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INFLUENCE OF ORGANIC AND POTASSIUM FERTILIZATION ON POTATO YIELD AND QUALITY

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ABSTRACT

Potato is considered strategic vegetable crop in the entire world. So, two field experiments were conducted in the experimental farm, Faculty of Agriculture, Mansoura University to study the effect of organic fertilization and foliar application with potassium (K) as well as rates of K soil fertilization and their interaction on vegetative growth (plant height, No of leaves/plant, fresh and dry weight), leaves chemical composition (Chlorophyll a, b, a+b, N, P and K), tuber yield (plant yield, No. of tuber/plant and total tuber yield) and its quality (TSS, reducing, non reducing, total sugar, vitamin C, starch and protein). The experiment was conducted in strip split plot design including 12 treatments *i.e.* 2 organic applications (compost and vermicompost), 2 foliar applications (tap water as a control and K at 2%) and three rates of K soil applications (120, 165 and 214 kg K_2O/hectare).

The obtained results clarified that using compost and foliar application with K at 2% as well 165 kg K_2O/ha significantly increased leaves chemical contents and tuber quality, while using vermicompost and foliar application with K at 2% plus 165 kg K_2O/ha gave the highest values of potato growth parameters and yield. Thus, it can be recommended that using compost or vermicompost at 9.5 and 7 ton/ ha and foliar application with K at 2% as well 165 kg K_2O/ha that gave the highest net return and improve quality of potato tubers.

Keywords: Compost, potato, potassium, vermicompost.

Introduction

Potato (*Solanum tuberosum* L.) is national crop following maize, rice and wheat. People depend on it almost time for nutrition and income. It is important source for carbohydrates, also has several nutrients vitamins, so it lower cost source of energy that human use it for diet. Total production of universal potato was 388,190,674 ton in 2017 (FAOSTAT 2017).

Using organic fertilization either compost or vermicompost as friendly environmental source for plant fertilization and producing healthy food (Lairon, 2009), however its low sufficient of nutrients. Organic fertilization participated in reducing environmental pollution and production cost. Compost improves the different properties of soils. As well supply of plants with available elements that increase its uptake, this reflects on plant growth and productivity (El-Sayed *et al.*, 2015 and Mijwel, 2018 on potato). Abd El-Nabi *et al.* (2016) showed that using compost increased potato growth, yield and quality. Vermicompost contains fundamental elements, enzymes, hormones, vitamins, N fixing and P solubilizing bacteria (Borah *et al.*, 2007 and Najar *et al.*, 2015). It promote microbial and enzyme activity that enhance soil particle aggregation and aeration. It fastens supply with micro elements in the soil to avoid leaching from soil and supplies the plant with its needs of the elements that reflect on plant growth and yield. Many researches showed the positive effect of vermicompost addition on potato growth, yield and quality (Agrowal *et al.*, 2017; Ferdous *et al.*, 2019a and Mostofa *et al.*, 2019)

K is one of essential macro elements that enhancing enzyme activity, protein and carbohydrates synthesis, movements of photosynthetic compounds (Salomi and Saadat, 2013 and Wang *et al.*, 2013). It can be added in several methods and sources. Foliar fertilization provides plants with nutrients in limited production conditions that prevent nutrient uptake from soil or inefficient (Hiller, 1995), also it corrects elements deficiencies on elements on plant growth and yield especially with mobile nutrients (Westennann, 2005). Many studies showed importance of k foliar application on growth and yield of potato (El-Sirafy *et al.*, 2008 and Salim *et al.*, 2014). Potato tuber size relies on potassium addition at all season of growth stage especially at the second part of potato due to its role in plant growth and participate several sides of potato quality. Neomerious studies cleared importance of potassium for potato growth, yield and quality (Zelelew *et al.*, 2016; Abou Zeid and Abd El-Latif, 2017 and Abdrabbo *et al.*, 2019).

Thus, the aim of research was to study the effect of organic fertilization, foliar and different rates of potassium soil additions in order to increase potato growth and yield having high quality as well decrease production costs.

Materials and Methods

The current study was conducted during two winter seasons 2018/2019 and 2019/2020 at the experimental farm, Faculty of Agriculture, Mansoura University to investigate

the effect of 12 treatments, organic amendments (compost and vermicompost), foliar application with K (tap water as control and foliar application at 2% K_2O) and three levels of K soil addition (120, 165 and 215 kg K_2O/ha) on potato Spunta cultivar growth, chemical composition, yield and quality.

The soil analysis is shown in Table 1 according to Jackson (1967).

Table 1: Some physical and chemical properties of experimental soil (average two seasons):

Soil particle distribution (%)				Texture class	OM (%)	$CaCO_3$ (gkg^{-1})	SP %	EC $dS.m^{-1}$, 1:5	pH (1:2.5)	Available (mg kg^{-1} soil)		
Coarse Sand	Fine Sand	Silt	Clay							N	P	K
4.35	25.42	35.51	34.72	Silty clay loam	1.59	4.83	59.4	0.93	8.06	53.4	6.2	100.2

SP: Saturation percentage OM: Organic matter EC: Electrical conductivity

A strip split plot design was applied with three replicates in the randomized complete block design, the organic fertilization was assigned in vertical plots, and foliar K application was allocated in the horizontal plots, while sub plots were contain addition of soil potassium rates.

Potato tubers were cut and planted on 3rd and 5th November during first and second seasons respectively. Pieces were sown every 25 cm apart in rows each row was (0.7m width X 8m length). The plot area was 11.2 m^2 consist of two rows.

Calcium super phosphate (15.5% P_2O_5) was added during soil preparation at 165 kg P_2O_5/ha. 355 kg N/ha was added at three doses as ammonim nitrate (33.5 N %), the first one during preparation soil, while the second after emergence and the third was added after two weeks. Potassium fertilizer was added as potassium sulphate (48% K_2O) at three levels (120, 165 and 215 kg K_2O/ha) and divided into two equal portions, the first one was added after one month from emergence while the second dose after one month later. All agricultural treatments were done according to the recommendation of Ministry of Agriculture in Egypt.

Foliar application with K in the form of potassium sulphate at rate of 2% K_2O (1.66 K) was added three times at 40, 55 and 70 days from planting by 20 L hand pressure sprayer. The volume of foliar application was 240, 355 and 480 liter/ha in the 1st, 2nd and 3rd foliar additions, respectively. To ameliorate permeation through leaves of plant used pervasion agent.

Compost rice straw and vermicompost were applied at 9.5 and 7 ton/ha respectively during preparation soil. Chemical analysis of compost and vermicompost are shown in Tables 2 and 3.

Table 2: Chemical analysis of compost.

%			C/N	%		Ppm			Sp (%)	pH 1:10	EC1:10, $dS-^1m$
OM	OC	N		P	K	Fe	Mn	Zn			
21.3	12.8	0.59	20.5	0.42	0.61	48.16	18.05	9.22	104.0	7.05	4.14

OM: Organic matter OC: Organic carbon

Table 3: Chemical analysis of vermicompost.

%			C/N	%			pH (1:10)	EC1:10, $dS-^1m$
OM	OC	N		P	K	SP		
34.62	34.62	1.69	15.65	2.12	1.31	164.00	7.55	2.22

OM: Organic matter TC: Total carbon SP: Saturation percent

Data recorded

Five plants were taken randomly after 80 days from planting to determine:

Vegetative growth characters *i.e.* plant height (cm); No of leaves/ plant and fresh weight (g/plant). To determine dry weight (g/plant) by oven, plant samples were dried at 70°C till constant weight.

Chemical composition of leaves:

- Chlorophyll a, b and a+b (mg/g Fw): were determined according to Goodwine (1965).
- Nitrogen, phosphorus and potassium percentage were estimated in dry leaves according to AOAC (2012).

Tubers yield

After 120 days from planting; plant yield (kg); No. of tuber/plant and total tuber yield (ton/ha) were listed, tubers were dried to record dry matter (%).

Tuber quality:

- Total dissolved solids (TDS) %: were determined by using Refract meter according to AOAC (2012).
- Total sugar %: was estimated by the method reported by Malik and Srivastava (1979).
- Reducing and non reducing sugar%: were determined as reported by Somogy (1952).
- -Vitamin C (mg/100 g Fw): It was determined by the method reported in AOAC (2012).
- Starch%: was determined according to Somogy (1952).
- Protein %: It was calculated by multiplying N in tuber percentage × 6.25.
- -At the end of the experiment available K of the soil was determined according to Jackson (1967).

Statistical analysis:

Data were statisticaly analyzed by ANOVA technique according to Gomez and Gomez (1984). The means of treatments were compared by Duncan Multiple Rang Test (Duncan, 1955).

Economic feasibility:

- Gross money return as marketable yield (Ton ha^{-1}) x 3000 LE /Ton
- Treatment cost was calculated according to the prices of all treatments: compost, vermicompost, foliar application, potassium sulphate.
- Total cost including: Treatment cost plus all agricultural practices that equal nearly 47850 LE ha^{-1}.
- Net return and benefit cost ratio were determined according to Boardman *et al.* (2001) as:

Net return = gross return - total variable cost

Benefit cost ratio: divided gross return on total variable.

Results and Discussion

Vegetative growth parameters:

Results shown in Table 4 clear that the effect of organic fertilization on vegetative growth parameters *i.e.* plant height, No. of leaves, fresh and dry weights were significantly affected by application methods. These values enhanced significantly by vermicompost as compared to compost addition in the two seasons.

Results in the same Table illustrate that foliar potassium application at 2% significantly increased vegetative growth parameters in both seasons compared with control. Regarding the soil potassium addition rates, vegetative growth parameters increased with increasing K up to 165 kg K_2O/ha in both seasons. Increasing K rates to 215 kg K_2O/ha didn't lead to the highest vegetative growth compared to 165 kg K_2O/ha.

There were significant interaction effect among the organic fertilization, foliar and soil K additions. The highest values of No. of leaves and dry weight were obtained from treatment fertilized with vermicompost, spraying with K at 2% and soil addition with 165 kg K_2O/ha in both seasons. This trend also has been obtained for fresh weight in the second season, while the maximum value of plant height was obtained from vermicompost application, spraying with K at 2% and soil addition at 215 kg K_2O/ha in both seasons. The same trend has been obtained for fresh weight in the first season.

Table 4: Vegetative growth parameters of potato plants as affected by organic fertilizers, foliar application and rates of soil potassium fertilization during 2018/2019 and 2019/2020 seasons.

Characters / Treatments			Plant height (cm)		No. of leaves/plant		Fresh weight (g/plant)		Dry weight (g/plant)	
			1st	2nd	1st	2nd	1st	2nd	1st	2nd
A- Organic fertilization treatments:										
compost			42.27	42.83	15.1	16.2	159.60	168.19	48.30	47.92
vermicompost			48.89	46.56	16.6	18.1	171.78	182.69	51.20	51.51
F. test			*	*	*	*	*	*	*	*
B- Potassium foliar application:										
Control			40.11	38.22	13.4	14.3	144.11	160.82	47.08	47.03
Foliar K			51.06	51.17	18.2	19.9	187.28	190.06	52.42	52.41
F. test			*	*	*	*	*	*	*	*
C- Rates of soil potassium fertilization:										
215 kg/K			46.08 b	46.75 b	15.8 b	17.5 b	170.37 b	182.23 b	50.45 b	50.03 b
165 kg K			51.50 a	50.83 a	18.6 a	20.1 a	189.32 a	198.12 a	53.02 a	52.98 a
120 kg/K			39.17 c	36.50 c	13.1 c	13.8 c	137.39 c	145.97 c	45.76 c	46.14 c
Interaction										
compost	Control	215 kg/K	36.00 f	36.00 j	12.0 f	13.0 fg	168.94 f	167.63 f	45.50 e	44.59 e
		165 kg K	44.33 d	44.33 f	16.3 cd	17.7 d	133.42 j	176.58 e	49.90 bc	49.38 cd
		120 kg/K	31.33 g	30.33 l	11.0 f	11.0 h	118.42 l	124.30 j	42.59 f	42.34 f
	Foliar K	215 kg/K	49.33 bc	50.00 d	18.3 bc	19.7 bc	190.12 d	192.9 d	52.57 b	51.70 bc
		165 kg K	52.33 b	54.00 c	18.3 bc	20.3 b	197.69 c	202.27 c	52.61 b	52.74 b
		120 kg/K	40.33 de	42.33 g	14.3 e	15.3 e	149.04 h	145.44 i	46.62 e	46.76 de
vermicompost	Control	215 kg/K	42.00 d	39.33 i	12.7 f	14.3 ef	179.09 e	157.21 g	47.43 de	47.54 de
		165 kg K	49.67 bc	46.67 e	17.0 cd	18.3 cd	140.92 i	187.77 d	52.32 b	52.45 b
		120 kg/K	37.33 ef	32.67 k	11.7 f	11.6 gh	123.85 k	151.44 h	44.72 e	45.86 e
	Foliar K	215 kg/K	57.00 a	61.67 a	20.0 b	23.0 a	219.15 a	211.17 b	56.33 a	56.28 a
		165 kg K	59.67 a	58.33 b	22.7 a	24.0 a	209.46 b	225.85 a	57.24 a	57.37 a
		120 kg/K	47.67 c	40.66 h	15.3 de	17.0 d	158.25 g	162.71 f	49.13 bc	49.58 cd

Different letters in the same column which indicate significant differences according to the Duncan Multiple Test ($P < 0.05$)

Leaves chemical composition:

Results listed in Tables 5 and 6 show the effect of organic additions, foliar and soil rates of K fertilizer on chlorophyll a, chlorophyll b, chlorophyll a+b, N, P and K contents of potato leaves. Obtained results indicated that using compost gave significant increases of these parameters compared to vermicompost in both seasons except K percentage in the second season.

Regarding the impact of K foliar application on chemical composition of leaves, results in the same Tables reveal that foliar application with K at 2% enhanced all leaves chemical contents compared to the control in both seasons.

As shown in the same Tables, results clear that the maximum leaves chemical contents values of potato obtained from addition with 165 kg K_2O/ha to soil.

The interaction influence among compost addition, K foliar application and 165 kg K_2O/ha of K fertilizer gave significant values of chemical contents of potato plant leaves moreover, th e interaction among compost addition, K foliar application and 120 kg K_2O/ha soil fertilization on K% in both seasons.

Tubers yield and its components:

Results in Table 7 indicate that using vermicompost as organic fertilizer significantly increased plant yield, No. of tubers/plant and total yield compared to compost soil addition in both seasons, except No. of tubers/plant in the second season.

Tabulated results in the same Table illustrate that spraying plants with K at 2% increased significantly potato yield and its components as compared to control. It enhanced total yield (20.55 and 24.45 %) in the first and second seasons, respectively.

Regarding the effect of soil K addition rates, results shown in the same Table reveal that the maximum values of potato yield were obtained from application of 165 kg K_2O/ha followed by 215 kg K_2O/ha soil addition in both seasons.

With respect to the interaction effect between among soil organic additions, foliar spraying with K and different rates of K, the results in the same Table show that the maximum values of plant yield, No. of tubers/plant and total yield were recorded from adding vermicompost and K foliar application at 2% combined with 165 kg K_2O/ha in both seasons.

Table 5: Chlorophyll a, b and a+b in potato plant leaves as affected by organic fertilizers, foliar application and rates of soil potassium fertilization during 2018/2019 and 2019/2020 seasons.

Characters / Treatments			Chlorophyll a (mg/g FW)		Chlorophyll b (mg/g FW)		Chlorophyll a+b (mg/g FW)	
			1st	2nd	1st	2nd	1st	2nd
A- Organic fertilization treatments:								
compost			0.705	0.737	0.399	0.427	1.104	1.164
vermicompost			0.686	0.717	0.386	0.415	1.073	1.133
F. test			*	*	*	*	*	*
B- Potassium foliar application:								
Control			0.676	0.707	0.377	0.407	1.053	1.114
Foliar K			0.716	0.747	0.408	0.435	1.124	1.182
F. test			*	*	*	*	*	*
C- Rates of soil potassium fertilization:								
215 kg/K			0.683 b	0.717 b	0.384 b	0.412 b	1.067 b	1.129 b
165 kg K			0.716 a	0.7465 a	0.410 a	0.438 a	1.125 a	1.184 a
120 kg/K			0.689 b	0.719 b	0.384 b	0.414 b	1.073 b	1.132 b
Interaction								
compost	Control	215 kg/K	0.716 e	0.756 c	0.406 d	0.437 d	1.122 e	1.193 d
		165 kg K	0.687 g	0.717 de	0.391 e	0.422 f	1.078 g	1.139 f
		120 kg/K	0.644 k	0.678 g	0.351 h	0.380 i	0.995 k	1.058 i
	Foliar K	215 kg/K	0.665 i	0.694 fg	0.371 f	0.394 h	1.036 i	1.088 h
		165 kg K	0.765 a	0.795 a	0.442 a	0.469 a	1.207 a	1.264 a
		120 kg/K	0.754 b	0.782 b	0.431 b	0.459 b	1.185 b	1.241 b
vermicompost	Control	215 kg/K	0.698 f	0.727 d	0.398 e	0.430 e	1.096 f	1.157 e
		165 kg K	0.677 h	0.705 ef	0.379 f	0.404 g	1.056 h	1.109 g
		120 kg/K	0.633 l	0.660 h	0.336 i	0.369 j	0.969 l	1.029 j
	Foliar K	215 kg/K	0.655 j	0.688 g	0.361 g	0.388 h	1.016 j	1.076 h
		165 kg K	0.732 c	0.769 bc	0.428 b	0.455 b	1.160 c	1.224 c
		120 kg/K	0.725 d	0.755 c	0.417 c	0.445 c	1.142 d	1.200 d

Different letters in the same column which indicate significant differences according to the Duncan Multiple Test ($P < 0.05$)

Table 6: N, P and K percentage in potato plant leaves as affected by organic fertilizers, foliar application and rates of soil potassium fertilization during 2018/2019 and 2019/2020 seasons.

Characters / Treatments			N (%)		P (%)		K (%)	
			1st	2nd	1st	2nd	1st	2nd
A- Organic fertilization treatments:								
compost			3.25	3.37	0.394	0.413	3.86	3.91
vermicompost			3.01	3.10	0.382	0.402	3.72	3.70
F. test			*	*	*	*	*	NS
B- Potassium foliar application:								
Control			2.91	3.00	0.371	0.390	3.62	3.67
Foliar K			3.37	3.47	0.405	0.424	3.96	3.95
F. test			*	*	*	*	*	*
C- Rates of soil potassium fertilization:								
215 kg/K			2.91 c	3.00 c	0.380 b	0.400 b	3.71 b	3.75 b
165 kg K			3.39 a	3.51 a	0.406 a	0.424 a	3.96 a	4.00 a
120 kg/K			3.11 b	3.20 b	0.379 b	0.398 b	3.71 b	3.70 b
Interaction								
compost	**Control**	215 kg/K	3.27 d	3.38 d	0.402 d	0.422 d	3.96 c	4.01 abc
		165 kg K	3.20 e	3.33 d	0.382 e	0.400 e	3.74 e	3.80 bcd
		120 kg/K	2.80 h	2.90 h	0.342 h	0.362 h	3.34 h	3.40 de
	Foliar K	215 kg/K	3.07 f	3.18 f	0.367 f	0.384 fg	3.57 f	3.62 cde
		165 kg K	3.65 a	3.78 a	0.443 a	0.461 a	4.32 a	4.37 a
		120 kg/K	3.54 b	3.65 b	0.431 b	0.447 b	4.25 a	4.29 a
vermicompost	**Control**	215 kg/K	2.35 j	2.45 j	0.395 d	0.414 d	3.84 d	3.90 abcd
		165 kg K	3.16 e	3.26 e	0.374 ef	0.391 f	3.62 f	3.64 cde
		120 kg/K	2.66 i	2.69 i	0.332 i	0.350 i	3.20 i	3.25 e
	Foliar K	215 kg/K	2.95 g	3.01 g	0.354 g	0.379 g	3.45 g	3.49 cde
		165 kg K	3.55 b	3.66 b	0.424 b	0.444 b	4.14 b	4.18 ab
		120 kg/K	3.45 c	3.56 c	0.413 c	0.431 c	4.05 c	3.74 bcde

Different letters in the same column which indicate significant differences according to the Duncan Multiple Test ($P < 0.05$)

Table 7: Potato tubers yield as affected by organic fertilizers, foliar K application and rates of potassium fertilization during 2018/2019 and 2019/2020 seasons.

Characters / Treatments			Yield/plant (kg)		No. of tuber/plant		Total yield (ton/ha)	
			1st	2nd	1st	2nd	1st	2nd
A- Organic fertilization treatments:								
compost			0.561	0.550	5.4	5.6	32.05	31.42
vermicompost			0.598	0.604	5.9	6.1	34.16	34.50
F. test			*	*	*	NS	*	*
B- Potassium foliar application:								
Control			0.525	0.514	4.9	5.0	30.02	29.37
Foliar K			0.633	0.639	6.4	6.7	36.19	36.55
F. test			*	*	*	*	*	*
C- Rates of potassium fertilizer:								
215 kg/K			0.578 b	0.581 b	5.7 b	5.9 b	33.05 b	33.22 b
165 kg K			0.650 a	0.649 a	6.4 a	6.8 a	37.15 a	37.07 a
120 kg/K			0.510 c	0.501 c	4.8 c	4.8 c	29.11 c	28.60 c
Interaction								
compost	**Control**	215 kg/K	0.491 j	0.473 j	4.3 gh	4.7 de	28.05 j	27.04 j
		165 kg K	0.585 f	0.576 f	5.7 def	6.0 bc	33.42 f	32.90 f
		120 kg/K	0.464 k	0.435 k	4.0 h	3.7 f	26.53 k	24.88 k
	Foliar K	215 kg/K	0.635 d	0.621 d	6.3 bcd	6.3 bc	36.29 d	35.50 d
		165 kg K	0.661 c	0.667 c	6.7 abc	7.0 ab	37.78 c	38.10 c
		120 kg/K	0.529 h	0.527 h	5.3 ef	5.7 c	30.23 h	30.11 h
vermicompost	**Control**	215 kg/K	0.510 i	0.514 i	5.0 fg	5.3 cd	29.15 i	29.38 i
		165 kg K	0.614 e	0.608 e	6.0 cde	6.3 bc	35.07 e	34.78 e
		120 kg/K	0.488 j	0.477 j	4.3 gh	4.0 ef	27.90 j	27.27 j
	Foliar K	215 kg/K	0.677 b	0.716 b	7.0 ab	7.3 a	38.72 b	40.94 b
		165 kg K	0.741 a	0.744 a	7.3 a	7.7 a	42.34 a	42.49 a
		120 kg/K	0.556 g	0.562 g	5.7 def	6.0 bc	31.79 g	32.13 g

Different letters in the same column which indicate significant differences according to the Duncan Multiple Test ($P < 0.05$)

Tubers quality

Results obtained in Tables 8 and 9 clear that compost soil additions significantly increased tubers contents of total sugars, dry matter, TDS, vitamin C and protein compared to vermicompost in both seasons as well as reducing and non reducing sugars in the first season only and starch in second season only.

Results listed in same Tables show that foliar application with K at 2% significantly increased all aforementioned quality parameters compared to control treatment.

As for potassium soil addition rates, results shown in the same Tables reveal that maximum values of these quality contents were obtained from soil adding 165 kg K_2O/ha in the first and second seasons.

Concerning the interaction effect among organic additions, foliar application and soil addition of K fertilizer, results in the same Tables clarify that combination between compost addition plus foliar application with K at 2% as well as soil addition of K fertilizer at 165 kg K_2O/ha gave the highest values of reducing, non reducing, total sugars, dry matter, starch, protein, vitamin C and TDS contents in both seasons.

The same superiority of total and reducing sugar and starch% in both seasons and non-reducing sugar in the second season were obtained by the interactions among compost plus K foliar application at 2% and K soil addition at 120 kg K_2O/ha.

Available K of experimental soil:

Obtained data in Table 1 clears that initial available of soil K was 100.2 mg kg^{-1}, it means that the soil of experiment suffer from K deficiency. Fig. 1 shows the effect of organic additions, foliar K and rates of K fertilizer on K available in soil. Results clear that interaction among compost additions plus foliar application with K at 2% and 215 kg K_2O/ha. As soil addition gave the highest value of available K, this may be due to release of K as reason for compost addition and the initial amount of K content in compost as shown in Table 2 that make plant more of it that reflexed on potato quality and leaves chemical contents. On the other hand the lowest value of available K obtained from adding vermicompost plus foliar application with tap water and fertilized with 120 kg K_2O/ha this may be due to high requirements of potato plants to K in soil especially at the second period of its cycle life. There was a positive correlation between available K and yield (ton/ha) as shown in Figure 2. A significant result at level of 95% with determination coefficients (R^2) of 0.2226.

Table 8: Reducing, non-reducing, total sugars and dry matter of potato tubers as affected by organic fertilizers, foliar K application and rates of soil potassium fertilization during 2018/2019 and 2019/2020 seasons.

Characters / Treatments			R. Sugar (%)		N. R. Sugar (%)		Total Sugar (%)		Dry matter (%)	
			1st	2nd	1st	2nd	1st	2nd	1st	2nd
A- Organic fertilization treatments:										
compost			2.31	2.42	4.28	4.38	6.59	6.80	14.75	14.98
vermicompost			2.25	2.36	4.16	4.24	6.41	6.60	14.33	14.62
F. test			*	NS	*	NS	*	*	*	*
B- Potassium foliar application:										
Control			2.21	2.33	4.07	4.14	6.28	6.47	14.06	14.31
Foliar K			2.35	2.45	4.37	4.48	6.72	6.93	15.01	15.29
F. test			*	*	*	*	*	*	*	*
C- Rates of added potassium fertilizer:										
215 kg/K			2.26 b	2.39 b	4.12 c	4.20 c	6.38 b	6.59 b	14.25 c	14.53 b
165 kg K			2.33 a	2.43 a	4.38 a	4.47 a	6.71 a	6.90 a	15.05 a	15.30 a
120 kg/K			2.26 b	2.36 b	4.16 b	4.27 b	6.42 b	6.63 b	14.31 b	14.56 b
Interaction										
compost	Control	215 kg/K	2.33 abcd	2.45 abc	4.34 e	4.42 c	6.67 cd	6.87 c	14.96 e	15.21 e
		165 kg K	2.26 bcde	2.37 abcd	4.18 g	4.25 cde	6.44 e	6.62 d	14.46 g	14.65 g
		120 kg/K	2.13 de	2.25 cd	3.82 k	3.89 gh	5.95 hi	6.14 f	13.23 k	13.42 k
	Foliar K	215 kg/K	2.19 bcde	2.32 bcd	4.01 i	4.08 ef	6.20 fg	6.40 e	13.85 i	14.10 i
		165 kg K	2.51 a	2.57 a	4.72 a	4.88 a	7.23 a	7.45 a	16.13 a	16.41 a
		120 kg/K	2.47 a	2.57 a	4.62 b	4.78 a	7.09 a	7.35 a	15.85 b	16.05 b
vermicompost	Control	215 kg/K	2.32 abcd	2.47 ab	4.25 f	4.31 cd	6.57 de	6.78 c	14.67 f	14.94 f
		165 kg K	2.16 cde	2.26 cd	4.13 h	4.15 def	6.29 f	6.41 e	14.12 h	14.41 h
		120 kg/K	2.07 e	2.19 d	3.75 l	3.81 h	5.82 i	6.00 g	12.91 l	13.19 l
	Foliar K	215 kg/K	2.18 cde	2.31 bcd	3.90 j	3.99 fg	6.08 gh	6.30 e	13.51 j	13.87 j
		165 kg K	2.40 ab	2.51 ab	4.52 c	4.61 b	6.92 b	7.12 b	15.48 c	15.74 c
		120 kg/K	2.36 abc	2.43 abc	4.44 d	4.58 b	6.80 bc	7.01 b	15.26 d	15.57 d

Different letters in the same column which indicate significant differences according to the Duncan Multiple Test ($P < 0.05$)

Table 9: Starch, protein, vitamin C and total dissolved solids (TDS) of potato tubers as affected by organic fertilizers, foliar K application and rates of potassium fertilization during 2018/2019 and 2019/2020 seasons.

Characters / Treatments			Starch (%)		Protein (%)		V. C (mg/100g)		TDS (%)	
			1st	2nd	1st	2nd	1st	2nd	1st	2nd
A- Organic fertilization treatments:										
compost			16.46	17.83	11.02	11.51	20.20	21.01	7.34	7.56
vermicompost			16.07	17.40	10.38	10.86	19.96	20.79	7.13	7.40
F. test			NS	*	*	*	*	*	*	*
B- Potassium foliar application:										
Control			15.79	17.12	9.87	10.35	19.73	20.56	6.97	7.21
Foliar K			16.74	18.11	11.52	12.02	20.42	21.23	7.51	7.75
F. test			*	*	*	*	*	*	*	*
C- Rates of potassium fertilizer:										
215 kg/K			15.95 b	17.33 b	10.21 b	10.73 b	19.88 c	20.68 b	7.08 c	7.34 b
165 kg K			16.79 a	18.12 a	11.59 a	12.06 a	20.42 a	21.26 a	7.53 a	7.75 a
120 kg/K			16.05 b	17.39 b	10.28 b	10.76 b	19.93 b	20.75 b	7.11 b	7.35 b
Interaction										
compost	Control	215 kg/K	16.75 abcd	18.14 bc	11.40 d	11.90 cd	20.36 d	21.15 d	7.46 e	7.70 d
		165 kg K	16.17 cde	17.37 de	10.46 ef	10.95 ef	19.95 ef	20.80 ef	7.14 g	7.33 e
		120 kg/K	15.04 fg	16.46 f	8.49 ij	9.00 ij	19.15 i	20.02 h	6.53 k	6.75 h
	Foliar K	215 kg/K	15.42 efg	16.79 ef	9.51 gh	10.02 gh	19.57 gh	20.26 g	6.86 i	7.10 f
		165 kg K	17.82 a	19.21 a	13.48 a	13.98 a	21.19 a	22.00 a	8.12 a	8.34 a
		120 kg/K	17.56 a	18.96 a	12.75 b	13.20 b	20.99 ab	21.81 ab	7.95 b	8.15 b
vermicompost	Control	215 kg/K	16.45 bcd	17.76 cd	10.96 de	11.45 de	20.18 de	21.01 de	7.33 d	7.62 d
		165 kg K	15.74 def	17.09 def	9.99 fg	10.47 fg	19.78 fg	20.61 f	7.01 h	7.28 e
		120 kg/K	14.58 g	15.88 g	7.93 j	8.34 j	18.98 i	19.77 i	6.34 l	6.60 i
	Foliar K	215 kg/K	15.20 efg	16.62 ef	8.97 hi	9.55 hi	19.42 h	20.31 g	6.66 j	6.93 g
		165 kg K	17.41 ab	18.81 ab	12.43 bc	12.85 b	20.77 bc	21.61 bc	7.83 c	8.07 b
		120 kg/K	17.04 abc	18.24 bc	11.97 c	12.51 bc	20.61 c	21.41 c	7.62 d	7.89 c

Different letters in the same column which indicate significant differences according to the Duncan Multiple Test ($P < 0.05$)

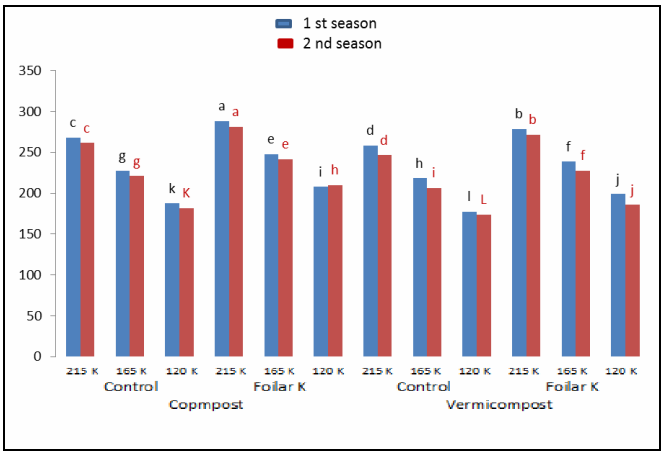

Fig 1: Effect of organic additions, foliar K and rates of K fertilizer on available K in soil

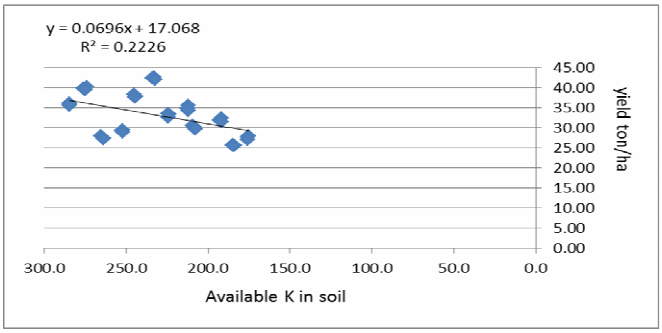

Fig. 2: Linear analysis of available K of soil and yield (ton/ha) of potato grown under organic additions, foliar K and rates of K fertilizer (average of the two seasons).

Discussion

Results shown in previous Tables have been proved that there were differences between organic additions. The enhancement of compost additions may be due to improving variable properties of soil as well enrichment soil with available form of nutrients this led to increase nutrients uptake (as shown in Table 6). The increment of plant growth enhance photosynthetic pigments (as shown in Table 5) and physiological activity which increase assimilation process to improve potato yield and quality. These results are in close harmony with those obtained by El-Sayed *et al.* (2015), Abd El-Nabi *et al.* (2016) and Mijwel (2018) on potato crop.

The benefits effect of vermicompost that is exemplary organic addition for preferable growth and yield of potato may be due to contain more nutritional values than conventional compost and the more suitable of C/N ratio and consequently enhance mineralization rate and grade of humication by earthworms action in Table (2 and 3) (Azarmi *et al.*, 2009) on Tomato. Vermicompost stimulate the activity of microorganisms that enhance phytohormones and plant growth regulators (Bhattacharya and Chattopadhyay, 2002) that influence positively potato growth (as shown in Table 4) and enhancing adsorbing capacity of fundamental elements against leaching this promote good absorption of nutrients and increase its contents in plant (as shown in Table 6). These findings agree with those recording by Ferdous *et al.* (2019a); Ferdous *et al.* (2019b); Gangele *et al.* (2019) and Mostofa *et al.* (2019) on potato.

Results reveal that increasing applied K rate to 165 kg K_2O/ha led to improve vegetative growth and potato yield, whereas raising K rate to 215 kg K_2O/ha had a negative impact this may be due to antagonism between nutrients (Abdrabbo *et al.*, 2019). The increment effect of 165 kg K_2O/ha on vegetative growth may be due to high response of foliar and bulk need to soil K additions as well easier absorption by penetration of K through leaves that enhances root imbibition with nutrients by enhancing root growth and nutrients mobilization from leaves to roots (El-Fouly and El-Sayed, 1997), the soil K content is insufficient to potato requirement as shown in Table 1, thus the improvement of potato growth according to K additions may be due to that K plays critical function in turgor regulation into guard cells through stomata mobilization (Marchner, 2012), as well its role in plant meristematic growth and nourishment i.e. enhance enzymes activity, photosynthesis and carbohydrate that eventually help to enhance tuber size (Al-Moshileh and Errebi, 2004). Increasing chlorophyll contents by enhancing enzyme activity with adequate amount of soil K that reflect on potato growth and definitive conversion in to sink (tubers) (Nazli *et al.*, 2018), translocate assimilates and synthesis of protein, this also reflexed on leaves chemical composition (as shown in Tables 5 and 6) that increased tuber yield (as shown in Table 7) and its quality (as shown in tables 8 and 9). These results are in harmony to those obtained by Salim *et al.* (2014); Zelelew *et al.* (2016); Abou zeid and Abd El-Latif (2017) and Agrawal *et al.* (2017) on potato.

Economic feasibility:

The economic feasibility of planting potato plants as influenced by organic applications, foliar K application and addition rates of K are cleared in Table 10. The results clarify that the maximum net return (53370 LE/ha) was obtained from compost addition plus foliar application with K at 2% as well as soil addition of K at 165 kg K_2O/ha, as well this treatment returns the highest benefit cost ratio (1.88) comparing with other treatments. Thus this treatment deemed to be economically for highly production of potato under the condition of this research.

Table 10: Economic performance of potato production as affected by organic soil additions, foliar K and soil addition rates of K treatment during both seasons as an average.

Treatments			Marketable yield (ton/ ha)	Cross return (£E ha^{-1})	Treatment cost (£E ha^{-1})	Total variable cost (£E ha^{-1})	Net return (£E ha^{-1})	Benefit cost ratio	Order
compost	Control	215 kg/K	27.55	82635	10675	58525	24110	1.41	7
		165 kg K	33.16	99480	9385	57235	42245	1.73	3
		120 kg/K	25.71	77115	8105	55955	21160	1.38	8
	Foliar K	215 kg/K	35.90	107685	13890	61740	45945	1.74	2
		165 kg K	37.94	113820	12600	60450	53370	1.88	1
		120 kg/K	30.17	90510	11320	59170	31340	1.53	5
vermicompost	Control	215 kg/K	29.27	87795	26925	74775	13020	1.17	10
		165 kg K	34.93	104775	25635	73485	31290	1.43	6
		120 kg/K	27.59	82755	24355	72205	10550	1.15	11
	Foliar K	215 kg/K	39.83	119490	30140	77990	41500	1.53	5
		165 kg K	42.42	127245	28850	76700	50545	1.66	4
		120 kg/K	31.96	95880	27570	75420	20460	1.27	9

Conclusion

The recommendation of this study is the usage of compost or vermicompost at 9.5 and 7 ton/ ha respectively and foliar application with K at 2% combined with 165 kg K_2O/ha to obtained the highest yield and improved quality of potato especially under insufficient K in soil.

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