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Improving Wheat Productivity and Soil Properties by Using Compost and Potassium under Water Stress Conditions

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ABSTRACT

A field experiment be located at Sids Agriculture Research Station, Beni-Suef Governorate, Egypt for two following seasons of 2021/ 2022 and 2022/ 2023, to examine effects of three levels of potassium (0.0, 47.0 and 94.0 kg K ha-1) via using two compost levels (0.0 and 12 t ha-1) on wheat (*Triticum aestivum* L.) that is grown in clay soil under three irrigation levels (3, 4 and 5 irrigations). The experimental design was split-split design in completely randomized block with four replications. Results show that physio-chemical soil properties, soil water retention was positively responded to compost application, meanwhile soil salinity increased. Soil available N and K were increased with increasing number of irrigation. Growth parameters, yield and yield components, and N, P and K uptake of wheat were significantly increased due to increasing number of irrigation, compost application or potassium levels. The results of the interaction indicate that added 12 t ha^{-1} compost plus 94 kg K ha^{-1} resulted in growth and yield and its components as well as N, P and K uptake under four irrigation statistically equal to five irrigation. Also, combined 12 t ha^{-1} compost with 47 kg K ha^{-1} gave wheat productivity equal to those under high potassium levels. It could be concluded that using 12 t ha^{-1} compost and 49 kg K ha^{-1} to gain maximum quantity and quality of wheat as well as soil properties under suitable water resources. While, under water stress, it concluded to supply wheat plants with 12 t ha^{-1} compost in combination with 94 kg K ha^{-1} to improve the water stress tolerance.

***Keywords*: wheat plants, compost, potassium, irrigation, soil properties and yield.**

INTRODUCTION

Wheat (*Triticum aestivum* L) is the most important crops in all over the world. FAO (2019) reported that wheat is the main source of calories and protein for permanently burgeoning world population. In Egypt, wheat it is the most important crop for food, which about 70% of production of food was used for human food, while 19 % used in animal feed and 11% is used for industrial purposes including biofuels (Galal, 2017). The importance of wheat grain is mainly due to it can ground into floor, semolina, etc. which induced in making bread and others like pastas and bakery products. It contains about 60-90 starch, 10.0-16.5% protein, 1.5-2.0% fat and 1.2-2.0 % minerals as well as B-complex and vitamins. Its straw is mainly used for animals feeding, particularly in summer season (Saad *et. al.*, 2023). In Egypt wheat production is not enough for meet human consumption, therefore great efforts are done to increase its production to minimize the gap between production and consumption (Farid *et. al.*, 2023).

The deficit of water during wheat growth considers the main factor affecting its yield (Abd El-Aty *et. al.*, 2024). Shortage of water adversely affected cell enlargement, gas exchange and assimilate partitioning, while under extreme shortage, it may affect various metabolic processes which reduced photosynthesis, cell elongation, cell divisions and finally death of cells. The shortage water during reproductive stage is more harmful than other stages (Al-Omary *et. al.*, 2021). Many investigators studied the mechanisms of plant tolerance to drought such as dehydration tolerance by genetic engineering under laboratory conditions by hormonal balance (Panhwar *et. al.*, 2021) and reactive of oxygen species detoxification (Salem *et. al.*, 2021). Moreover, Pouri *et. al.*, (2019) indicated that water stress negatively affect seed germination, seedling growth, plant dry matter as well as root growth, root extension and root depth. Also, Panhwar (2021) added that water shortage during seed filling resulted in about 70% reduction in wheat grain yield, while a lesser reduction in grain yield was obtained when water shortages occur during growth stage. They consider the anthesis stage is the very sensitive stages to deficit water. Potassium is one of the most important macronutrient for plants, where it regulates many physiological, biochemical and phonological processes in plants (Hasanuzzaman *et. al.*, 2018) and (Johnson *et. al.*, 2022) including water absorption (Sardans and Penuelas, 2021), translocation of nutrients (Xu *et. al.*, 2020), photosynthesis (Siddiqui *et. al.*, 2021), enzyme activation (Hasanuzzaman *et al, 2020), synthesis of protein (Sahi et. al., 2021), energy transfer (Sardans and Penuelas, 2021), stress resistance like drought and salinity (Adhikari et. al., 2020), stomata opening (Anokye et. al., 2021),* heat (Singh and Singh, 2020) and the pollution by heavy metals (Yasin *et. al.*, 2018). Therefore, it is one of the key factors for affecting quality and quantity of crop yield. Soils of Egypt are poor in available potassium especially after the High Dam building which led to the prevention of fertile sediments to Egyptian soils, beside the recently used of high yielding varieties and imbalanced application of fertilizer (Abdelfattah *et. al.*, 2021).

Compost is being used for crop production to supply plants with nutrients, improved soil organic matter and some soil properties (Kelbesa 2021 and Kelly *et. al.*, 2023). Hussein *et. al.*, (2022) stated that compost consists of relatively stable organic

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materials caused by degradation of organic materials by microorganisms under aerobic conditions. Compost manure is made from the remains of plants and animals. Elbaalawy *et. al.,* (2023) indicated that the decomposition of organic residues converted toxic organic materials to stabilized materials that can improve soil chemical and physical properties as well as microbial activity accordingly plant growth. Kelbesa (2021) reported that composting the plant or animal residues has other positive effects, such as converting landfills wastes to alternative beneficial use, erosion control and source of many nutrients for sustainable non- fertile soil as well as removal seeds of weed, pathogen inoculate, pesticide or herbicide residues and petroleum decomposition. Zhai *et. al.,* (2023) found that application of organic manure, improved soil fertility after harvest as well as increased N, P, K, Fe, Mn, Zn and Cu uptake in seeds and /or straw. Also, Imran *et. al.,* (2017) illustrated that all wheat growth parameters, and yield components of wheat were positively responded to compost application. Recently Pan (2022) stated that not only soil fertility is improved by using compost, but also nutrition food and high quality, economy and healthy environment were improved.

Therefore, the purpose of this research was to investigate how to eliminate the adverse effect of deficit irrigation water by using potassium and/or compost application.

MATERIALS AND METHODS

Two field experiments were implemented during two successive seasons of 2021/2022 and 2022/2023 at the Experimental Farm of Sids Agricultural Research Station, ARC, Beni-Suef Governorate, Egypt (Lat. 29° 04- N, Long 31° 06- E and 30-40 m above the sea level). The soil was clay in texture with pH of 7.9 and 8.0, EC of 1.24 and 1.32 dsm^{-1}, organic matter of 2.1 and 1.9 %, soil available N 21 and 19 mg kg^{-1}, soil available P 19 and 17 mg kg^{-1}, soil available K 180 and 181 mg kg^{-1} in both seasons, respectively (according to the methods described in A.O.A.C, 2000). The experimental design was split-split in completely randomized block in four replicates, where the irrigation treatments (3, 4 and 5 irrigation, I_1, I_2 and I_3 respectively) were arranged in the main plots and compost levels (0.0 (C_1) and 12.0 (C_2) t ha^{-1}) were devoted in sub-plots, while potassium fertilizer levels (0.0 (K_1), 47.0 (K_2) and 94.0 (K_3) kg K ha^{-1}) were located in sub-sub plots. The plot area was 2.0 x 1.4 m (2.8 m^2 = 1/3570 hectare). Wheat (*Triticum aestivum* L) grains, Sids 12 variety were sown at 10 and 15 November at rate of 145 kg ha^{-1} in both seasons, respectively. Compost were applied before wheat planting during the land preparation (Some chemical constituents of compost were determined according to A.O.A.C (2000) and listed in Table 1.

Table 1. Some chemical constituents of compost used in the experiment in both seasons.

Chemical constituents	2021/2022	2022/2023
pH (1:10) soil- water suspension	7.06	7.13
EC, dS m^{-1} (1:10 soil water extraction)	5.23	5.07
Organic matter (g kg^{-1})	379.1	367.2
Organic carbon (g kg^{-1})	219.9	213.0
Total nitrogen (g kg^{-1})	11.05	10.52
C / N ratio	20:1	20:1
Total phosphorus (g kg^{-1})	7.31	7.15
Total potassium (g kg^{-1})	12.15	11.72

The potassium fertilizer levels as potassium sulphate (48 % K_2O) were added as soil application in two equal doses before the first irrigation and the second before the second irrigation. Number of irrigation as following:

1- I_1: Three irrigation at 40 days (intermediate tillering), 70 days (botting) and 100 days (heading)
2- I_2: Four irrigation at 20 days (crown and root initiation), 40 days (intermediate tillering), 70 days (botting) and 100 days (heading)
3- I_3: Five irrigation at 20 days (crown and root initiation), 40 days (intermediate tillering), 70 days (botting), 100 days (heading) and125 days (milk stages)

Superphosphate (15.5%. P_2O_5) was added at rate of 22.8 kg P ha^{-1} before sowing during land preparation, while nitrogen fertilizer was supplied at rate of 178 kg N ha^{-1} as ammonium nitrate fertilizer (33.5% N) at two equal doses, the first before the first irrigation and the other before the second irrigation. Maize plants was the preceding crop in both seasons. Other culture practices for wheat production were done as in the district.

Ten wheat plants were randomly taken to measure growth parameters (plant height, cm; number of tillers plant^{-1} and dry weight plant^{-1}, g), yield components (number of spikes m^{-2}, number of grains spike^{-1} and 1000 grain weight, g). The yields of wheat/plot (grain, straw and biological yields t ha^{-1}) were measured and converted to t/fed. The concentration of N, P and K in both grains and straw (g kg^{-1}) were determined (according to A.O.A.C 2000) and converted to nutrient uptake. Also after harvest surface soil samples (0-30 cm) were randomly taken from each plot to determine some physical and chemical soil properties, (pH, EC, organic matter and bulk density), soil fertility (soil available N, P and K) according to A.O.A.C (2000). Also, some water relations (field capacity, wilting point and available water) were measured according to Page *et. al.,* (1982).

Results obtained were subjected to statistical analysis according to Snedecor and Cochran (1980). Least significant differences at 5% probability were used to compare between means of treatments.

RESULTS AND DISCUSSION

Results

Soil physio-chemical characteristics

The soil used in the current research was clay in texture, non-saline with pH about 8, low in organic matter and poor in its fertility. Data in Figs. 1, 2 and 3 indicate that application of 12.0 t ha^{-1} of compost were significantly improved soil pH, organic matter, bulk density, soil available N, P and K as well as water retentions, i.e., field capacity, wilting point and available water, where it decreased soil pH and bulk density and increased soil organic matter, soil fertility and water retention parameters in both seasons. Added 12 t ha^{-1} compost resulted in decreased soil pH and bulk density from 8.03 to 7.96 and from 1.23 to 1.19 g cm^{-3} in first season, respectively. The corresponding decrement in the second season were from 8.17 to 8.08 and from 1.21 to 1.18 g cm^{-3}. On the other hand, application of 12 t ha^{-1} compost increased soil organic matter, available N, available P, available K, field capacity, welting point and available water by about 6.9, 37.2, 28.1, 6.2, 7.3, 5.3 and 9.2 % over no composting in first season, respectively. Same trends were obtained in the second season. Unfortunately, added compost to soil led to increase in soil salinity from 1.24 to 1.46 and from 1.32 to 1.51 d Sm-1 in both seasons respectively.

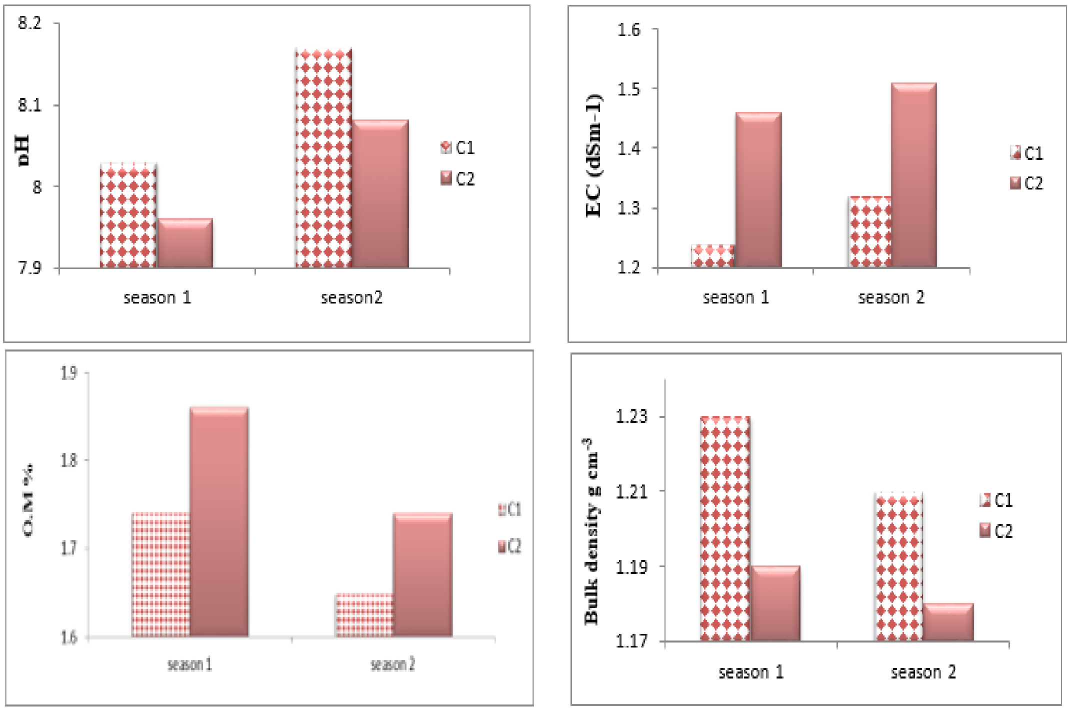

Fig 1. Effect of compost levels on soil pH, EC, organic matter and bulk density

Where, C1: without compost; C2: 12 t ha^{-1} compost

The means of each criterion followed by the different letters within each column are significantly different using Duncan's Multiple Range Test at P- value of ≤0.05

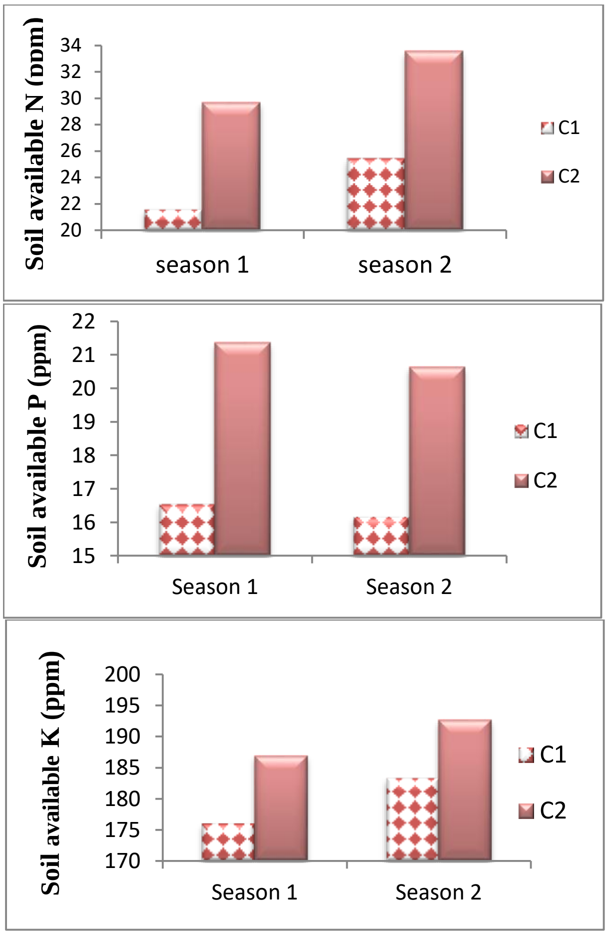

Fig 2. Effect of compost levels on soil available N, P and K

Where, C1: without compost; C2: 12 t ha^{-1} compost

-The means of each criterion followed by the different letters within each column are significantly different using Duncan's Multiple Range Test at P- value of ≤0.05

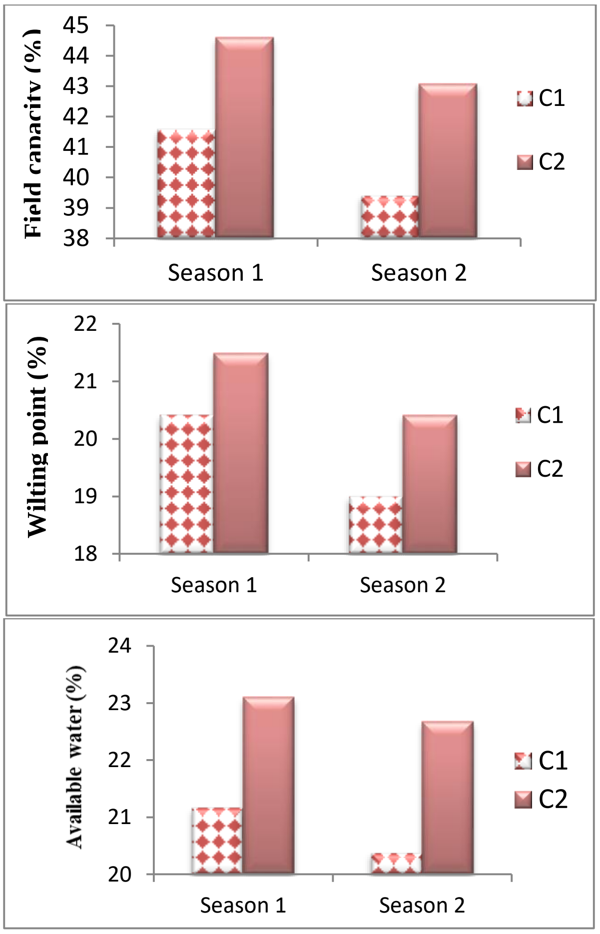

Fig 3. Effect of compost levels on field capacity, wilting point and available water

Where, C1: without compost; C2: 12 t ha^{-1} compost

The means of each criterion followed by the different letters within each column are significantly different using Duncan's Multiple Range Test at P- value of ≤0.05

Also, the data reveal that irrigation treatments affected only soil available N and K (Fig 4). Increasing the amount of applied water significantly reduced the levels of available N and K in the soil after harvest. The relative decreasing of soil available N and K due to increasing number of irrigation from 3 to 5 reached to about 16.08 and 5.28 % in the first season and 16.79 and 7.22 % in the second season, respectively. Moreover, soil available K affected only by potassium fertilization, where increased the levels of potassium application were significantly increased this trait (Fig 5). Increased potassium levels up to 115 kg K ha^{-1} led to increased soil available potassium up to 8.8 and 8.0 % over without K application in the two studied seasons, respectively.

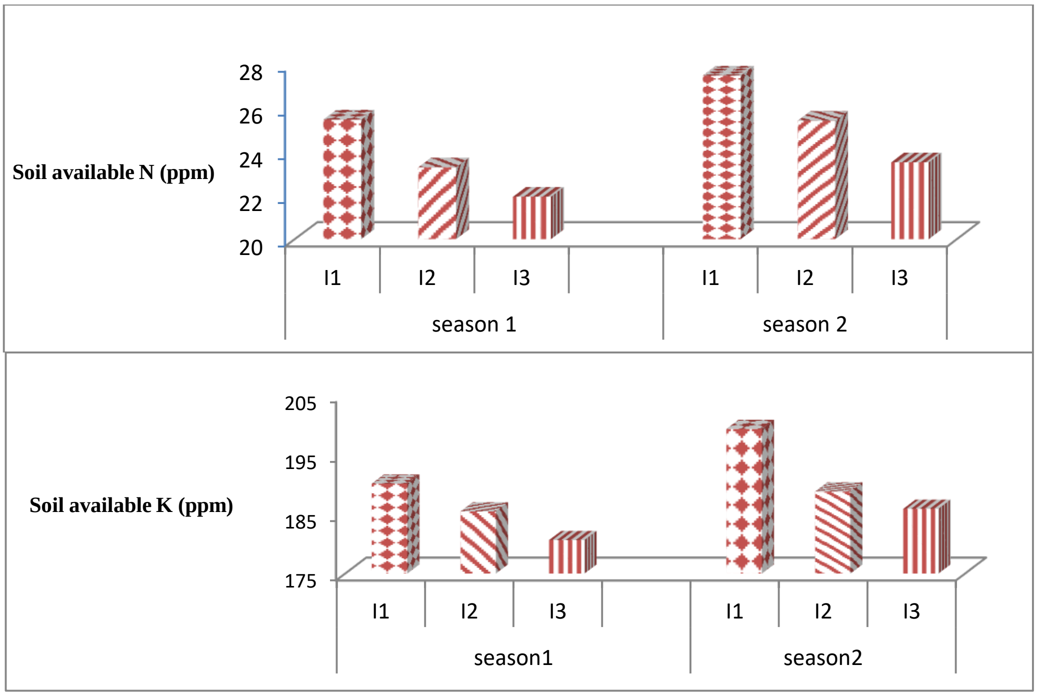

Fig 4. Effect of number of irrigation on soil available N and K

Where, I1: 3 irrigation ; I2: 4 irrigation; I3: 5 irrigation

The means of each criterion followed by the different letters within each column are significantly different using Duncan's Multiple Range Test at P-value of ≤0.05

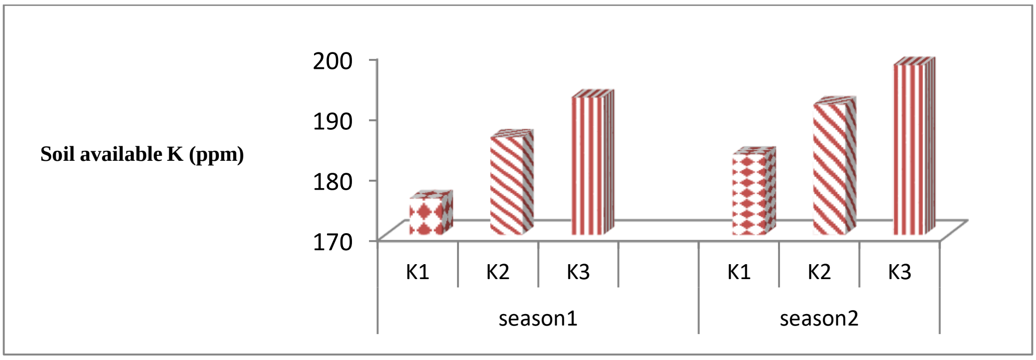

Fig 5. Effect of potassium levels on soil available K

Where, K1: without K ; K2: 47.0 kg K ha^{-1}; K3: 94.0 kg p ha^{-}

The means of each criterion followed by the different letters within each column are significantly different using Duncan's Multiple Range Test at P- value of ≤0.05

Growth and yield and its components traits

Data in Tables 2,3 and 4 represent the effect of studied factors on growth parameters (plant height, dry weight plant^{-1} and number of tillers plant^{-1}), yield components (number of spikes m^{-2}, number of grains spike^{-1} and 1000-grain weight), and yield measurements (grain yield, straw yield and biological yield). The results clearly show that all studied abovementioned parameters were significantly affected by number of irrigation. Increasing number of irrigation led to significant increases in these parameters. The relative increasing in these parameters due to watered wheat plants with full irrigation reached to 15.88, 3.05, 16.50, 5.50, 13.49, 7.66, 14.75, 4.73 and 7.59 % when compared with 3 irrigation in the first season, respectively. Similar trends were obtained in second season.

The data indicate that The addition 12 t/ha compost were positively increased these parameters. The relative increments reached to 2.78, 2.45, 2.76, 1.87, 3.47, 2.93, 4.16, 3.19 and 3.53 % over without composting in first season, respectively. In the second season, the corresponding increases were 2.12, 2.47, 2.80, 3.28, 1.49, 2.34, 4.74, 3.68 and 4.04 %, respectively. Similarly, increasing potassium levels gradually improved the same parameters in both seasons. Increased potassium fertilization from 0.0 to 96.0 kg K ha^{-1} resulted in increasing these parameters by about 4.54, 5.59, 2.74, 3.36, 5.94, 5.98, 7.50, 6.56 and 6.93 % in first season, respectively. Similarly, trends were obtained in the second season

Table 2. Growth parameters as affected by number of irrigation, compost and potassium application.

Treatments			Plant height (cm)		Dry weight /plant (g)		Number of tillers/plant	
Number of irrigation	Compost (t ha^{-1})	K (k ha^{-1})	2021/2022	2022/2023	2021/2022	2022/2023	2021/2022	2022/2023
3	0.0	0.0	91.2	85.5	3.11	3.08	1.93	1.90
		47.0	93.6	87.4	3.21	3.19	1.97	1.93
		94.0	96.0	89.8	3.33	3.30	2.02	2.00
	mean		93.60	87.57	3.22	3.19	1.97	1.94
	12.0	0.0	94.1	87.9	3.20	3.18	1.98	1.95
		47.0	96.6	89.3	3.35	3.32	2.05	2.02
		94.0	98.0	92.5	3.43	3.39	2.07	2.05
	mean		96.23	89.90	3.33	3.30	2.03	2.01
mean			94.92	**88.74**	**3.28**	**3.25**	**2.00**	**1.98**
4	0.0	0.0	101.5	94.4	3.15	3.13	2.11	2.08
		47.0	104.2	96.7	3.26	3.24	2.22	2.20
		94.0	106.7	100.2	3.33	3.31	2.26	2.23
	mean		104.13	97.10	3.25	3.23	2.20	2.18
	12.0	0.0	105.5	96.2	3.24	3.22	2.23	2.20
		47.0	108.3	98.1	3.30	3.27	2.29	2.26
		94.0	112.2	102.7	3.44	3.41	2.38	2.35
	mean		108.67	99.00	3.33	3.30	2.30	2.27
mean			106.4	**98.05**	**3.29**	**3.27**	**2.26**	**2.23**
5	0.0	0.0	107.6	97.2	3.29	3.26	2.27	2.24
		47.0	109.0	100.1	3.36	3.32	2.30	2.27
		94.0	111.3	105.5	3.39	3.34	2.36	2.33
	mean		109.30	100.93	3.35	3.31	2.31	2.28
	12.0	0.0	108.9	99.8	3.34	3.31	2.31	2.28
		47.0	110.5	102.4	3.40	3.35	2.34	2.32
		94.0	112.6	106.1	3.46	3.42	2.39	3.36
	mean		110.67	102.77	3.40	3.36	2.35	2.32
mean			109.99	**101.85**	**3.38**	**3.34**	**2.33**	**2.30**
Mean of compost		0.0	102.34	95.20	3.27	3.24	2.17	2.14
		12.0	105.19	97.22	3.35	3.32	2.23	2.20
Mean of potassium		0.0	101.47a	93.50a	3.22a	3.20a	2.14a	2.11a
		47.0	103.70b	95.67b	3.31b	3.28b	2.19b	2.17b
		94.0	106.13c	99.47c	3.40c	3.36c	2.25c	2.22c
L.S.D at 5%								
A			1.95	1.88	0.07	0.06	0.03	0.03
B			2.17	2.11	0.06	0.05	0.05	0.04
C			1.64	1.67	0.05	0.05	0.05	0.05
AB			2.50	2.46	0.09	0.06	0.07	0.06
AC			3.16	3.02	0.12	0.10	0.07	0.07
BC			4.33	4.66	0.10	0.11	0.08	0.07
ABC			5.65	5.31	0.15	0.13	0.13	0.12

Table 3. Yield components as affected by number of irrigation, compost and potassium application.

Treatments			Number of spikes/m2		Number of grains/spike		1000-grain weight (g)	
Number of irrigation	Compost (t ha^{-1})	K (k ha^{-1})	2021/2022	2022/2023	2021/2022	2022/2023	2021/2022	2022/2023
3	0.0	0.0	380.1	362.1	60.2	60.0	45.3	45.1
		47.0	391.5	375.0	62.5	62.2	46.9	46.7
		94.0	396.4	381.5	63.9	63.5	48.2	47.8
	mean		389.33	372.87	62.20	61.90	46.80	46.53
	12.0	0.0	390.6	372.3	62.3	61.9	46.5	46.2
		47.0	397.1	379.6	64.6	64.0	48.1	47.8
		94.0	405.0	389.7	66.9	66.1	49.4	49.1
	mean		397.57	380.53	64.60	64.0	48.00	47.70
mean			393.45	376.70	63.40	62.95	47.40	47.12
4	0.0	0.0	395.3	379.7	64.3	63.8	47.8	47.0
		47.0	403.7	382.2	67.2	66.9	49.3	49.1
		94.0	410.5	391.3	69.5	68.5	51.2	59.8
	mean		403.17	384.40	67.00	66.40	49.43	51.97
	12.0	0.0	406.2	390.2	67.7	66.1	48.8	48.5
		47.0	411.6	395.5	69.2	68.2	51.3	51.1
		94.0	421.8	416.1	73.2	72.0	52.7	52.4
	mean		413.20	400.60	70.03	68.77	50.93	50.67
mean			408.18	392.50	68.52	67.58	50.18	51.32
5	0.0	0.0	409.1	397.3	70.1	69.3	49.1	48.9
		47.0	413.1	402.3	71.6	70.4	50.6	50.0
		94.0	416.6	409.5	72.5	71.7	51.0	50.8
	mean		412.93	403.03	71.40	70.47	50.23	49.90
	12.0	0.0	412.0	400.4	71.3	70.4	50.7	50.5
		47.0	416.3	407.1	72.8	71.3	51.9	51.3
		94.0	423.4	417.0	73.4	72.0	52.9	52.5
	mean		417.23	417.23	72.50	71.23	51.83	51.43
mean			415.08	410.13	71.95	70.85	51.03	50.67
Mean of compost		0.0	401.81	386.77	66.87	66.26	48.82	49.47
		12.0	409.33	399.45	69.19	67.25	50.25	50.63
Mean of potassium		0.0	398.88	383.67	65.98	65.25	48.03	47.70
		47.0	405.55	390.28	67.98	67.17	49.68	49.33
		94.0	412.28	400.85	69.90	68.97	50.90	52.07
L.S.D at 5%								
A			5.21	4.18	2.31	2.30	2.02	2.00
B			5.02	4.13	1.68	1.62	1.52	1.43
C			3.19	3.07	1.20	1.22	1.13	1.02
AB			6.01	N.S	N.S	N.S	N.S	N.S
AC			6.13	5.52	2.85	2.63	2.66	2.53
BC			5.21	5.13	2.19	2.03	2.31	2.15
ABC			7.36	6.53	3.21	3.15	2.92	2.56

Table 4. Yield measurements as affected by number of irrigation, compost and potassium application.

Treatments			**Grain yield (t ha^{-1})**		**Straw yield (t ha^{-1})**		**Biological yield (t ha^{-1})**	
Number of irrigation	**Compost (t ha^{-1})**	**K (k ha^{-1})**	**2021/2022**	**2022/2023**	**2021/2022**	**2022/2023**	**2021/2022**	**2022/2023**
3	0.0	0.0	6.95	6.51	13.93	13.71	20.88	20.22
		47.0	7.61	7.26	15.57	15.23	23.18	22.49
		94.0	8.30	7.90	16.06	15.80	24.36	23.7
	mean		7.62	7.22	15.19	14.91	22.81	22.14
	12.0	0.0	7.75	7.52	15.61	15.41	23.36	22.93
		47.0	8.32	7.95	16.10	16.00	24.42	23.95
		94.0	8.62	8.22	16.55	16.37	25.17	24.59
	mean		8.23	7.90	16.09	15.93	24.32	23.82
mean			7.93	7.56	15.64	15.42	23.56	22.98
4	0.0	0.0	8.29	7.96	15.17	15.01	23.46	22.97
		47.0	8.67	8.25	15.91	15.69	24.58	23.94
		94.0	8.91	8.54	16.13	16.03	25.04	24.57
	mean		8.62	8.25	15.74	15.58	24.36	23.83
	12.0	0.0	8.71	8.34	15.70	15.51	24.41	23.85
		47.0	8.99	8.59	15.94	15.76	24.93	24.35
		94.0	9.21	8.85	16.61	16.50	25.82	25.35
	mean		8.97	8.59	16.08	15.92	25.05	24.52
mean			8.80	8.42	16.08	15.92	25.05	24.52
5	0.0	0.0	8.91	8.41	15.74	15.52	24.65	23.93
		47.0	9.00	8.61	16.21	16.07	25.21	24.68
		94.0	9.11	8.73	16.39	16.25	25.5	24.98
	mean		9.01	8.58	16.11	15.95	25.12	24.53
	12.0	0.0	8.99	8.56	16.17	16.09	25.16	24.65
		47.0	9.10	8.74	16.33	16.26	25.43	25.00
		94.0	9.21	8.87	16.63	16.52	25.84	25.39
	mean		9.10	8.72	16.38	16.29	25.48	25.01
mean			9.10	8.72	16.38	16.29	25.30	24.77
Mean of compost		0.0	8.42	8.02	15.68	15.48	24.10	23.50
		12.0	8.77	8.40	16.18	16.05	24.95	24.45
Mean of potassium		0.0	8.27	7.88	15.39	15.21	23.65	23.09
		47.0	8.62	8.23	16.01	15.84	24.63	24.07
		94.0	8.89	8.52	16.40	16.25	25.29	24.76
L.S.D at 5%								
A			0.16	0.16	0.21	0.19	0.31	0.42
B			0.15	0.13	0.18	0.15	0.29	0.32
C			0.13	0.11	0.16	0.14	0.15	0.30
AB			0.29	0.27	0.28	0.27	0.55	0.53
AC			0.32	0.35	0.35	0.32	0.61	0.59
BC			0.25	0.24	0.33	0.30	0.44	0.61
ABC			0.43	0.42	0.51	0.52	0.50	1.01

As for the interaction, the results reveal that these parameters were affected by all studied interaction, except number of spikes m^{-2} in the second season and number of grains spike^{-1} and 1000-grain weight in both seasons, which did not affect by the interaction between number of irrigation and compost application factors. In general, under high level of compost and potassium, these parameters with four irrigation, were statistically equal to those with five irrigation. Also, with 12.0 t ha^{-1} compost, added 47.0 kg Kha^{-1} led to growth parameters, and yield and yield components equal to those under 94.0 kg Kha^{-1}.

Nutrient uptake

The data of the effect of the studied factors on total N, P and K uptake are given in Table 5. The data indicate that total N, P or K are positively responded to increasing number of irrigation. Wheat plants watered 3,4 and 5 irrigation absorbed 151.69, 171.37 and 179.73 kg ha^{-1} N; 47.97, 66.43 and 74.17 kg P ha^{-1}; and 252.05, 285.84 and 290.43 kg K ha^{-1} in first season, respectively. The corresponding values in the second season were 143.25, 163.45 and 172.16 kg N ha^{-1}; 45.62, 65.50 and 72.13 kg P ha^{-1}; and 244.37, 280.93 and 285.74 kg K ha^{-1}.

Also, nutrient uptake was significantly affected by compost application. The relative increments in N, P and K uptake due to added 12 t ha^{-1} compost reached to 6.47, 13.88 and 6.89 % as comparing with no compost in first season, respectively. Similar trends were obtained in the second season. Furthermore, potassium application was positively increased N, P and K uptake in both seasons. Wheat plant received 94 kg K ha^{-1} absorbed N, P and K surpassed no potassium by about 15.29, 8.18 and 11.58 % in first season. These increments in second season were 15.20, 7.64 and 12.00 % in the abovementioned respect.

The data of the interaction between any two factors (A × B, A × C and B × C) or among them (A × B × C) reveal that N, P and K uptake were affected by these interactions. In general, the effect of 47.0 kg K ha^{-1} on nutrient uptake are statistically equal to 94 kg K ha^{-1} under 12.0 t ha^{-1} compost. Also, adding 94 kg K ha^{-1} and 12.0 t ha^{-1} compost led to N, P and K uptake under four irrigation equal to those with five irrigation, which means the possibility to eliminate the negative effect of deficit water.

Table 5. Total N, P and K as affected by number of irrigation, compost and potassium application.

Treatments			**Total N uptake (kg ha^{-1})**		**Total P uptake (kg ha^{-1})**		**Total K uptake (kg ha^{-1})**	
Number of irrigation	**Compost (t ha^{-1})**	**K (k ha^{-1})**	**2021/2022**	**2022/2023**	**2021/2022**	**2022/2023**	**2021/2022**	**2022/2023**
3	0.0	0.0	124.53	114.65	38.24	37.30	206.79	198.87
		47.0	143.49	135.85	42.98	39.97	238.75	230.88
		94.0	162.44	154.07	47.53	45.05	259.43	248.09
	mean		143.49	134.86	42.92	40.77	234.99	225.95
	12.0	0.0	146.08	141.03	49.76	47.87	253.33	247.79
		47.0	160.33	151.37	52.52	51.85	270.47	264.52
		94.0	173.25	162.53	56.77	51.66	283.51	276.04
	mean		159.89	151.64	53.02	50.46	269.10	262.78
mean			151.69	143.25	47.97	45.62	252.05	244.37
4	0.0	0.0	154.36	147.41	55.94	54.29	258.23	251.21
		47.0	167.37	157.33	59.45	57.25	275.65	266.90
		94.0	177.15	167.01	60.71	58.13	287.66	280.01
	mean		166.29	157.25	58.70	56.56	273.85	266.04
	12.0	0.0	164.73	157.83	65.75	63.63	272.24	264.35
		47.0	174.01	168.28	65.74	65.19	284.78	278.93
		94.0	190.57	182.80	67.81	67.67	303.49	299.51
	mean		176.44	169.64	66.43	65.50	286.84	280.93
mean			171.37	163.45	66.43	65.50	286.84	280.93
5	0.0	0.0	169.85	161.17	69.13	67.93	276.47	268.82
		47.0	177.69	170.50	70.38	70.62	288.69	284.27
		94.0	184.14	175.21	73.79	70.79	294.53	290.15
	mean		177.23	168.96	71.10	69.78	286.56	281.08
	12.0	0.0	174.93	167.48	76.25	73.09	285.53	281.73
		47.0	181.97	175.45	77.95	73.31	293.57	289.48
		94.0	189.78	183.13	77.49	77.05	303.79	299.97
	mean		182.23	175.35	77.23	74.48	294.30	290.39
mean			179.73	172.16	74.17	72.13	290.43	285.74
Mean of compost		0.0	162.34	153.69	57.57	55.70	265.13	257.69
		12.0	172.85	165.54	65.56	63.48	283.41	278.04
Mean of potassium		0.0	155.75	148.26	59.18	57.35	258.77	252.13
		47.0	167.48	159.80	61.50	59.70	275.32	269.16
		94.0	179.56	170.79	64.02	61.73	288.74	282.30
L.S.D at 5%								
A			4.49	3.29	2.31	2.15	5.31	5.18
B			3.12	3.00	2.79	2.33	5.05	4.86
C			4.15	4.10	2.16	2.11	5.72	5.26
AB			5.05	5.02	3.35	3.17	6.25	6.71
AC			5.47	5.01	3.62	3.51	6.81	6.95
BC			4.57	4.29	3.73	3.48	6.52	6.46
ABC			6.61	6.37	4.52	4.13	7.49	7.17

Discussion

The major limitations in Egyptian production are water deficiency, nutrient imbalances and declining soil organic matter. Drought is the most limiting factor for plant growth over the world, especially wheat plant. In basis of this research, soil properties were affected only by compost application, except soil available N and K, which affected also by number of irrigation, and soil available K which responded also only by potassium application. Compost application decrease soil pH and bulk density as well as increased soil salinity, soil organic matter, soil available N, P and K as well as enhanced water relations. The decrement in soil reaction due to compost application is mainly attributed to acidifying effect of compost throughout its continuous decomposition (Mohamed *et al*, 2018). In addition, Reimer *et al* (2023) reported that the reduction in soil pH after using organic materials may be due to the production of organic acids during mineralization of these materials by soil microorganisms. Similar results were obtained by Galal *et al* (2017) and Yassin *et al* (2023). Using compost lowering soil bulk density due to mixture of these low density of compost (Table 1) into soil fraction, consequently enhanced soil structure in turn increased pore space and improved water relations. In this concern, Kelbesa (2021) and Ghazi *et al* (2022) mentioned that compost application improved soil aggregation and its stability by many microorganisms in soil, consequently improved water relations. Hoang *et al* (2023) reported that adding compost at higher rate increased soil water capacity. Additionally, Elbaalawy *et al* (2023) stated that high rate of compost resulted in improved water infiltration, consequently increased water use efficiency. These results agree with those obtained by Atoloye *et al* (2022) and Kelbesa (2021) for bulk density, and Rashwan *et al* (2024) for water relations. Compost consists of sable organic materials caused by biological decomposition of organic matter in aerobic conditions (Hussein *et al*, 2022), therefore these organic materials released slowly after added compost and these materials are less exposed to leaching as in chemical fertilizers. Kelbesa, (2021) pointed out that soil organic matter increased due to compost application. Pan (2022) indicates that compost carbon is poorly decomposition, therefore compost increased carbon sequestration in soil. These results are in line with those obtained by Mohamed *et al* (2018) and Rashwan *et al* (2024).

Compost application led to significant increase in soil available N, P and K in soil after harvest. The beneficial effect of compost on soil available N, P and K content may be due to the decomposition of compost resulted in related the chelated compounds which increased nutrient availability (Abdou *et al*, 2023). Appling compost led to increases in soil salinity. The negative effect of compost on soil salinity may be attributed to the used compost contain a relatively high EC value (Table 1). In these respect, Elbaalawy *et al* (2023) pointed out that compost contain several ions which needed for plant, especially when contain low level of heavy metals, but high content of some ions can potentially increase soil salinity. These results are confirmed by the finding of Galal *et al* (2017) and Keibesa (2021) who stated that organic manure application increased nutrient availability and soil salinity. Also, the data reveal that soil available N and K were significantly decreased by increasing the applied water, which mainly due to leaching effect of high amount of water. Moreover, soil available K enhanced by increasing potassium levels.

Drought stress had negative effect on vegetative growth, yield and its components and nutrient uptake. Highest amount of the measurements were related to irrigated wheat plant five irrigations, while irrigated the plant three irrigations (deficit conditions) exhibited the lowest ones. The grain yield is depended by three components, namely number of spikes /m^2, number of grains spike^{-1} and 1000-grain weight. Pouri *et al* (2019) and Abd El-Aty (2024) found that deficit water negatively affects number of grains spike^{-1}, especially in flowering stage due to lowering the rate of pollination under deficit water in this stage. Also, water stress decrease the grain weight may be owing to the rate of respiration associated with stomata closure, inhibited the leaf development and decreasing the period of grain filling (Al-Omary *et al*, 2021). The straw yield of plants is influenced by deficit water, because drought had negative effect on leaves, stems and grains (Awwad *et al*, 2022). In addition, Wasaya *et al* (2021) reported that drought conditions resulted in reduction in absorption of water and nutrients from soil solutions, decrease photosynthesis, consequently reduce growth and grain yield. Mubarak *et al* (2016) stated that deficit water adversely affect absorption and use of nutrients, hence vegetative growth and yield. Abd-Elrahman *et al* (2022) added that the nutrient uptake was reduced due to drought. Similar finding were obtained by Pouri *et al* (2019) and Saudy *et al* (2023) who stated that reducing irrigation water significantly decreasing growth parameters, yield and yield components and nutrient uptake.

Compost application positively increased wheat growth and yield productivity and well as N, P and K uptake. Amirahmadi *et al* (2024) stated that multiple positive effect of compost on improving soil properties as discussed earlier resulted in increase in crop yield and its quality. Our results reveal that compost application increased plant height, number of tillers /plant and dry weight /plant, number of spikes /spike, number of grains /spike and weight of grains due to high content of nutrient in compost, consequently increased wheat productivity (Imran *et al* 2017). Moreover, compost is rich in humic acid that help plants for uptake nutrients and water by prevent in them from leaching. Beside humic acid could positively increase crop productivity (Ren, 2020). According to Rabie (2019) and Kelbesa (2021), organic manure increased available nutrients in soil, hence enhanced root proliferation, which in turn increased nutrient uptake in plants. These results are in accordance with those obtained by Galal *et al* (2017), Imran *et al* (2017) and Mohamed *et al* (2018) and Reimer *et al* (2023) who illustrated that wheat productivity and quality were positively responded to compost application.

Potassium being an essential nutrient for many plant processes, hence potassium application led to improve yield for higher plants. Nevertheless, potassium fertilizer is almost negligible by most farmers due to economic status of farmers and high cost of potassium using. However, most soils of Egypt have low amount of soluble K (Abdelfattah *et al*, 2021). Our results clearly show that split application of K significantly increased vegetative growth and yield and yield components as well as N, P and K uptake. These increment increased as potassium levels increased up to 94 kg K ha^{-1}. The primitive effect of potassium application on vegetative growth may be due to application of potassium improved nutrient uptake and enhanced physiological responses of plant, consequently increased plant growth (Abd El-Mageed *et al*, 2023). In this concern, Xu *et al* (2020) and Sardans and Penuels (2021) stated the beneficial effect of K application on plant growth may be attributed to stomata opening system, cell elongation and cell turgidity is mostly regulating by potassium in plant. Moreover, Tränkner *et al* (2018) and Siddiqni *et al* (2021) pointed out that potassium has stimulating effect on the production of ATP as in plasma membrane led to better vegetative growth, yield attributes (number of spikes/plant, number of grains/spike and 1000-grain weight) as well yield measurements, i.e. grain yield, straw yield and biological yield showed a significant increase due to K-application. This may be due to application of potassium improved chlorophyll fluorescent in turn increased plant growth and yield and its components. These parameters increase as levels of potassium increased. Also, they added that the translocation of photosynthesis and sugars in plant are related to K-application, consequently improved plant yield. In addition, Siddiqui *et al* (2021) and Johnson *et al* (2022) indicated that the beneficial effect of potassium on growth and yield may be attributed to the primitive effect of potassium on biosynthesis, nutrient and water uptake, and metabolite processes. The positive effect of potassium on nutrient uptake due to K-application enhanced root growth, in turn increased nutrient concentration in plant Ali *et al* (2019) and Abd El-Mageed *et al* (2023).

The data clearly reveal that wheat growth, yield and its components and N, P and K uptake were significantly affected by the interaction between any two factors or among the three factors. In general high level of both compost and/or potassium eliminate the adversely effect of drought on the above parameters. Also, compost application in combined with 47 kg K ha^{-1} resulted in wheat productivity equal to under 94 kg K ha^{-1}. This may be due to K affect plant osmotic adjustment, hence improving maintaining osmatic charge and assimilates translocation (Mubarak *et al*, 2016), consequently supplying the plant with potassium was minimizing the negative effect of deficit water (Salem *et al*, 2022). Also, Raza *et al* (2013) reported that potassium application reduced the adverse effect of water deficiency by decreasing the rate of adsorb sodium by plant under deficit water. They added that application of potassium maintained the internal balance of water in plant leaves. As for compost, it formed from high content of humic acids that help the plant to tolerant the water shortage by enhancing water retention. These results are in similar to those obtained by Al-Omary *et al* (2021) and Panhwar *et al* (2021) for drought, Messaoudi *et al* (2023) and Saudy *et al* (2023) for potassium, and Elbaalawy *et al* (2023) and Rashwan *et al* (2024) for compost.

CONCLUSION

Under alluvial clay soil it could be recommended to applying 12 t ha^{-1} compost and 47 kg K ha^{-1} to wheat plants under optimal irrigation conditions. However, under drought conditions it could be recommended to use 12 t ha^{-1} compost with 94 kg K ha^{-1} to mitigate drought stress.

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تحسين إنتاجية القمح وصفات التربة بأستخدام الكمبوست والبوتاسيوم تحت ظروف الاجهاد المائي

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الملخص

أجريت التجربة موضع الدراسة بمحطة بحوث سدس- بني سويف- مصر للموسمين التاليين 2021/ 2022 و 2022/ 2023 لدراسة تأثير إضافة ثلاث مستويات من البوتاسيوم مع مستويين من الكمبوست تحت ثلاث مستويات للري علي تحسين خواص التربة والإنتاجية. استخدم تصميم القطع المنشقة مرتين في قطاعات عشوائية في أربع مكررات. وتشير النتائج الي مايلي: - أدي إضافة 12 طن كمبوست/هكتار الي تقليل درجة الحموضة والكثافة الظاهرية وزيادة المادة العضوية والملوحة وصلاحية النيتروجين والفوسفور والبوتاسيوم وتحسين العلاقات المائية. - أدي زيادة عدد الريات الي زيادة النتروجين والبوتاسيوم الصالح في التربة بعد الحصاد. - أدي زيادة عدد الريات وإضافة الكمبوست وزيادة معدل التسميد البوتاسي الي زيادة عوامل النمو، ومكونات المحصول، ومقاييس النمو وكذلك أمتصاص عناصر النيتروجين والفوسفور والبوتاسيوم. -أدت إضافة 12 طن كمبوست/هكتار مع 47 كجم بوتاسيوم/ هكتار في مقاييس نمو المحصول ومكوناته وامتصاص العناصر لاستجابة مساوية لأضافة 12 طن كمبوست/ هكتار مع 94 كجم بوتاسيوم/ هكتار، مما يشير الي إمكانية تخفيض معدل التسميد البوتاسي الي النصف بإضافة الكمبوست. - أدي ري القمح أربع ريات مع إضافة 12 طن كمبوست/ هكتار مع 94 كجم بوتاسيوم/هكتار الي إنتاجية محصول يساوي إنتاجية المحصول باستخدام خمس ريات، مما يشير الي إمكانية تقليل الضرر الناتج من نقص المياه بإضافة الكمبوست والبوتاسيوم. من نتائج الدراسة يمكن التوصية بإضافة 12 طن كمبوست/ هكتار مع 47 كجم بوتاسيوم/ هكتار لتعظيم إنتاجية القمح مع تحسين خواص التربة تحت ظروف وفرة من مياه الري، أما في حالة نقص المياه فيوصي بإضافة 12 طن كمبوست/ هكتار مع 94 كجم بو/ هكتار لعدم تأثر إنتاجية القمح بظروف نقص المياه.