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Effect of Water Deficit, Organic Fertilization and Some Soil Additions on Potato Productivity

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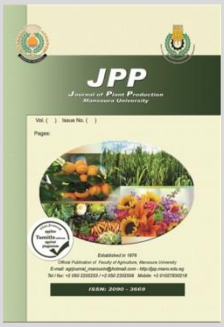

ABSTRACT

Two field experiments were conducted in a silty clay soil at a private farm at Al Arid, Belqas Center, Dakahlia Governorate, Arab Republic of Egypt, during the two successive seasons of 2019/2020 and 2020/2021, to study the impact of water deficit (WD), organic fertilization as vermicompost and some soil additions (without, HA and EM), moreover their interactions on growth, yield and its components and quality of potato Spunta cultivar. Data cleared that water deficit treatments have significant effect on vegetative growth, yield and its components and quality parameters in both seasons. The maximum means of these characters are recorded as a result of irrigation of potato plants regularly in both seasons, except, proline content in tubers of potato, which resulted under the influence of irrigation deficit in both seasons. While, vermicompost addition increased significantly all studied characters except, proline, nitrate (NO_3) and nitrite (NO_2) contents in tubers of potato, in both seasons. As for the impact of soil additions (without, HA and EM), the same data are increased significantly with HA compared to other treatments, except, proline, nitrate (NO_3) and nitrite (NO_2) contents in tubers and which were recorded for them the lowest values with the addition of EM in both seasons. As for the interaction among full irrigation plus vermicompost and HA soil addition treatment gave the best values of all studied characters. However, the interaction among irrigation deficit plus vermicompost and HA addition gave superiority compared with plants have full irrigation without vermicompost and without soil addition treatments.

Keywords: Potato, WD, vermicompost, HA, EM.

INTRODUCTION

Potato (*Solanum tuberosum* L.) is one of the most important vegetable crops in Egypt, due to its wide local consumption and exportation. It is one of the most important of the Solanaceae family plants. It is cheap source of energy, since it has a lot of carbohydrates, adequate amounts of vitamins B and C, protein and minerals, it is relatively considered rich in fiber, some free amino acids and very small amounts of fat that does not exceed milligrams.

Water is a critical factor in plant physiology, nutrition and growth, as the absorption of nutrients occurs primarily through the root, which is practically and completely dependent on water, in view of the water deficit targeting the whole world, especially the Middle East and North Africa regions, it is expected that the population will exceed the current number and the food security requirements will increase, as well as the climate changes occurring in the whole world that warn of drought, it was necessary to think about the process of rationalizing the amount of irrigation water, improving productivity in terms of quantity and quality and economic return. Too much irrigation causes soil erosion, increased susceptibility to diseases, water loss, nitrogen loss, in addition to the energy costs needed to pump water.

On potato Metwaly and El-Shatoury (2017) found that increasing water quantity up to1300 m^3 per fed. led to a significant increase of leaves number, plant height, foliage fresh weight/plant and number of main stem in addition to N, P, K, chlorophyll a and chlorophyll b content in the leaves, as well as tubers weight and number per plant, marketable and total yield as well as, vitamin C, TSS, N, P and K content in tubers. Also, Tartoura *et al.* (2021) on artichoke, showed that the mean values of number of heads and heads weight for early and total yield per fed. significantly increased when the plants irrigated with all intervals (10, 20 and 30 days). The maximum values for early and total yield in both seasons were realized for the treatment of 20 days followed by 10 days interval, while the lowest one was recorded for the plants irrigated with 30 days. Also, on potato, Hassan and Suleiman (2022) showed a decrease in yield kg per m^2 at irrigation level 40 percent of field capacity, while tubers content of proline increased. Also, on potato, the results indicated that chlorophyll content, tuber yield, aboveground dry matter, starch and vitamin C content improved with the increase of irrigation amount Zhang *et al.* (2022).

Vermicompost is an organic material that contributes significantly to the vegetative growth and development of plants by providing some essential minerals in their accessible forms and boosting the physical, chemical, and biological characteristics of soils. It improves soil aeration,

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hydraulic conductivity, and water holding capacity while lowering the incidence of plant diseases. Due to the aforementioned effects, vermicompost has received attention in a number of recent studies and has established itself as one of the most crucial supplemental agents for fertilization and the enhancement of soil qualities.

Pathma and Sakthivel (2012) summarized that vermicompost improves soil biodiversity by encouraging beneficial microbes, which in turn promotes plant growth directly by producing hormones and enzymes that regulate plant growth, as well as indirectly by preventing the spread of plant pathogens, nematodes, and other pests, thereby improving plant health and reducing yield loss. Additionally, on head lettuce, the results of Doklega and Imryed (2020) demonstrated that the fertilizing plants with vermicompost at a rate of 3.5 tons per fed. with N application at a rate of 75 percent in both seasons led to the maximum values of fresh weight, dry matter %, yield per fed., chemical and quality parameters, in addition to the lowest values of nitrate (NO_3) and nitrite (NO_2) contents. Also, Liu *et al.* (2021) showed that the influence of vermicompost on microbial quantity, enzyme activities, soil nutrients, tomato growth, quality and yield in the greenhouse were tested. The findings demonstrated that applying vermicompost in both a broadcast and a furrow manner improved soil environment and greatly increased soil organic matter and nutrients (N, P and K). The application of vermicompost dramatically boosted catalase and sucrase activity, bacterial and actinomycete abundance, and decreased fungus abundance in the soil. Additionally, it encouraged root growth and leaf photosynthesis and raised chlorophyll, nitrogen, and potassium levels in leaves, all of which had a beneficial impact on plant yield and growth.

Humic acid (HA) is also organic material, it reduces evaporation, soil erosion by increasing the cohesive forces of its fine particles, improves its structure and water holding capacity, in addition to enhancing chemical and biological properties of the soil. It is very important as a medium for transporting nutrients from the soil to the plant because it can hold onto ionized nutrients, where leaching away is prohibited. It is also attracted to the depletion zone of the plant root, it brings along water and nutrients the plant needs. It also enhances cell division, root growth, and decreases stress deterioration, resisting the negative influence of salt that would inhibit the uptake of nutrients and the growth of plants. Under the influence of HA, plants get stronger and have the best plant disease resistance. Also, potassium humate, as a source of HA, contains potassium (K), which plays among main nutrients vital role in plant metabolism such as regulation of plant process, transpiration, photosynthesis, translocation of photosynthetic, diseases resistance and activation of plant catalyst. It improves quality standards, dry matter and the transition of foodstuffs to the economic part.

According to El-Sayed *et al.* (2019), soil application of HA resulted in significantly higher numbers of leaves per plant, fresh and dry weight per plant, yield per plant, total yield, chlorophylls a, b, and total chlorophyll in sweet pepper leaves, as well as vitamin C and total soluble solids (TSS) in pepper fruits in both seasons as compared to controls. Also, about common bean according to Rady *et al.* (2019), all potassium humate treatments significantly enhanced the growth parameters (number of leaves per plant and shoot fresh and dry weights plant), yield parameters of green pods and dry seeds, including average pod weight, number of pods per plant, pod weight per plant, dry seed weight per plant, and 100-seed weight, leaf photosynthetic pigments *i.e.*, total chlorophylls, as well as leaf contents of N, P, and K.

Effective Microorganisms (EM) are microbial mixtures of advantageous organisms that can be used as inoculants to increase the microbial diversity of soil ecosystems. They mostly comprise of lactic acid bacteria, yeasts, actinomycetes, photosynthesizing bacteria, and fermenting fungi. All of these are claimed to be can coexist in liquid culture and physiologically compatible with one another. These microorganisms perform a set of beneficial functions for improving soil fertility, as well as the vital role it plays in enhancing plants growth and development.

Abdel-Naby *et al.* (2018) reported that on sweet potato, EM provided the best values of all examined parameters. The interactions between 0% NPK plus EM dramatically reduced the contents of nitrate and nitrite in both seasons, whereas doses of 100 percent and 50 percent NPK plus EM generated the best significant increases in the examined parameters in both seasons. Also, Doklega (2018) conducted research on okra and discovered that the combination treatment of farmyard manure at a rate of 20 m^3 per fed, 75 percent NPK from authorized doses, and EM (2 ml/L) addition offered the maximum values of quality and yield with significant differences in both seasons.

This investigation aimed to study the influence of water deficit, organic fertilization as vermicompost and some soil additions (without, HA and EM), moreover their interactions on growth, yield and its components and quality of potato Spunta cultivar under Al Arid, Belqas Center, Dakahlia Governorate, Arab Republic of Egypt ecological conditions.

MATERIALS AND METHODS

Analysis of soil:

Before planting, a soil sample was randomly collected from the experimental field area at a depth of 0-30 cm from the soil surface before soil preparation to estimate some physical and chemical properties of the used soil, as shown in Table 1. All these characteristics were analyzed according to Buurman *et al.* (1996).

Table 1. Some physical and chemical characteristics of the experimental soil before planting during the two seasons of study.

Soil characters		1st	2nd
Particle size distribution (%)	Coarse sand	1.430	1.510
	Fine sand	12.76	13.92
	Silt	42.65	43.89
	Clay	43.16	40.86
	Texture class	Silty clay	Silty clay
pH		7.900	8.100
EC dS m^{-1}		2.490	2.130
Total CaCO3 g kg^{-1}		2.520	2.950
Organic matter g kg^{-1}		1.320	1.380
Bulk density kg.m^{-3}		1.330	1.380
Field capacity %		33.71	34.26
Welting point %		16.85	17.13
Saturation percentage %		70.53	72.05
Available nutrients (mg kg^{-1})	N	38.17	40.19
	P	7.260	7.920
	K	212.35	217.52

The experimental design and treatments:

This experiment was carried out in a strip-split plot design with 3 replicates. Each experiment included 12 treatments. The vertical-plots were allocated to two irrigation treatments (main plots) as follow:

1- Full irrigation (4 irrigation times).

2- Irrigation deficit *i.e.*, half the number of irrigation times (the first and third irrigation).

The horizontal plots were devoted into organic fertilization two treatments (sub plots) as follows:

1- Without vermicompost.

2- Vermicompost addition 2 t/fed was incorporated in the soil before planting.

The sub – sub plots were located to three other soil addition treatments as follow:

1- Without soil addition.

2- Humic acid (10 kg/fed) in the form of potassium humate.

3- Effective Microorganisms (EM) was used at the rate of 10 L/fed.

Humic acid and EM were added in a soil application in two equal doses one with irrigation before planting and the other with the first irrigation.

Each experimental plot included three ridges, each of 0.75 m in width and 5 m in length resulted an area of 11.25 m^2.

Table 2. Average some chemical analysis and saturation percentage % of used vermicompost during the two seasons of study.

Parameters	1st	2nd
Organic matter%	23.46	25.12
Organic carbon%	15.2	19.6
Total N%	1.13	1.15
C/N	13.45	17.04
Total P%	1.28	1.17
Total K%	0.82	0.69
Saturation percentage %	118	136
EC dS m^{-1}	4.02	4.13
pH	5.95	6.19

Agricultural practices:

Nitrogen fertilizer is 165 kg /fed, it was added in the form of ammonium sulfate (20.6 % N) and ammonium nitrate (33.5 % N), potassium fertilizer dose is 96 kg /fed, it was added in the form of potassium sulfate (48.0 % K_2O), while phosphorous fertilizer dose is 65 kg P_2O_5/fed, it was added in the form of calcium super phosphate (12.5 % P_2O_5).

The experimental field was prepared for each experiment through two division and then divided into the experimental units with dimensions as previously mentioned and the method of furrow irrigation was used.

Tubers pieces of potato Spunta local were used in this study. When the soil dries up, it is suitable for planting, tubers pieces were planted manually on the 17th and 26th of November in the first and the second seasons, respectively at 25 cm apart between each other, depth (10-15 cm) and on one side. The planting was carried out with about 1.2 t/fed of segmented tubers the day before planting.

Except as otherwise interfere with experimental treatments and planting area conditions, all the other cultural practices for potato production were used according to the recommendation of the Ministry of Agriculture and Land Reclamation, Arab Republic of Egypt.

Studied Characters:

1- Vegetative growth:

Five plants at random from each experimental unit were sampled after 85 days of planting to determine the following parameters:

- Plant height.
- Plant fresh weight.

- Plant dry weight: The plant was oven dried till constant weight at 70 °C.

- **Chlorophylls content:** Chlorophylls (a+b) were estimated by a spectrophotometric method in the leaves of potato at 85 days of planting according to Gavrilenko and Zigalova (2003).

2- Yield and its components:

At harvest time, after 120 days of planting the following were determined:

- Average number of tuber/plant.
- Average fresh weight of tuber of marketable yield.

- Total yield: Was determined as a yield of each plot then calculated as (t/fed).

3- Tubers quality:

- **Total soluble solids percentage (TSS):** Was estimated in the juice of potato tubers by using Gali 110 Refractometer according to AOAC (2019).
- **Dry matter percent in tubers:** Was determined by weighing a certain weight of fresh tuber to dry at 70° C till constant weight.
- **Total carbohydrates percentage:** Was determined according to Sadasivam and Manickam, (1996).
- **Starch:** Was estimated by the method of Antheron reagent as described by Thymanavan and Sadasivam (1984).
- **Crude protein:** Was calculated by multiplying nitrogen percentage by the factor of 5.75 according to AOAC (2019).
- **Vitamin C (mg 100g^{-1} FW):** Was estimated according to the method described by Mazumdar and Majumder (2003).
- **Proline:** Was colorimetric determination proceeded according to (Bates *et al*., 1973).
- **Nitrate (NO_3) and nitrite (NO_2) contents:** Determinations in potato tubers were measured as described by Singh (1988).
- **Total soluble sugar and reducing sugar:** Were determined according to the method described by Sadasivam and Manickam (1996).
- **Non-reducing sugars (%):** Was calculated from the difference between total sugars and reducing sugar .

Statistical analysis

Using "MSTAT-C" computer software package. Data were statistically evaluated using the analysis of variance (ANOVA) technique for the strip-split plot design as described by Gomez and Gomez (1984). According to Snedecor and Cochran (1980) the least significant difference (LSD) method was employed to examine the differences between treatment means at the 5% level of probability.

RESULTS AND DISCUSSION

Effect of water deficit treatments:

Data present in Tables 3, 5, 7, 9, 11 and 13 show that water deficit treatments have significant effect on vegetative growth parameters, *i.e.*, plant height, fresh weight/plant, dry weight/plant and chlorophylls (a+b) content in the plant of potato after 85 days of planting, yield and its components *i.e.*, average number of tuber/plant, average fresh weight of tuber of marketable yield and total yield of potato at harvest and quality parameters *i.e.,* TSS, dry matter, total carbohydrates, starch, crude protein percentages, vitamin C, proline, nitrate (NO_3), nitrite (NO_2) contents, reducing sugar, non-reducing sugars and total soluble sugar percentages in potato tubers at harvest, in both seasons. The maximum means of these characters are recorded as a result of irrigation of potato plants regularly in both seasons, except, proline content in tubers of potato, which resulted under the influence of irrigation deficit in both seasons. The increases of these characters due to full irrigation may be ascribed to that it is appropriate to save the water around roots which caused good conditions to plant roots to absorb the required sufficient water and the available mineral elements which in turn affects the final outcome of the plants. Water shortage around the plant roots, especially in the beginning of the setting and formation of tubers, caused decrease in the amount of dissolved nutrients, and consequently, the amount of the absorbed nutrients, also the speed of transfer of the solution within the plant tissue decreased, and this caused a decrement in the plants ability to form dry matter, which was reflected on productivity. These results are in a similar direction of view to those mentioned before about Metwaly and El-Shatoury (2017) on potato, Tartoura *et al*. (2021) on artichoke, Hassan and Suleiman (2022) and Zhang *et al.* (2022) on potato.

Effect of organic fertilization treatments:

In relation to the impact of organic fertilizers, data in the same tables reveal a significant effect on vegetative growth parameters, yield and its components and quality parameters, in the two seasons. It can be seen that the maximum values are formed with vermicompost addition compared to untreated potato plants (without vermicompost) in both seasons, except, proline, nitrate (NO_3) and nitrite (NO_2) contents in tubers of potato, which resulted from untreated potato plants (without vermicompost) in both seasons. This improvement could be credited to the positive influence of vermicompost fertilizer components as shown in Table 2, which shows the C/N ratio is considered optimum in the two seasons for increasing the nutrients mineralization moreover, vermicompost get better soil drainage, a positive effect of vermicompost on soil biodiversity, aeration and to improve the soil water retain. As well as, vermicompost used as a soil amendment, which improve soils water holding capacity and increases the availability of some essential micronutrients for plant roots, which are important for formation of amino acids, growth regulators, cell wall, nucleic acid, enzymes and etc, also it facilitates sugar translocation in plants where these factors caused an increase in chlorophyll a and b, which reflected positively on an increase in the efficiency of the photosynthesis process, and thus increased the dry matter formation as well as influences development of cell and elongation which in turn affects the final outcome of the plants. These results are in a similar direction of view to those mentioned before about Pathma and Sakthivel (2012) on review vermicompost, Doklega and Imryed (2020) on head lettuce and Liu *et al.* (2021) on tomato.

Effect of soil addition treatments:

As for the impact of soil additions (without, HA and EM), the same data are increased significantly with HA compared to other treatments, except, proline, nitrate (NO_3) and nitrite (NO_2) contents in tubers of potato and which were recorded for them the lowest values with the addition of EM in both seasons. These results may be due to the important role of HA, it plays an important role in increase aggregation of fine particles, improve soil structure and water holding capacity, in addition to enhancing the chemical and biological properties of the soil. It is crucial as a means of transferring nutrients from the soil to plants because it can hold onto ionized nutrients and prevent them from draining away. It is also drawn to the plant's depletion zone, where it delivers water and nutrients that the roots of the plant require. While, EM are microbial mixtures of advantageous organisms that can be used as inoculants to boost the microbial diversity of soil ecosystems. They mostly comprise of lactic acid bacteria, yeasts, actinomycetes, photosynthesizing bacteria, and fermenting fungi. All of these are claimed to be can coexist in liquid culture and physiologically compatible with one another. These microorganisms perform a set of beneficial functions for improving soil fertility, as well as the vital role it plays in enhancing plant growth and development. These results are in a similar direction of view to those mentioned before about Abdel-Naby *et al.* (2018) on sweet potato, Doklega (2018) on okra, El-Sayed *et al.* (2019) on sweet pepper and Rady *et al.* (2019) on common bean.

Effect of interactions:

The various interactions (water deficit × organic fertilization), (deficit water × soil addition), (organic fertilization × soil addition) and (deficit water × organic fertilization × soil addition) have many significant effect on vegetative growth parameters, yield and its components and quality parameters of potato in both seasons as present in Tables 3 to 14.

The interactions among water deficit, organic fertilizer as vermicompost and soil additions (without, HA and EM) have significant effect on vegetative growth parameters, *i.e.,* plant height, fresh weight/plant, dry weight/plant and chlorophylls (a+b) content in the plant of potato after 85 days of planting in both seasons, yield and its components *i.e.,* average number of tuber/plant, average fresh weight of tuber of marketable yield and total yield of potato at harvest in both seasons and quality parameters *i.e.,* TSS, dry matter percentages in both seasons, total carbohydrates percentage in the second season, starch, crude protein percentages in both seasons, vitamin C content in the second season, proline content in the first season, reducing sugar and total soluble sugar percentages in the second season as present in Tables 3 to 14. As for the interaction among full irrigation plus vermicompost and HA soil addition treatment gave the best values of all studied characters. However, the interaction among irrigation deficit plus vermicompost and HA addition gave superiority compared with plants have full irrigation without vermicompost and without soil addition treatments as shown from data present in Tables 4, 6, 8, 10, 12 and 14. When plants irrigated with 50% of the number of irrigation times plus materials added to the soil, gave a satisfactory yield in both seasons.

Table 3. Plant height, fresh and dry weights/plant and (chlorophylls (a+b) content in leaves) of potato as affected by water deficit, organic fertilization and some soil additions as well as their interactions during 2019/2020 and 2020/2021 seasons.

Characters	Plant height (cm)		Fresh weight (g/plant)		Dry weight (g/plant)		Chlorophylls (a+b) (mg/g FW)	
Treatments	2019/ 2020	2020/ 2021	2019/ 2020	2020/ 2021	2019/ 2020	2020/ 2021	2019/ 2020	2020/ 2021
A- Water deficit treatments:								
Irrigation deficit	64.72	67.45	343.1	365.1	46.45	52.07	1.039	1.078
Full irrigation	70.08	72.80	389.0	406.8	50.44	56.84	1.095	1.124
F. test	*	*	*	*	*	*	*	*
B- Organic fertilization treatments:								
Without	63.55	65.56	330.8	350.5	45.14	50.47	1.025	1.060
Vermicompost	71.25	74.68	401.3	421.4	51.76	58.44	1.110	1.141
F. test	*	*	*	*	*	*	*	*
C- Soil addition treatments:								
Without	61.23	62.66	307.5	321.8	43.02	47.46	0.994	1.029
Humic acid	71.45	75.65	403.3	426.9	52.00	58.96	1.113	1.146
EM	69.53	72.06	387.4	409.2	50.33	56.96	1.094	1.127
LSD at 5%	0.41	0.39	2.4	3.0	0.31	0.35	0.004	0.005
D- Interactions:								
A × B	NS	NS	*	*	*	*	*	NS
A × C	NS	*	*	*	*	NS	*	*
B × C	*	*	*	*	*	*	NS	NS
A × B × C	*	*	*	*	*	*	*	*

EM = Effective microorganisms, * = Significant, NS = Non-significant.

Table 4. Plant height, fresh and dry weights/plant and (chlorophylls (a+b) content in leaves) of potato as affected by the interaction among water deficit, organic fertilization and some soil additions during 2019/2020 and 2020/2021 seasons.

Characters			Plant height (cm)		Fresh weight (g/plant)		Dry weight (g/plant)		Chlorophylls (a+b) (mg/g FW)	
Water deficit	Organic	Soil addition	2019/ 2020	2020/ 2021	2019/ 2020	2020/ 2021	2019/ 2020	2020/ 2021	2019/ 2020	2020/ 2021
Irrigation deficit	Without	Without	55.00	57.46	276.5	279.5	39.76	42.97	0.951	0.980
		Humic acid	64.66	66.33	339.4	363.7	46.43	51.73	1.038	1.073
		EM	63.46	64.53	324.6	344.1	44.58	49.53	1.021	1.056
	Vermicompost	Without	62.33	63.06	307.4	323.6	43.30	47.53	0.995	1.036
		Humic acid	72.40	79.00	411.6	448.2	53.22	61.32	1.128	1.171
		EM	70.46	74.33	399.0	431.8	51.45	59.37	1.103	1.150
Full irrigation	Without	Without	60.73	62.00	293.4	302.4	41.69	45.48	0.972	1.008
		Humic acid	69.80	73.53	384.7	415.5	49.79	57.53	1.094	1.130
		EM	67.66	69.53	366.5	398.0	48.59	55.61	1.073	1.112
	Vermicompost	Without	66.86	68.13	352.6	381.5	47.34	53.85	1.058	1.093
		Humic acid	78.93	83.73	477.4	480.3	58.57	65.25	1.194	1.208
		EM	76.53	79.86	459.6	462.8	56.69	63.34	1.180	1.191
LSD at 5%			0.83	0.79	4.8	5.2	0.61	0.71	0.009	0.011

EM = Effective microorganisms, * = Significant, NS = Non-significant.

Table 5. Average number of tuber/plant, average fresh weight of tuber of marketable yield of potato at harvest as affected by water deficit, organic fertilization and some soil additions as well as their interactions during 2019/2020 and 2020/2021 seasons.

Characters	Average number of tuber/plant		Average fresh weight of tuber of marketable yield (g)		Total tubers yield (t/fed)	
Treatments	2019/ 2020	2020/ 2021	2019/ 2020	2020/ 2021	2019/ 2020	2020/ 2021
A- Water deficit treatments:						
Irrigation deficit	4.21	4.73	328.6	356.4	12.33	13.29
Full irrigation	4.58	5.28	396.8	433.6	14.36	15.07
F. test	*	*	*	*	*	*
B- Organic fertilization treatments:						
Without	4.05	4.58	307.8	327.6	12.10	12.92
Vermicompost	4.73	5.43	417.7	462.3	14.59	15.44
F. test	*	*	*	*	*	*
C- Soil addition treatments:						
Without	3.83	4.42	265.1	274.9	11.23	12.01
Humic acid	4.79	5.47	424.6	474.9	14.73	15.70
EM	4.56	5.12	398.5	435.0	14.08	14.83
LSD at 5%	0.04	0.03	1.4	1.5	0.06	0.07
D- Interactions:						
A × B	*	*	*	*	*	NS
A × C	*	*	*	*	*	*
B × C	*	*	*	*	*	*
A × B × C	*	*	*	*	*	*

EM = Effective microorganisms, * = Significant, NS = Non-significant.

Table 6. Average number of tuber/plant, average fresh weight of tuber of marketable yield of potato at harvest as affected by the interaction among water deficit, organic fertilization and some soil additions during 2019/2020 and 2020/2021 seasons.

Characters			Average number of tuber/plant		Average fresh weight of tuber of marketable yield (g)		Total tubers yield (t/fed)	
Water deficit	Organic	Soil addition	2019/ 2020	2020/ 2021	2019/ 2020	2020/ 2021	2019/ 2020	2020/ 2021
Irrigation deficit	Without	Without	3.35	4.12	195.5	203.2	9.15	9.98
		Humic acid	4.25	4.63	325.7	348.1	12.42	13.32
		EM	4.08	4.55	294.1	310.9	11.59	12.73
	Vermicompost	Without	3.97	4.47	265.5	275.0	11.28	12.41
		Humic acid	4.88	5.51	457.4	515.5	14.96	15.89
		EM	4.71	5.10	433.3	485.5	14.59	15.41
Full irrigation	Without	Without	3.73	4.37	243.1	234.9	10.85	11.76
		Humic acid	4.54	5.01	404.7	450.9	14.51	15.23
		EM	4.36	4.78	383.5	417.7	14.08	14.49
	Vermicompost	Without	4.27	4.71	356.2	386.6	13.63	13.91
		Humic acid	5.50	6.73	510.5	585.3	17.02	18.35
		EM	5.08	6.06	483.1	526.0	16.08	16.70
	LSD at 5%		0.08	0.07	2.8	3.0	0.14	0.13

EM = Effective microorganisms, * = Significant, NS = Non-significant.

Table 7. Total soluble solids (TSS), dry matter (DM) and total carbohydrates percentages in potato tubers at harvest as affected by water deficit, organic fertilization and some soil additions as well as their interactions during 2019/2020 and 2020/2021 seasons.

Characters	TSS (%)		Dry matter (%)		Total carbohydrates (%)	
Treatments	2019/ 2020	2020/ 2021	2019/ 2020	2020/ 2021	2019/ 2020	2020/ 2021
A- Water deficit treatments:						
Irrigation deficit	6.79	7.00	19.02	19.86	23.78	25.99
Full irrigation	7.09	7.33	20.33	20.94	25.11	27.50
F. test	*	*	*	*	*	*
B- Organic fertilization treatments:						
Without	6.70	6.89	18.65	19.49	23.44	25.46
Vermicompost	7.18	7.45	20.71	21.31	25.45	28.03
F. test	*	*	*	*	*	*
C- Soil addition treatments:						
Without	6.43	6.68	18.00	18.79	22.78	24.51
Humic acid	7.27	7.48	20.78	21.45	25.53	28.20
EM	7.12	7.34	20.25	20.98	25.03	27.53
LSD at 5%	0.09	0.08	0.23	0.27	0.40	0.32
D- Interactions:						
A × B	NS	NS	*	NS	*	NS
A × C	*	NS	*	NS	NS	NS
B × C	NS	*	*	*	*	*
A × B × C	*	*	*	*	NS	*

EM = Effective microorganisms, * = Significant, NS = Non-significant.

Table 8. Total soluble solids (TSS), dry matter (DM) and total carbohydrates percentages in potato tubers at harvest as affected by the interaction among water deficit, organic fertilization and some soil additions during 2019/2020 and 2020/2021 seasons.

Characters			TSS (%)		Dry matter (%)		Total carbohydrates (%)	
Water deficit	Organic	Soil addition	2019/ 2020	2020/ 2021	2019/ 2020	2020/ 2021	2019/ 2020	2020/ 2021
Irrigation deficit	Without	Without	6.10	6.40	17.13	17.86	21.96	23.16
		Humic acid	6.89	6.97	18.86	19.75	23.55	25.79
		EM	6.60	6.80	18.42	19.27	23.13	25.12
	Vermicompost	Without	6.33	6.69	18.02	18.74	22.73	24.57
		Humic acid	7.44	7.64	21.15	22.00	25.97	29.02
		EM	7.37	7.53	20.55	21.56	25.33	28.32
Full irrigation	Without	Without	6.22	6.54	17.45	18.27	22.41	23.92
		Humic acid	7.23	7.39	20.32	21.15	25.04	27.73
		EM	7.16	7.22	19.72	20.67	24.53	27.04
	Vermicompost	Without	7.07	7.11	19.41	20.28	24.01	26.40
		Humic acid	7.54	7.94	22.79	22.88	27.55	30.26
		EM	7.33	7.82	22.34	22.41	27.15	29.64
	LSD at 5%		0.18	0.17	0.46	0.50	NS	0.64

EM = Effective microorganisms, * = Significant, NS = Non-significant.

Table 9. Starch and crude protein percentages and vitamin-c (VC) content in potato tubers at harvest as affected by water deficit, organic fertilization and some soil additions as well as their interactions during 2019/2020 and 2020/2021 seasons.

Characters Treatments	Starch (%)		Crude protein (%)		VC (mg/100 g^{-1} FW)	
	2019/ 2020	2020/ 2021	2019/ 2020	2020/ 2021	2019/ 2020	2020/ 2021
A- Water deficit treatments:						
Irrigation deficit	18.41	19.34	12.28	13.91	19.07	20.72
Full irrigation	19.93	20.49	13.10	14.77	20.12	21.84
F. test	*	*	*	*	*	*
B- Organic fertilization treatments:						
Without	17.97	18.89	12.03	13.61	18.77	20.37
Vermicompost	20.37	20.94	13.35	15.07	20.41	22.19
F. test	*	*	*	*	*	*
C- Soil addition treatments:						
Without	17.49	18.12	11.65	13.11	18.23	19.68
Humic acid	20.57	21.05	13.37	15.13	20.41	22.31
EM	19.45	20.57	13.05	14.78	20.13	21.85
LSD at 5%	0.21	0.17	0.12	0.10	0.30	0.28
D- Interactions:						
A × B	*	*	*	NS	NS	NS
A × C	*	*	*	NS	NS	NS
B × C	*	*	*	*	*	*
A × B × C	*	*	*	*	NS	*

EM = Effective microorganisms, * = Significant, NS = Non-significant.

Table 10. Starch and crude protein percentages and vitamin-c (VC) content in potato tubers at harvest as affected by the interaction among water deficit, organic fertilization and some soil additions during 2019/2020 and 2020/2021 seasons.

Characters			Starch (%)		Crude protein (%)		VC (mg/100 g^{-1} FW)	
Water deficit	Organic	Soil addition	2019/ 2020	2020/ 2021	2019/ 2020	2020/ 2021	2019/ 2020	2020/ 2021
Irrigation deficit	Without	Without	16.64	17.10	11.10	12.25	17.50	18.68
		Humic acid	18.02	19.17	12.09	13.84	18.84	20.59
		EM	17.68	18.69	11.90	13.38	18.68	20.13
	Vermicompost	Without	17.44	18.14	11.65	13.15	18.17	19.63
		Humic acid	20.83	21.67	13.65	15.56	20.75	22.90
		EM	19.84	21.26	13.30	15.33	20.45	22.39
Full irrigation	Without	Without	17.05	17.53	11.40	12.82	17.97	19.29
		Humic acid	19.42	20.69	13.05	14.89	19.94	21.95
		EM	19.02	20.16	12.63	14.53	19.68	21.57
	Vermicompost	Without	18.84	19.71	12.46	14.24	19.27	21.12
		Humic acid	24.01	22.69	14.68	16.25	22.12	23.81
		EM	21.25	22.20	14.39	15.91	21.73	23.33
LSD at 5%			0.41	0.35	0.24	0.20	NS	0.57

EM = Effective microorganisms, * = Significant, NS = Non-significant.

Table 11. Proline, nitrate (NO_3-N) and nitrite (NO_2-N) contents in potato tubers at harvest as affected by water deficit, organic fertilization and some soil additions as well as their interactions during 2019/2020 and 2020/2021 seasons.

Characters Treatments	Proline (µmoles g^{-1} FW)		NO_3-N (ppm)		NO_2-N (ppm)	
	2019/ 2020	2020/ 2021	2019/ 2020	2020/ 2021	2019/ 2020	2020/ 2021
A- Water deficit treatments:						
Irrigation deficit	5.85	6.61	34.81	37.77	1.17	1.23
Full irrigation	4.80	5.94	37.87	40.50	1.34	1.40
F. test	*	*	*	*	*	*
B- Organic fertilization treatments:						
Without	5.58	6.42	39.14	41.89	1.41	1.50
Vermicompost	5.07	6.14	33.55	36.38	1.10	1.13
F. test	*	*	*	*	*	*
C- Soil addition treatments:						
Without	5.50	6.37	37.49	40.01	1.32	1.37
Humic acid	5.33	6.27	36.07	39.12	1.25	1.32
EM	5.15	6.19	35.46	38.28	1.18	1.26
LSD at 5%	0.04	0.07	0.50	0.46	0.03	0.03
D- Interactions:						
A × B	*	NS	NS	*	*	NS
A × C	*	*	NS	NS	NS	NS
B × C	NS	NS	NS	*	NS	NS
A × B × C	*	NS	NS	NS	NS	NS

EM = Effective microorganisms, * = Significant, NS = Non-significant.

Table 12. Proline, nitrate (NO_3-N) and nitrite (NO_2-N) contents in potato tubers at harvest as affected by the interaction among water deficit, organic fertilization and some soil additions during 2019/2020 and 2020/2021 seasons.

Characters			Proline (µmoles g^{-1} FW)		NO_3-N (ppm)		NO_2-N (ppm)	
Water deficit	Organic	Soil addition	2019/ 2020	2020/ 2021	2019/ 2020	2020/ 2021	2019/ 2020	2020/ 2021
Irrigation deficit	Without	Without	6.35	6.90	38.80	41.56	1.40	1.47
		Humic acid	6.10	6.78	37.80	40.75	1.34	1.43
		EM	6.08	6.69	37.27	40.09	1.26	1.37
	Vermicompost	Without	5.83	6.56	32.99	35.69	1.10	1.11
		Humic acid	5.51	6.41	31.10	34.69	0.99	1.04
		EM	5.25	6.32	30.90	33.84	0.92	0.94
Full irrigation	Without	Without	5.15	6.12	41.38	43.71	1.55	1.62
		Humic acid	5.03	6.05	40.05	42.97	1.47	1.59
		EM	4.77	5.97	39.53	42.30	1.42	1.53
	Vermicompost	Without	4.67	5.92	36.80	39.09	1.24	1.27
		Humic acid	4.66	5.84	35.33	38.06	1.20	1.22
		EM	4.49	5.77	34.16	36.91	1.14	1.19
	LSD at 5%		0.08	NS	NS	NS	NS	NS

EM = Effective microorganisms, * = Significant, NS = Non-significant.

Table 13. Reducing, non-reducing and total sugars percentages in potato tubers at harvest as affected by water deficit, organic fertilization and some soil additions as well as their interactions during 2019/2020 and 2020/2021 seasons.

Characters	Reducing sugars (%)		Non-Reducing sugars (%)		Total sugars (%)	
Treatments	2019/ 2020	2020/ 2021	2019/ 2020	2020/ 2021	2019/ 2020	2020/ 2021
A- Water deficit treatments:						
Irrigation deficit	2.43	2.92	4.03	4.10	6.46	7.02
Full irrigation	2.62	3.12	4.18	4.28	6.80	7.40
F. test	*	*	*	*	*	*
B- Organic fertilization treatments:						
Without	2.37	2.83	3.98	4.04	6.36	6.87
Vermicompost	2.68	3.20	4.22	4.34	6.91	7.55
F. test	*	*	*	*	*	*
C- Soil addition treatments:						
Without	2.29	2.70	3.88	3.92	6.18	6.63
Humic acid	2.68	3.22	4.23	4.36	6.92	7.59
EM	2.61	3.13	4.19	4.28	6.80	7.42
LSD at 5%	0.06	0.04	0.08	0.07	0.08	0.06
D- Interactions:						
A × B	*	NS	NS	NS	*	NS
A × C	NS	NS	NS	NS	NS	NS
B × C	*	*	NS	NS	*	*
A × B × C	NS	*	NS	NS	NS	*

EM = Effective microorganisms, * = Significant, NS = Non-significant.

Table 14. Reducing, non-reducing and total sugars percentages in potato tubers at harvest as affected by the interaction among water deficit, organic fertilization and some soil additions during 2019/2020 and 2020/2021 seasons.

Characters			Reducing sugars (%)		Non-Reducing sugars (%)		Total sugars (%)	
Water deficit	Organic	Soil addition	2019/ 2020	2020/ 2021	2019/ 2020	2020/ 2021	2019/ 2020	2020/ 2021
Irrigation deficit	Without	Without	2.20	2.50	3.77	3.73	5.97	6.23
		Humic acid	2.44	2.88	3.99	4.10	6.44	6.98
		EM	2.36	2.81	3.97	4.01	6.33	6.82
	Vermicompost	Without	2.22	2.72	3.91	3.91	6.14	6.63
		Humic acid	2.69	3.35	4.30	4.46	6.99	7.81
		EM	2.68	3.25	4.23	4.40	6.91	7.66
Full irrigation	Without	Without	2.21	2.60	3.84	3.86	6.05	6.47
		Humic acid	2.53	3.16	4.18	4.31	6.72	7.47
		EM	2.49	3.07	4.14	4.21	6.64	7.28
	Vermicompost	Without	2.52	2.99	4.02	4.19	6.55	7.18
		Humic acid	3.06	3.51	4.47	4.59	7.53	8.10
		EM	2.91	3.41	4.42	4.52	7.34	7.94
	LSD at 5%		NS	0.08	NS	NS	NS	0.10

EM = Effective microorganisms, * = Significant, NS = Non-significant.

CONCLUSION

In light of the obtained results and their discussion, it became clear the extent of response of potato plants Spunta cultivar to the organic fertilizer treatments vermicompost and the soil addition of HA and EM under the conditions of full irrigation and irrigation deficit, as well as the vital role of these materials in resisting water deficit and improve soil fertility, productivity and economic return in addition to improving consumer health and environmental preservation by reducing pollution.

This study recommends the use of interaction treatment among irrigation deficit plus vermicompost and HA addition, although it ranks third in terms of productivity, it provides half the number of irrigation times, which is enough to cultivate a similar area, in addition, its yield was satisfactory compared to the two treatments in the first and second rank and acceptable for the Egyptian markets.

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تأثير العجز المائي والتسميد العضوي وبعض الاضافات الارضية على انتاجية البطاطس

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الملخص

أجريت تجربتان حقليتان في تربة طينية سلتية بمزرعة خاصة بالعريض - مركز بلقاس - محافظة الدقهلية - جمهورية مصر العربية خلال الموسمين المتتاليين ٢٠٢٠/٢٠١٩ و ٢٠٢١/٢٠٢٠ لدراسة تأثير العجز المائي - السماد العضوي فيرميكمبوست - بعض الاضافات الارضية (بدون - حمض الهيومك - EM) وكذلك تفاعلاتها على النمو , المحصول ومكوناته ، صفات الجودة للبطاطس صنف اسبونتا. أوضحت البيانات أن معاملات عجز الماء لها تأثير معنوي على النمو الخضري ، المحصول ومكوناته ، صفات الجودة في كلا الموسمين. تم تسجيل أقصى متوسطات لهذه الصفات نتيجة لري نباتات البطاطس بانتظام في كلا الموسمين ، باستثناء محتوى البرولين في درنات البطاطس ، والذي نتج تحت تأثير نقص الري في كلا الموسمين. بينما أدت إضافة الفيرميكمبوست إلى زيادة معنوية في جميع الصفات المدروسة فيما عدا محتوى البرولين والنترات والنتريت في درنات البطاطس في كلا الموسمين. أما بالنسبة لتأثير إضافات التربة (بدون - حمض الهيومك - EM) ، فان نفس البيانات زادت معنويا مع حمض الهيومك مقارنة بالمعاملات الأخرى ، باستثناء محتويات البرولين والنترات والنتريت في الدرنات والتي سجلت لها أدنى القيم مع الإضافة EM في كلا الموسمين. أما بالنسبة للتفاعل بين الري الكامل بالإضافة إلى الفيرميكمبوست ومعاملة اضافة التربة حمض الهيومك ، فقد أعطت أفضل القيم لجميع الصفات المدروسة. ومع ذلك ، أعطى التفاعل بين عجز الري بالإضافة إلى الفيرميكمبوست وإضافة حمض الهيومك تفوقًا مقارنة بالنباتات ذات الري الكامل بدون الفيرميكمبوست وبدون معاملات الاضافة الارضية.