A	219.67	d	304.67	ab	262.17	A
MNP + F	183.00	cde	284.67	a	233.84	A	214.67	d	304.33	ab	259.50	A
MNK + RP	184.33	cd	285.67	a	235.00	A	220.33	d	306.00	a	263.17	A
MN + RP + F	186.67	c	291.67	a	239.17	A	222.67	d	308.00	a	265.34	A
C + MPK	148.00	f	250.00	b	199.00	B	177.00	e	277.67	bc	227.33	B
C + MP + F	151.67	def	247.33	b	199.50	B	180.67	e	273.00	c	226.83	B
C + RP + MK	149.67	ef	243.33	b	196.50	B	178.67	e	275.67	c	227.17	B
C + RP + F	148.00	f	250.00	b	199.00	B	177.00	e	276.67	c	226.83	B
Mean	166.88	B	267.54	A			198.83	B	290.75	A		
	Stem Number											
MNPK	2.11	a	2.33	a	2.33	A	2.67	a	2.33	a	2.67	A
MNP + F	2.11	a	2.55	a	2.34	A	2.67	a	3.00	a	2.83	A
MNK + RP	2.22	a	2.53	a	2.38	A	2.67	a	2.67	a	2.67	A
MN + RP + F	2.33	a	2.44	a	2.28	A	3.00	a	2.67	a	2.67	A
C + MPK	2.11	a	2.22	a	2.17	A	3.00	a	2.67	a	2.83	A
C + MP + F	2.33	a	2.22	a	2.28	A	3.33	a	2.67	a	3.00	A
C + RP + MK	2.33	a	2.22	a	2.28	A	2.67	a	2.33	a	2.50	A
C + RP + F	2.11	a	2.22	a	2.17	A	2.33	a	2.67	a	2.50	A
Mean	2.21	A	2.34	A			2.79	A	2.63	A		

Means followed in same column by similar letters are not statistically different at 0.05 level according to Tukey test.

MNPK = mineral NPK
C = compost + N fixing bacteria
F = feldspar + K releasing bacteria
RP = rock phosphate + P dissolving bacteria

The interaction between fertilizer treatments and cultivars had significant effect on vegetative growth characteristics of potato plants in both seasons. However, the highest values of plant height, leaf number and shoot fresh weight/plant were recorded by all mineral N treatments with cv. Lady Balfour. Meanwhile, the lowest values were obtained by all compost treatments with cv. Lady Rosetta. On contrarily, all compost treatments with Rosetta cultivar gave the highest values of chlorophyll reading of leaves. Whereas, the lowest values were resulted by all mineral N treatments with cv. Lady Balfour. This might be related to genetic factors resulted from genetic makeup relations for the cultivars.

Table 5. Effect of treatments on vegetative growth characteristics of two potato cultivars during 2016 and 2017 seasons

Fertilizer treatments	First season			Second season		
	Cultivars					
	Rosetta	Balfour	Mean	Rosetta	Balfour	Mean
			Plant height (cm)			
MNPK	49.78 b	57.13 a	53.46 A	51.33 de	60.56 a	55.95 A
MNP + F	50.11 b	56.57 a	53.34 A	51.33 de	60.00 a	55.67 A
MNK + RP	49.66 b	57.35 a	53.51 A	50.00 ef	60.78 a	55.39 A
MN + RP + F	51.45 b	58.35 a	54.90 A	52.33 cde	61.78 a	57.06 A
C + MPK	43.89 c	50.11 b	47.00 B	45.67 g	55.11 bcd	50.39 BC
C + MP + F	44.67 c	48.89 b	46.78 B	47.33 fg	53.89 bcd	50.61 C
C + RP + MK	43.00 c	50.45 b	46.72 B	45.33 g	55.45 bcd	50.39 BC
C + RP + F	43.89 c	51.11 b	47.50 B	47.67 fg	56.11 b	51.89 B
Mean	47.06 B	53.74 A		48.88 B	57.96 A	
			Leaf number/plant			
MNPK	46.67 bc	63.67 a	55.17 A	52.33 bcd	75.33 a	63.83 A
MNP + F	46.00 bc	64.00 a	55.00 A	51.67 b-e	73.67 a	62.67 A
MNK + RP	46.00 bc	66.33 a	56.17 A	52.33 bcd	76.33 a	64.33 A
MN + RP + F	47.33 b	64.00 a	55.67 A	52.67 bc	78.33 a	65.50 A
C + MPK	39.33 bc	44.33 bc	41.83 B	44.67 cde	55.33 b	50.00 B
C + MP + F	39.33 bc	43.67 bc	41.50 B	43.33 e	54.67 b	49.00 B
C + RP + MK	38.00 c	43.00 bc	40.50 B	44.67 cde	54.00 b	49.33 B
C + RP + F	39.00 bc	45.00 bc	42.00 B	43.67 de	56.00 b	49.83 B
Mean	42.71 B	54.25 A		47.67 B	65.67 A	

Means followed in same column by similar letters are not statistically different at 0.05 level according to Tukey test.

MNPK = mineral NPK
C = compost + N fixing bacteria
F = feldspar + K releasing bacteria
RP = rock phosphate + P dissolving bacteria

Nutritional status

Data in Table 6 indicated that NPK content in leaves of Lady Balfour cultivar was significantly higher than Lady Rosetta in both seasons. These results might be correlated with the gene action of the tested cultivars (Zelelew *et al.,* 2016).

Fertilizer treatments showed significant effect on NK content of potato leaves, whereas there were no effects on P content in both seasons. The highest N content was obtained by plants that fertilized by mineral N + rocks of PK + P dissolving and K releasing bacteria, with no

significant differences with mineral NPK treatment. Meanwhile, compost with N fixing bacteria + rocks of PK + P dissolving and K releasing bacteria gave the highest K content compared to mineral NPK, with no significant differences with other compost treatments. The high content of N in potato leaves with treatments of mineral N fertilizer might be due to it is easy decomposition, so the plants absorb large quantities from it. While, superiority of compost + rocks of P and K in presence of bio fertilizers treatments in K content, may be due to the role of bacteria in releasing K from feldspar (Sheng *et al.,* 2002), as well as the role of compost as organic matter is characterized by a high cation exchange capacity preserves the nutrients without loss by leaching, so plants can uptake them as needed (Abdel–Mouty and El-Greadly, 2008; Fiorentino and Fagnano, 2011).

Table 6. Effect of treatments on nutritional status of two potato cultivars during 2016 and 2017 seasons

Fertilizer treatments	First season			Second season		
	Cultivars					
	Rosetta	Balfour	Mean	Rosetta	Balfour	Mean
	% N					
MNPK	4.253 b	4.493 a	4.373 A	4.317 b	4.573 a	4.445 A
MNP + F	4.143 b	4.270 b	4.207 B	4.213 b	4.347 b	4.280 B
MNK + RP	4.160 b	4.280 b	4.220 B	4.230 b	4.357 b	4.293 B
MN + RP + F	4.290 b	4.550 a	4.420 A	4.363 b	4.627 a	4.495 A
C + MPK	3.177 f	3.337 de	3.257 D	3.333 e	3.437 de	3.385 D
C + MP + F	3.243 def	3.303 def	3.273 D	3.350 e	3.410 de	3.380 D
C + RP + MK	3.287 def	3.437 def	3.362 D	3.380 e	3.543 d	3.462 D
C + RP + F	3.353 de	3.743 c	3.548 C	3.483 de	3.873 cd	3.678 C
Mean	3.738 B	3.927 A		3.834 B	4.021 A	
	% P					
MNPK	0.338 b	0.418 a	0.378 A	0.408 c	0.486 ab	0.447 A
MNP + F	0.335 b	0.419 a	0.377 A	0.402 c	0.496 ab	0.445 A
MNK + RP	0.344 b	0.433 a	0.388 A	0.408 c	0.499 a	0.454 A
MN + RP + F	0.351 b	0.433 a	0.392 A	0.415 c	0.490 ab	0.453 A
C + MPK	0.349 b	0.440 a	0.394 A	0.427 c	0.494 a	0.460 A
C + MP + F	0.351 b	0.429 a	0.390 A	0.429 c	0.496 a	0.463 A
C + RP + MK	0.356 b	0.443 a	0.400 A	0.434 bc	0.496 a	0.465 A
C + RP + F	0.365 b	0.452 a	0.408 A	0.435 bc	0.501 a	0.468 A
Mean	0.349 B	0.433 A		0.420 B	0.495 A	
	% K					
MNPK	5.560 g	6.152 de	5.856 C	5.627 fg	6.230 cd	5.927 C
MNP + F	5.620 fg	6.171 de	5.895 C	5.683 fg	6.247 cd	5.964 C
MNK + RP	5.531 g	6.169 de	5.850 C	5.573 g	6.247 cd	5.909 C
MN + RP + F	5.625 fg	6.185 cde	5.905 BC	5.697 fg	6.273 cd	5.985 BC
C + MPK	5.810 fg	6.288 bcd	6.049 ABC	5.910 ef	6.507 bc	6.208 AB
C + MP + F	5.800 fg	6.497 abc	6.148 AB	5.900 ef	6.597 ab	6.248 A
C + RP + MK	5.780 fg	6.533 ab	6.157 AB	5.893 ef	6.633 ab	6.263 A
C + RP + F	5.916 ef	6.660 a	6.288 A	6.017 de	6.830 a	6.423 A
Mean	5.705 B	6.332 A		5.788 B	6.445 A	

Means followed in same column by similar letters are not statistically different at 0.05 level according to Tukey test.

MNPK = mineral NPK

F = feldspar + K releasing bacteria

C = compost + N fixing bacteria

RP = rock phosphate + P dissolving bacteria

The interaction between fertilizer treatments and cultivars had significant effect on NK content of potato plants in the two seasons. The highest values of N content were recorded by treatments of mineral N + PK in form rocks or minerals with Lady Balfour cultivar. Meanwhile, the lowest values were obtained by all compost treatments with Lady Rosetta cultivar. On other hand, compost with N fixing bacteria + rocks of PK + P dissolving and K releasing bacteria treatment with Lady Balfour cultivar gave the highest value of K content of leaves. Whereas, the lowest values were resulted by all mineral N treatments with Lady Rosetta.

Yield components

The data are shown in Table 7 that there were significant differences among the various treatments for yield components of potato. In both seasons, Lady Balfour cultivar significantly gave the higher values of yield and number of potato tubers than Lady Rosetta cultivar. This result was consistent with findings of Kandi *et al.* (2011) and Vaezzadeh *et al.* (2012) they indicated that the differences in yield components of potato cultivars are mainly due to difference genotype between cultivars.

Fertilizer treatments had significant effect on yield components. However, the treatment of mineral N + rocks of PK + P dissolving and K releasing bacteria produced the highest yield and number of tubers, with no significant differences with other treatments of mineral N. On contrarily, all treatments of compost + PK in the form of minerals or rocks reduced of yield and tuber number/plant compared to mineral NPK. The lowest reductions in tuber yield/fed. were 12.2 and 10.6% by compost + rocks of PK treatment, respectively in both seasons, with no significant differences with compost + mineral PK treatment. The highest reductions of tuber yield/fed. were 18.1 and 15.4% by compost + rock P + mineral K treatment, respectively in both seasons, with no significant differences with compost + mineral P + rock K treatment. The reduction of yield by compost treatments might be due to organic fertilizer is too slow release, which leads to the nutrients available from them are insufficient for the plant requirements and thus reduce the vegetable growth, which reflected on reducing yield of tubers. These results are supported by the work of Abou-zeid *et al.* (2011) and Shehata *et al.* (2014).

Effect of interaction between fertilizer treatments and cultivars, Lady Balfour cultivar treated by mineral nitrogen treatments with the addition of PK in the form of minerals or rocks, gave the highest values of yield and number of potato tubers. The lowest values of yield and number of potato tuber were resulted from all compost treatments with Lady Rosetta cultivar.

Table 7. Effect of treatments on yield components of two potato cultivars during 2016 and 2017 seasons

Fertilizer treatments	First season						Second season					
	Cultivars											
	Rosetta		Balfour		Mean		Rosetta		Balfour		Mean	
	Yield (ton/fed.)											
MNPK	14.015	cde	18.280	a	16.160	A	23.700	c	27.010	ab	25.390	A
MNP + F	13.785	cde	17.870	a	15.820	A	23.580	c	26.470	ab	25.020	A
MNK + RP	13.877	cde	17.780	a	15.830	A	23.440	cd	26.230	b	24.840	A
MN + RP + F	14.043	cde	18.750	a	16.380	A	23.770	c	27.810	a	25.750	A
C + MPK	12.936	ef	14.735	bc	13.833	BC	21.393	ef	23.013	cd	22.203	BC
C + MP + F	12.571	f	14.364	bc	13.467	C	20.910	f	22.410	cde	21.660	C
C + RP + MK	12.271	f	14.198	bcd	13.233	C	20.800	f	22.173	def	21.487	C
C + RP + F	13.190	def	15.192	b	14.190	B	21.613	ef	23.773	c	22.693	B
Mean	13.337	B	16.397	A			22.400	B	24.860	A		
	Yield (kg/plant)											
MNPK	0.508	cde	0.662	a	0.585	A	0.850	b	0.973	a	0.912	A
MNP + F	0.499	cde	0.647	a	0.573	A	0.847	bc	0.953	a	0.900	A
MNK + RP	0.503	cde	0.644	a	0.574	A	0.847	bc	0.947	a	0.897	A
MN + RP + F	0.508	cde	0.679	a	0.594	A	0.853	b	0.983	a	0.918	A
C + MPK	0.469	ef	0.534	bc	0.501	BC	0.767	de	0.830	bc	0.798	BC
C + MP + F	0.456	f	0.520	bc	0.488	BC	0.753	e	0.810	bcd	0.782	C
C + RP + MK	0.446	f	0.515	bcd	0.480	C	0.747	e	0.797	cde	0.772	C
C + RP + F	0.478	def	0.550	b	0.514	B	0.777	de	0.857	b	0.817	B
Mean	0.483	B	0.594	A			0.805	B	0.894	A		
	Tuber number/plant											
MNPK	8.140	ef	13.334	a	10.737	A	12.287	bcd	19.763	a	16.025	A
MNP + F	8.910	de	12.355	ab	10.633	A	12.003	d	19.907	a	15.955	A
MNK + RP	8.390	ef	12.368	ab	10.379	A	12.237	cd	18.333	a	15.285	A
MN + RP + F	8.177	ef	13.587	a	10.882	A	12.237	cd	18.813	a	15.525	A
C + MPK	7.560	ef	10.232	cd	8.896	B	11.050	d	14.333	bc	12.692	B
C + MP + F	7.420	f	10.765	c	9.092	B	11.380	d	14.430	bc	12.905	B
C + RP + MK	7.117	f	10.292	cd	8.704	B	12.477	bcd	14.570	b	13.523	B
C + RP + F	7.290	f	11.293	bc	9.292	B	11.140	d	14.570	b	12.855	B
Mean	7.875	B	11.778	A			11.851	B	16.840	A		

Means followed in same column by similar letters are not statistically different at 0.05 level according to Tukey test.

MNPK = mineral NPK

F = feldspar + K releasing bacteria

C = compost + N fixing bacteria

RP = rock phosphate + P dissolving bacteria

Tubers quality

Data in Table 8 are showed effects of different fertilizers on tubers quality for two cultivars of potato. Lady Rosetta cultivar was higher than Lady Balfour cultivar in the percent of medium tubers. On the other hand, Lady Balfour cultivar produced the highest percent of small tubers. While, no significant differences were detected between both cultivars in percentage of large sizes and specific gravity of tubers. These results were noticed in the two seasons. The differences between cultivars in some properties of quality might be related to genetic factors as mentioned

Vaezzadeh *et al.* (2012) and Zelelew *et al.* (2016). Effect of different fertilizers on tubers quality of potato, there were no significant differences among all treatments in percent of different potato sizes and specific gravity of tubers. Thus, the effect of interaction between fertilizer treatments and cultivars was not significant.

Table 8. Effect of treatments on the size and specific gravity of potato tubers during 2016 and 2017 seasons

Fertilizer treatments	First season			Second season		
	Cultivars					
	Rosetta	Balfour	Mean	Rosetta	Balfour	Mean
	% Large tubers					
MNPK	0.00 a	0.00 a	0.00 A	2.81 a	1.92 a	2.36 A
MNP + F	0.00 a	0.00 a	0.00 A	2.79 a	2.10 a	2.45 A
MNK + RP	0.00 a	0.00 a	0.00 A	2.64 a	2.60 a	2.62 A
MN + RP + F	0.00 a	0.00 a	0.00 A	2.26 a	2.53 a	2.40 A
C + MPK	0.00 a	0.00 a	0.00 A	2.59 a	3.66 a	3.13 A
C + MP + F	0.00 a	0.00 a	0.00 A	2.52 a	3.61 a	3.07 A
C + RP + MK	0.00 a	0.00 a	0.00 A	2.00 a	2.97 a	2.48 A
C + RP + F	0.00 a	0.00 a	0.00 A	2.94 a	3.54 a	3.24 A
Mean	0.00 A	0.00 A		2.19 A	2.99 A	
	% Medium tubers					
MNPK	74.05 a	58.89 b	66.47 A	71.31 a	62.40 b	66.86 A
MNP + F	72.61 a	58.36 b	65.49 A	72.62 a	61.69 b	67.16 A
MNK + RP	73.75 a	61.31 b	67.53 A	71.83 a	62.51 b	67.17 A
MN + RP + F	76.28 a	59.14 b	67.71 A	71.79 a	62.73 b	67.26 A
C + MPK	70.06 a	57.38 b	63.72 A	70.05 a	63.17 b	66.61 A
C + MP + F	71.37 a	57.75 b	64.56 A	70.08 a	62.16 b	66.12 A
C + RP + MK	70.11 a	61.29 b	65.70 A	71.62 a	62.61 b	67.12 A
C + RP + F	70.53 a	60.74 b	65.64 A	71.42 a	62.66 b	67.04 A
Mean	72.35 A	59.36 B		71.34 A	62.49 B	
	% Small tubers					
MNPK	25.95 b	41.11 a	33.53 A	25.88 c	35.68 a	30.78 A
MNP + F	27.39 b	41.64 a	34.51 A	24.59 c	36.21 a	30.40 A
MNK + RP	26.25 b	38.69 a	32.47 A	25.53 c	34.89 a	30.21 A
MN + RP + F	23.72 b	40.86 a	32.29 A	25.96 c	34.74 a	30.35 A
C + MPK	29.94 b	42.62 a	36.28 A	27.35 bc	33.17 ab	30.26 A
C + MP + F	28.63 b	42.25 a	35.44 A	27.40 bc	34.22 a	30.81 A
C + RP + MK	29.89 b	38.71 a	34.30 A	26.38 c	34.42 a	30.40 A
C + RP + F	29.47 b	39.26 a	34.36 A	26.30 c	33.80 ab	30.05 A
Mean	27.65 B	40.64 A		26.17 B	34.64 A	
	Specific gravity of tuber (g/cm^2)					
MNPK	1.06 a	1.09 a	1.08 A	1.07 a	1.06 a	1.07 A
MNP + F	1.09 a	1.09 a	1.09 A	1.04 a	1.09 a	1.07 A
MNK + RP	1.06 a	1.06 a	1.06 A	1.07 a	1.07 a	1.07 A
MN + RP + F	1.11 a	1.04 a	1.07 A	1.06 a	1.06 a	1.06 A
C + MPK	1.07 a	1.10 a	1.08 A	1.08 a	1.06 a	1.07 A
C + MP + F	1.06 a	1.05 a	1.06 A	1.06 a	1.04 a	1.05 A
C + RP + MK	1.07 a	1.07 a	1.07 A	1.10 a	1.05 a	1.08 A
C + RP + F	1.07 a	1.07 a	1.07 A	1.10 a	1.07 a	1.09 A
Mean	1.07 A	1.07 A		1.07 A	1.06 A	

Means followed in same column by similar letters are not statistically different at 0.05 level according to Tukey test.

MNPK = mineral NPK
C = compost + N fixing bacteria
F = feldspar + K releasing bacteria
RP = rock phosphate + P dissolving bacteria

Tuber compositions

Data pertaining to the effect of the replacement of mineral fertilizers by natural ones on potato tuber compositions are tabulated in Table 9 and 10. The tubers of Lady Rosetta cultivar were higher in contents of TSS, dry mater, starch and carbohydrate than Lady Balfour tubers. While, Lady Balfour tubers were higher in nitrate content. Superiority of Lady Rosetta cultivar in these traits may be due to genotype for cultivar. These results are supported by Yaghbani and Mohammadzadeh (2005), they reported that there was significant difference in dry matter starch and carbohydrate contents between different cultivars of potato. Since starch forms 60-80% of dry matter, this makes a positive correlation between starch content and dry matter of potatoes. In addition, starch is the predominant component of carbohydrates in potatoes so potato cultivars that contain high dry matter, also contain high starch and carbohydrates as reported by Kandi *et al.* (2011).

Table 9. Effect of treatments on TSS and dry matter of potato tubers during 2016 and 2017 seasons

Fertilizer treatments	First season			Second season		
	Cultivars					
	Rosetta	Balfour	Mean	Rosetta	Balfour	Mean
	TSS in tuber (%)					
MNPK	7.22 a	4.31 b	5.77 A	6.10 a	4.57 b	5.33 A
MNP + F	7.20 a	4.38 b	5.79 A	6.13 a	4.27 b	5.20 A
MNK + RP	7.45 a	4.51 b	5.98 A	6.63 a	4.23 b	5.43 A
MN + RP + F	7.10 a	4.18 b	5.64 A	6.13 a	4.27 b	5.20 A
C + MPK	7.47 a	4.65 b	6.06 A	5.93 a	4.20 b	5.07 A
C + MP + F	7.24 a	4.41 b	5.83 A	6.40 a	4.10 b	5.25 A
C + RP + MK	7.50 a	4.44 b	5.97 A	6.27 a	3.97 b	5.12 A
C + RP + F	7.50 a	4.14 b	5.82 A	6.13 a	4.07 b	5.10 A
Mean	7.33 A	4.38 B		6.22 A	4.21 B	
	Dry matter in tuber (%)					
MNPK	22.48 c	17.90 f	20.19 C	21.67 cd	16.43 e	19.05 CD
MNP + F	22.60 bc	18.16 ef	20.38 C	21.87 bcd	16.70 e	19.28 BCD
MNK + RP	22.62 bc	18.53 def	20.58 C	20.77 d	16.40 e	18.58 D
MN + RP + F	22.91 bc	18.81 def	20.86 BC	22.37 bc	16.83 e	19.60 BC
C + MPK	22.99 bc	19.00 def	20.99 BC	22.97 ab	16.90 e	19.93 AB
C + MP + F	23.74 ab	19.16 de	21.45 AB	23.07 ab	16.90 e	19.98 AB
C + RP + MK	23.63 abc	19.23 de	21.43 AB	23.73 a	17.07 e	20.40 A
C + RP + F	24.44 a	19.63 d	22.03 A	23.83 a	17.07 e	20.45 A
Mean	23.18 A	18.80 B		22.53 A	16.79 B	

Means followed in same column by similar letters are not statistically different at 0.05 level according to Tukey test.

MNPK = mineral NPK
C = compost + N fixing bacteria
F = feldspar + K releasing bacteria
RP = rock phosphate + P dissolving bacteria

Effect of different fertilizers on potato tuber contents, there were no significant differences among all treatments in tuber content of TSS. All treatments of compost + rocks of P and K individual or in combinations increased tuber contents of dry matter, starch and carbohydrate compared to mineral NPK. In contrast, these treatments decreased nitrate content in tuber. The superiority of compost treatments over mineral fertilizer in dry matter, starch and carbohydrate in tubers may be due to the degradation of organic

matter and the releasing CO_2 in soil (Jarvan and Edesi, 2009). It may also be due to available nitrogen in organic fertilizer is low, which leads to metabolism more toward to formation of carbon compounds, such as starch and cellulose (Rembialkowska, 2007). These results were in accordance with those obtained by Abdel-Salam & Shams (2012) and Shehata *et al.* (2014). Using compost + rocks of PK treatment led to reduction 45% of nitrate content in tuber compared to mineral NPK treatment as average in both seasons. This is very important, because nitrate can easily converted into nitrite, which causes methaemoglobinaemia illness especially in children. Moreover, nitrite can react with amines to create nitrosamines, which are carcinogenic (Mahmoud *et al.,* 2009). This was attributed to the supply of readily available nitrate from mineral N fertilizers to the plants while, in the organic N treatments, nitrate release was comparatively slow. The nitrate concentrations of tubers increased with mineral N fertilizers. Similar finding was obtained by Mohammadi *et al.* (2013) and El-Sayed *et al.* (2015)

Table 10. Effect of treatments on starch, carbohydrate and nitrate in dry matter of potato tubers during 2016 and 2017 seasons

Fertilizer treatments	First season			Second season		
	Cultivars					
	Rosetta	Balfour	Mean	Rosetta	Balfour	Mean
	% Starch					
MNPK	75.52 bc	71.23 ef	73.37 B	74.90 b	70.50 f	72.70 B
MNP + F	75.58 bc	71.21 ef	73.39 B	74.83 bc	70.53 f	72.68 B
MNK + RP	75.66 b	71.15 f	73.41 B	74.90 b	70.47 f	72.68 B
MN + RP + F	75.60 bc	71.29 ef	73.45 B	74.87 bc	70.63 ef	72.75 B
C + MPK	77.20 ab	72.86 de	75.03 A	76.43 ab	72.20 de	74.32 A
C + MP + F	77.66 a	73.81 d	75.74 A	76.87 a	73.13 d	75.00 A
C + RP + MK	77.66 a	73.75 d	75.71 A	76.85 a	73.03 d	74.94 A
C + RP + F	77.65 a	73.91 cd	75.78 A	76.87 a	73.23 cd	75.05 A
Mean	76.57 A	72.40 B		75.81 A	71.72 B	
	% Carbohydrate					
MNPK	84.60 bc	79.79 ef	82.20 B	83.82 b	78.89 f	81.36 B
MNP + F	84.67 bc	79.77 ef	82.22 B	83.74 bc	78.94 f	81.34 B
MNK + RP	84.76 b	79.71 f	82.24 B	83.84 b	78.88 f	81.36 B
MN + RP + F	84.70 bc	79.87 ef	82.28 B	83.77 bc	79.03 ef	81.40 B
C + MPK	86.49 ab	81.62 de	84.06 A	85.52 ab	80.77 de	83.15 A
C + MP + F	87.00 a	82.69 d	84.85 A	86.02 a	81.83 d	83.93 A
C + RP + MK	86.99 a	82.62 d	84.81 A	86.02 a	81.76 d	83.89 A
C + RP + F	86.99 a	82.80 cd	84.90 A	86.02 a	81.94 cd	83.98 A
Mean	85.78 A	81.11 B		75.81 A	80.26 B	
	% Nitrate					
MNPK	0.320 b	0.398 a	0.359 A	0.284 b	0.361 a	0.322 A
MNP + F	0.314 b	0.392 a	0.353 A	0.278 b	0.359 a	0.319 A
MNK + RP	0.316 b	0.402 a	0.359 A	0.280 b	0.365 a	0.323 A
MN + RP + F	0.323 b	0.398 a	0.361 A	0.282 b	0.361 a	0.322 A
C + MPK	0.179 d	0.221 c	0.200 B	0.154 c	0.194 c	0.174 B
C + MP + F	0.179 d	0.216 c	0.197 B	0.154 c	0.189 c	0.171 B
C + RP + MK	0.188 d	0.215 c	0.201 B	0.163 c	0.188 c	0.175 B
C + RP + F	0.187 d	0.213 c	0.200 B	0.162 c	0.188 c	0.175 B
Mean	0.251 B	0.307 A		0.220 B	0.276 A	

Means followed in same column by similar letters are not statistically different at 0.05 level according to Tukey test.

MNPK = mineral NPK
C = compost + N fixing bacteria
F = feldspar + K releasing bacteria
RP = rock phosphate + P dissolving bacteria

The interaction between fertilizer treatments and cultivars had a significant effect on potato tuber contents in both seasons except TSS, which showed no significant differences among all treatments. The highest contents of dry matter, starch and carbohydrate in tubers were recorded by all compost treatments with Lady Rosetta cultivar. On other hand, all mineral N treatments with Lady Balfour gave the highest nitrate content in tuber.

Economic evaluate

The economic evaluation in Table 11 clearly indicated that although Lady Balfour cultivar was superior to Lady Rosetta cultivar in the yield quantity, Lady Rosetta was higher than Lady Balfour in the gross and net return. This is attributed that the sale price of Lady Rosetta tubers was higher than the Lady Balfour tubers. Concerning the treatments, using mineral N + rocks of PK + P dissolving and K releasing bacteria recorded the highest gross and net return. This may be due to the superiority of this treatment to other treatments in the yield quantity. In regard the interaction between cultivars and fertilizer treatments, Lady Balfour cultivar with application of mineral N + rocks of PK + P dissolving and K releasing bacteria gave the highest gross and net return. While, Lady Balfour cultivar with using C + RP + MK gave the lowest gross and net return. It can be noted that Lady Balfour cultivar with all the treatments of nitrogen mineral fertilizer recorded higher net returns than Lady Rosetta for the same treatments. Conversely, Lady Rosetta was superior to Lady Balfour with same compost treatments.

Table 11. Economic evaluate of different treatments as gross return and net return of two potato cultivars as mean for both seasons (2016 and 2017)

Treatments	Total cost (L.E./fed.)	Yield (ton/fed.)		Gross return (L.E./fed.)			Net return (L.E./fed.)		
		Rosseta	Balfour	Rosseta	Balfour	Mean	Rosseta	Balfour	Mean
MNPK	18547	18.857	22.645	37715	38497	38106	19168	19949	19559
MNP + F	17815	18.682	22.170	37365	37689	37527	19550	19874	19712
MNK + RP	18384	18.658	22.005	37317	37409	37363	18933	19025	18979
MN + RP + F	17652	18.906	23.280	37813	39576	38694	20161	21924	21042
C + MPK	20603	17.165	18.874	34330	32086	33208	13727	11483	12605
C + MP + F	19871	16.741	18.387	33481	31258	32370	13610	11387	12499
C + RP + MK	20440	16.535	18.186	33071	30916	31993	12631	10476	11553
C + RP + F	19708	17.402	19.483	34803	33121	33962	15095	13413	14254
Mean		17.868	20.629	35737	35069		16609	15941	

MNPK = mineral NPK
F = feldspar + K releasing bacteria
C = compost + N fixing bacteria
RP = rock phosphate + P dissolving bacteria

Sale price of Lady Rosseta tubers = 2000 L.E./ton
Sale price of Lady Balfour tubers = 1700 L.E./ton

CONCLUTION

It could be concluded that rock phosphate and feldspar with phosphate dissolving bacteria and K releasing bacteria could be an alternatives to mineral PK for similar yield and

quality of potatoes, as well as obtain the highest net return. While, compost with N fixing bacteria could be an alternative to mineral N obtain slightly low yield of potatoes but it's distinguished by high quality and healthy.

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إنتاج البطاطس عن طريق الاضافات الطبيعية والعضوية والحيوية

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1. *قسم البساتين - كلية الزراعة - جامعة المنيا- مصر*
2. *المعمل المركزى للزراعة العضوية - مركز البحوث الزراعية - الجيزة - مصر*

أجريت تجربة حقلية لتقييم ما إذا كان استخدام الكمبوست والصخور الطبيعية من الفوسفات والبوتاسيوم مع الأسمدة الحيوية يمكن أن تحل محل الأسمدة المعدنية في إنتاج البطاطس. أجريت التجربة في محطة الجيزة للبحوث الزراعية، مصر. تم زراعة درنات البطاطس (صنفى ليدي روزيتا و ليدي بالفور) خلال الأسبوع الثالث من يناير مواسم 2016 و 2017. تم استخدام معاملات فردية أو مخلوطة من صخر الفوسفات مع البكتيريا المذيبة للفوسفات (*Bacillus megaterium*) والفلسبار مع البكتيريا الميسرة للبوتاسيوم (*Bacillus circulans*) في وجود إما النتروجين المعدنى أو الكمبوست مع البكتيريا المثبتة للنتروجين (*Azotobacter chroococcum* + *Azospirillium brasilense*). تمت مقارنة تأثير هذه المعاملات على خصائص النمو ومحتوى النباتات من العناصر الغذائية ومكونات المحصول وتركيبات درنات البطاطس مع الجرعة الموصى بها من النتروجين والفوسفور والبوتاسيوم كأسمدة معدنية.

اشارت النتائج الى ان الصنف ليدى بالفور كان أفضل معنوياً في معظم الصفات الخضرية ومحتوى النباتات من العناصر الغذائية ومكونات المحصول من صنف ليدى روزيتا. وكان صنف ليدي روزيتا أعلى في نسبة الدرنات المتوسطة ومعظم تركيبات الدرنات. لم تظهر جميع المعاملات الفردية أو المجمعة من صخر الفوسفات والفلسبار مع النتروجين المعدنى اى فروق معنوية في خصائص النمو والمحصول مقارنة بالاسمدة المعدنية من النتروجين والفوسفور والبوتاسيوم. جميع معاملات صخر الفوسفات والفلسبار مع الكمبوست خفضت من خصائص النمو و المحصول مقارنة بالاسمدة المعدنية. وتم الحصول على أدنى انخفاض في المحصول من معاملة الكمبوست مع البكتيريا المثبتة للنتروجين + صخر الفوسفات مع البكتيريا المذيبة للفوسفات + الفلسبار مع البكتيريا الميسرة للبوتاسيوم. ويمكن استخلاص أن صخر الفوسفات والفلسبار مع البكتيريا المذيبة للفوسفات والبكتيريا الميسرة للبوتاسيوم يمكن ان يكونا بديلين عن اسمدة الفوسفور والبوتاسيوم المعدنية للحصول على محصول وجودة متماثلة من البطاطس وكذلك الحصول على أعلى صافى عائد. يمكن أن يكون الكمبوست مع البكتيريا المثبتة للنتروجين بديلا عن النتروجين المعدنى للحصول على محصول منخفض قليلا من البطاطس ولكنها تتميز بالجودة العالية وصحية.