

Spraying with Some Safety Materials to Reduce the Effects of Climate Changes in the Autumn Season and its Impact on Productivity and Heat Use Efficiency in Potatoes

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ABSTRACT

In a private farm in Meet Faris village, Dekarns District, Dakhliya Governorate, Egypt, two field experiments were conducted during two consecutive autumn seasons of 2022/2023 and 2023/2024 to examine the effects of planting dates (15 September, 30 September, and 15 October) and spraying with a natural stimulant substance, i.e., Seaweed extract (SWE) at 2 ml/l, salicylic acid (SA) at 200 ppm, melatonin (Me) at 30 ppm, beside water (control treatment) on growth, productivity, and tuber quality of potato Spunta cultivar under clay soil conditions using a drip irrigation system.

Planting potato spunta cultivar on 15th Oct. during autumn plantation and spraying with seaweed extract at 2 ml/l produced the highest leaf area index, dry weight of shoots, leaf pigments, average tuber weight, number of tubers/plant, yield/plant and total yield/fad., heat use efficiency, N, P and K (%), specific gravity, dry matter and starch contents in tubers, followed by the same planting date and spraying with salicylic acid at 200 ppm. The results also showed the possibility of obtaining a crop close to that of plants planted on October 15 without using any stimulants, with a planting date of 30th Sept. and spraying with seaweed extract at a concentration of 2 ml/liter.

KEYWORDS: Potato, planting date, seaweed extract, salicylic acid, melatonin, yield and tuber quality.

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1. INTRODUCTION

In Egypt, the potato (*Solanum tuberosum*, L.) is a vital food for both domestic consumption and exportation. As one of the sources of national income and an export crop to the European and Arab markets, it is quite significant. The total area for potato cultivated in Egypt during 2022 /2023 was 566 520 fad. which produced 7594220 tons with average

13.40 ton/faddan. The cultivated area in old land was 331411 fad) about 58.49% from the total area, which produced 4006967 tons with average 12.09 ton/fad., whereas the cultivated area in new land was 235109 fad (about 41.50 %from the total area) which produced 3587253 tons with average 15.25 ton/fad. (FAO, 2024).

Planting and harvesting date of the three plantations of potato, for autumn plantation) planted from Mid. Sept. to Mid. Oct. and harvested from Mid. Jan. to Mid. Feb., (for winter plantation) planted from Mid. Oct. to Mid. Nov. and harvested from Mid. Feb. to Mid. March, (and for summer plantation) planted from Mid. Jan. to Mid. Feb. and harvested from 1st April to Mid. May. This means that the period from planting to harvest potato plants are from Sept. to May (About 9 months).

The timing of planting is crucial for potato production since it allows for some degree of control over temperature and light. The potato crop requires long day conditions for growth and short day circumstances for tuberization in order to provide the highest yields (Chadha, 2009). 15–25°C is ideal for net photosynthesis and foliage growth, whereas 20°C is ideal for tuberization. Assimilate partitioning to the tubers is decreased, net photosynthesis is increased, foliage growth is encouraged, and tuberization is hindered at temperatures higher than 29°C (Levy, 1992).

Plant growth, productivity, and potato tuber quality varied significantly depending on when the plants were planted. (Haile *et al.*, 2015, Barakat *et al.*, 2016, Thongam *et al.*, 2017, Dash *et al.*, 2018, Mansour and Abu El-Fotoh, 2018, Navneet *et al.*, 2020, Lamsal *et al.*, 2022, Singh *et al.*, 2022, Kumar *et al.*, 2023 and Salari *et al.*, 2025).

Stimulants compound such as seaweed extract, salicylic acid and melatonin are organic molecules that play essential roles in improving plant growth, and agronomic parameters. Although seaweeds are low in nitrogen, phosphorus, and potassium, they contain all the trace elements and plant growth regulators, including auxins, gibberellins, and cytokinins, in varying amounts, making them a promising biostimulant and biofertilizer for enhancing the growth and yield of many crops worldwide (Zhang and Ervin, 2008). Plant growth, productivity, and tuber quality were affected by spraying with seaweed extract (Ahmed *et al.*, 2018, Issa *et al.*, 2019, Wadas and Dziugiel, 2019, Dziugiel and Wadas, 2020, Garai *et al.*, 2021, Ammar *et al.*, 2022 and Saleh *et al.*, 2024).

Plant growth, development, and responses to biotic and abiotic stressors are all regulated by the phenolic molecule salicylic acid (SA). Additionally, SA helps plants protect themselves from abiotic stressors by regulating key physiological processes like photosynthesis, nitrogen metabolism, proline metabolism, glycinebetaine production, antioxidant defense system, and plant-water relations under stress (Miura and Tada, 2014). N-acetyl-5-methoxytryptamine, or melatonin, has been suggested as a natural biostimulant for environmentally friendly and sustainable farming (Huang *et al.*, 2022). Some authors showed that spraying potato plants with SA produced the best growth and productivity (Metwaly and El-Shatoury 2017, Suleiman *et al.*, 2018, Alhoshan *et al.*, 2019, Hassan *et al.*, 2022, Morovvat *et al.*, 2022, Dinarvandi *et al.*, 2023, Acevedo *et al.*, 2024).

Melatonin aids in the resistance of numerous physiological systems to abiotic stressors, including stomatal conductance, photosynthesis, root dynamics, glucose intake, and water relations. According to Moustafa *et al.* (2020), melatonin therapy also enhances respiration, ROS scavenging, and antioxidant enzyme activity, all of which work together to lessen oxidative damage to proteins, lipids, and nucleic acids, in this regard spraying potato plants with melatonin recorded the highest productivity and best quality of potato as compared to unsprayed plants (Abou El-Yazied *et al.*, 2022 and Abdel-Razik *et al.*, 2024 on potato).

The aim of this research under different climatic conditions was to determine the appropriate date for planting potatoes in the autumn season with the best natural stimulant substance in order to obtain the highest productivity and best quality specifications of potato tubers.

2. MATERIALS AND METHODS

In order to investigate the effects of planting dates and spraying with a natural stimulant substance on growth, productivity, and tuber quality under clay soil conditions using a drip irrigation system. Two field experiments were carried out in a private farm in Meet Faris village, Dekarns District, Dakhlia Governorate, Egypt, during two

consecutive autumn seasons of 2022/2023 and 2023/2024. The experimental soil physical and chemical (0-30 cm depth) analyses (average of the seasons) were texture: Clayey (55.91%

clay, 24.41% silt, and 19.68 % sand), Chemical properties were organic matter: 1.73 %, total N 0.165 % , available P 0.033 % and , available K 0.61 % and pH 7.68.

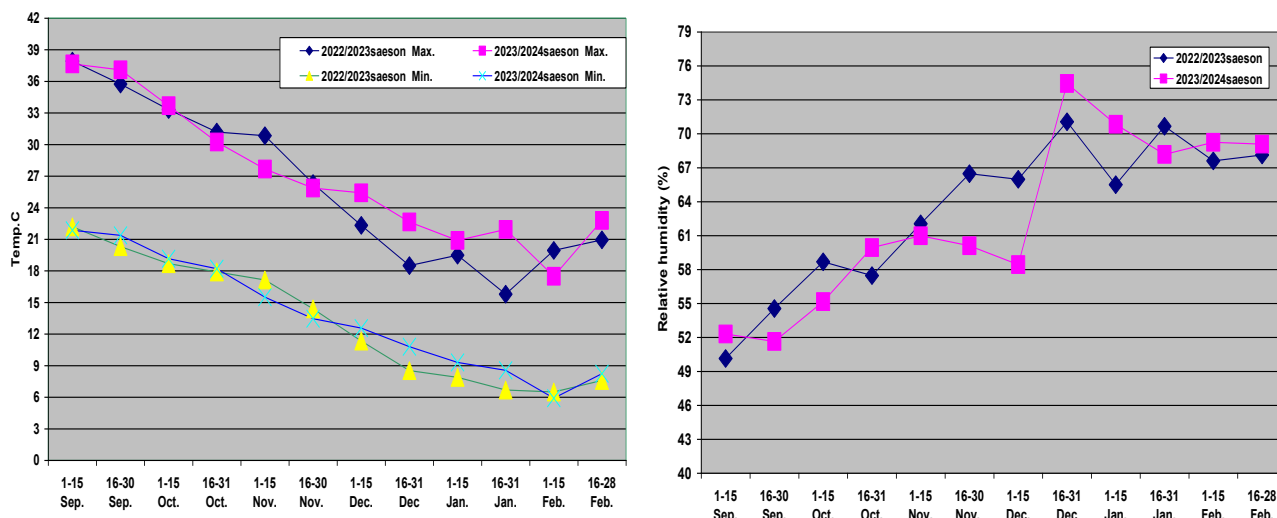


Fig . (1). Average of maximum , minimum temperature and relative humidity (%) during plant growth period in 2022/2023 and 2023 and 2024 seasons under at Dakhlia Governorate, Egypt according to Central Laboratory for Agricultural Climate (CLAC).

There were twelve treatments in this experiment, which included the interaction of three planting dates (15th Sept., 30th Sept., and 15th Oct.) with three natural stimulant substances as foliar sprays with SWE at 2 ml/l, SA at 200 ppm, and Me at 30 ppm, bedside control treatment (water spraying).

With three replicates, these treatments were set up in a split-plot design. The main plots' planting dates were chosen at random, while the subplots' applications of various stimulant substances were also chosen at random.

In both seasons, tuber seeds of the potato cultivar Spunta were sown 20 cm apart. Technogene Company imported various SWE, SA, and Me materials that were made in China.

Using a manual atomizer, SWE, SA, and Me sprayed the potato plants four times at 30, 45, 60 and 75 days to guarantee even and thorough coverage of the leaves. A spreading agent (reflective materials) was used to apply two liters of a distinct stimulant chemical solution to each plot. The untreated plants (control) were given a single watering in the interim.

The area of the experimental plot was 12.6 m². With a gap of 70 cm between each of

the three dripper lines, each line is 6 meters long. The physiological characteristics were measured on one line, and yield calculations were made on the other two lines. To prevent the overlapping infiltration of spraying solutions, a guard row was also left between each pair of experimental plots.

Calcium super phosphate (15.5% P₂O₅), potassium sulphate (48–52%), ammonium sulphate (20.6% N), and 80 kg P₂O₅ were administered to each treatment in the following amounts: 120 kg N, 80 kg P₂O₅, and 96 kg K₂O kg/. During soil preparation, one-third of the N, K₂O, and P₂O₅ were added. One month after planting, the remaining N and K₂O (two thirds) were added as fertigation at six-day intervals. Normal agricultural practices were carried out in the district under inquiry, as is customary.

2.1. Data recorded

2.1.1. Growth parameters

Five plants were chosen at random from each plot 90 days after planting in both study seasons in order to assess the following aspects of potato plant growth: Plant height (cm), leaf number per plant, leaf area /plant (m²), Leaf area index (LAI) was calculated by dividing the actual leaf area per plant by the land area

occupied by the same plant according to Watson, (1952) and shoot/plant dry weight (gm) was recorded .

2.1.2. Leaf pigments

Following the procedure outlined by Wettstein (1957), a disc sample from the fourth outer leaf of the potato plant was randomly selected from each experimental unit 90 days after sowing in both growing seasons in order to measure the levels of carotenoids and chlorophyll a and b. at 90 days after planting in both growing seasons, a disc sample from the potato plant's fourth outer leaf was chosen at random from each experimental unit to measure the amounts of chlorophyll a , b and carotenoids.

2.1.3. 3Yield and its components

For the spunta cultivar, tubers from each plot were weighed, measured, and numbered at harvest, which was about 120 days following planting. The parameters listed below were calculated: Number of tubers/plant, tuber yield per plant (gm), average tuber weight (gm), and total yield (ton/faddan). Faddan= 4200 m²= 0.42 hectare.

2.1.4. Some Agro-meteorological indices: such as growing degree days (GDD) and heat use efficiency HUE according to (Narayan *et al.*, 2014).

For every planting date, growing degree days (GDD) were computed during the season. The formula $GDD = [(min\ T + max\ T)/2 - T_b]$. T_b = Base temperature/or minimum threshold temperature taken as 4.5 for potato.

$$\text{Heat use efficiency (HUE)} = \frac{\text{Yield of potato (kg /fed.)}}{\text{GDD}}$$

2.1.5. Tuber Quality

Nitrogen, phosphorus and potassium contents

Total nitrogen, phosphorous and potassium were determined in the dry matter of tubers according to the methods described by A.O.A.C. (2008).

Specific gravity : It was determined according to the method of Murphy and Govern (1959).

Dry matter (%) : it was calculated after 100 g of the shredded mixture were dried at 105 °C until their weight remained constant.

Starch content (%) : It was determined according to the method reported by A.O.A.C. (2008).

2.2. Statistical analysis:

Snedecor and Cochran (1980) provided the statistical analysis of variance for the recorded data, and Duncan (1955) provided the means separation.

3. RESULTS AND DISCUSSION

3.1. Plant growth

3.1.1. Effect of planting date

There were significant differences among three planting dates (15th Sep. 30th Sept. and 15th Oct.) during autumn plantation for plant height, number of leaves / plant, leaf area/ plant, leaf area index and dry weight of shoots/ plant at 90 days after planting in both seasons (Table 1). The late planting significantly influenced the all plant growth parameters in potato as compared to early planting in both seasons .

Planting seeds of potato Spunta cv. on 15th Oct. (late planting) gave the tallest plants (66.41 and 66.00) and recorded maximum values of number of leaves / plant (25.83 and 27.00 leaf / plant), leaf area/ plant (0.380 and 0.371 m²), leaf area index (2.71 and 2.65) and dry weight of shoots/ plant (31.16 and 30.91 g) in both seasons, followed by planting on 30th Sept. The lowest values of all plant growth parameters in both seasons were obtained during planting on September 15th . Planting on October 15th increased shoot dry weight by approximately 36.48 and 32.94% in the first and second seasons, respectively, compared to planting on September 15th .

Potato is characterized by specific temperature requirements and develops best at about 20 C°. Growth of potato plants have difficulty with hot weather conditions because respiration increased, dry matter accumulation decreased and net assimilation rate is few. Therefore, optimum seed planting time is so vital and reflected on potato plant growth (Dehdar *et al.*, 2012).

Table 1. Effect of planting date on plant growth of potato plants cv spunta at 90 days after planting during autumn 2022/2023 and 2023/ 2024 seasons

Treatments	Plant height (cm)	Number of leaves/ plant	Leaf area/ plant (m ²)	Leaf area index	Dry weight of shoots (g/ plant
2022/2023 season					
15 th Sept.	57.75 c	21.16 c	0.286 c	2.04 c	22.83 c
30 th Sept.	64.08 b	23.66 b	0.335 b	2.39 b	26.25 b
15 th Oct.	66.41 a	25.83 a	0.380 a	2.71 a	31.16 a
2023/2024 season					
15 th Sept.	58.66 c	22.16 c	0.292 c	2.08 c	23.25 c
30 th Sept.	63.66 b	25.66 b	0.333 b	2.38 b	26.83 b
15 th Oct.	66.00 a	27.00 a	0.371 a	2.65 a	30.91 a

Due to favorable environmental circumstances in general and temperature in particular, plants grew more when planted on October 15th than when planted on 15th September (Thongam *et al.* 2017) and also, as shown in Fig 1 . These results are harmony with those reported by Khan *et al.* (2011), Sandhu *et al.* (2014) and Thongam *et al.* (2017) and Mansour and Abu El-Fotoh (2018) they reported that potato plant growth parameters were significantly higher at planting date on 15th Oct. as compared to the early and medium planting.

3.1.2. Effect of some stimulants

At 90 days after planting in both seasons, spraying with SWE at 2 ml/l, SA at 200 ppm, and Me at 30 ppm enhanced plant height, number of leaves/plant, leaf area/plant, and dry weight of shoots/plant in comparison to the control treatment (water spraying) (Table

2). Foliar spray with SWE at 2 ml/l produced the highest values of plant height (67.55 and 67.55 cm), number of leaves/ plant (25.33 and 27.33 leaf / plant), leaf area (0.365 and 0.375 m²) , leaf area index (2.60 and 2.67) and dry weight of shoots (29.11 and 29.66g), followed by spraying with SA at 200 ppm which produced (64.33 and 64.44cm), 24.66 and 23.89 leaf / plant), (0.354 and 0.349 m²) and (27.55 and 27.67 g) correspondingly for plant height, leaf area/plant, number of leaves/plant, and dry weight of shoots/plant in both seasons.

The shoot dry weight gains were roughly 20.74 and 20.78 for spraying with SWE at 2 ml/l , 14.27 and 12.21 for spraying with SA at 200 ppm and 8.75 and 5.43 for spraying with Me at 30 ppm over control treatment (spraying with water) in the 1st and the 2nd seasons, respectively.

Table 2. Effect of some stimulants on plant growth of potato plants cv spunta at 90 days after planting during autumn 2022/2023 and 2023/ 2024 seasons

Treatments	Plant height (cm)	Number of leaves/ plant	Leaf area/ plant (m ²)	Leaf area index	Dry weight of shoots (g/ plant
2022/2023 season					
Control	57.33 d	21.89 d	0.289 d	2.06 d	24.11 d
SWE	67.55 a	25.33 a	0.365 a	2.60 a	29.11 a
SA	64.33 b	23.89 b	0.354 b	2.52 b	27.55 b
Me	61.77 c	23.11 c	0.328 c	2.34 c	26.22 c
2023/2024 season					
Control	57.22 d	22.33 d	0.281 d	2.00 d	24.66 d
SWE	67.55 a	27.33 a	0.375 a	2.67 a	29.66 a
SA	64.44 b	25.55 b	0.349 b	2.49 b	27.67 b
Me	61.89 c	24.55 c	0.324 c	2.31 c	26.00 c

Control : spraying with water , Seaweed extract (SWE) at 2ml /l , Salicylic acid (SA) at 200 ppm and Melatonin (Me) at 30 ppm

The results obtained were consistent with those Dawood, 2013, Pramanick *et al.*, 2017, and Ammar *et al.*, 2022 for SWE, AL-Jeboori *et al.*, 2017, Metwaly, and El-Shatoury 2017 regarding SA and Hanci and Bingo, 2020 on garlic and Ibrahim *et al.*, 2020 on tomato as for Me. effect.

3.1.3. Effect of the interaction

The interaction between planting date and spraying with some stimulants had significant effect on plant height, number of leaves / plant, leaf area/ plant and dry weight of shoots/ plant (Table 3).

Planting on October 15th and applying SWE at a rate of 2 milliliters per liter enhanced plant height (74.00 and 71.33 cm), number of

leaves / plant (28.33 and 29.67 leaf / plant), leaf area/ plant (0.450 and 0.453 m²), leaf area index (3.21 and 3.10) and dry weight of shoots/ plant (34.33 and 35.00 g) , The combination between planting on October 15th and applying a 200 ppm SA spray in both seasons comes next. On the other hand, planting on 15th Sept. and spraying with water produced the lowest values of all plant growth parameters.

Planting on October 15th and applying SWE at a rate of 2 milliliters per liter resulted in increases in shoot dry weight of roughly 60.94 and 56.73%, respectively, compared to planting on September 15th and applying water spraying in the first and second season.

Table 3. Interaction between planting date and some stimulants as foliar spray on plant growth of potato plants cv spunta at 90 days after planting during autumn 2022/2023 and 2023/ 2024 seasons

Treatments		Plant height (cm)	Number of leaves/ plant	Leaf area/ plant (m ²)	Leaf area index	Dry weight of shoots (g/ plant)
Planting date	Stimulants	2022/2023 season				
15 th Sept.	Control	52.00 i	18.33 g	0.268 g	1.91 f	21.33 i
	SWE	61.00 f	22.67 de	0.284 f	2.02 f	24.33 g
	SA	59.33 gh	21.33 ef	0.309 e	2.20 de	23.00 h
	Me	58.67 h	20.00 f	0.283 f	2.02 f	22.67 h
30 th Sept.	Control	59.67 gh	22.00 de	0.286 f	2.04 ef	24.00 g
	SWE	67.67 b	25.00 c	0.361 c	2.57 c	28.67 d
	SA	66.67 c	23.33 d	0.356 c	2.54 c	27.00 e
	Me	62.33 e	23.00 d	0.340 d	2.42 c	25.33 f
15 th Oct.	Control	60.33 fg	25.33 c	0.313 e	2.23 d	27.00 e
	SWE	74.00 a	28.33 a	0.450 a	3.21a	34.33 a
	SA	67.00 bc	27.00 ab	0.397 b	2.83 b	32.67 b
	Me	64.33 d	26.33 bc	0.362 c	2.58 c	30.67 c
2023/2024 season						
15 th Sept.	Control	53.67 i	20.00 g	0.251 h	1.79 h	22.33 i
	SWE	61.67 f	24.33 d	0.318 de	2.27 de	25.00 fg
	SA	61.33 f	22.67 e	0.306 ef	2.18 ef	23.67 h
	Me	58.00 h	21.67 f	0.293 fg	2.09 fg	22.00 i
30 th Sept.	Control	58.00 h	23.00 e	0.281 g	2.00 g	24.67 gh
	SWE	69.67 b	28.00 b	0.372 b	2.65 bc	29.00 c
	SA	64.00 d	25.67 c	0.353 c	2.52 c	27.67 d
	Me	63.00 e	26.00 c	0.327 d	2.33 d	26.00 ef
15 th Oct.	Control	60.00 g	24.00 d	0.312 de	2.22 def	27.00 de
	SWE	71.33 a	29.67 a	0.435 a	3.10 a	35.00 a
	SA	68.00 c	28.33 b	0.388 b	2.77 b	31.67 b
	Me	64.67 d	26.00 c	0.352 c	2.51 c	30.00 c

Control : spraying with water , Seaweed extract (SWE) at 2ml /l , Salicylic acid (SA) at 200 ppm and Melatonin (Me) at 30 ppm

In general , Spunta plants which planted on 15th Sept., 30th Sept. and 15th Oct. during autumn plantation and sprayed with SWE at 2ml/l , SA at 200 ppm and Me at 30 ppm were the best in plant height, number of leaves / plant, leaf area/ plant and dry weight of shoots/ plant compared to which planted in the same planting dates without spraying with the some stimulants.

3.2. Leaf pigment

3.2.1. Effect of planting date

Planting potato plant on 15th Oct. increased the concentrations of chlorophyll a (3.81 and 3.77), b (2.05 and 2.05), total (a+b) (5.87 and 5.82) and carotenoides (1.96 and 1.95) mg /g DW in leaf tissues in both seasons followed by planting on 30th Sept. (Table 4). Planting on 15th Sept. gave the minimum concentrations of all leaf pigments traits in both seasons.

Table 3. Effect of planting date on leaf pigments (mg/g DW) at 90 days after planting of potato plants cv spunta during autumn 2022/2023 and 2023/ 2024 seasons

Treatments	Chlorophyll (a)	Chlorophyll (b)	Chlorophyll (a+b)	Carotenoides
2022/2023 season				
15 th Sept.	2.70 c	1.58 c	4.28 c	1.70 c
30 th Sept.	3.39 b	1.75 b	5.14 b	1.83 b
15 th Oct.	3.81 a	2.05 a	5.87 a	1.96 a
2023/2024 season				
15 th Sept.	2.71 c	1.55 c	4.26 c	1.68 c
30 th Sept.	3.39 b	1.73 b	5.12 b	1.82 b
15 th Oct.	3.77 a	2.05 a	5.82 a	1.95 a

The increases in total chlorophyll (a+b) in leaf tissues of potato plants due to planting on 15th Oct. were about 37.14 and 36.61% over planting on 15th Sept. in the 1st and the 2nd seasons, respectively.

The findings are consistent with those published by Navneet *et al.* (2020), Haile *et al.* (2015), and Lamsal *et al.* (2022). They demonstrated that the potato's leaf photosynthetic pigments varied significantly depending on the planting date

3.2.2. Effect of some stimulants

Table 5 shows that, in comparison to the control treatment in both seasons, the concentrations of chlorophyll a, b, total (a+b), and carotenoides in leaf tissues rose when SWE, SA, and Me were sprayed. The highest values of chlorophyll a, b, total (a+b) and carotenoides in leaf tissues were the best by praying with SWE at 2 ml/l and SA at 200 ppm .

Table 5. Effect of some stimulants on leaf pigments (mg /g DW) at 90 days after planting of potato plants cv spunta during autumn 2022/2023 and 2023/ 2024 seasons

Treatments	Chlorophyll (a)	Chlorophyll (b)	Chlorophyll (a+b)	Carotenoides
2022/2023 season				
Control	3.18 c	1.65 c	4.83 c	1.72 c
SWE	3.43 a	1.90 a	5.33 a	1.89 a
SA	3.32 b	1.86 ab	5.18 b	1.90 a
Me	3.28 b	1.77 b	5.05 b	1.81 b
2023/2024 season				
Control	3.20 c	1.66 b	4.86 c	1.73 b
SWE	3.38 a	1.84 a	5.22 a	1.88 a
SA	3.33 ab	1.83 a	5.17 ab	1.87 a
Me	3.25 bc	1.76 ab	5.01 bc	1.81 ab

Control : spraying with water , Seaweed extract (SWE) at 2ml /l , Salicylic acid (SA) at 200 ppm and Melatonin (Me) at 30 ppm

The increases in total chlorophyll (a+b) in leaf tissues of potato plants due to spraying with SWE at 2 ml/l were about 10.35 and 6.99 % over control treatment (spraying with water) in the 1st and the 2nd seasons, respectively.

A common phenolic molecule called salicylic acid (SA) influences a number of physiological processes and biochemical reactions to improve photosynthesis and regulate plant development under heat stress (Raskin, 1992). According to studies, SA reduced drought, salinity, and temperature stress (Wang *et al.*, 2010).

These results are harmony with these reported with Al-Juthery *et al.*, 2018, Wadas and Dziugiel. 2019 for seaweed extract, Hassan

et al., 2022 and Morovvat *et al.*, 2022 for salicylic acid, Abou El-Yazied *et al.*, 2022, for melatonin effect. All on potato, they showed that spraying with seaweed extract, salicylic acid and melatonin significantly increased the concentrations of leaf pigments as compared to spraying with water.

3.2.3. Effect of the interaction

The interaction between planting on 15th Oct. and spraying with SWE at 2 ml/l increased and the interaction between planting on 15th Oct. and spraying with SA at 200 ppm were the best interaction treatments for enhancing the concentrations of chlorophyll a, b, total (a+b) and carotenoides in leaf tissues (Table 6).

Table 6. interaction between planting date and some stimulants as foliar spray on leaf pigments (mg /g DW) at 90 days after planting of potato plants cv spunta during autumn 2022/2023 and 2023/ 2024 seasons

Treatments		Chlorophyll (a)	Chlorophyll (b)	Chlorophyll (a+b)	Carotenoides
Planting date	Stimulants	2022/2023 season			
15 th Sept.	Control	2.61 h	1.41 g	4.02 i	1.54 f
	SWE	2.77 g	1.76 cde	4.53 g	1.82 d
	SA	2.72 gh	1.67 def	4.39 gh	1.82 d
	Me	2.71 gh	1.49 fg	4.20 hi	1.62 ef
30 th Sept.	Control	3.28 f	1.57 efg	4.85 f	1.71 e
	SWE	3.55 cd	1.82 bcd	5.37 d	1.88 cd
	SA	3.42 de	1.85 bcd	5.27 de	1.89 bcd
	Me	3.31 ef	1.79 cd	5.10 e	1.85 d
15 th Oct.	Control	3.65 c	1.97 abc	5.62 c	1.92 abcd
	SWE	3.97 a	2.14 a	6.11 a	1.99 ab
	SA	3.83 b	2.07 a	5.90 ab	2.00 a
	Me	3.82 b	2.03 ab	5.85 bc	1.96 abc
2023/2024 season					
15 th Sept.	Control	2.66 h	1.44 g	4.10 f	1.56 f
	SWE	2.70 h	1.66 def	4.36 f	1.81 cd
	SA	2.75 h	1.59 efg	4.34 f	1.73 de
	Me	2.73 h	1.51 fg	4.24 f	1.65 ef
30 th Sept.	Control	3.31 fg	1.59 efg	4.90 e	1.73 de
	SWE	3.49 de	1.68 def	5.17 d	1.83 bcd
	SA	3.46 ef	1.87 bcd	5.33 cd	1.91 abc
	Me	3.30 g	1.78 cde	5.08 de	1.84 bcd
15 th Oct.	Control	3.63 cd	1.96 bc	5.59 bc	1.90 abc
	SWE	3.96 a	2.18 a	6.14 a	2.01 a
	SA	3.79 b	2.05 ab	5.84 b	1.98 ab
	Me	3.72 bc	2.01 abc	5.73 b	1.94 abc

Control : spraying with water, Seaweed extract (SWE) at 2ml /l, Salicylic acid (SA) at 200 ppm and Melatonin (Me) at 30 ppm

In the first and second seasons, respectively, the increases in total chlorophyll (a+b) in potato plant leaf tissues caused by the combination with planting on October 15th and spraying with SWE at 2 ml/l and planting on October 15th and spraying with SA at 200 ppm were approximately 51.99 and 49.76 percent, 46.77 and 42.44 percent, and the combination with planting on October 15th and the control treatment (spraying with water).

3.3. Yield and its components as well as heat use efficiency (HUE)

3.3.1. Effect of planting date

There were significant differences three planting dates on yield and its components as well as HUE of potato cv. Spunta during autumn plantation (Table 7) and planting on 15th Oct. recorded maximum values of total yield (13.889 and 13.784 ton /fad.) and HUE (6.689 and 6.215 kg tuber / °C day). Planting on 15th Sep. gave the lowest values of average tuber weight, average tuber number / plant , yield / plant and total yield /fed. as well as HUE in both seasons.

Table 7. Effect of planting date on yield and its components heat use efficiency (HUE) of potato plants cv spunta during autumn 2022/2023 and 2023/ 2024 seasons

Treatments	Average tuber weight (g)	Average tuber number / plant	Yield / plant (kg)	Total yield (ton/fad.)	HUE
2022/2023 season					
15 th Sept.	133.42 c	2.91 c	0.388 c	9.266 c	3.609 c
30 th Sept.	157.75 b	3.08 b	0.487 b	11.603 b	5.085 b
15 th Oct.	171.25 a	3.41 a	0.585 a	13.889 a	6.689 a
2023/2024 season					
15 th Sept.	137.42 c	3.00 b	0.412 c	9.779 c	3.738 c
30 th Sept.	160.33 b	3.08 b	0.494 b	11.759 b	4.857 b
15 th Oct.	173.92 a	3.33 a	0.580 a	13.748 a	6.215 a

HUE showed how much heat was needed to create a single garlic bulb. Heat usage efficiency, or how well heat is used to accumulate dry matter, is influenced by the type of crop, genetics, and timing of sowing.

In the first and second seasons, planting on September 30th increased total yield/feed by roughly 2.337 and 1.980 tons, respectively, whereas planting on October 15th increased total yield/feed by 4.623 and 3.969 tons, respectively.

A higher yield may have been preferred at the October 15th planting date due to the strong vegetative development in terms of height and number of leaves, as well as the stronger reproductive growth in terms of increased quantity (Table 1) and weight of tubers (Table 7).

Lower production was the result of earlier planting and exposure to high temperatures during the plant growth phase, especially during tuberization (Hassanpanah *et al.*, 2009). It makes sense to increase tuber

yield when planting later since plants have more time to grow in conditions of ideal moisture and temperature. Early planting shortens the growing period, and high temperatures during tuberization reduce potato output and tuber weight. As time goes on, late planting dates are probably warranted, although it appears that late planting could boost tuber output if there is enough radiation for growth and the trends are obviously too erratic to predict planting dates with certainty (Hassanpanah *et al.*, 2009).

Further, Khan *et al.* (2011) reported significantly higher tuber yield including at optimum planting date treatment, i.e., 15th Oct. as compared to the early and medium planting. Also Gomaa, 2014, Sandhu *et al.*, 2014, Dash *et al.* 2018, Mansour and Abu El-Fotoh, 2018, Kumar *et al.*, 2023 and Salari *et al.*, 2025) reported the similar findings.

3.3.2. Effect of some stimulants

Foliar spray with SWE at 23 ml/l, SA at 200 ppm and Me at 30 ppm significantly increased average tuber weight, average tuber number / plant, yield / plant and total yield /fed. as well as HUE in both seasons compared to control (spraying with water) as shown in Table 8. Spraying with SWE at 2 ml /l gave

the highest values of average tuber weight (162.44 and 165.00 g), average tuber number / plant (3.34 and 3.33), yield / plant (0.544 and 0.553 g /plant) and total yield /fed. (12.953 and 13.119 ton /fed.) as well as HUE (5.729 and 5.511 kg tuber / °C day) in the 1st and 2nd seasons, respectively, followed by spraying g with SA at 200 ppm.

Table 8. Effect of some stimulants as foliar spray on yield and its components heat use efficiency (HUE) of potato cv spunta during autumn 2022/2023 and 2023/ 2024 seasons

Treatments	Average tuber weight (g)	Average tuber number / plant	Yield / plant (kg)	Total yield (ton/fad.)	HUE
2022/2023 season					
Control	141.67 d	3.00 c	0.426 d	10.171 d	4.511 c
SWE	162.44 a	3.34 a	0.544 a	12.953 a	5.729 a
SA	158.11 b	3.11 b	0.495 b	11.762 b	5.207 b
Me	154.34 c	3.11 b	0.481 c	11.457 c	5.063 b
2023/2024 season					
Control	144.11 c	3.00 c	0.432 d	10.226 d	4.294 c
SWE	165.00 a	3.33 a	0.553 a	13.119 a	5.511 a
SA	162.33 a	3.11 b	0.506 b	12.032 b	5.044 b
Me	157.44 b	3.11 b	0.491 c	11.670 c	4.897 b

Control : spraying with water, Seaweed extract (SWE) at 2ml /l, Salicylic acid (SA) at 200 ppm and Melatonin (Me) at 30 ppm

The increases in total yield /fed. were about 2.782 and 2.893 ton /fed. for spraying with SWE, 1.591 and 1.806 ton /fed. for spraying with SA and 1.286 and 1.444 ton /fed. for spraying with Me at 30 over spraying with water (control treatment) in seasons one and two, respectively.

The rise in dry weight of shoots (Table 2), leaf pigments (Table 5), average tuber weight (Table 8), and average number of tubers/plant (Table 8) may be the cause of the stimulative effect of SWE, SA, and Me on total yield.

Seaweed extracts exerted positive effect on growth of the plant and thus significantly improving the total yield of potato, Auxins included in seaweed extracts will boost the treated plant's synthesis of vitamins and other hormones. In addition, seaweed extracts naturally include chelated versions of vitamins, minerals, and hormones GA₃, GA₇, which are easily absorbed by plants and improve photosynthetic efficiency, which in turn increases tuber output (O'Dell, 2003).

These results agree with those reported by Prajapati, *et al.*, 2016, Ahmed *et al.* 2018, Issa *et al.*, 2019, Dziugiel and Wadas, 2020, Garai *et al.*, 2021, and Saleh *et al.*, 2024 for SWE effect, Dinarvandi *et al.*, 2023 and Acevedo *et al.*, 2024 for SA effect and Abdel-Razik *et al.*, 2024 for Me. effect. All on potato, they showed that spraying plant with different stimulants had significant effect on yield and its components of potato than unsprayed plants.

3.3.3. Effect of the interaction

Planting potato plants during autumn plantation (15th Sep., 30th Sept. and 15th Oct.) and spraying with SWE at 2 ml/l, SA at 200 ppm and Me at 30 ppm increased average tuber weight, average tuber number / plant, yield / plant and total yield /fed. compared to planting in the same planting date without spraying with these stimulants.

The combination between planting on 15th Oct. and spraying with SWE at 20ml/l was the best interaction treatment for enhancing average tuber weight, average tuber number /

plant, yield / plant and total yield /fed. (15.489 and 15.517 ton) and HUE (7.460 and 7.015 kg tuber / °C day), followed by planting on October 15th and applying either a 200 ppm SA spray or a 30 ppm Me spray during both seasons interact (Table 9). While, planting on 15th Sep. only produced the lowest HUE values (3.154 and 3.108 kg tuber /one °C) in both seasons. For all interaction treatments, average tuber weight for Spunta cultivar were about from 112.67 to 178.00 in the 1st season and

from 115.00 to 179.33 in the 2nd season, total yield /fed. were about from 8.098 to 15.489 ton /fed. in the 1st season and from 8.130 to 15.517 ton/fed. in the 2nd season.

The stimulative effect of planting on 15th Oct. and interacted with SWE at 2 ml/l on total yield may be due to that this treatments increased dry weight of shoots (Table 3), leaf pigments (Table 6), average tuber weight and average number of tubers/ plant (Table 9).

Table 9. Effect of interaction between planting date and some stimulants as foliar spray on yield and its components as well as heat use efficiency (HUE) of potato cv spunta during autumn 2022/2023 and 2023/ 2024 seasons

Treatments		Average tuber weight (g)		Average tuber number / plant		Yield / plant (kg)		Total yield (ton/fad.)		HUE	
Planting date	Stimulants	2022/2023 season									
15 th Sept.	Control	112.67	g	3.00	c	0.338	h	8.098	h	3.154	g
	SWE	147.33	d	3.00	c	0.442	e	10.540	e	4.105	f
	SA	141.00	e	2.67	d	0.376	g	8.975	g	3.496	g
	Me	132.67	f	3.00	c	0.398	f	9.452	f	3.681	fg
30 th Sept.	Control	150.33	d	2.67	d	0.401	f	9.600	f	4.208	f
	SWE	162.00	c	3.35	b	0.539	c	12.830	c	5.624	cd
	SA	159.00	c	3.33	b	0.529	c	12.580	c	5.514	de
	Me	159.67	c	3.00	c	0.479	d	11.400	d	4.997	e
15 th Oct.	Control	162.00	c	3.33	b	0.539	c	12.815	c	6.172	bc
	SWE	178.00	a	3.67	a	0.653	a	15.489	a	7.460	a
	SA	174.33	ab	3.33	b	0.581	b	13.730	b	6.613	b
	Me	170.67	b	3.33	b	0.568	b	13.520	b	6.512	b
2023/2024 season											
15 th Sept.	Control	115.00	f	3.00	c	0.345	g	8.130	h	3.108	g
	SWE	150.00	d	3.00	c	0.450	e	10.689	f	4.087	ef
	SA	147.33	d	3.00	c	0.442	e	10.508	f	4.017	f
	Me	137.33	e	3.00	c	0.412	f	9.788	g	3.742	fg
30 th Sept.	Control	151.00	d	3.00	c	0.453	e	10.715	f	4.426	ef
	SWE	165.67	bc	3.33	b	0.552	c	13.151	d	5.432	cd
	SA	163.33	c	3.00	c	0.490	d	11.589	e	4.787	de
	Me	161.33	c	3.00	c	0.484	d	11.580	e	4.783	de
15 th Oct.	Control	166.33	bc	3.00	c	0.499	d	11.834	e	5.350	d
	SWE	179.33	a	3.67	a	0.658	a	15.517	a	7.015	a
	SA	176.33	a	3.33	b	0.587	b	14.000	b	6.330	ab
	Me	173.67	ab	3.33	b	0.578	b	13.642	c	6.168	bc

Control : spraying with water , Seaweed extract (SWE) at 2ml /l , Salicylic acid (SA) at 200 ppm and Melatonin (Me) at 30 ppm

3.4. Tuber quality

3.4.1. Effect of planting date

The obtained results in Table 10 indicate that planting potato plants on 15th Oct. increased N (1.45 and 1.49 %), P(0.309

and 0.323 %) and K(2.40 and 2.39 %) , specific gravity (1.118 and 1.148 g/cm³) , dry matter (23.58 and 23.08 %) and starch (13.79 and 13.76 %) in tubers in the 1st and 2nd seasons, respectively, followed by planting on 30th Sept. in both seasons.

Table 10. Effect of planting dates on tuber quality at harvesting time of potato cv spunta during autumn 2022/2023 and 2023/ 2024 seasons

Treatments	Tuber mineral percentage			Tuber quality		
	N	P	K	Specific gravity (g/cm ³)	Dry matter (%)	Starch content (%)
2022/2023 season						
15 th Sept.	1.13 c	0.221 c	1.76 c	0.973 c	20.16 c	11.75 c
30 th Sept.	1.23 b	0.258 b	1.96 b	1.056 b	21.91 b	12.53 b
15 th Oct.	1.45 a	0.309 a	2.40 a	1.118 a	23.58 a	13.79 a
2023/2024 season						
15 th Sept.	1.18 c	0.221 c	1.78 c	0.968 c	20.25 c	11.75 c
30 th Sept.	1.26 b	0.261 b	2.00 b	1.068 b	22.08 b	12.64 b
15 th Oct.	1.49 a	0.323 a	2.39 a	1.148 a	23.08 a	13.76 a

The increases in starch % in tubers due to planting on 15th Oct. were about 17.36 and 17.11 %, 6.64 and 7.57 % for planting on 30th Sept. over planting on 15th Sept. in the 1st and 2nd seasons, respectively.

The outcomes obtained are in good agreement with those documented by (Thongam *et al.* 2017, Mansour and Abu El-Fotoh, 2018, Navneet *et al.*, 2020, Singh *et al.*, 2022, and Salari *et al.*, 2025). They demonstrated that there were notable variations in potato tuber quality depending on the planting date.

3.4.2. Effect of some stimulants

Spraying with SWE at 2 ml/l significantly increased N (1.35 and 1.38 %), P (0.279 and 0.288 %) and K (2.19 and 2.22 %) , specific gravity (1.096 and 1.114 g/cm³) , dry matter (23.22 and 22.55 %) and starch (13.32 and 13.37 %) in tubers in the 1st and 2nd seasons, respectively (Table 11). Foliar spray with some stimulants increased tuber quality compared to control treatment I both seasons.

Table 11. Effect of some stimulants as foliar spray on tuber quality at harvesting time of potato cv spunta during autumn 2022/2023 and 2023/ 2024 seasons

Treatments	Tuber mineral percentage			Tuber quality		
	N	P	K	Specific gravity (g/cm ³)	Dry matter (%)	Starch content (%)
2022/2023 season						
Spraying (water)	1.22 c	0.244 d	1.87 d	0.993 d	20.66 d	12.13 d
SWE	1.35 a	0.279 a	2.19 a	1.096 a	23.22 a	13.32 a
SA	1.27 b	0.271 b	2.10 b	1.072 b	22.22 b	12.78 b
Me	1.25 bc	0.256 c	2.00 c	1.034 c	21.44 c	12.53 c
2023/2024 season						
Spraying (water)	1.25 c	0.250 d	1.87 d	1.008 d	21.00 c	12.15 d
SWE	1.38 a	0.288 a	2.22 a	1.114 a	22.55 a	13.37 a
SA	1.33 b	0.275 b	2.12 b	1.079 b	22.33 a	12.87 b
Me	1.29 b	0.261 c	2.03 c	1.045 c	21.33 b	12.47 c

Control : spraying with water , Seaweed extract (SWE) at 2ml /l , Salicylic acid (SA) at 200 ppm and Melatonin (Me) at 30 ppm

The increases in starch % in tubers due to spraying with SWE were about 9.81 and 10.04 % , 5.36 and 5.93 % for spraying with SA and 3.30 and 6.32 % for spraying with Me over control treatment (spraying with water) in the 1st and 2nd seasons, respectively.

Tuber quality were affected by spraying with SWE (Dawood, 2013, Gharakhani, et al., 2016, Ahmed et al. 2018, Al-Juthery et al., 2018 and , Issa et al., 2019,) SA (Morovvat et al., 2022, Dinarvandi et al., 2023, Acevedo et al., 2024) and Me. (Yagmur and Hanci, 2021 on onion, and Abdel-Razik et al., 2024 on potato).

3.4.3. Effect of the interaction treatment

The obtained results in Table 12 illustrate that the interaction between planting on 15th Oct. and spraying with SWE at 2 ml/l significantly increased N (1.61 and 1.63 %), P(0.336 and 0.351 %) and K(2.65 and 2.59 %) , specific gravity (1.186 and 1.199 g/cm³) , dry matter (25.33 and 24.33 %) and starch (14.81 and 14.73 %) in Spunta tubers in the 1st and 2nd seasons, respectively, followed by the interaction between planting on 15th Oct. and spraying with SA at 200 ppm in both seasons.

Table 12. Effect of interaction between planting date and some stimulants as foliar spray on tuber quality at harvesting time of potato cv spunta during 2022/2023 and 2023/ 2024 seasons

Treatments		Tuber mineral percentage			Tuber quality		
		N	P	K	Specific gravity (g/cm ³)	Dry matter (%)	Starch content (%)
Planting date	Stimulants	2022/2023 season					
15 th Sept.	Control	1.12 fg	0.213 g	1.65 h	0.937 i	19.00 f	11.03 j
	SWE	1.16 fg	0.231 e	1.82 g	1.016 g	21.33 cde	12.36 g
	SA	1.15 fg	0.226 ef	1.80 g	0.994 h	21.00 de	11.92 h
	Me	1.11 g	0.215 fg	1.77 g	0.946 i	19.33 f	11.71 i
30 th Sept.	Control	1.18 ef	0.232 e	1.81 g	1.021 g	21.00 e	12.31 g
	SWE	1.29 c	0.272 d	2.12 d	1.088 d	23.00 b	12.81 e
	SA	1.25 cd	0.268 d	2.02 e	1.072 e	22.00 c	12.62 f
	Me	1.23 de	0.261 d	1.92 f	1.044 f	21.67 cd	12.39 g
15 th Oct.	Control	1.37 b	0.288 c	2.17 d	1.022 g	22.00 c	13.05 d
	SWE	1.61 a	0.336a	2.65 a	1.186 a	25.33 a	14.81 a
	SA	1.42 b	0.321 b	2.48 b	1.152 b	23.67 b	13.82 b
	Me	1.41 b	0.292 c	2.31 c	1.114 c	23.33 b	13.51 c
		2023/2024 season					
15 th Sept.	Control	1.16 g	0.211 h	1.63 g	0.928 h	20.00 g	11.12 h
	SWE	1.21 efg	0.232 g	1.92 e	1.021 f	20.67 f	12.42 e
	SA	1.19 fg	0.221 h	1.81 f	0.972 g	21.00 ef	11.95 f
	Me	1.18 fg	0.221 h	1.78 f	0.952 g	19.33 h	11.52 g
30 th Sept.	Control	1.21 fg	0.238 g	1.80 f	1.004 f	21.33 de	12.32 e
	SWE	1.32 cd	0.281 e	2.15 d	1.124 c	22.67 c	12.96 d
	SA	1.29 de	0.275 e	2.11 d	1.100 d	22.67 c	12.87 d
	Me	1.25 def	0.251 f	1.95 e	1.047 e	21.67 d	12.41 e
15 th Oct.	Control	1.38 c	0.301 d	2.19 d	1.092 d	21.67 d	13.03 d
	SWE	1.63 a	0.351 a	2.59 a	1.199 a	24.33 a	14.73a
	SA	1.52 b	0.331 b	2.45 b	1.167 b	23.33 b	13.79 b
	Me	1.46 b	0.312 c	2.36 c	1.137 c	23.00 bc	13.49 c

Control : spraying with water , Seaweed extract (SWE) at 2ml /l , Salicylic acid (SA) at 200 ppm and Melatonin (Me) at 30 ppm

For all interaction treatments, dry matter in Spunta tubers about from 19.00 to 25.00 in the 1st season and from 19.33 to 24.37 % in the 2nd season, and starch content were about from 11.03 to 14.81 % in the 1st seasons and from 11.12 to 14.73 % in the 2nd season .There were positive correlation among average tuber weight, dry matter and starch content.

4. CONCLUSION

Based on the results above, it can be said that planting Spunta cultivar on 15th Oct. during autumn plantation and spraying with seaweed extract at 2 ml/l increased dry weight of shoots, leaf pigments, average tuber weigh, number of tubers/ plant, yield / plant and total yield /fed. N, P and K (%) , specific gravity, dry matter and starch contents in tubers, followed by the same planting date and spraying with salicylic acid at 200 ppm. Also, from the results obtained when planting on September 30th and using seaweed extract at a concentration of 2 ml/L, it was possible to obtain a crop close to the crop of plants planted on October 15th and without using any stimulants.

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الملخص العربي

الرش ببعض المواد الآمنة للحد من آثار التغيرات المناخية في العروة الخريفية وأثر ذلك على الإنتاجية وكفاءته استخدام الحرارة في البطاطس

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في مزرعة خاصة بقرية ميت فارس، منطقة دكرنس، محافظة الدقهلية، مصر، أجريت تجربتان حقليتان خلال موسمي خريف متتاليين في عامي ٢٠٢٢/٢٠٢٣ ، ٢٠٢٣/٢٠٢٤ بهدف دراسته تأثير مواعيد الزراعة (١٥ سبتمبر، ٣٠ سبتمبر، و ١٥ أكتوبر) والرش ببعض المواد الطبيعية المنشطة (مستخلص الطحالب البحرية بتركيز ٢ مل/لتر، حمض الساليسيليك بتركيز ٢٠٠ جزء في المليون، والميلاتونين بتركيز ٣٠ جزء في المليون) بالإضافة للماء (معاملة مقارنة) على النمو والإنتاجية وجودة الدرنات تحت ظروف الأرض الطينية باستخدام نظام الري بالتنقيط.

أدت زراعة البطاطس صنف سبونتا في ١٥ أكتوبر خلال الزراعة الخريفية، مع رشه بمستخلص الطحالب البحرية بتركيز ٢ مل/لتر، الى الحصول على أعلى القيم في الوزن الجاف للعرش، وصبغات الأوراق، ومتوسط وزن الدرنات، وعدد الدرنات/نبات، محصول النبات، والمحصول الكلى للفدان وكذلك كفاءته استخدام الحرارة. كما أظهرت النتائج ارتفاعاً في محتوى الدرنات من النيتروجين والفوسفور والبوتاسيوم كنسب مئوية، والكثافة النوعية، ومحتوى المادة الجافة والنشا، وذلك عند الزراعة في نفس الموعد مع رشها بـحمض الساليسيليك بتركيز ٢٠٠ جزء في المليون .

كما أظهرت النتائج التي تم الحصول عليها إمكانية الحصول على محصول قريب من محصول النباتات المزروعة في ١٥ أكتوبر بدون استخدام أي منشطات مع ميعاد الزراعة في ٣٠ سبتمبر والرش بمستخلص الطحالب البحرية بتركيز ٢ مل/لتر،.