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Improving the Growth and Yield of Potato Plants in the Winter Season

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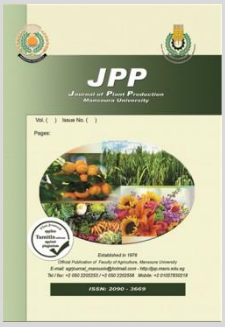

ABSTRACT

Two field experiments were carried out at Kaha, Qalubia Governorate, Egypt, during winter seasons to investigate the response of potato plants (Synergy variety) to compost rice straw (CRS) application with seven foliar spray treatments (Sorbitol, Seaweed extracts and Amino acid). Results indicate that 5 m^3/fed (CRS) gave a superior impact in all vegetative growth characters, chemical constituents and caused an increase in yield and its components compared with the control treatment for both seasons. The highest values of total yield per feddan, marketable yield, yield per plant and average tuber were obtained by spraying plants with the highest level of amino acids (AA-1000) followed by Sorbitol (SrB-50 g/L) compared with other treatments in both seasons. However, application of CRS to soil and spray with a high concentration of amino acid or Sorbitol lead to a significant increment in total yield per feddan, marketable yield, total yield per plant, number of tubers/plant and average tuber weight, as well as large size tubers comparing with other interactions in both season.

***Keywords**: potato, compost, Sorbitol, seaweed, amino acids*

INTRODUCTION

Potato (*Solanum tuberosum* L.) is an important food, its ranks as the fourth food crop after Wheat, Maize and rice. At the same time, potato is the second exported crop from Egypt after citrus. Furthermore, Egyptian potatoes in 2021 globally ranked Fifth in the quantity of fresh potatoes exported (about 678 thousand tons) and ranked tenth in processed potatoes (GAPQR., 2021). Moreover, potato is considered the second vegetable crop in terms of area in Egypt after tomatoes, the cultivated area in 2021 was 501026 feddan produced about 5,811,901 tones, while the winter season (2018/2019) was 299,185fed. (Reports Ministry of Agriculture and Land Reclamation, Egypt, 2021). The winter season represents about 56% of the potato cultivated area in Egypt. In Egypt winter season, potato cultivation faces many factors that affect the growth and yield, *i.e.,* lower local seed grade; hence it is produced from the previous summer season. Also, some abiotic stress as frost and low temperature, as well as biotic stress as late blight.

Inorganic fertilizer consumption is currently heavily reliant on potato crop production. However, because access to this fertilizer is becoming increasingly difficult and expensive, suitable technology that lowers the usage of inorganic fertilizers, such as the use of organic fertilizers, is essential. Rice straw is a readily available raw material for organic fertilizer. Farmers in rice production areas usually burn rice straw after the harvesting period, which results in environmental problems and community health disorders because dense smoke can create respiratory diseases (El Safty, 2020. Compost is an organic matter that plays a vital role in enhancing soil properties, sustainability, and quality that commercial fertilizers cannot do. Compost has two main effects on soil properties, particularly in poor fertile soil; it improves organic matter content and provides essential macro and micronutrients for plant growth. Moreover, the favourable special effects of compost are to increase water holding capacity and available water (Khan *et al.,* 2017 and Gewaily, 2019). Organic fertilizer formulated with rice straw-based compost can substitute inorganic fertilizer in potatoes cultivation and could potentially increase productivity (Salamba *et al.*, 2021).

A biostimulant is any microorganism or substance used to enhance the efficiency of nutrition, tolerance to abiotic stress and/or quality traits of crops, depending on its contents from nutrients. Plant biostimulants like compost Rice, Sorbitol, Seaweed extracts and Amino acid are a strategic trend for managing stressed crops by promoting nutritional and hormonal balance, regulating osmotic protectors, antioxidants, and genetic potential reflecting plant growth and productivity.

Sorbitol belongs to a natural alcohol sugar with the chemical formula $C_6H_{14}O_6$. Generally, Sorbitol is in white, odourless non-cariogenic crystalline powder with a molecular weight of 182.17 g/mol and pH of around 7, and solubility of 2350 g/L. Its use in the food industry is extensive, as sweetener, moisturizer, texture forming and softener. Sorbitol can also be used in diabetic diets since its metabolic route is not insulin-dependent becauseit has minimal energy and cannot be metabolized (Marques *et al.*, 2016). Applying a foliar spray of Sorbitol on the strawberry plant at 25 g/L achieved a significant increase in leave number, leaf area, leave area per plant and the vegetative dry weight compared with control (Moulin and Obaid, 2019). Foliar application of spinach plants with different concentrations of Sorbitol showed significant improvement in total chlorophylls, carotenoids, reducing sugars, non-reducing sugars, carbohydrates, and total proteins in saline and non-saline conditions (Humaira *et al.*, 2017).

Soil conditioners made from seaweed extracts have been utilized as fertilizers and foliar spray for many crops (Norrie and Keathley 2006). The inclusion of trace elements (N, P, Fe, Cu, Zn, Co, Mo, Mn, Ni) and metabolites increased the value of seaweeds and algal extracts. Hormones are also included in the extract. *i.e.,* auxins (IAA and IBA), cytokinins, vitamins, enzymes and amino acids (Khan *et al.*, 2009). Stress resistance has been demonstrated to be improved by using seaweed extracts and improving yield in many other crops, such as Celeriac Plant (Shehata *et al.*, 2011) common bean,

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(Zewail, 2014), spinach (Xu and Leskovar, 2015), also, in this regard, plants sprayed with algae extract enhanced growth characters, *e.g.*, plant height, numbers of leaves, leaves area, fresh and dry weight of shoot, yield and its components on Globe Artichoke (Sayed *et al.*, 2018; Madian *et al.*,2020; Elsharkawy., *et al.*, 2021), on sweet potato (Helaly, 2021), on tomato (Hussain *et al.*, 2021), on potato (Negm *et al.*, 2021).

Amino acids are involved in forming amines, alkaloids, vitamins, enzymes, and protein, among other chemical molecules. Additionally, the commercially available amino acid stimulation can boost fertilizer absorption, nutrient and water uptake, photosynthetic average, and dry matter fractionate promotion, increasing crop output (Shafeek *et al.*, 2016). In regards to the beneficial properties of amino acid foliar spraying, several researchers have reported that amino acids have beneficial impacts on growth and production of garlic (El-Shabasi *et al.*, 2005), potato (Awad *et al.*, 2007), onion (Shafeek *et al.*, 2012; 2018), Furthermore, Abd El-Rheem *et al.* (2020) and Murashev *et al.* (2020) reported that foliar amino acids significantly improved all potato plant growth characters, total yield, and components.

Therefore, the aim of this study is to apply spraying with sorbitol, seaweed extracts and amino acids as foliar nourishment (to study their improved effect) and interaction with compost Rice Straw on growth, yield and nutritional balance of potato plants in winters 2019/2020 and 2020/2021.

MATERIALS AND METHODS

The field experiment was conducted at the Experimental Vegetable Research Farm of Kaha, Qalyubia Governorate, Egypt, during the two seasons of 2019/ 2020 and 2020/2021 in clay loam soil. The site is at an altitude of 21.1 m above sea level, latitude 30°16' N and longitude 31°12' E. with clay loam soil in texture. The chemical and physical properties of the experimental soil are shown in Table 1.

Table 1. The physical and chemical properties of the experimental soil.

Physical Properties (%)	Seasons 2019	Seasons 2020	Chemical (available) (ppm)	Seasons 2019	Seasons 2020
Clay	60.60	61.24	N	78.82	85.24
Silt	18.70	17.98	P	5.20	4.92
Sand	20.70	20.78	K	194.12	189.06
Texture class	Clay loam		pH (1- 2.5 suspension)	7.30	7.44

Table 2. Chemical analysis of composted rice straw (CRS.)

Organic fertilizer	Season	C %	N %	C:N Ratio	P %	K %	Fe (ppm)	Mn (ppm)	Zn (ppm)
Composted	2019	35.50	1.43	24.83	0.62	0.80	558.40	266.52	43.36
rice straw (CRS.)	2020	36.50	1.45	25.17	0.60	0.81	568.65	278.42	46.07

Table 3. Spirulina platensi seaweed extract analysis (Koru *et al.*, 2008).

Parameters	Values	Parameters	Values
(per100g)		(per100g) Colorants	
Moisture	3.50 g	Phycocyanin	15.6 g
Protein	63.50 g	Carotenoids	456.00 mg.
Fat (Lipids)	9.50 g	Chlorophyll a	1.30 g.
Fibre	3.00 g	Vitamins	(mg)
Ash	6.70 g	Provitamin A	213
N free extract	15.00 g	Thiamin (V.B1)	1.92
Minerals		Riboflavin (V. B2)	3.44
Phosphorus	916.00 mg.	Vitamin-B6	0.49
Iron	53.60 mg.	Vitamin-B12	0.12
Calcium	168.00 mg.	Vitamin-E	10.4
Potassium	1.83 g.	Niacin	11.3
Sodium	1.09 g.	Folic acid	40.00
Magnesium	250 mg.	Pantothenic acid	0.94
		Inositol	76.00

Representative soil samples were collected from the experimental location and chemically analyzed according to the standard protocols outlined by Cottenie *et al.* (1982). This study investigates the response of potato plants (Synergy variety) to compost rice straw (CRS) application and plants spraying with Sorbitol, Seaweed extracts and Amino acid at 45 and 60 days after planting in the winter season. The planting date was 1st November in both seasons. The NPK fertilizers at the rate of 150 kg N/ fed., 70 kg P_2O_5/fed and 48 kg K_2O/fed were applied to all treatments where calcium superphosphate (15.5% P_2O_5) was added during soil preparation; nNitrogen quantity was divided into three equal doses, the first dose (Ammonium sulfate 20.5 % N) was applied during soil preparation, the second and third doses were ammonium nitrate (33.5 % N) applied after 30 and 60 days after planting and before irrigation. Potassium as potassium sulphate (48-52 % K_2O) was used at 96 kg K_2O /fed. at two times, *i.e.,* 50 % of the total potassium was applied before planting (during soil preparation), whereas the rest of the potassium was added at complete planting emergence (45 days from planting). All other agricultural applications were accomplished as recommended for potato cultivation. A split-plot in a randomized complete block design with three replications was used. The area of each sub-plot was 18.75 m^2, as five rows, 0.75 m wide and 5 m long, while potato tuber seeds were planted at 0.25 m spacing.

The main plots were allocated for two soil addition, whereas the seven foliar spray treatments were arranged in the sub-plots to obtain 14 treatments as follows:

Main-plot (Soil application):

a): Control (without compost)

b): Compost rice straw (CRS) (5 ton/fed.).

Sub-plot (Foliar spray at 45 and 60 days after planting):

- Control (Spray with distilled water, DW.)
- Sorbitol 25 g/L (SrB-25)
- Sorbitol 50 g/L (SrB-50)
- Seaweed extracts 2 ml/L (SW-2)
- Seaweed extracts 4 ml/L (SW-4)
- Amino acids 500 mg/L (AA-500)
- Amino acids 1000 mg/L (AA-1000)

Tables 2 and 3 show the chemical and biological features of compost rice straw (CRS) and Spirulina platensis (Seaweed extract) studies (Koru *et al.*, 2008).

Algae extract (AE): The blue alga *Spirulina platensis* was produced at Algal Biotechnology Unit, National Research Centre (Table 3). Amino acids (AA): applied as a foliar spray at (500 and 1000 mg/l). The commercial product "Amino total" was used as a source of amino acids. In the amino total, 17 different amino acids are present viz., Glutamic acids (7.2-9.2%), Threonine (3.1-3.6 %), Aspartic acids (3.2-3.45%), Serine (3.76-4.49%), proline (2.2-3.5%), Glycine (1.9-2.5%), Alanine (2.0-2.2), Cysteine (1.9-2.5%), Valine (2.8-3.1%), Methionine (0.3-0.3%), Isoleucine (1.26-1.7%), Leucine (2.0-2.8%) Tyrosine (0.5-1.0%), Phenylalanine (1.3-1.8%), Lysine (1.4-2.3%), Histidine(0.4-0.9%.) and Arginine (5.2-6.2%).

Data recorded:

Vegetative Growth Characters

Random samples of six plants from each experimental unit were taken 75 days after planting. The following measurements were recorded: Stem length (SL, cm), main stem number (NS), leaves number per plant (NL), tubers number per plant (NT), leave area/ plant (LA, cm^2), leaf area index (LAI). Also, total plant fresh weight (TFW, g) and total plant dry weight (TDW, g) were determined after oven-drying the samples at 70 ˚C for 48 hours.

Quality and Chemical Constituents

Leaf chlorophyll (Tch) reading (SPAD), tuber dry matter content (DM, %) were obtained by drying the tuber slices at 70 ºC for 72 hours (Dogras *et al.*, 1991), each starch content (SC, %), total sugars (TSG, %) and total soluble solids (TSS, %) using the method of AOAC (1990) were determined. The Rosein (1957) method was used to determine total free amino acid (TFA). However, to determine the specific gravity (SG, g/cm^3) of potato tubers, tubers were cleaned and weighed in both air and water using the (Rastovski et al. (1987) technique and SG was calculated using the formula: Specific gravity = (weight in air) / [(weight in air) - (weight in water)]

Yield and its components

At harvesting time (120 days after planting), yield characteristics, *i.e.*, number of produced tubers/ plant (NT), tuber weight (ATW, g), tuber yield (g/plant) and total yield (ton/fed.) as well as marketable yield (MY) and weight of three size class's, *i.e.*, small tubers (TSz < 35 mm), medium tubers (35 < TSz < 55 mm) and large tubers (TSz > 55 mm) were recorded.

Statistix 11 statistical software was used to analyze variance in the collected data. Means were separated by LSD testing at a 5% level.

RESULTS AND DISCUSSION

Results

Vegetative growth characters

The effects of composted rice straw (CRS) and some Biostimulants (Sorbitol, Seaweed extracts and Amino acids) on growth characteristics of potato plants shown in Tables 4 and Fig.1. of the CRS treatment (5 m^3/fed.), resulting in a superior effect on all vegetative characters, *i.e.,* stem length, stems number, leaves number and tubers number per plant (Fig.1) as well as, total plant fresh weight (TFW, g), total plant dry weight (TDW, g), leave area (LA) and leaf area index (LAI) compared to control in an average of both seasons (Fig.1) and both 2019 and 2020 seasons (Table 4).

Table 4. Effect of Compost Rice Straw (Mean of both seasons) on vegetative, quality and yield traits of potatoes at 2019/2020 and 2020/2021seasons.

Trait*	2019 CRS	2019 Control	2019 LSD 0.05	2020 CRS	2020 Control	2020 LSD 0.05
SL (cm)	48.52	45.62	1.64	51.90	49.38	ns
NS	4.19	3.57	0.41	4.29	3.86	0.35
NL	62.71	55.52	3.59	65.38	58.81	1.88
NT	9.00	7.71	0.26	9.62	8.19	0.20
TFW (g)	487.3	472.2	8.54	505.1	495.78	ns
TDW (g)	64.15	60.67	3.04	67.40	64.37	1.48
LA (cm^2)	5846.6	5416.1	128.2	6156.3	5767.5	201.3
LAI	3.12	2.89	0.07	3.28	3.08	0.11
Total yield (ton/fed)	16.193	15.302	0.379	17.18	15.68	0.553
TSz > 55	8.76	8.13	0.26	9.41	8.38	0.31
35< TSz < 55	5.22	4.93	0.14	5.58	5.10	0.18
TSz < 35	2.11	2.18	ns	2.26	2.25	ns
Yield (g/plant)	777.6	714.3	19.1	810	754.9	24.6
N. tubers per plant	7.24	6.76	ns	7.29	7.00	ns
ATW	107.63	106.06	ns	111.41	108.29	ns
MY	13.979	13.119	0.515	14.98	13.43	0.374
DM %	19.93	19.43	0.04	19.98	19.57	0.01
SC %	13.76	13.31	0.04	13.81	13.44	0.01
SG (g/cm^3)	1.08	1.08	0.00	1.08	1.08	0.00
TSg %	0.46	0.42	0.01	0.46	0.42	0.01
TSS %	18.61	18.57	0.00	18.62	18.58	0.00
Tch (Spad)	41.76	40.33	0.54	41.28	40.01	0.62
TFA	23.23	22.65	0.04	23.29	22.81	0.01

- **SL: Stem length; NS : Number of stems; NL: Number of leaves; NT: Number of tubers; TFW: Total fresh; TDW: Total dry weight; LA: Leaf area; LAI: Leaf area index; TSz: Tuber size; ATW: Average tuber weight; MY: Marketable yield; DM: Dry matter; SC: Starch content; SG: Specific gravity; TSg: Total sugars; TSS: Total soluble solids; Tch: Total chlorophyll and TFA: Total free amino acid.**

Illustrated data in the exact figure 1 and Table 5 indicated that the application of Sorbitol, seaweed extract and amino acids achieved improvement in vegetative growth characteristics compared to control. The results showed that significantly highest values were obtained by 1000 mg/L amino acids (AA) foliar spray in all studied traits in both seasons except stem numbers (Table 4) compared with other treatments.

Regarding the effect of interactions, Table 6 and Fig. 2 shows that adding the CRS to soil with any spray treatments by Sorbitol, seaweed extract, or amino acids gave statistically equivalent or increased values in all vegetative growth traits compared to the corresponding common agricultural practice treatments in both winter season 2019/2020 and 2020/2021.

Table 5. Effect of bio-stimulants treatments on stem length (SL) and number of stems (NS), leaves (NL)and tubers (NL) at 75 days after planting of both 2019 and 2020 seasons.

Trait *	SL (cm)	NS	NL	NT	TFW (g)	TDW (g)	LA (cm^2)	LAI
				2019				
DW	38.00	3.33	37.00	5.83	332.00	27.85	2936.39	1.57
SrB 25g/L	42.67	3.50	59.33	7.33	454.88	38.70	5010.76	2.67
SrB 50 g/L	49.50	4.33	62.67	8.50	519.78	85.93	6342.04	3.38
SW 2ml/L	44.33	4.17	54.83	7.33	456.80	48.47	5449.30	2.91
SW 4ml/L	50.00	4.17	64.83	9.33	515.32	81.81	6623.56	3.53
AA 500 mg/L	46.50	3.67	64.17	9.50	498.10	62.58	5447.95	2.91
AA 1000 mg/L	58.50	4.00	71.00	10.67	581.47	91.54	7609.43	4.06
LSD 0.05	2.79	0.41	3.30	0.47	12.97	4.10	235.83	0.13
				2020				
DW	39.33	3.50	41.00	6.83	354.38	32.88	3284.75	1.75
SrB 25g/L	44.50	3.83	62.00	7.50	468.67	44.22	5293.40	2.82
SrB 50 g/L	53.50	4.50	67.00	9.00	546.58	90.64	7026.54	3.75
SW 2ml/L	46.00	4.17	57.00	7.83	465.21	49.58	5613.62	2.99
SW 4ml/L	55.33	4.33	67.67	9.83	540.32	84.25	6985.07	3.73
AA 500 mg/L	51.83	4.00	67.00	10.00	514.92	63.47	5559.91	2.97
AA 1000 mg/L	64.00	4.17	73.00	11.33	613.00	96.24	7970.11	4.25
LSD 0.05	1.87	0.42	2.91	0.55	23.11	3.41	834.43	0.45

- **SL: Stem length; NS: Number of stems; NL: Number of leaves; NT: Number of tubers; TFW: Total fresh; TDW: Dry weight; LA: Leaf area and LAI: Leaf area index.**
- **DW: Control (Spray with distilled water); SrB25: Sorbitol 25g/L; SrB50: Sorbitol 50g/L; SW2: Seaweed extracts 2ml/L; SW4: Seaweed extracts 4ml/L; AA500: Amino acids 500 mg/L and AA1000: Amino acids 1000 mg/L.**

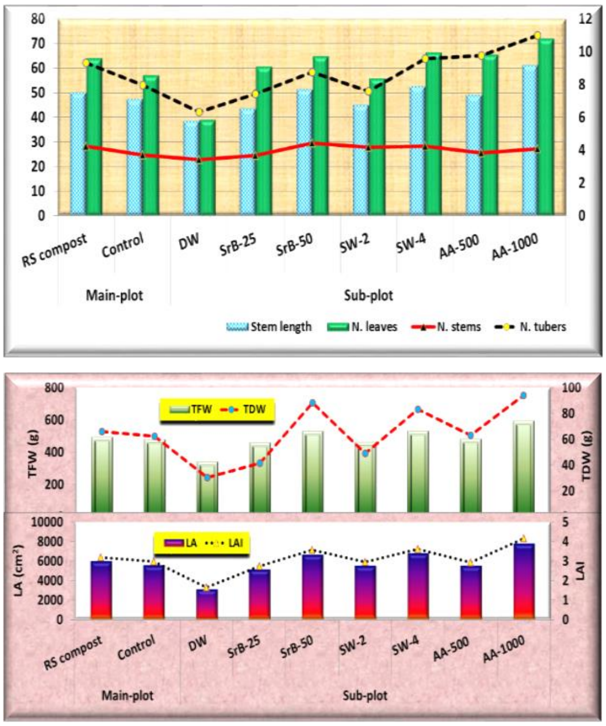

Fig. 1. Effect of Compost Rice Straw and some Biostimulants (Mean of both seasons) on stem length and number of stems, leaves and tubers (Upper) as well as total fresh (TFW) and dry weight (TDW), leaf area (LA) and leaf area index (LAI) (Down) at 75 after planting.

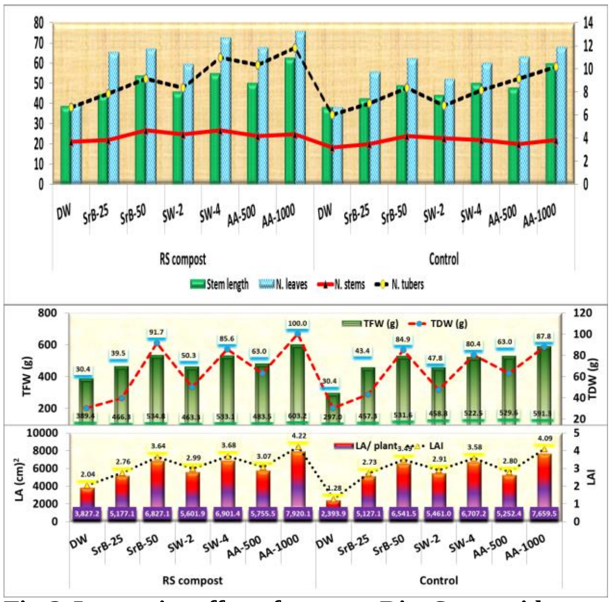

Fig. 2. Interaction effect of compost Rice Straw with some Bio-stimulants (Mean of both seasons) on stem length and number of stems, leaves and tubers (Upper) as well as total fresh (TFW) and dry weight (TDW), leaf area (LA) and leaf area index (LAI)(Down) at 75 after planting.

- **SL: Stem length; NS: number of stems; NL: number of leaves; NT: number of tubers; TFW: total fresh; TDW: dry weight; LA: leaf area and LAI: leaf area index.**
- **DW: Control (Spray with distilled water); SrB25: Sorbitol 25g/L; SrB50: Sorbitol 50g/L; SW2: Seaweed extracts 2ml/L SW4: Seaweed extracts 4ml/L; AA500: Amino acids 500 mg/L and AA1000: Amino acids 1000 mg/L.**

Table 6. Interaction effect of compost Rice Straw and some Bio-stimulants on vegetative traits at 75 days after planting.

		SL (cm)	NS	NL	NT	TFW (g)	TDW (g)	LA (cm^2)	LAI
Main	**Sub**	**2019**							
CRS	DW	38.67	3.67	37.67	6.33	382.00	27.85	3786.39	2.02
	SrB 25g/L	43.33	3.67	64.33	7.67	461.55	36.52	5010.76	2.67
	SrB 50 g/L	52.33	4.67	66.00	9.00	521.45	89.34	6477.58	3.45
	SW 2ml/L	45.33	4.33	59.00	8.00	459.00	49.64	5515.96	2.94
	SW 4ml/L	52.33	4.67	71.67	10.67	518.94	85.31	6717.71	3.58
	AA 500 mg/L	47.67	4.00	66.33	10.00	480.00	62.58	5681.28	3.03
	AA 1000 mg/L	60.00	4.33	74.00	11.33	588.31	97.79	7736.67	4.13
Control	DW	37.33	3.00	36.33	5.33	282.00	27.85	2086.39	1.11
	SrB 25g/L	42.00	3.33	54.33	7.00	448.21	40.88	5010.76	2.67
	SrB 50 g/L	46.67	4.00	59.33	8.00	518.12	82.51	6206.51	3.31
	SW 2ml/L	43.33	4.00	50.67	6.67	454.60	47.30	5382.63	2.87
	SW 4ml/L	47.67	3.67	58.00	8.00	511.70	78.31	6529.40	3.48
	AA 500 mg/L	45.33	3.33	62.00	9.00	516.20	62.58	5214.62	2.78
	AA 1000 mg/L	57.00	3.67	68.00	10.00	574.64	85.29	7482.20	3.99
LSD 0.05		3.94	0.58	4.67	0.66	18.34	5.79	333.51	0.18
Main	Sub	2020							
CRS	DW	39.33	3.67	42.00	7.00	396.71	32.88	3868.08	2.06
	SrB 25g/L	45.67	4.00	66.67	8.00	471.00	42.55	5343.40	2.85
	SrB 50 g/L	55.33	4.67	68.67	9.33	548.15	93.97	7176.54	3.83
	SW 2ml/L	46.67	4.33	60.00	8.67	467.51	50.91	5687.83	3.03
	SW 4ml/L	58.00	4.67	73.33	11.33	547.33	85.93	7085.07	3.78
	AA 500 mg/L	53.00	4.33	69.33	10.67	486.94	63.47	5829.63	3.11
	AA 1000 mg/L	65.33	4.33	77.67	12.33	618.00	102.24	8103.44	4.32
Control	DW	39.33	3.33	40.00	6.67	312.04	32.88	2701.42	1.44
	SrB 25g/L	43.33	3.67	57.33	7.00	466.33	45.90	5243.40	2.80
	SrB 50 g/L	51.67	4.33	65.33	8.67	545.00	87.30	6876.54	3.67
	SW 2ml/L	45.33	4.00	54.00	7.00	462.90	48.24	5539.40	2.95
	SW 4ml/L	52.67	4.00	62.00	8.33	533.30	82.58	6885.07	3.67
	AA 500 mg/L	50.67	3.67	64.67	9.33	542.90	63.47	5290.19	2.82
	AA 1000 mg/L	62.67	4.00	68.33	10.33	608.00	90.24	7836.77	4.18
LSD 0.05		2.64	0.59	4.11	0.78	32.69	4.83	1180.10	0.63

- **SL: Stem length; NS: number of stems; NL: number of leaves; NT: number of tubers; TFW: total fresh; TDW: dry weight; LA: leaf area and LAI: leaf area index.**
- **DW: Control (Spray with distilled water); SrB25: Sorbitol 25g/L; SrB50: Sorbitol 50g/L; SW2: Seaweed extracts 2ml/L SW4: Seaweed extracts 4ml/L; AA500: Amino acids 500 mg/L and AA1000: Amino acids 1000 mg/L.**

Quality and Chemical Constituents

Data presented in Fig. 3 and Table 4 show that the addition of CRS to soil achieved a significant increase in chemical constituents (Total chlorophyll in potato leaves as well as, Dry mater, starch content, specific gravity, total sugars, TSS and total free amino acid in potato tubers) in the average of both seasons.

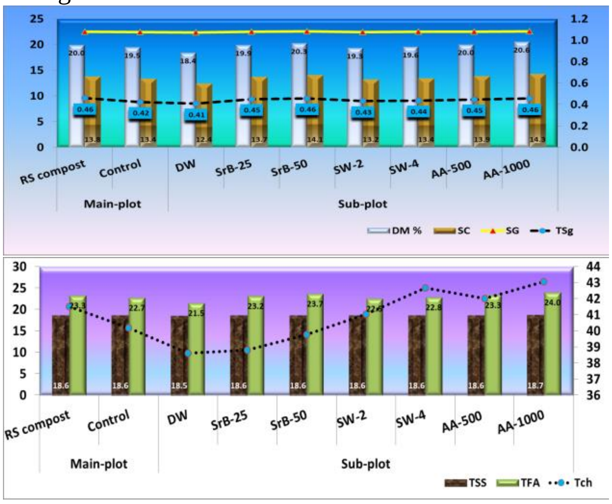

Fig. 3. Effect of Compost Rice Straw and some Biostimulants (Mean of both seasons) on Dry mater (DM), starch content (SC), specific gravity (SG) and total sugars (TSg) (Upper); TSS%, Total free amino acid (TFA) and total chlorophyll (Tch) (Down)

- **DW: Control (Spray with distilled water); SrB25: Sorbitol 25g/L; SrB50: Sorbitol 50g/L; SW2: Seaweed extracts 2ml/L SW4: Seaweed extracts 4ml/L; AA500: Amino acids 500 mg/L and AA1000: Amino acids 1000 mg/L.**

Regarding the effects of sorbitol, seaweed and amino acids on quality and chemical constituents in leaves and tubers results in an average of both seasons (Fig. 3) and individually seasons of 2019/2020 and 2020/2021 (Table 7) show that spraying plants with amino acids, sorbitol and seaweed at both investigated levels had a significant effect on chemical constituents and quality compared to control treatment) in winter seasons 2019/2020 and 2020/2021. While there was an increment in all qualities traits when spraying plants with an amino acid with clear superiority to the higher level (AA-1000) followed by AA-500, SrB-50 and SW-4 (with no significant differences) in total soluble solids (TSS), total sugars (TSG) and total chlorophyll content in leaves, respectively in both seasons.

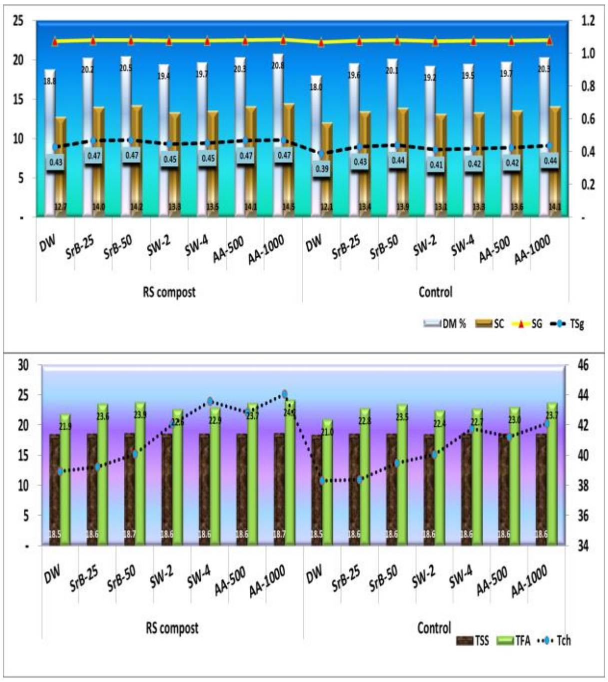

Fig. 4. Interaction effect of compost rice straw and some bio-stimulants on tuber qualities traits after curing.

- **DW: Control (Spray with distilled water); SrB25: Sorbitol 25g/L; SrB50: Sorbitol 50g/L; SW2: Seaweed extracts 2ml/L; SW4: Seaweed extracts 4ml/L; AA500: Amino acids 500 mg/L and AA1000: Amino acids 1000 mg/L.**

Table 7. Effect of bio-stimulants on tuber qualities as well as yield and related traits

	Tuber quality traits							Yield and related traits							
	DM %	SC %	SG (g/cm^3)	TSg %	TSS %	Tch (Spad)	TFA	ATW g	TSz>55 (t/f)	35<TSz<55 (t/f)	TSz< 35 (t/f)	NT	Y/ plant	TY (t/f)	MY (t/f)
2019															
DW	18.34	12.35	1.07	0.40	18.48	38.30	21.38	99.48	5.16	5.16	2.58	6.17	612.8	13.12	10.32
SrB 25	19.89	13.73	1.08	0.45	18.61	38.67	23.19	102.65	7.47	4.80	2.43	6.83	698.46	14.76	12.44
SrB 50	20.22	14.02	1.08	0.45	18.64	39.86	23.58	116.14	9.72	7.00	0.73	7.17	831.24	17.24	16.72
SW 2	19.27	13.17	1.08	0.43	18.56	41.64	22.46	97.76	7.58	4.39	2.44	7.17	695.26	14.56	12.01
SW 4	19.55	13.42	1.08	0.44	18.58	43.23	22.79	108.76	9.01	4.14	3.62	7.33	795.95	16.93	13.14
AA 500	19.95	13.78	1.08	0.44	18.61	41.98	23.25	103.74	8.56	4.67	2.33	7.17	738.61	15.68	13.22
AA 1000	20.52	14.29	1.08	0.45	18.66	43.64	23.92	119.37	11.62	5.37	0.89	7.17	849.43	17.94	16.99
LSD 0.05	0.06	0.05	0.0002	0.005	0.005	0.75	0.07	7.82	0.16	0.10	0.17	0.39	13.77	0.29	0.20
2020															
DW	18.47	12.46	1.07	0.41	18.49	38.91	21.54	102.3	5.59	5.59	2.80	6.50	662.53	13.76	11.18
SrB 25	19.92	13.75	1.08	0.45	18.61	38.91	23.22	106.87	7.73	5.05	2.52	6.83	724.89	15.24	12.62
SrB 50	20.36	14.15	1.08	0.46	18.65	39.66	23.74	115.12	10.37	7.27	0.78	7.50	861.02	18.43	17.64
SW 2	19.38	13.27	1.08	0.43	18.57	40.41	22.59	100.55	7.76	4.44	2.52	7.17	715.38	14.88	12.16
SW 4	19.58	13.45	1.08	0.44	18.58	42.08	22.82	112.04	9.48	4.42	3.79	7.50	838.34	17.52	13.9
AA 500	20.11	13.92	1.08	0.45	18.63	42.05	23.45	109.34	9.02	4.92	2.46	7.17	777.55	16.28	13.94
AA 1000	20.6	14.36	1.08	0.46	18.67	42.48	24.01	122.73	12.31	5.68	0.95	7.33	897.23	18.88	17.99
LSD 0.05	0.02	0.02	0.0001	0.005	0.002	0.91	0.03	4.28	0.12	0.06	0.13	0.40	7.51	0.22	0.19

- **DM: Dry matter; SC: Starch content; SG: Specific gravity; TSg: Total sugars; TSS: Total soluble solids; Tch: Total chlorophyll and TFA: Total free amino acid; ATW: Average tuber weight; TSz: Tuber size; NT: number of tubers; Y/plant: yield per plant; TY: Tptal yield; MY: Marketable yield;**
- **DW: Control (Spray with distilled water); SrB25: Sorbitol 25g/L; SrB50: Sorbitol 50g/L; SW2: Seaweed extracts 2ml/L; SW4: Seaweed extracts 4ml/L; AA500: Amino acids 500 mg/L and AA1000: Amino acids 1000 mg/L.**

Data of the interaction in Table 8 and Fig. 4 revealed that the best values of dry matter (DM %), starch content (SC %), specific gravity (SG, g/cm3), total sugars (TSG %), TSS (%) and total free amino acid in tubers, as well as, total chlorophyll in leaves, were obtained by the interaction of CRS×AA-1000 treatment, i.e., application 5 ton/fed composted rice straw to the soil interacted with spraying plants by amino acids 1000 mg/L compared with other the interactions in two seasons (with no significant differences between all interacted treatments in case of specific gravity.

Table 8. Interaction effect of compost Rice Straw (CRS) and some bio-stimulants on tuber qualities traits after curing in 2019/2020 and 2020/2021

		DM	SC	SG	TS/L	TSS	Tch	TFA
Main	**Sub**				**2019/2020**			
CRS	DW	18.77	12.73	1.07	0.42	18.52	38.57	21.88
	SrB 25g/L	20.22	14.02	1.08	0.47	18.64	39.17	23.58
	SrB 50 g/L	20.39	14.17	1.08	0.47	18.65	40.19	23.77
	SW 2ml/L	19.40	13.29	1.08	0.45	18.57	42.65	22.62
	SW 4ml/L	19.65	13.51	1.08	0.45	18.59	44.13	22.91
	AA 500 mg/L	20.28	14.08	1.08	0.47	18.64	42.80	23.64
	AA 1000 mg/L	20.77	14.51	1.08	0.47	18.68	44.79	24.21
Control	DW	17.91	11.96	1.07	0.39	18.45	38.03	20.88
	SrB 25g/L	19.56	13.43	1.08	0.43	18.58	38.17	22.80
	SrB 50 g/L	20.06	13.88	1.08	0.44	18.62	39.53	23.38
	SW 2ml/L	19.13	13.05	1.07	0.41	18.55	40.63	22.31
	SW 4ml/L	19.45	13.33	1.08	0.42	18.57	42.33	22.67
	AA 500 mg/L	19.61	13.48	1.08	0.42	18.59	41.16	22.86
	AA 1000 mg/L	20.27	14.06	1.08	0.44	18.64	42.49	23.63
LSD 0.05		0.08	0.08	0.00	0.01	0.01	1.06	0.10
Main	Sub				2020/2021			
CRS	DW	18.80	12.76	1.07	0.43	18.52	39.24	21.92
	SrB 25g/L	20.25	14.05	1.08	0.47	18.64	39.24	23.61
	SrB 50 g/L	20.53	14.29	1.08	0.47	18.66	39.91	23.93
	SW 2ml/L	19.45	13.33	1.08	0.45	18.57	41.42	22.67
	SW 4ml/L	19.68	13.54	1.08	0.45	18.59	42.98	22.94
	AA 500 mg/L	20.36	14.15	1.08	0.47	18.65	42.87	23.74
	AA 1000 mg/L	20.78	14.52	1.08	0.47	18.68	43.30	24.23
Control	DW	18.14	12.17	1.07	0.39	18.47	38.58	21.15
	SrB 25g/L	19.59	13.46	1.08	0.43	18.59	38.58	22.84
	SrB 50 g/L	20.19	14.00	1.08	0.44	18.63	39.41	23.54
	SW 2ml/L	19.31	13.21	1.08	0.42	18.56	39.40	22.52
	SW 4ml/L	19.48	13.36	1.08	0.42	18.58	41.18	22.71
	AA 500 mg/L	19.86	13.70	1.08	0.43	18.61	41.23	23.15
	AA 1000 mg/L	20.41	14.19	1.08	0.44	18.65	41.66	23.80
LSD 0.05		0.03	0.03	0.00	0.01	0.00	1.29	0.04

- **DM: Dry matter; SC: Starch content; SG: Specific gravity; TSg: Total sugars; TSS: Total soluble solids; Tch: Total chlorophyll and TFA: Total free amino acid.**

Yield and related traits:

Regarding the effect of application of compost rice straw (CRS) on yield and its components, the data presented in Table 4 and Fig. 5 indicate that the added compost rice straw caused an increase in yield and its components (total yield per feddan, marketable yield, total yield per plant, number of tubers/plant and average tuber weight as well as, both medium and large tubers' sizes compared with control treatment for both seasons. Also, data presented in Table 7 and Fig.5 clearly showed significant differences in yield and components when spraying plants with amino acids, Sorbitol and seaweed compared to spraying plants with tap water in both winter seasons.

The highest values of total yield per feddan, marketable product, yield per plant and average tuber were obtained by spraying plants with the highest level of amino acids (AA-1000) followed by Sorbitol (SrB-50 g/ L) compared with other treatments in both seasons. As for tubers number per plant, four m/L algal treatments (SW-4) exhibited numerous tubers/plant followed by SrB-50 g/L, SW-2 ml/ L, AA-500 mg/ L and AA-1000 mg/ L in similar effects compared with control.

Results illustrated in Fig. 6 and Table 9 demonstrated that the interaction between added compost rice straw and spraying plants with amino acids, Sorbitol and seaweed recorded a significant effect on yield and its components (total yield per feddan, marketable yield, total yield per plant, number of tubers/plant and average tuber weight as well as, tuber size). However, added CRS to soil and spraying with the high concentration of amino acid or Sorbitol lead to significant increment in total yield per feddan, marketable yield, total yield per plant, number of tubers/plant and average tuber weight as well as tubers large size comparing with other the interactions in two winter seasons.

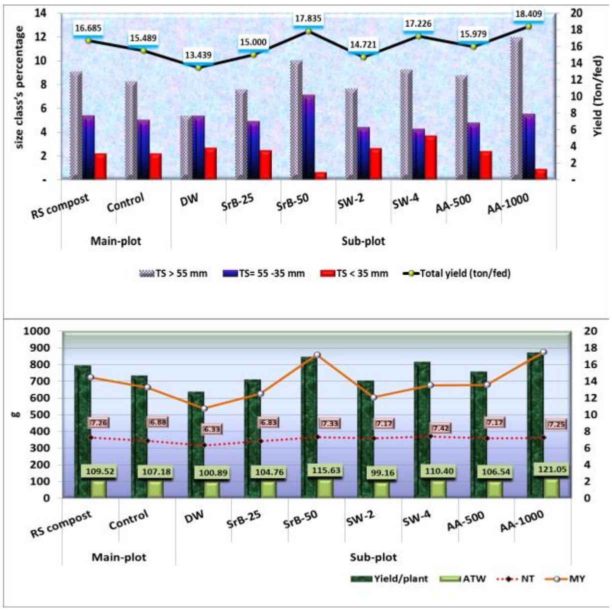

Fig. 5. Effect of Compost Rice Straw and some Biostimulants (Mean of both seasons) on tuber sizes (TS) and total yield/fed (Upper); yield/plant, average tuber weight (ATW), number of tubers/plant (NT) and marketable yield/fed (MY), (Down)

- **DW: Control (Spray with distilled water); SrB25: Sorbitol 25g/L; SrB50: Sorbitol 50g/L; SW2: Seaweed extracts 2ml/L SW4: Seaweed extracts 4ml/L; AA500: Amino acids 500 mg/L and AA1000: Amino acids 1000 mg/L.**

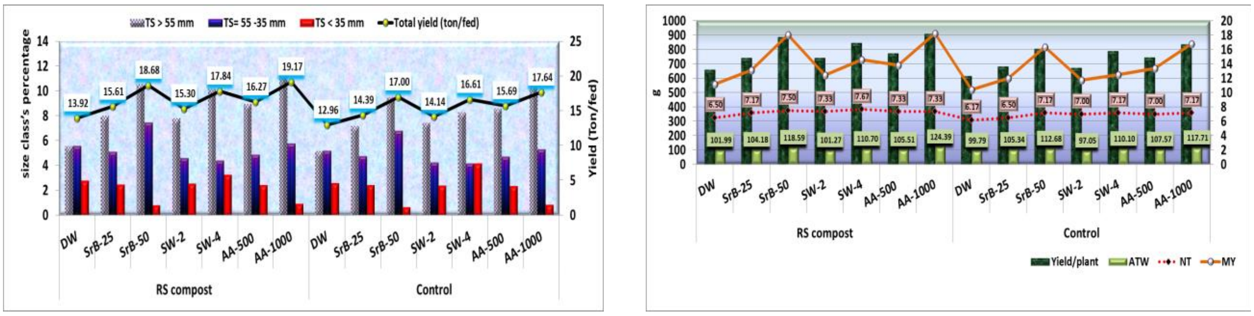

Fig. 6. Interaction Effect between Compost Rice Straw and some Biostimulants (Mean of both seasons) on tuber sizes (TS) and total yield/fed (Upper); yield/plant, average tuber weight (ATW), number of tubers/plant (NT) and marketable yield/fed (MY), (Down)

DW: Control (Spray with distilled water); SrB25: Sorbitol 25g/L; SrB50: Sorbitol 50g/L; SW2: Seaweed extracts 2ml/L SW4: Seaweed extracts 4ml/L; AA500: Amino acids 500 mg/L and AA1000: Amino acids 1000 mg/L.

Table 9. Interaction effect of compost Rice Straw and some bio-stimulants on yield and related traits in 2019/2020 and 2020/2021

Treatments		TSz>55	35<TSz<55	TSz< 35	ATW	NT	Y/plant	TY	MY
Main	**Sub**				2019/2020				
CRS	DW	5.37	5.37	2.68	102.21	6.33	645.08	13.62	10.73
	SrB 25g/L	7.85	4.92	2.45	99.97	7.33	731.62	15.32	12.77
	SrB 50 g/L	9.98	7.25	0.77	119.21	7.33	871.03	17.60	17.22
	SW 2ml/L	7.69	4.56	2.49	99.95	7.33	730.18	15.04	12.25
	SW 4ml/L	9.78	4.16	3.12	107.29	7.67	820.26	17.32	13.94
	AA 500 mg/L	8.65	4.72	2.36	103.21	7.33	755.87	15.89	13.36
	AA 1000 mg/L	12.02	5.55	0.92	121.56	7.33	889.18	18.56	17.57
Control	DW	4.95	4.95	2.48	96.75	6.00	580.52	12.61	9.91
	SrB 25g/L	7.10	4.68	2.41	105.34	6.33	665.29	14.19	12.10
	SrB 50 g/L	9.46	6.75	0.68	113.06	7.00	791.45	16.89	16.21
	SW 2ml/L	7.47	4.23	2.39	95.58	7.00	660.34	14.09	11.78
	SW 4ml/L	8.23	4.12	4.12	110.23	7.00	771.64	16.54	12.35
	AA 500 mg/L	8.46	4.62	2.31	104.27	7.00	721.36	15.48	13.08
	AA 1000 mg/L	11.23	5.18	0.86	117.19	7.00	809.68	17.31	16.41
LSD 0.05		0.22	0.15	0.24	11.06	0.55	19.48	0.41	0.28
Main	**Sub**				2020/2021				
CRS	DW	5.77	5.77	2.89	101.77	6.67	676.28	14.23	11.54
	SrB 25g/L	8.17	5.28	2.55	108.39	7.00	750.29	15.90	13.45
	SrB 50 g/L	11.17	7.69	0.89	117.96	7.67	901.58	19.75	18.86
	SW 2ml/L	8.00	4.63	2.62	102.59	7.33	750.29	15.57	12.63
	SW 4ml/L	10.58	4.65	3.38	114.12	7.67	872.51	18.35	15.23
	AA 500 mg/L	9.25	5.05	2.52	107.82	7.33	788.40	16.65	14.30
	AA 1000 mg/L	12.90	5.95	0.99	127.23	7.33	930.47	19.78	18.86
Control	DW	5.41	5.41	2.71	102.83	6.33	648.78	13.30	10.82
	SrB 25g/L	7.29	4.81	2.48	105.35	6.67	699.49	14.58	11.78
	SrB 50 g/L	9.58	6.84	0.68	112.29	7.33	820.46	17.10	16.42
	SW 2ml/L	7.52	4.26	2.41	98.51	7.00	680.46	14.19	11.69
	SW 4ml/L	8.38	4.19	4.19	109.97	7.33	804.16	16.69	12.58
	AA 500 mg/L	8.79	4.80	2.40	110.86	7.00	766.70	15.90	13.59
	AA 1000 mg/L	11.71	5.40	0.90	118.23	7.33	864.00	17.98	17.12
LSD 0.05		0.17	0.09	0.19	6.05	0.57	25.23	0.31	0.27

- **DW: Control (Spray with distilled water); SrB25: Sorbitol 25g/L; SrB50: Sorbitol 50g/L; SW2: Seaweed extracts 2ml/L SW4: Seaweed extracts 4ml/L; AA500: Amino acids 500 mg/L and AA1000: Amino acids 1000 mg/L.**

Discussion

The experiment showed that both the compost applied to soil and biostimulants (amino acids, Sorbitol and seaweed) improved all growth parameters of potato plants. The positive effect of composted rice straw addition on all vegetative growth traits may be due to compost improving organic matter content and then providing essential macro and micronutrients for plant growth. Moreover, favourable special effects of compost are increased water holding capacity and available plant water (CIWMB, 2004; Curtis and Claassen, 2005; Farrell and Jones, 2009; Tejada *et al*., 2009 and Khan *et al*., 2017). Furthermore, the rice straw provide a good source of potassium (K) and silicate (Si); approximately 80% of K absorbed is stored in its foliage. Potassium requirments for potato plant in high amounts, attributable to their relatively small root system. Generally, in cope with the obtained results of vegetative growth traits, many authors reported that adding compost rice straw to soil increases all vegetative growth traits compared with control (Abbas *et al.*, 2014 on the potato; Khan *et al.*, 2017 on tomato; Gewaily, 2019 on rice and Salamba, 2021 on the potato).

As for the results of bio-stimulants foliar spray, similar results were obtained by Shehata *et al.* (2011), who indicated that either amino acids or seaweed extract increased total sugar content of celeriac plants. Furthermore, amino total (amino acids source) played a vital function in plant metabolism and protein absorption, which is required for cell formation and, as a result, increases fresh and dry matter. However, similar effects and findings of amino acids were reported by El-Zohiri and Asfour

(2009) on potatoes and Abo Sedra *et al.* (2010) on strawberries. It could be concluded that amino acids may directly or indirectly benefit the physiological activities of the plant and its chelating effect on the micronutrients leads to the uptake and transport of micronutrients within the plant easily (Ibrahim *et al*., 2010) as well as amino acids is the basis of the active ingredients in protein synthesis (Shafeek *et al.,* 2012). These results are in harmony with those obtained by El-Shabasi *et al.* (2005) on garlic, Awad *et al.* (2007) on potato, El-Zohiri and Asfour (2009) on potato, Shafeek *et al.* (2012) On onion, Ghaith and Galal (2014) on pea, Shafeek *et al.,* (2016) broad bean and Kahlel and Sultan (2019) on some potato varieties.

CONCLUSION

The current research concluded that increasing potato production in the winter under Egyptian conditions can be achieved by fertilizing with compost of rice straw fertilizer and spraying plants with Amino acids or Sorbitol.

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تحسين نمو وإنتاجية نباتات البطاطس في فصل الشتاء

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أجريت تجربتان حقليتان بمزرعة بحوث الخضر بقها - محافظة القليوبية - مصر، وذلك خلال موسمي الشتاء المتتاليين 2020/2019 و 2021/2020 لدراسة إستجابة نباتات البطاطس (صنف سينرجي Synergy) لإضافة كمبوست قش الأرز كسماد للتربة مع سبع معاملات رش ورقي (السوربيتول 25 ، 50 جرام/اللتر ومستخلص الأعشاب البحرية 2 ، 4 مللي/اللتر والأحماض الأمينية 500، 1000 مليجرام/ اللتر بالإضافة إلى معاملة الكنترول) عند 45 و 60 يوما بعد الزراعة. تم تخصيص قطع الأراضي الرئيسية لإضافة وعدم إضافة قش الأرز في التربة، في حين تم تطبيق معاملات الرش الورقية السبعة في القطع الفرعية للحصول على 14 معاملة. أظهرت النتائج تأثيرا إيجابيا عند إضافة 5 م3 كمبوست/ فدان على جميع صفات النمو الخضري والمكونات الكيميائية. كما أدى أضافة الكمبوست إلى التربة إلى زيادة المحصول ومكوناته مقارنة بمعاملة الكنترول (عدم إضافة الكمبوست) لكلا الموسمين. كما تم الحصول على أعلى قيم للمحصول الكلي للفدان والمحصول التسويقي ومحصول النبات ومتوسط الدرنات مع الرش النباتات بأعلى مستوى من الأحماض الأمينية (1000 مليجرام/اللتر) (يليه السوربيتول50 جم/لتر) مقارنة بالمعاملات الأخرى في كلا الموسمين ، أما بالنسبة لعدد الدرنات لكل نبات فقد أدي رش النباتات ب 4 مللي/لتر من مستخلص الطحالب لأكبر عدد من الدرنات/نبات تليها 50 جم/لتر سوربتول ، 2مللي/لتر مستخلص طحالب. ومع ذلك، فإن إضافة كمبوست قش الأرز على التربة والرش بالتركيز المرتفع من الأحماض الأمينية أو السوربيتول أدى إلى زيادة معنوية في المحصول الكلي للفدان ، والمحصول التسويقي ، والإنتاج الكلي للنبات ، وعدد الدرنات/نبات ومتوسط وزن الدرنات وكذلك مقارنة الدرنات كبيرة الحجم مع التفاعلات الأخرى في الموسمين.