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Effect of some Treatments Stimulating Growth and Yield on Pea Plants Grown under High Temperature Conditions

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ABSTRACT

To investigate the impact of some stimulants on the pea plants grown under high-temperature conditions, a field experiment was conducted to assess the effects of vitamin C, melatonin, potassium citrate, and cytokinin, in addition to a control group that did not receive any spray, on pea cultivars including A (master b), B (sweet 1), and C (sweet 2), which were assigned to the main plots. While, the stimulants were arranged in the sub-main plots. The experiment measured various growth and yield parameters, including plant height, leaf area, fresh and dry weights, chlorophyll content, carotene content, days required for fruit setting, No. of pods, pod length, pod yield and protein content. The results showed that the cultivar "C" performed the best across all studied treatments, except for days required for fruit setting. Following "C" cultivar, the performance of cultivar "B" was observed to be superior, while cultivar "A" ranked third in terms of growth and yield characteristics. In terms of fruit setting, cultivars "A" and "B" exhibited early fruit setting, whereas cultivar "C" experienced a delay in fruit set. Regarding the stimulants, spraying cytokinin yielded the highest values for all the studied characteristics. Potassium citrate treatment ranked second in terms of performance, followed by melatonin then vitamin C treatments, respectively, while the control group showed the lowest values. Overall, the application of cytokinin had the most positive impact on the growth and yield of pea plants under high-temperature conditions. Other studied stimulants also had positive effects, although to a lesser extent.

Keywords: Vitamin C, melatonin, potassium citrate, cytokinin

INTRODUCTION

Garden peas (*Pisum sativum* L.) plants hold significant importance in terms of economic and food aspects in Egypt. Pea cultivation contributes to the agricultural economy of Egypt. The production and sale of peas provide income for farmers and support rural livelihoods (Mileek and Mahmoud, 2021). The pea industry also generates employment opportunities, including farm labor, transportation, packaging, and processing. Egypt has the potential to export peas to international markets (Abo-Hamda, 2019). With proper cultivation and quality control practices, Egyptian peas can meet the demands of foreign markets, contributing to foreign exchange earnings and expanding trade opportunities. Peas are a valuable source of nutrition and play a vital role in addressing food security in Egypt (Abou-El-Hassan and Elbatran, 2020). They are a rich source of protein, dietary fiber, vitamins (such as vitamin C, vitamin A, and B-vitamins), minerals (including iron and potassium), and antioxidants (Guo *at al.*, 2020). Peas provide essential nutrients to the population, especially when included in a balanced diet. Peas are commonly used as a rotational crop in Egyptian agriculture. They have nitrogen-fixing properties, meaning they can convert atmospheric nitrogen into a usable form for plants (Abi-Ghanem *at al.*, 2011). This helps improve soil fertility and reduces the reliance on synthetic fertilizers, leading to sustainable agricultural practices (Knight, 2012). The Ministry of Agriculture in Egypt, specifically the Agriculture Extension services, reported that during the 2019 winter season, the cultivated area for green peas in Egypt covered 46,889 feddan. This cultivation resulted in a total production of 199,138 metric tons, with an average yield of 4.35 metric tons per feddan. It is noteworthy that the Egyptian government has formulated a strategy with the objective of expanding the area dedicated to pea cultivation, as mentioned by Slima and Ahmed (2020).

Under high-temperature conditions, pea plants can experience various physiological and metabolic changes that negatively affect their growth and yield (Sousa-Majer *et al.*, 2004). Heat stress often leads to the accumulation of reactive oxygen species (ROS) in plant tissues, causing oxidative damage (Abdulmajeed *et al.*, 2017; Osorio *et al.*, 2023). However, certain treatments can help stimulate growth and improve yield even in such adverse conditions. Plant breeders have developed heat-tolerant pea cultivars that are better adapted to high-temperature conditions. These cultivars possess genetic traits that enable them to withstand heat stress and maintain better growth and yield compared to traditional varieties (Sharma *et al.*, 2022). Also, certain growth regulators, such as cytokinins can stimulate plant growth and yield even under high-temperature conditions (Abd El-Hady et al., 2016; Mok, 2019), as this hormone promotes cell division, elongation, and flowering, which can enhance the overall productivity of pea plants. On the other hand, the application of antioxidants, such as ascorbic acid (Hamail *et al.*, 2015; Noufal, 2018) or melatonin (Yusuf *et al.*, 2020; EL-Baoume *et al.*, 2022; El-Beltagi *et al.*, 2023), can help scavenge ROS and protect pea plants from oxidative stress. Also, the application of chemical compounds such as potassium citrate, a combination of potassium and citric acid, can improve nutrient uptake, root growth, and stress tolerance in pea plants (Gebaly *et al.*, 2013).

It's important to note that the effectiveness of these treatments may vary depending on the severity and duration of high-temperature conditions, as well as the specific cultivar of the

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pea plant being grown. So, the aim of the current research work was to evaluate the response of three cultivars of pea plants grown under high-temperature conditions to some growth stimulants.

MATERIALS AND METHODS

1. Experimental Site.

The present research was conducted at the Experimental Farm of the Agricultural Research Center (ARC) located in Paramon Village, Mansoura City, Egypt. The soil at the experimental site is characterized by a clayey texture, comprising 24.14% sand, 26.20% silt, and 49.66% clay. The pH of the soil is 8.10, and its electrical conductivity (EC) value is 2.75 dSm^{-1}. The available nutrient levels in the soil are as follows: 45 mg kg-1 of nitrogen (N), 7.60 mg kg^{-1} of phosphorus (P), and 220 mg kg^{-1} of potassium (K). The initial soil analysis was performed according to the methods described by Dane and Topp (2020) and Sparks *et al.* (2020).

2. Pea seeds and substances studied

Pea seeds [Cv A (master b), B (sweet 1), and C (sweet 2)] were acquired from the ARC, while vitamin C, melatonin, potassium citrate and cytokinin were procured from the agricultural commercial market.

3. Experimental setup and cultivation.

This experiment was carried out in a split- plot design with three replicates to assess the effects of above aforementioned stimulants at rate of 5 mg L^{-1} for each one with volume of 900 L ha^{-1} for each one, in addition to a control group that did not receive any spray on the studied pea cultivars (A, B and C) which were assigned to the main plots. The stimulants were arranged in the sub-main plots. This experimental setup allowed for evaluating the responses of different pea cultivars to the various stimulants in high-temperature conditions (in the last of August). Pea seeds were planted during the last week of August in both the 2020 and 2021 seasons. The sowing took place on two sides of the ridge in hilly areas with moderately moist soil, with an initial planting density of 3-4 seeds per hill. Thinning was carried out after germination and before the first irrigation, reducing the number of plants to two per hill. All agricultural practices for commercial pea production, including mineral and organic fertilization, were performed in accordance with the recommendations provided by the Egyptian Ministry of Agriculture. The cultivation followed a flood irrigation system. As for the studied stimulants (Vitamin C, melatonin, potassium citrate, and cytokinin), they were applied as foliar treatments twice during the growth period, specifically at 35 and 45 days after sowing.

4. Harvest Process.

The green pods were harvested at the appropriate stage of maturity for each of the different cultivars under study. The harvesting process took place at different time intervals, specifically after 80, 81, and 90 days from the date of sowing for the master b, sweet 1, and sweet 2 cultivars, respectively, during both seasons of investigation.

5. Measurement traits and statistical analysis

- At a period of 55 days after pea sowing some growth criteria, including plant height (cm), leaf area (cm^2 $plant^{-1}$) and fresh and dry weights (g $plant^{-1}$) as well as photosynthetic pigments *i.e.,* chlorophyll (SPAD reading value) and carotene (mg g^{-1}, Kitada *et al*., 1989) were determined. Also, days for fruit setting was calculated for the three cultivars.
- At harvest stage, yield and its components, including No. of pods, pod length (cm), weight of pods, weight of 100 seed (g), pods yield (ton ha^{-1}) were determined as well as pods quality characteristics including protein, carbohydrates, total sugars, total dissolved solids (TDS, %) and vitamin C mg 100 g^{-1}(VC) were determined according to AOAC (2000).
- Statistical analysis was conducted according to Gomez and Gomez (1984), using CoStat (Version 6.303, CoHort, USA, 1998–2004)].

RESULTS AND DISCUSSION

The results obtained, presented in the subsequent tables, demonstrate that the examined varieties (A, B, and C) and substances such as vitamin C, melatonin, potassium citrate, and cytokinin had a significant impact on the growth of peas. This impact was reflected in various aspects, including plant height (cm), leaf area (cm^2 $plant^{-1}$), fresh and dry weights (g $plant^{-1}$) (Table 1), chlorophyll reading (SPAD, value), carotene content (mg g^{-1}), days for fruit setting (Table 2), No. of pods $plant^{-1}$, pod length (cm), weight of pods (g) $plant^{-1}$, weight of 100 seed (g), pods yield (metric ton ha^{-1}) (Table 3), total protein, total carbohydrates, total sugars, TDS (%) and VC (mg $100g^{-1}$) (Table 4). These effects were observed during the seasons of 2020 and 2021.

The results showed that the cultivar "C" performed the best across all studied treatments, except for days required for fruit setting. Following "C" cultivar, the performance of cultivar "B" was observed to be superior, while cultivar "A" ranked third in terms of growth and yield characteristics. In terms of fruit setting, cultivars "A" and "B" exhibited early fruit setting, whereas cultivar "C" experienced a delay in fruit set. Regarding the foliar application of stimulants, cytokinin treatment yielded the highest values for all the studied growth and yield characteristics. Potassium citrate treatment ranked second in terms of performance, followed by melatonin and vitamin C treatments. The control group showed the lowest values for the measured parameters. Overall, the findings suggest that the application of cytokinin as a foliar treatment had the most positive impact on the growth and yield of pea plants under high-temperature conditions. Potassium citrate, melatonin, and vitamin C treatments also had positive effects, although to a lesser extent. The superiority of cultivar C (sweet 2), over other varieties (master b and sweet 1) can be attributed to that cultivar C (sweet 2) may possess genetic characteristics that make it more resilient and adapted to high-temperature circumstances. These traits could include heat tolerance, better water use efficiency, improved photosynthetic efficiency or enhanced stress response mechanisms. Cultivar C's delayed fruit setting may actually be advantageous under high-temperature circumstances. Late fruit set allows the pea plants to avoid extreme heat stress during the critical reproductive stage, ensuring better fruit development and yield. Cultivar C (sweet 2) might have a higher inherent yield potential compared to the other varieties (master b and sweet 1). It could produce more pods $plant^{-1}$, larger pods, or a higher No. of seeds pod^{-1}, resulting in increased overall yield. Cultivar C (sweet 2) could have a superior nutritional composition, with higher levels of important compounds such as proteins, carbohydrates, vitamins and total sugars. This could contribute to improved plant growth and productivity. Cultivar C (sweet 2) may exhibit better resistance to common pests and diseases prevalent in high-temperature circumstances. This resistance helped in protecting the pea plants from damage, reducing yield losses and the need for excessive pesticide use. Cultivar C (sweet 2) may possess desirable agronomic characteristics including better branching, improved root system, higher leaf area, or efficient nutrient uptake. These traits contribute to overall plant vigor and productivity. It is possible that cultivar C (sweet 2) responded more favorably to specific management practices like the application of the studied stimulants or optimized irrigation and fertilization strategies. These practices could enhance its growth and yield potential. The obtained results are in harmony with those of (Ghazi and Ahmed, 2022).

The control treatment, without any stimulant application, serves as a baseline reference. It lacks the additional benefits provided by the studied stimulants, resulting in lower growth performance and yield characteristics compared to the treated groups. The ranking of the treatments in the following order: Cytokinin, potassium citrate, melatonin, vitamin C, and control, could be attributed to the specific effects and mechanisms of action of each treatment. Cytokinin came in the first order and this may be attributed to its vital role in promoting cell division and expansion. Also, it can enhance shoot development, increase the number and size of pods, and stimulate overall biomass production. on the other hand, it might influence various hormonal pathways in the studied cultivars of the pea plants, including auxin and gibberellin, which are involved in regulating pea plants' growth and development. This hormonal regulation may contribute to the observed superior growth performance and yield characteristics. Also, in this respect, cytokinin can have positive impacts on flowering and fruit sets, leading to improved yield. It may stimulate flower initiation and prolong the flowering period as well as enhance fruit development and retention. The findings obtained are consistent with those of Mok (2019).

Potassium citrate came in the second order for enhancing the growth performance and yield, as it outperformed the other studied stimulants, except cytokinin, due to potassium (K) being an essential macronutrient for pea plants growth and development, where potassium citrate provides a readily available form of potassium for pea plants, promoting healthy pea plant growth performance and improving various physiological processes. Also, K plays a crucial role in regulating osmotic potential in pea plant cells, maintaining turgor pressure, and facilitating water movement within the plant. This can help plants cope with high-temperature stress and optimize their physiological functions (El-Sherpiny *et al.,* 2022). On the other hand, it is involved in the activation of numerous enzymes, which are essential for metabolic processes. Finally, this can affect various biochemical reactions related to growth performances, thus yield, and nutrient uptake. The obtained results are in agreement with the findings reported by previous studies conducted by Gebaly *et al.,* (2013); Soliman *et al.,* (2022).

Melatonin is arranged in the third order due to it acts as a powerful antioxidant in pea plants, helping to scavenge ROS and reduce oxidative damage caused by high-temperature stress, thus protecting plant cells and improving overall growth performance, yield and its components. Moreover, it can modulate stress-responsive proteins as well as regulate gene expression and thus improving pea plants' tolerance to heat stress. The obtained results align with those of Yusuf *et al.* (2020).

Vitamin C came in penultimate order because it functions as a widely recognized antioxidant that counteracts ROS and safeguards plant cells against oxidative harm induced by heat stress. It plays a crucial role in numerous biochemical mechanisms, including photosynthesis. By enhancing the performance of the photosynthetic system, it has the capacity to improve carbon assimilation, enhance biomass generation, and ultimately increase crop yield. The obtained results are in harmony with those of Noufal (2018). The same trend was found for both studied seasons.

Table 1. Comparison of growth performance of three pea cultivars with different stimulants over a 55-day period from sowing in the seasons of 2020 and 2021

Treatments		Plant height, cm		Leaf area, cm^2 $plant^{-1}$		Fresh weight ($g\ plant^{-1}$)		Dry weight ($g\ plant^{-1}$)	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd
Main factor: Cultivars									
A (Master b)		42.26c	43.77c	266.11c	269.18c	37.01c	37.91c	8.91c	9.02c
B (Sweet 1)		47.54b	49.27b	275.69b	278.53b	47.93b	48.76b	11.11b	11.22b
C (Sweet 2)		72.94a	74.96a	285.26a	288.69a	68.27a	69.42a	16.05a	16.24a
LSD at 5%		0.14	0.73	2.01	0.60	0.74	0.49	0.08	0.02
Sub main factor: Foliar application treatments									
Control (without spraying)		51.83e	53.78d	271.31c	274.44d	48.56d	49.72d	11.30c	11.43d
Vitamin C		55.09b	57.10b	276.73ab	279.58b	51.72b	52.63b	12.10b	12.23b
Melatonin		53.79c	55.22c	274.99b	277.92c	50.84c	51.85c	11.97b	12.10c
Potassium citrate		53.48d	54.93c	276.00ab	279.36b	51.33bc	52.36b	12.11b	12.25b
cytokinin		57.06a	58.96a	279.41a	282.69a	52.90a	53.58a	12.65a	12.79a
LSD at 5%		0.22	0.59	3.62	1.09	0.68	0.45	0.16	0.05
Interaction									
A	Control	40.46o	41.91h	261.81j	265.47h	34.16i	36.07j	8.16m	8.28o
	Vitamin C	43.22l	44.82fg	268.34ghi	271.87f	38.47fg	39.51h	9.26jk	9.39l
	Melatonin	41.24n	42.58h	264.39ij	266.93h	35.70h	36.53h	8.63l	8.71n
	Potassium citrate	42.19m	43.94g	265.77hij	269.18g	37.35g	38.05i	9.02k	9.14m
	Cytokinin	44.21k	45.60f	270.25f-i	272.43f	39.39f	39.39h	9.48j	9.56k
B	Control	45.19j	47.12e	271.91e0h	274.53e	46.78e	47.49g	10.29i	10.37j
	Vitamin C	46.01i	47.70de	273.86d-g	275.41e	47.17e	48.04fg	10.67h	10.73i
	Melatonin	49.38g	51.15c	278.08b-e	280.38d	48.72d	49.67e	11.53fg	11.63g
	Potassium citrate	46.93h	48.39d	275.37c-f	278.69d	47.54e	48.57f	11.26g	11.38h
	Cytokinin	50.19f	51.99c	279.25bcd	283.63c	49.44d	50.01e	11.80f	11.98f
C	Control	69.85e	72.32b	280.21bc	283.31c	64.75c	65.61d	15.44e	15.63e
	Vitamin C	76.04b	78.78a	288.00a	291.45a	69.52a	70.34b	16.37b	16.56b
	Melatonin	70.74d	71.94b	282.51ab	286.46b	68.10b	69.35c	15.74d	15.97d
	Potassium citrate	71.32c	72.47b	286.87a	290.20a	69.09ab	70.47b	16.04c	16.22c
	Cytokinin	76.78a	79.30a	288.74a	292.00a	69.87a	71.33a	16.66a	16.84a
LSD at 5%		0.38	1.02	3.27	1.89	1.17	0.79	0.28	0.09

Table 2. Comparison of photosynthetic pigments at period of 55 days from sowing as well as days for fruit setting of three pea cultivars with different stimulants during the seasons of 2020 and 2021

Treatments		Chlorophyll, SPAD		Carotene, mg g^{-1}		Days for fruit setting	
		1st	2nd	1st	2nd	1st	2nd
Main factor: Cultivars							
A (Master b)		41.30c	41.75c	0.470c	0.478c	42.27c	43.07c
B (Sweet 1)		43.63b	44.07b	0.508b	0.516b	45.47b	47.13b
C (Sweet 2)		45.86a	46.40a	0.542a	0.552a	58.73a	60.47a
LSD at 5%		0.09	0.32	0.006	0.006	0.80	2.74
Sub main factor: Foliar application treatments							
Control (without spraying)		42.67e	43.10c	0.497c	0.505c	46.89c	48.78b
Vitamin C		43.81b	44.31b	0.509b	0.519b	48.89b	50.22ab
Melatonin		43.37d	43.79b	0.502bc	0.510c	48.22bc	50.11ab
Potassium citrate		43.57c	44.08b	0.505b	0.512bc	49.22ab	50.22ab
Cytokinin		44.56a	45.08a	0.521a	0.531a	50.89a	51.78a
LSD at 5%		0.18	0.57	0.007	0.007	1.77	2.08
Interaction							
A	Control	40.29o	40.76l	0.469jk	0.478ij	39.67g	42.33e
	Vitamin C	41.86l	42.47ij	0.476ij	0.486hi	42.67d-g	43.67de
	Melatonin	40.69n	41.06kl	0.457k	0.466j	41.fg33	42.33e
	Potassium citrate	41.31m	41.77jk	0.463k	0.468j	42.3efg3	42.67e
	Cytokinin	42.34k	42.69hij	0.484hi	0.494gh	45.33b-e	44.33cde
B	Control	42.76j	43.11ghi	0.491gh	0.503fg	43.67c-f	45.00cde
	Vitamin C	43.25i	43.56fgh	0.500fg	0.510f	44.67b-e	46.67bcd
	Melatonin	44.01g	44.34ef	0.514de	0.524de	45.67bcd	47.67bc
	Potassium citrate	43.60h	44.07fg	0.509ef	0.514ef	46.33bc	47.67bc
	Cytokinin	44.53f	45.25de	0.524cd	0.529cd	47.00b	48.67b
C	Control	44.96e	45.43cd	0.529c	0.535cd	57.33a	59.00a
	Vitamin C	46.32b	46.90ab	0.550a	0.561ab	59.33a	60.33a
	Melatonin	45.42d	45.98bcd	0.535bc	0.540c	57.67a	60.33a
	Potassium citrate	45.81c	46.39abc	0.543ab	0.554b	59.00a	60.33a
	Cytokinin	46.81a	47.28a	0.554a	0.571a	60.33a	62.33a
LSD at 5%		0.32	0.99	0.012	0.013	3.07	3.61

Table 3. Comparison of yield and its components of three pea cultivars with different stimulants in the seasons of 2020 and 2021

Treatments		No. of pods plant^{-1}		Pod length, c m		Weight of pods plant^{-1}		Weight of 100 fresh seed, g		Green pods yield, metric ton ha^{-1}	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Main factor: Cultivars											
A (Master b)		11.60b	12.87c	6.21c	6.42c	35.30c	35.98c	38.06c	38.86c	5.85c	5.98c
B (Sweet 1)		13.00b	14.67b	7.30b	7.54b	37.56b	38.20b	39.84b	40.44b	7.49b	7.64b
C (Sweet 2)		21.13a	22.53a	9.32a	9.63a	43.11a	43.83a	41.65a	42.27a	9.06a	9.26a
LSD at 5%		1.49	1.28	0.23	0.22	0.08	0.09	0.31	0.30	0.16	0.09
Sub main factor: Foliar application treatments											
Control (without)		14.22c	15.67c	7.12c	7.36c	37.34d	38.00d	39.06c	39.82c	6.97d	7.12d
Vitamin C		15.67ab	17.00ab	7.69b	7.92b	38.94b	39.69b	39.99b	40.61b	7.56b	7.73b
Melatonin		14.89bc	16.22bc	7.56b	7.82b	38.35c	39.09c	39.74b	40.42b	7.41c	7.57c
Potassium citrate		15.22b	16.78b	7.66b	7.90b	38.85b	39.66b	39.95b	40.59b	7.50b	7.66bc
Cytokinin		16.22a	17.78a	8.02a	8.32a	39.79a	40.23a	40.52a	41.17a	7.89a	8.05a
LSD at 5%		0.96	0.78	0.19	0.20	0.17	0.17	0.29	0.53	0.08	0.11
Interaction											
A	Control	11.00i	12.00j	5.40k	5.60j	34.61n	35.56k	37.24j	38.16j	5.12n	5.25l
	Vitamin C	12.00f-i	13.33g-j	6.47hi	6.70h	35.79k	36.79i	38.46gh	39.19ghi	6.21k	6.35i
	Melatonin	11.33hi	12.33ij	6.10j	6.30i	34.92m	35.71jk	37.70ij	38.58ij	5.59m	5.71k
	Potassium citrate	11.67ghi	13.00hij	6.37ij	6.60hi	35.25l	35.89j	38.14hi	39.01hij	5.92l	6.05j
	Cytokinin	12.00f-i	13.67f-i	6.70gh	6.90gh	35.91k	35.95j	38.75fg	39.34ghi	6.40j	6.54i
B	Control	12.33e-i	14.00e-h	7.00fg	7.20fg	36.40j	36.95i	39.11ef	39.65fgh	7.03i	7.17h
	Vitamin C	12.67e-h	14.33e-h	7.10f	7.30f	36.83i	37.49h	39.44de	40.08efg	7.27h	7.44g
	Melatonin	13.33ef	15.00ef	7.50e	7.80de	38.21g	38.94f	40.36c	40.74de	7.71f	7.87f
	Potassium citrate	13.00efg	14.67efg	7.30ef	7.50ef	37.51h	38.36g	39.75d	40.31ef	7.51g	7.64g
	Cytokinin	13.67e	15.33e	7.60e	7.90d	38.85f	39.24e	40.55c	41.41cd	7.93e	8.07e
C	Control	19.33d	21.00d	8.97d	9.27c	41.00e	41.49d	40.84bc	41.65bcd	8.77d	8.94d
	Vitamin C	22.33ab	23.33ab	9.50ab	9.77b	44.21b	44.79b	42.06a	42.56ab	9.21ab	9.40ab
	Melatonin	20.00cd	21.33cd	9.07cd	9.37c	41.92d	42.63c	41.16b	41.94abc	8.93c	9.14cd
	Potassium citrate	21.00bc	22.67bc	9.30bc	9.60bc	43.79c	44.71b	41.96a	42.45ab	9.07bc	9.30bc
	Cytokinin	23.00a	24.33a	9.77a	10.17a	44.63a	45.52a	42.25a	42.77a	9.33a	9.53a
LSD at 5%		1.65	1.35	0.33	0.35	0.28	0.29	0.51	0.92	0.14	0.20

Table 4. Comparison of quality parameters of three pea cultivars with different stimulants at harvest stage in the seasons of 2020 and 2021

Treatments		Protein, %		Carbohydrates, %		Total sugar, %		TDS, %		V.C, mg $100g^{-1}$	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Main factor: Cultivars											
A (Master b)		18.80c	19.19c	45.91c	46.94c	13.47c	13.76c	15.63c	15.81c	28.57c	29.58c
B (Sweet 1)		20.67b	21.03b	47.31b	48.25b	14.68b	14.91b	16.57b	16.74b	29.90b	30.93b
C (Sweet 2)		22.38a	22.75a	48.49a	49.52a	15.47a	15.69a	17.49a	17.71a	31.00a	32.07a
LSD at 5%		0.14	0.05	0.89	0.60	0.11	0.11	0.32	0.23	0.23	0.06
Sub main factor: Foliar application treatments											
Control (without)		19.87d	20.23d	46.62b	47.61b	14.13d	14.41c	16.18c	16.36c	29.34c	30.37d
Vitamin C		20.71b	21.16b	47.36a	48.41a	14.60b	14.83b	16.62b	16.80b	29.86b	30.93b
Melatonin		20.50c	20.89c	47.17ab	48.19ab	14.48c	14.70b	16.49b	16.67b	29.77b	30.74c
Potassium citrate		20.67b	21.10b	47.30a	48.25ab	14.53bc	14.76b	16.56b	16.76b	29.83b	30.84bc
Cytokinin		21.33a	21.57a	47.73a	48.72a	14.97a	15.22a	16.96a	17.18a	30.31a	31.43a
LSD at 5%		0.16	0.09	0.60	0.69	0.11	0.19	0.20	0.18	0.22	0.13
Interaction											
A	Control	18.02m	18.53m	44.97j	46.11i	12.92m	13.24j	15.20l	15.42m	27.95l	28.99j
	Vitamin C	19.15k	19.82i	46.32ghi	47.39fgh	13.71j	13.98h	15.79jk	16.00jk	28.78j	29.79h
	Melatonin	18.41l	18.83l	45.74ij	46.66hi	13.20l	13.50ij	15.46kl	15.58lm	28.31kl	29.22i
	Potassium citrate	18.92k	19.25k	45.98hi	47.00ghi	13.45k	13.75hi	15.58k	15.79kl	28.60jk	29.72h
	Cytokinin	19.50j	19.53j	46.56fi	47.54eh	14.09i	14.31g	16.10ij	16.25ij	29.20i	30.20g
B	Control	19.95i	20.27h	46.88eh	47.78dh	14.27i	14.46fg	16.26hi	16.38i	29.45hi	30.40g
	Vitamin C	20.25h	20.64g	47.07g	48.12dg	14.49h	14.74ef	16.39ghi	16.50hi	29.65gh	30.70f
	Melatonin	21.09f	21.46e	47.52cf	48.55bf	14.90f	15.04de	16.73fg	16.89fg	30.16ef	31.21e
	Potassium citrate	20.69g	21.17f	47.36cf	48.18cg	14.70g	14.91e	16.58fgh	16.75gh	29.88fg	30.86f
	Cytokinin	21.37e	21.60e	47.73be	48.61be	15.06ef	15.37cd	16.88ef	17.18ef	30.37de	31.50d
C	Control	21.63e	21.88d	48.02ad	48.95ad	15.21de	15.52bc	17.08de	17.27de	30.64cd	31.72cd
	Vitamin C	22.72b	23.03b	48.70ab	49.74ab	15.59ab	15.77ab	17.68ab	17.91ab	31.16ab	32.29b
	Melatonin	22.00d	22.39c	48.25abc	49.36abc	15.34cd	15.56bc	17.28cd	17.53cd	30.84bc	31.80c
	Potassium citrate	22.41c	22.89b	48.55ab	49.56ab	15.45bc	15.63bc	17.52bc	17.73bc	31.01abc	31.94c
	Cytokinin	23.11a	23.57a	48.91a	50.00a	15.77a	15.97a	17.88a	18.10a	31.36a	32.58a
LSD at 5%		0.27	0.16	0.99	1.19	0.19	0.33	0.34	0.32	0.38	0.23

CONCLUSION

According to the obtained results, cultivar C (sweet 2) consistently outperformed the other cultivars across all studied treatments, except for days required for fruit setting. Cultivar B (sweet 1) demonstrated superior performance compared to cultivar A (master b). In terms of fruit setting, cultivars A (master b) and B (sweet 1) exhibited early fruit setting, while cultivar C (sweet 2) experienced a delay in fruit set. Cytokinin resulted in the highest values for all measured growth and yield parameters. Potassium citrate ranked second, followed by melatonin and vitamin C. Based on these findings, it can be concluded that cytokinin application as a foliar treatment had the most significant positive impact on the growth and yield of pea plants under high-temperature conditions. Potassium citrate, melatonin, and vitamin C treatments also had beneficial effects, albeit to a lesser extent. Despite the fact that Master B and Sweet 1 cultivars exhibit lower vegetative growth and productivity compared to the Sweet 2 cultivar, they have the advantage of early maturation. As a result, these cultivars can potentially generate higher economic profits than the Sweet A variety, which ripens later.

RECOMMENDATIONS

1. Farmers and growers cultivating pea plants in high-temperature conditions should consider using cultivar C (sweet 2), as it demonstrated superior performance in terms of growth and yield compared to cultivars A (master b) and B (sweet 1).
2. Cytokinin can be recommended as an effective stimulant for foliar application to enhance the growth and yield of pea plants under high-temperature conditions. Its application should be considered during critical growth stages.
3. Potassium citrate, melatonin, and vitamin C can also be utilized as stimulants, although their effects were not as pronounced as cytokinin. Farmers may consider using these stimulants as supplementary treatments to improve growth and yield.
4. Further research is warranted to investigate the optimal application rates and timings of the stimulants under varying high-temperature conditions. Additionally, exploring the synergistic effects of combining multiple stimulants could be beneficial.
5. It is advisable to conduct similar experiments in different locations and seasons to validate the findings and assess the consistency of the stimulant effects on different pea cultivars.

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تأثير بعض المعاملات المحفزة للنمو والمحصول على نباتات البسلة المنزرعة تحت ظروف الحرارة المرتفعة

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الملخص

لدراسة تأثير بعض المحفزات على نباتات البسلة النامية تحت ظروف درجات الحرارة العالية، تم إجراء تجربة حقليه لتقييم تأثير حمض الأسكوربيك والميلاتونين وسترات البوتاسيوم والسايتوكينين، بالإضافة إلى معاملة الكنترول التي لم تتلقي أي رش، على الأصناف A (الماستر بي) وB (السويت 1) وC (السويت 2) من البازلاء، والتي تم توزيعها في القطع الرئيسية. بينما تم ترتيب المحفزات في القطع الفرعية المنشقة. تم قياس مختلف معايير النمو والإنتاجية، مثل ارتفاع النبات، والمساحة الورقية، والأوزان الطازجة والجافة، ومحتوى الكلوروفيل، ومحتوى الكاروتين، والفترة الواجبة للعقد، وعدد القرون، وطول القرون، ومحصول القرون ومحتوى البروتين. أظهرت النتائج أن الصنف "C" كان الأفضل في جميع المعاملات المدروسة، باستثناء الفترة الواجبة للعقد. بعد الصنف "C"، لوحظ أن أداء الصنف "B" كان أفضل، في حين احتل الصنف "A" المركز الثالث من حيث خصائص النمو والإنتاجية. من حيث الفترة الواجبة للعقد، أظهر الصنفان "A" و "B" عقدا مبكرًا للثمار، بينما تأخر العقد مع الصنف "C". بالنسبة للمحفزات، أعطي الرش بالسايتوكينين أعلى قيم لجميع الخصائص المدروسة. بينما جائت معاملة سترات البوتاسيوم في المرتبة الثانية من حيث الأداء، تليها معاملتي الميلاتونين وفيتامين سي على الترتيب. بينما أعطت معاملة الكنترول اقل القيم. بشكل عام، كان لتطبيق السيتوكينين التأثير الأكثر إيجابية على نمو وإنتاج نباتات البسلة تحت ظروف درجات الحرارة العالية. كان للمنشطات المدروسة الأخرى أيضًا تأثيرات إيجابية، وإن كانت بدرجة أقل.