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Ameliorating Growth, Yield and Bioconstituents of Taro Plant Grown Under Water Stress Levels Using Anti-Stress Agents

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Abstract

The effects of varying irrigation water levels (100, 75, and 50% of crop requirements) as well as foliar application of certain anti-stress agents (proline at 100 and 200 Mg L^{-1}, potassium silicate at 1000 and 2000 Mg L^{-1} and algae extract at 2.5 and 5 Ml L^{-1}) on the growth characteristics, chemical compositions, and final corm yield components of the taro plant (*Colocasia esculenta* L. Schott) under drip irrigation systems were examined in two field experiments carried out at the experimental farm station, Faculty of Agriculture, Benha University, Egypt, during the growing seasons of 2022 and 2023. The findings demonstrated that raising the water stress level from 75% to 50% gradually reduced all taro plant growth characteristics. The amount of photosynthetic pigments decreased as the irrigation water stress level increased. Additionally, increased water stress led to higher proline concentration and antioxidant enzyme activity in taro corms, while reducing levels of N, P, K, crude protein, and total carbohydrates. Yield parameters, such as corm length, diameter, number, and weight $plant^{-1}$, along with main corm fresh and dry biomass, all decreased with increasing irrigation deficit compared to full irrigation (100%). The 50% irrigation level showed the most significant reduction in these metrics. The anti-stress treatments substantially reduced the adverse effects of water stress, resulting in significant enhancements in growth parameters and bioconstituents studied across all irrigation levels. Potassium silicate at 2000 mg L^{-1} was the most effective treatment, followed by algae extract at 5 ml L^{-1} and proline at 200 mg L^{-1}.

Keywords: taro, stress, proline, potassium silicate and algae extract.

Introduction

The most significant vegetable crop in the Araceae family is taro (*Colocasia esculenta* L. Schott). It is widely grown around the world, particularly in tropical and subtropical areas. The primary issue limiting taro productivity is water. It thrives in regions that are damp and dark **(Rashmi *et al.*, 2018).** Without taking into account the crops' true water requirements, Egyptian taro is cultivated in the Nile Valley under flood irrigation, which results in a 30% decrease in irrigation efficiency **(Abd El-Aal *et al.*, 2019).** In both natural and agricultural settings, plants are subjected to a variety of environmental challenges during their growth and development. One of the harshest environmental stressors influencing plant productivity is drought **(Brodersen *et al.*, 2019).** According to **O'Connell (2017)**, water limitation and the rise in food demand brought on by the world's worrisome population growth exacerbate the effects of drought in agriculture.

One sustainable agricultural technique that can enhance yield, improve fertilizer and water use efficiency, and boost profitability, especially in drought conditions, is the use of plant bioregulators. Proline, for instance, functions as an osmoregulator, balancing osmotic stress between the vacuole, cytoplasm, and environment. It maintains membrane integrity, acts as an antioxidant by neutralizing reactive oxygen species, and reduces oxidative damage. Additionally, proline serves as a storage form for nitrogen and carbon during plant recovery from stress **(Ashraf and Foolad, 2007; Lehmann *et al.*, 2010; Hayat *et al.*, 2012).**

Potassium (K) is necessary for many physiological functions, including photosynthesis, the activation of metabolic enzymes, protein synthesis, the transfer of photosynthates into sink organs, regulation of stomata opening and closing, the relationship between water and plants, and the construction of cells. Additionally, it is crucial for controlling a number of metabolic functions and boosting resistance to drought **(Liaqat *et al.*, 2022).** In terms of promoting plant growth, silicon (Si) is a benign and ecologically suitable substance. According to reports, silicon can lessen the harmful impacts of a number of abiotic stressors, including drought stress **(Verma *et al.*, 2020).** As for seaweed extract It also has many beneficial effects on plants because it contains growth hormones (IAA and IBA, cytokinins), micronutrients (Fe, Cu, Zn, Mo, and Mn), vitamins and amino acids **(Pise and Sabale, 2010).**

Materials and Methods

In order to investigate the effects of proline, algae extract, and potassium silicate on the growth, morphology, chemical compositions, and ultimate yield of taro plants grown under three levels of water stress 50%, 75%, and 100% of the taro plant's water requirements two field experiments were carried out at the experimental farm station, Faculty of Agriculture, Moshtohor, Benha University, during the 2022 and 2023 seasons.

1. Plant material and experimental design

Corms and jaws were cultivated on terraces spaced 30 cm apart and 0.8 m wide. The Egyptian Ministry of Agriculture's guidelines were followed for land preparation. Irrigation was applied immediately after planting and then every 10 days for two months. Afterward, drip irrigation applied water stress at 75% and 50% of total water needs, as well as 100% (as a control) until harvest. Anti-stressor spraying, starting 75 days after planting and repeated every 15 days, used Proline (100 and 200 mg L^{-1}), algae extract (2.5 and 5 ml L^{-1}), and potassium silicate (1000 and 2000 mg L^{-1}). The experiment was laid out as a split-plot design with three replicates. The volume of irrigation water added (m^3/feddan) as well as the applied levels of irrigation water are presented in **Table 1**.

Table 1. Water irrigation levels for a growing season.

Irrigation water levels	% of ETc	Irrigation water quantity applied m^3 fed.^{1}
1-WL_1 full irrigation (control)	**100%**	**irrigation with 4537.92 m^3 water fed.$^{-1}$**
2- WL_2 moderate water stress	**75%**	**irrigation with 3403.44 m^3 water fed.$^{-1}$**
3- WL_3 severe water stress	**50%**	**irrigation with 2268.96 m^3 water fed.$^{-1}$**

2. Sampling and collecting data

2.1. Growth measurements

After 150 days of planting, three plants were randomly selected from the center rows of each replicate to record the following growth traits of the taro plant:

1- Plant height (cm) 2- Number of leaves, plant^{-1}.
3- Fresh and dry weight of leaves (g) plant^{-1}.
4- Total area of leaves (cm^2) plant^{-1} according to **Pierozan Junior and Kawakami (2013).**
5- Fresh weight of the main corm (g) plant^{-1}.
6-Total early yield g plant^{-1}

The plant's dry weight was determined after samples of its vegetative components were dried in an oven set to 70°C for 48 hours to a consistent weight. For chemical investigation, these desiccated leaf samples were preserved.

2.2. Phytochemical determinations:

3.2.1. Photosynthetic pigments.

photosynthetic pigments were estimated by the method of **Wettstein (1957**) method and are expressed as mgg^{-1} of fresh weight.

3.2.2. Total carbohydrates content:

Total carbohydrates were determined in the dry leaves at 150 days and corms at 240 days following planting in 2022 season by using the phenol-sulfuric acid method according to **Dubois *et al.,* (1956)** and calculated as gg^{-100} of dry weight.

3.2.3. Determination of proline content:

The amount of proline content in leaves was determined by the method of **Bates *et al.,* (1973)** and was expressed in mgg^{-100} dry weight.

3.2.4. Determination of total phenols content:

The **Miliauska *et al.,* (2004)** method was used to determine the total phenolic content and was expressed in mgg^{-1} dry weight.

4. Antioxidant enzymes activity:

The activities of catalase, peroxidase, polyphenol oxidase, and superoxide dismutase were measured in accordance with **Cao *et al.* (2005)** and computed in accordance with **Kong *et al.* (1999).**

5. Yield components:

Three plants were selected at random from each replicate at harvest in order to estimate the following attribute:

1. Main corm length (cm) 2- Main corm diameter (cm) 3- Number of corms plant^{-1}
4- Main corm fresh weight plant^{-1} (g) 5- Main corm dry weight plant^{-1} (g) 6- Corms fresh weight plant^{-1} (kg) 7- Corms dry weight plant^{-1} (g)

6. Statical analysis:

Two-way ANOVA was used in the statistical analysis, which was conducted using SPSS, version 27 **(IBM Corp. Released 2013)**. In accordance with to **Steel *et al.* (1997)**, the data were handled as a split plot design. Using the Duncun test (**Duncun, 1980**), many comparisons were conducted. A significance criterion of less than 0.05 was established.

Results and Discussion

3.1. Effect of foliar application with some anti-stressors on vegetative growth parameters of taro plants grown under different water irrigation levels

Data in **Table 2** demonstrate the effects of irrigation water levels (50, 75, and 100% of crop water requirements) and foliar spray treatments (proline at 100 and 200 mg L^{-1}, algae extract at 2.5 and 5 ml L^{-1} and potassium silicate at 1000 and 2000 mg L^{-1}), as well as their interactions on some vegetative growth parameters of the taro plant.

In the first season, a 75% irrigation level yielded the highest increases in plant height, leaf number, leaf area, fresh weight, and dry weight. In contrast, 100% irrigation produced the best results in the second season. Notably, after 150 days in both seasons, reducing the irrigation level from 75% to 50% significantly decreased all growth parameters compared to full irrigation (100% of crop water needs). The 50% irrigation level caused the most substantial decline in these metrics.

Foliar application of the two assigned anti-stressor concentrations significantly improved plant height, total leaf area, early corm yield per plant, and both fresh and dry weights of leaves and corms compared to untreated plants under the three irrigation levels across both growing seasons. The most substantial improvements, often reaching statistical significance, were observed with 200 mg L^{-1} of potassium silicate, followed by 5 ml L^{-1} of algae extract, and then 200 mg L^{-1} of proline. However, the number of leaves per plant was not significantly affected, particularly during the second season.

Potassium silicate at 2000 mg L^{-1} with water level 75% provided the highest growth results in terms of the interaction between various foliar spray treatments and water irrigation levels.

Our results show that water irrigation deficit negatively affected various growth aspects, consistent with **Abd El-Aal *et al.,* (2019).** This negative impact could be mainly attributed to stomatal closure, impaired photosynthesis, and hindered cell proliferation and elongation under water stress conditions, ultimately reducing growth rate **(Martinez *et al.,* 2004; Taize *et al.,* 2014).**

3.2. Effect of foliar application with some anti-stressors on bioconstituents level of taro plants grown under different water irrigation levels

3.2.1. Photosynthetic pigments:

As shown in **Table 3**, water stress significantly increased chlorophyll a, b, and carotenoid concentrations in taro plants compared to the control. The highest pigment levels were achieved by irrigating with 75% of water needs in the first season and with 50% in the second season.

Under applied irrigation levels, proline, algae extract, and potassium silicate treatments significantly enhanced photosynthetic pigment concentrations compared to untreated plants across both growing seasons. The increases were generally proportional to the concentration of the applied anti-stressors. At 75% irrigation level, the highest chlorophyll a concentration was achieved with 200 mg L^{-1} proline in the first season and 2000 mg L^{-1} potassium silicate in the second. Chlorophyll b reached maximum concentrations at 1000 mg L^{-1} and 2000 mg L^{-1} potassium silicate in the first and second seasons, respectively. Carotenoids, however, showed the highest levels with 2000 mg L^{-1} potassium silicate in the first season and with algae extract in the second.

Our findings contradict those of **Farouk *et al.,* (2009)**, who associated drought-induced chlorophyll reduction with oxidative stress, attributing it to pigment photooxidation and degradation. Photosynthetic pigments are essential for plants, primarily for light absorption and energy generation. Soil dryness affects both chlorophyll a and chlorophyll b.

The stimulating effect of proline might result from its pivotal role in water relation in plant cells, which maintains cells' turgidity under water stress and hastens photosynthesis **(Hayat *et al.,* 2012)**.

Regarding potassium silicate, our findings are likewise in line with those of **Salim *et al.,* (2021)** on squash, **El-Sayed *et al.,* (2022)** on tomato, and **Ebeed *et al.,* (2023)** on wheat. They observed that silicon significantly increased chlorophyll a, b, and carotenoids of treated plants under deficit irrigation levels.

3.2.2. Crude protein, total carbohydrates, total phenolics and proline content:

The interaction between irrigation water levels and foliar spray treatments affects the levels of crude protein, total carbohydrates, total phenolics, and proline in taro leaves 150 days after planting, as detailed in **Table 4**. Under non-stressed conditions (WL_1), the highest total carbohydrate concentrations were achieved with algae extract at 5 ml L^{-1} and then 2.5 ml L^{-1}, followed by potassium silicate at 2000 mg L^{-1} and 1000 mg L^{-1}. However, total carbohydrate content decreased under stressed conditions (WL_2 at 75% and 50%) compared to non-stress conditions (WL_1 at 100%).

Additionally, the maximum values of total phenols and proline content were obtained at irrigation level 50% with the application of algal extract at 5 ml L^{-1}, followed by irrigation level 75% with algae extract at 2.5 ml L^{-1}.

These findings are in line with those of **Abd El-Aal *et al.,* (2019),** who observed that when taro plants were subjected to water stress levels ranging from 75% to 50%, plant bioactive components were impacted and decreased as the stress level rose

According to **Zhang *et al.,* (2024)** starch accumulation in taro plants is inhibited by drought due to plants under drought stress have altered enzymes that are involved in the manufacture of starch.

Regarding potassium silicate, our results align with those of **Yaghubi *et al.,* (2016),** who indicated that the concentration of soluble carbohydrates in strawberry plant rose with increasing the concentration of potassium silicate from 1000 to 1500 mg L^{-1}.

The positive results obtained with algae extract are in harmony with the findings of **Liu *et al.*, (2014),** who revealed the maximum levels of total phenolics and total flavonoids in *Brassica oleraceae* were recorded via foliar application of 2 mg g^{-1} seaweed extract.

Drought-tolerant plants have adapted to water stress through a variety of processes, such as storing osmotic fluids to reduce water loss **(Bahadur *et al.*, 2011).** Proline is one of the amino acids found in accumulated osmotic fluids. In conditions with low water activity, these substances are essential for halting membrane breakdown and enzyme inactivation.

3.3. Effect of foliar applied treatments on antioxidant enzyme activity

The data collected in **Table 5** show how the activity of antioxidant enzymes (unit min^{-1} mgg^{-1} protein) such as catalase, peroxidase, polyphenol oxidase, and superoxide dismutase in taro leaves during the 2022 season was affected by irrigation water levels (50, 75, and 100% of crop water requirement) and foliar spray treatments (proline at 100 & 200 mg L^{-1}, algae extract at 2.5 & 5 ml L^{-1} and potassium silicate at 1000 & 2000 mg L^{-1}), and their interactions.

The data show that there were no significant variations in the impacts of water irrigation levels on catalase, peroxidase, or polyphenol oxidase, but there were significant reductions in the activity of the superoxide dismutase enzyme at 75 and 50%.

Regarding foliar spraying treatments, catalase enzyme activity gave the highest value with proline at 100 mg L^{-1}, meanwhile algae extract at 5 ml L^{-1} and potassium silicate at 1000 and 2000 mg L^{-1} decreased the enzyme activity. Proline at 200 mg L^{-1}, algae extract at 2.5 ml L^{-1} and control recorded in-between values.

For peroxidase enzyme activity, control gave the lowest value, while proline at 100 and 200 mg L^{-1}, algae extract at 2.5 ml L^{-1} significantly increased the enzyme activity values. All other treatments had no significant effects.

There were no significant differences on polyphenol oxidase enzyme activity values with foliar spray treatments.

For superoxide dismutase activity, it was significantly decreased with all anti-stress treatments compared to untreated plants under the three applied irrigation levels.

Different enzyme activity values, such as those of catalase, peroxidase, polyphenol oxidase, and superoxide dismutase, varied in relation to the interaction between various foliar spray treatments and water irrigation levels. When compared to all interaction treatments, the control value under each irrigation level for superoxide dismutase enzyme activity indicates a considerable increase. About the impact of proline **Li *et al.*, (2024)** demonstrated that proline foliar spraying controlled the amount and activity of antioxidant enzymes, thereby mitigating the effects of drought stress. Similar findings regarding the impact of potassium silicate were reported by **Azab *et al.*, (2022)** They found that external applications of potassium silicate at a concentration of 20 g ml significantly increased the antioxidant activities of superoxide dismutase (SOD), catalase (CAT), and peroxidase (POX) under severe drought stress at 50% ET and then 75% ET.

According to **Mansori *et al.*, (2015)**, the seaweed extract markedly increased the catalase (CAT) and superoxide dismutase (SOD) enzyme activity. The antioxidant enzyme activity was highest in stressed green bean plants treated with seaweed extract, which may help prevent peroxidation and lessen the severity of water deficit.

3.4. Effect of anti-stress foliar treatments on yield components of taro plants grown under water irrigation levels

After 240 days of planting during the growing seasons of 2022 and 2023, the productivity characteristics of the taro plant in response to irrigation water levels (50, 75, and 100% of crop water requirements) and foliar spray treatments (proline at 100 and 200 mg L^{-1}, algae extract at 2.5 and 5 ml L^{-1}, and potassium silicate at 1000 and 2000 mg L^{-1}) and their interactions were examined and presented in **Table 6.**

As indicated in **Table 6**, reducing irrigation water to 75% and 50% of plant water requirements led to a decline in total corm yield (fresh weight in kg $plant^{-1}$) and its components, including corm number, main corm diameter and length, and fresh and dry weights. Reductions were generally insignificant at 75% irrigation but became substantial and statistically significant at 50% irrigation. Foliar application with the two assigned concentrations of each proline, algae extract, and potassium silicate on taro plants grown under various irrigation water levels significantly improved total corm yield $plant^{-1}$ and its associated traits compared to untreated plants under each irrigation level. The increases were directly proportional to the concentration of each anti-stressor, with 2000 mg L^{-1} potassium silicate being the most effective, followed by 1000 mg L^{-1}, 5 ml L^{-1} algae extract, and 200 mg L^{-1} proline. The interaction between anti-stressors and irrigation levels was more pronounced under deficit irrigation (WL_2, 75%, and WL_3, 50%) than under full irrigation (WL_1, 100%). This interaction was particularly strong under WL2 (75% irrigation), where potassium silicate at 2000 mg L^{-1}, followed by algae extract at 5 ml L^{-1} and 2.5 ml L^{-1}, proline at 200 mg L^{-1}, and then potassium silicate at 1000 mg L^{-1} effectively mitigated the adverse effects of irrigation water deficit, resulting in a notable increase in total yield and its components compared to control plants irrigated at 100% of water requirements.

Our study showed that water stress at 50% drip irrigation caused the largest reductions in taro yield characteristics compared to plants under 75% drip irrigation and non-stressed plants (100% drip irrigation), aligning with findings by **(Abuzeed *et al.,* 2018 and Abd El-Aal *et al.,* (2019).** Potassium silicate spraying significantly enhanced various productivity and quality traits of taro plants, as reported by **(Abuzeed *et al.,* 2018).**

Water scarcity, exacerbated by the global rise in human population, is a major constraint on crop productivity worldwide **(Moussa and Mohammed, 2011).** This study highlights the potential for cultivating taro under deficit irrigation (75% of its water needs), where it grew and yielded well. Furthermore, using anti-stressors such as potassium silicate, algae extract, and proline can enhance taro growth and yield under deficit irrigation, even surpassing non-stressed plants.

Table 2. Effects of foliar application with the assigned anti-stressors on some vegetative growth parameters of taro plants cultivated under various irrigation levels after 150 days of planting during the 2022 and 2023 seasons.

Treatments	Characteristics	Plant height (cm)		Leaves number		Leaf area (cm^2)		Total early yield (g)		leaves fresh weight (g)		leaves dry weight (g)		Stem fresh weight (g)		Stem dry weight (g)	
	season 2022 and 2023	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
WL_1 (100%)	Control	95	76	7	3	2773	2101	285	107	153	120	38	27	837	436	52	18
	Proline at 100 Mg L^{-1}	99	84	9	4	2588	2695	304	111	208	130	39	32	901	529	54	32
	Proline at 200 Mg L^{-1}	98	80	10	4	2999	2575	421	190	214	175	46	29	1047	742	64	24
	Algae extract at 2.5 ml L^{-1}	101	87	7	3	2851	2873	340	109	198	121	45	32	808	544	57	30
	Algae extract at 5 ml L^{-1}	106	82	10	3	3803	2427	340	116	210	133	50	30	1040	577	66	21
	Potassium silicate at 1000 Mg L^{-1}	101	95	8	4	2906	2719	479	142	214	158	56	31	1011	665	72	29
	Potassium silicate at 2000 Mg L^{-1}	108	99	7	3	3275	2338	397	170	204	178	65	28	841	799	58	37
WL_2 (75%)	Control	86	68	7	3	2431	2330	366	82	166	106	43	26	612	425	42	21
	Proline at 100 Mg L^{-1}	96	78	8	3	3130	2718	431	84	228	127	63	28	732	478	57	22
	Proline at 200 Mg L^{-1}	93	85	9	4	3104	2577	475	102	253	143	49	29	949	568	54	24
	Algae extract at 2.5 ml L^{-1}	144	78	10	3	3272	2061	417	84	207	109	49	30	1055	440	49	31
	Algae extract at 5 ml L^{-1}	101	87	10	4	2789	2904	467	115	212	138	53	32	1184	643	47	26
	Potassium silicate at 1000 Mg L^{-1}	113	85	9	4	3938	2780	488	98	230	138	60	31	1027	526	67	25
	Potassium silicate at 2000 Mg L^{-1}	109	85	14	3	3069	2359	393	89	197	152	45	29	955	613	65	33
WL_3 (50%)	Control	73	72	5	3	1681	2697	287	52	95	80	32	21	391	309	45	16
	Proline at 100 Mg L^{-1}	105	68	6	3	2164	3505	375	59	178	86	42	31	607	324	72	26
	Proline at 200 Mg L^{-1}	89	75	8	3	3130	3493	347	81	202	103	48	27	851	360	52	26
	Algae extract at 2.5 ml L^{-1}	84	72	9	3	2946	2942	535	80	299	128	50	25	796	489	51	20
	Algae extract at 5 ml L^{-1}	91	83	8	3	3131	2797	373	80	200	99	50	26	871	406	51	19
	Potassium silicate at 1000 Mg L^{-1}	97	86	7	3	2841	2942	309	85	278	103	38	25	950	429	68	26
	Potassium silicate at 2000 Mg L^{-1}	112	88	7	3	3901	3552	296	104	160	123	56	27	983	551	65	40
	LSD at 0.05	10.04	5.89	1.9	0.39	612.61	545.72	75.27	7.88	39.65	35.62	7.06	2.60	147.29	127.24	10.36	6.71
Means of irrigation levels	WL_1 (100%)	101	86	8	3	3028	3133	367	135	202	145	52	30	926	613	60	27
	WL_2 (75%)	106	81	10	3	3105	2533	434	94	213	130	48	29	931	458	58	26
	WL_3 (50%)	93	78	7	3	2828	2532	360	77	200	103	45	26	779	410	55	25
	LSD at 0.05	3.80	3.	0.72	0.23	3.92	315.	28.4	14.9	14.9	20.5	2.67	1.50	55.6	82.1	3.91	3.87

			41				08	5	4	9	6			7	5		
Means of foliar treatments	Control	89	72	7	3	2466	2543	334	84	156	105	38	27	675	413	50	22
	Proline at 100 Mg L^{-1}	119	76	7	3	2904	2973	441	85	170	111	57	30	948	421	61	27
	Proline at 200 Mg L^{-1}	93	80	9	3	3077	2882	414	124	223	140	48	28	867	556	57	25
	Algae extract at 2.5 ml L^{-1}	90	79	9	3	2743	2664	431	91	235	119	48	29	739	491	52	23
	Algae extract at 5 ml L^{-1}	100	84	9	3	3241	2709	360	100	207	123	51	27	1032	542	59	23
	Potassium silicate at 1000 Mg L^{-1}	104	88	8	3	3228	2608	367	108	241	133	51	29	963	540	69	27
	Potassium silicate at 2000 Mg L^{-1}	106	91	9	3	3248	2750	362	121	203	151	47	28	926	654	55	37
	LSD at 0.05	5.8	0.15	1.09	0.14	5.98	206.26	43.46	9.78	22.89	13.19	4.08	0.98	85.03	53.78	5.98	2.53

Table 3. Effects of foliar application with utilized anti-stressors on photosynthetic pigments (mgg^{-1} FW) in taro leaves grown under three irrigation levels after 150 days of planting during the 2022 and 2023 seasons.

Treatments	Characteristics	Chlorophyll (a)	Chlorophyll (b)	Carotenoids	Chlorophyll (a)	Chlorophyll (b)	Carotenoids
		season 2022			season 2023		
WL_1 (100%)	Control	0.213	0.057	0.136	0.694	0.011	1.020
	Proline at 100 Mg L^{-1}	0.449	0.111	0.251	1.460	0.150	1.350
	Proline at 200 Mg L^{-1}	0.653	0.055	0.167	1.627	0.253	1.233
	Algae extract at 2.5 ml L^{-1}	0.525	0.168	0.356	1.657	0.517	1.070
	Algae extract at 5 ml L^{-1}	0.606	0.132	0.404	1.700	0.233	1.143
	Potassium silicate at 1000 Mg L^{-1}	0.453	0.141	0.291	1.750	0.437	0.903
	Potassium silicate at 2000 Mg L^{-1}	0.225	0.170	0.443	1.680	0.347	1.120
WL_2 (75%)	Control	0.390	0.008	0.295	1.140	0.020	1.010
	Proline at 100 Mg L^{-1}	0.741	0.276	0.324	1.653	0.250	1.620
	Proline at 200 Mg L^{-1}	1.146	0.197	0.456	1.713	0.353	1.807
	Algae extract at 2.5 ml L^{-1}	0.536	0.085	0.405	1.877	0.657	1.350
	Algae extract at 5 ml L^{-1}	0.715	0.203	0.455	2.040	0.833	1.677
	Potassium silicate at 1000 Mg L^{-1}	0.916	0.265	0.587	2.250	0.587	1.267
	Potassium silicate at 2000 Mg L^{-1}	0.486	0.174	0.695	1.963	0.660	1.163
WL_3 (50%)	Control	0.125	0.064	0.067	1.350	1.057	1.190
	Proline at 100 Mg L^{-1}	0.255	0.235	0.198	1.730	0.333	1.770
	Proline at 200 Mg L^{-1}	0.485	0.121	0.340	1.833	0.643	1.953
	Algae extract at 2.5 ml L^{-1}	0.401	0.155	0.313	1.913	0.943	1.607
	Algae extract at 5 ml L^{-1}	0.301	0.083	0.251	2.063	0.240	1.537
	Potassium silicate at 1000 Mg L^{-1}	0.611	0.155	0.413	2.357	0.680	1.380
	Potassium silicate at 2000 Mg L^{-1}	0.996	0.251	0.640	2.257	1.013	1.590
	LSD	0.004	0.004	0.005	0.110	0.133	0.034
Mean of Irrigation Levels	WL_1 (100%)	0.446	0.119	0.292	1.510	0.278	1.120
	WL_2 (75%)	0.704	0.173	0.459	1.805	0.480	1.413
	WL_3 (50%)	0.453	0.152	0.317	1.929	0.701	1.575
	LSD	0.002	0.002	0.003	0.072	0.087	0.022
Means of foliar treatments	Control	0.243	0.043	0.166	1.061	0.363	1.073
	Proline at 100 Mg L^{-1}	0.482	0.207	0.258	1.614	0.244	1.580
	Proline at 200 Mg L^{-1}	0.761	0.124	0.321	1.724	0.417	1.664
	Algae extract at 2.5 ml L^{-1}	0.487	0.136	0.358	1.816	0.706	1.342
	Algae extract at 5 ml L^{-1}	0.540	0.139	0.370	1.934	0.436	1.452
	Potassium silicate at 1000 Mg L^{-1}	0.660	0.187	0.430	2.119	0.568	1.183
	Potassium silicate at 2000 Mg L^{-1}	0.569	0.198	0.593	1.967	0.673	1.291
	LSD	0.006	0.006	0.008	0.191	0.230	0.059

Table 4. Effect of interaction between irrigation water levels and anti-stress foliar treatments on some bioconstituents of taro leaves at 150 days after planting during season of 2022.

Treatments	Crude protein (mgg^{-1})			Total Carbohydrate %			Total phenolics (mgg $^{-1}$ DW)			Proline (mgg^{-100} DW)		
	WL$_1$(100)	**WL$_2$(75)**	**WL$_3$(50)**	**WL$_1$(100)**	**WL$_2$(75)**	**WL$_3$(50)**	**WL$_1$(100)**	**WL$_2$(75)**	**WL$_3$(50)**	**WL$_1$(100)**	**WL$_2$(75)**	WL$_3$(50)
Control	**7.506**	**8.144**	**6.881**	**57.18**	**47.31**	**36.33**	**0.136**	**0.168**	**0.153**	**25.79**	**31.83**	43.67
Proline at 100 Mg L^{-1}	**8.131**	**8.144**	**6.388**	**65.31**	**55.44**	**39.45**	**0.202**	**0.193**	**0.153**	**26.67**	**18.87**	80.67
Proline at 200 Mg L^{-1}	**7.844**	**8.069**	**7.219**	**62.61**	**53.79**	**39.99**	**0.203**	**0.165**	**0.126**	**12.84**	**8.53**	17.44
Algae extract at 2.5 ml L^{-1}	**8.319**	**7.638**	**6.944**	**67.62**	**48.93**	**46.5**	**0.231**	**0.286**	**0.104**	**23.63**	**20.80**	29.38
Algae extract at 5 ml L^{-1}	**8.844**	**10.644**	**8.163**	**71.82**	**60.18**	**46.35**	**0.305**	**0.271**	**0.173**	**24.59**	**23.78**	11.15
Potassium silicate at 1000 Mg L^{-1}	**12.494**	**8.769**	**8.138**	**65.73**	**54.06**	**47.97**	**0.213**	**0.258**	**0.105**	**9.66**	**25.04**	19.13
Potassium silicate at 2000 Mg L^{-1}	12.181	11.194	8.319	66.54	55.17	36.99	0.263	0.104	0.060	13.98	18.09	13.49

Table 5. Effect of irrigation water levels, foliar treatments and their interactions on the activity of antioxidant enzymes (unit min^{-1} mgg^{-1} protein) of taro plant.

Irrigation levels	Enzymes / Treatments	Catalase	Peroxidase	Polyphenol oxidase	Superoxide dismutase
WL_1(100%)	**Control**	**0.904**	**0.132**	**0.281**	1.027
	Proline at 100 Mg L^{-1}	**1.151**	**0.728**	**0.401**	0.693
	Proline at 200 Mg L^{-1}	**0.777**	**0.804**	**0.463**	0.666
	Algae extract at 2.5 ml L^{-1}	**1.084**	**1.014**	**0.585**	0.707
	Algae extract at 5 ml L^{-1}	**0.901**	**0.582**	**0.560**	0.656
	Potassium silicate at 1000 Mg L^{-1}	**0.894**	**0.445**	**0.354**	0.656
	Potassium silicate at 2000 Mg L^{-1}	**0.671**	**0.400**	**0.501**	0.681
WL_2(75%)	**Control**	**0.862**	**0.208**	**0.540**	1.127
	Proline at 100 Mg L^{-1}	**1.304**	**0.496**	**0.579**	0.715
	Proline at 200 Mg L^{-1}	**0.928**	**0.490**	**0.520**	0.653
	Algae extract at 2.5 ml L^{-1}	**0.911**	**0.560**	**0.577**	0.729
	Algae extract at 5 ml L^{-1}	**0.181**	**0.562**	**0.375**	0.764
	Potassium silicate at 1000 Mg L^{-1}	**0.625**	**0.380**	**0.437**	0.956
	Potassium silicate at 2000 Mg L^{-1}	**0.869**	**0.503**	**0.402**	0.857
WL_3(50%)	**Control**	**1.211**	**0.457**	**0.531**	1.166
	Proline at 100 Mg L^{-1}	**0.969**	**0.548**	**0.617**	0.754
	Proline at 200 Mg L^{-1}	**1.095**	**0.602**	**0.520**	0.676
	Algae extract at 2.5 ml L^{-1}	**0.989**	**0.365**	**0.419**	0.757
	Algae extract at 5 ml L^{-1}	**1.058**	**0.463**	**0.469**	0.695
	Potassium silicate at 1000 Mg L^{-1}	**0.735**	**0.399**	**0.450**	0.983
	Potassium silicate at 2000 Mg L^{-1}	**0.718**	**0.363**	**0.267**	0.884
Mean of Irrigation levels	**WL_1 (100%)**	**0.968**	**0.457**	**0.468**	0.845
	WL_2 (75%)	**0.811**	**0.457**	**0.490**	0.829
	WL_3 (50%)	**0.912**	**0.586**	**0.44**	0.727
LSD at 0.05		**0.178**	**0.185**	**0.123**	0.077
Means of foliar treatments	**Control**	**0.992**	**0.266**	**0.451**	1.107
	Proline at 100 Mg L^{-1}	**1.141**	**0.591**	**0.532**	0.721
	Proline at 200 Mg L^{-1}	**0.933**	**0.632**	**0.501**	0.665
	Algae extract at 2.5 ml L^{-1}	**0.995**	**0.646**	**0.527**	0.731
	Algae extract at 5 ml L^{-1}	**0.713**	**0.536**	**0.468**	0.705
	Potassium silicate at 1000 Mg L^{-1}	**0.751**	**0.408**	**0.414**	0.865
	Potassium silicate at 2000 Mg L^{-1}	**0.753**	**0.422**	**0.390**	0.807
LSD at 0.05		0.272	0.282	0.188	0.117

Table 6: Effect of irrigation water levels, foliar treatments and their interactions on the productivity characteristics of taro plant during seasons of 2022 and 2023.

Treatments	Characteristics	Corms FW (kg) plant^{-1}		Main corm diameter (cm)		Main corm length (cm)		Corms No. plant^{-1}		Main corm fresh weight (g)		Main corm dry weight (g)		Dry weight of corms plant^{-1}	
Season (2022) and (2023)		1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
WL1 (100%)	Control	825	859	30	31	34	13	2	3	540	634	126	112	430	294
	Proline at 100 Mg L^{-1}	900	1069	31	34	37	14	3	4	548	832	152	146	464	380
	Proline at 200 Mg L^{-1}	1357	1345	35	33	40	14	6	4	904	636	212	122	636	568
	Algae extract at 2.5 ml L^{-1}	1003	1230	32	34	36	14	4	4	588	756	146	130	480	422
	Algae extract at 5 ml L^{-1}	1018	896	33	33	39	14	4	3	650	738	158	126	494	302
	Potassium silicate at 1000 Mg L^{-1}	2007	1156	39	35	45	15	6	6	1024	650	248	148	972	584
	Potassium silicate at 2000 Mg L^{-1}	2542	1313	42	34	48	14	5	6	1366	828	270	142	1004	456
WL2 (75%	Control	500	722	27	30	29	13	3	3	306	622	136	114	314	268
	Proline at 100 Mg L^{-1}	707	981	29	32	35	14	4	4	490	720	160	128	392	352
	Proline at 200 Mg L^{-1}	1459	943	36	32	42	15	5	5	952	668	206	122	632	346
	Algae extract at 2.5 ml L^{-1}	1604	945	37	32	44	14	4	3	974	748	96	132	526	334
	Algae extract at 5 ml L^{-1}	1638	1083	38	32	43	14	4	5	976	658	246	114	826	378
	Potassium silicate at 1000 Mg L^{-1}	1021	1126	33	32	36	13	4	4	612	672	144	116	480	390
	Potassium silicate at 2000 Mg L^{-1}	1502	1123	36	35	39	14	3	6	780	850	158	142	608	378
WL3 (50%	Control	520	436	27	27	31	11	3	2	422	236	118	63	290	150
	Proline at 100 Mg L^{-1}	1234	451	35	30	38	13	4	2	880	274	200	71	560	164
	Proline at 200 Mg L^{-1}	933	445	32	31	37	13	3	2	604	305	150	81	434	160
	Algae extract at 2.5 ml L^{-1}	1489	512	37	37	42	16	5	2	852	494	192	117	672	158
	Algae extract at 5 ml L^{-1}	807	591	29	36	32	15	4	2	492	375	132	108	464	230
	Potassium silicate at 1000 Mg L^{-1}	1384	628	35	29	40	12	4	2	824	350	196	77	658	192
	Potassium silicate at 2000 Mg L^{-1}	1296	579	36	33	41	14	5	2	788	359	154	102	506	222
	LSD at 0.05	310.24	151.66	2.53	2.85	3.75	1.52	1.09	0.78	95.29	82.47	20.10	15.41	74.60	46.61
Irrigation Levels	WL1 (100%)	1379	1124	35	33	48	14	4	4	804	724	188	132	644	430
	WL2 (75%)	1204	989	34	32	41	14	4	4	728	706	164	124	542	350
	WL3 (50%)	1095	520	33	32	39	13	4	2	694	684	162	118	512	182
	LSD at 0.05	117.26	87.56	0.96	1.65	1.42	0.85	0.41	0.45	36.02	47.61	7.60	8.90	46.40	26.91
Mean of Treatment	Control	922	677	32	31	36	13	3	3	582	634	152	112	470	244
	Proline at 100 Mg L^{-1}	1146	829	33	32	39	14	4	3	636	642	162	114	490	294
	Proline at 200 Mg L^{-1}	1112	911	33	32	38	14	5	4	760	638	178	118	520	358
	Algae extract at 2.5 ml L^{-1}	997	896	32	34	36	14	4	3	710	830	138	138	472	304
	Algae extract at 5 ml L^{-1}	1154	857	33	34	38	14	4	3	706	716	178	128	582	300
	Potassium silicate at 1000 Mg L^{-1}	1470	970	36	31	40	13	5	3	820	674	196	122	702	388
	Potassium silicate at 2000 Mg L^{-1}	1780	1005	38	34	43	14	5	5	978	798	194	140	706	352
	LSD at 0.05	179.115	57.32	1.46	1.075	2.165	0.575	0.63	0.295	55.015	31.17	11.6	5.825	61.14	17.615

3.5.Chemical compositions of taro corms:

The information in **Table (7)** displays the amount of crude protein, total carbs, and total sugars in taro corms during harvest, which occurs 240 days after planting. According to the data, potassium silicate at 1000 mg L^{-1} with WL_1 (100) and potassium silicate at 2000 mg L^{-1} with WL_2 (75%) were the next highest values, followed by algal extract at 5 ml L^{-1} with WL_2 (75% of crop water requirements).

According to **Yassen *et al.*, (2018)**, foliar spraying with algae extract considerably raised the amounts and uptake of iron, zinc, copper, phosphorus, potassium, and nitrogen in Allium plants.

El-Sharkawy *et al.*, (2019) found that foliar spraying seaweed extract at 0, 5, and 10 mlL^{-1} significantly increased the contents of nitrogen, protein, phosphorus, and potassium (%) on pea plants (*Pisum Sativum* L.). These results are also in line with their findings.

The results obtained are consistent with those published by **Badr *et al.*, (2019**) and **Saif El-Deen *et al.*, (2014).** According to **Abu El-Azm and Youssef (2015),** when tomato plants were sprayed with potassium silicate, the percentages of potassium and nitrogen improved significantly when compared to the control plant.

According to **Yaghubi *et al.*, (2016),** the strawberry plant's carbohydrate content rose with additional silicon.

Also, our findings align with those reported by **Urmi *et al.*, (2023) and Hadid *et al.*, (2023).**

Table 7. Effect of interaction between irrigation water levels and foliar treatments on crude protein, total carbohydrates and total sugars content (%) of taro corms

Treatments	Characteristics	Crude protein%	Corm total carbohydrate %	Corm total sugars %
WL_1 (100%)	Control	9.369	46.08	6.42
	Potassium silicate at 1000 Mg L^{-1}	12.494	52.45	8.75
	Potassium silicate at 2000 Mg L^{-1}	11.363	53.80	8.27
WL_2 (75%)	Control	8.719	37.40	6.38
	Algae extract at 5 ml L^{-1}	11.981	54.84	9.39
	Potassium silicate at 2000 Mg L^{-1}	11.281	39.93	8.94
WL_3 (50%)	Control	7.913	34.06	5.23
	Algae extract at 2.5 ml L^{-1}	8.113	36.23	6.94
	Potassium silicate at 1000 Mg L^{-1}	8.206	35.60	6.98

Conclusion

According to the results, foliar spraying with potassium silicate at 2000 mg L^{-1} and algal extract at 5 ml L^{-1} is advised, especially at the 75% irrigation level, to strike the optimal balance between improved taro plant yield and quality and water use efficiency.

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