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Enhanced Growth and Yield Parameters of Tomato (*Solanum lycopersicum* L.) var. peto 111 Plant Using *Cladophoropsis gerloffii* Aqueous Extract Foliar

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Abstract

Unlike chemical fertilizers, extracts of seaweeds are biodegradable, non-toxic, nonpolluting, and nonhazardous and safe to the living organisms. Seaweeds contain novel secondary metabolites and it have potential applications in different areas. To improve the germination rate, growth, and productivity of Tomato (*Solanum lycopersicum* L.) var. peto 111, the effects of different concentrations of *Cladophoropsis gerloffii* aqueous extract were investigated. Seeds were soaked with *C. gerloffii* aqueous extract at different concentrations, namely 0, 0.025, 0.05, 0.075, and 0.1 g/100 mL, and growth rate in percentage was evaluated after one week of treatment. The Seedling plant were treated with seaweed extracts in the form of foliar spray. The greatest germination rate (100%) was shown at 0.1 g/100 ml. The foliar spray of seaweed increased tomato yield, and improved fruit quality. The extract of the green alga, *C. gerloffii*, was concluded to be suitable for application on tomato plants to increase their growth percentage, vegetative growth and yield.

Keywords: *Seaweeds; Cladophoropsis gerloffii; Solanum lycopersicum; Foliar Spray; Vegetative Growth and Yield*

Abbreviation

C. gerloffii: Cladophoropsis gerloffii

Introduction

Because of their excessive utilization for enhancing plant yield, pesticides and fungicides pose genuine risk to the treated plant and the environment, as well. Therefore, an options approach to the enhancement of tomato productivity without causing damage to the ecosystem is advocated. Unlike chemical fertilizers, extracts of seaweeds are biodegradable, non-toxic, nonpolluting, and nonhazardous and safe to the living organisms. Seaweed extracts are used to enhance the quality and quantity of harvest in the field of agriculture. The beneficial effect of seaweed extract application results from many components possibly working synergistically at different concentrations despite the way of their activity are is still unknown [1]. Seaweeds Liquid extracts recently, used as foliar sprays for several crops plants [2]. Seaweed foliar sprays are cost-effective, and have longer lives than chemical fertilizers, as well [3]. They are easy to apply, and have been observed to be highly effective in improving the growth and yield of tomato. The influence is explained by the content of plant growth- promoting hormones, such as cytokinins, auxins, gibberellins, and abscisic acid [4,5] in addition to its content of trace elements (Fe, Cu, Zn, Co, Mo, Mn, and Ni), vitamins, and amino acids [6].

Objective of the Study

The main objective of this study was to evaluate the effects of the application of seaweed extract at different concentrations on the enhancement of germination percentage, plant growth, and fruit yield and quality of tomato cultivated under greenhouse conditions.

Materials and Methods

Seeds preparation and estimation of germination percentage

Pots Experiment of Tomato, (*Solanum lycopersicum* L.) var. peto 111, was conducted during 2017 seasons in greenhouse at Misurata University. The experiment was designed as a randomized complete block (RCB) with three replicates.

Tomato seeds (peto 111) were obtained from the seed collection center of the Market Centre, Misurata, Libya, and sown in November under laboratory conditions. The tomato seeds were surface-sterilized with 0.1% mercuric chloride for one minute, and washed thoroughly with sterilized distilled water. Germination analysis was performed according to [7] there were three replicates of 5 seeds in each treatment. Five seeds per Petri-dish placed on top of two layers Whatman No. 1 filter paper, moistened using *Cladophoropsis gerloffii* aqueous extract at concentrations of 0, 0.025, 0.05, 0.075 and 0.1 g/100ml. The treated seeds were placed in an incubator at 25°C. Germination count was performed every day for 10 days. Germination was considered to have occurred when the radical length exceeded two millimeters [8]. Germination percentage was counted using method of Alalwani., *et al* [9].

Cultivation practices

- **Seedling transplant to greenhouse:** Seedlings, 11-day old, were transplanted into pots contain 79g of peat moss. Foliar spraying was performed twice (11 days after germination) with the aqueous *Cladophoropsis gerloffii* extract at different concentrations, namely 0.025, 0.05, 0.075, and 0.1 g/100 ml. The control plant was sprayed with tap water. The experimental unit was one plant per pot. Transplanted seedlings were allowed to grow under controlled conditions (19°C ± 2). Four replicates per treatment were used. After one month, the plants were transplanted into large pots containing 770g of peat moss. Foliar spraying was performed until fruits were completely harvested from the plants.
- **Preparation of aqueous *Cladophoropsis gerloffii* extract:** *Cladophoropsis gerloffii* was collected from Ganat Sea, Misutate city, Libya during February, March, and April, 2015 - 2016. The collected seaweed was initially washed with seawater to remove macroscopic epiphytes and sand particles, and any unwanted impurities, and any unwanted impurities. Samples of seaweed dried for two days at 40°C, then powdered using with electric grinder. Seaweed powder, 5g, was mixed with 100 ml of distilled water in a Soxhlet extractor at 80°C for 4h. Various concentrations of *C. gerloffii* aqueous extract (0.025, 0.05 and 0.1 w/v) were prepared by dilution from the stock solutions in distilled.
- **Determination of pH and total dissolved salt (TDS) of aqueous *C. gerloffii* extract:** The pH of the aqueous *C. gerloffii* extract measured by Jenway 3505 pH meter. TDS was calculated according to equation of Alalwani., *et al* (2012). The conductivity of the aqueous extract was measured using Conductivity Meter, model 470.
- Data recorded and analyzed.

Growth parameters

Randomly three tomato plants were selected from each plot after 6 months after transplantation for evaluating the growth parameters of the plants, including plant height (cm), number of leaves/plant, and leaf area (cm^2).

Fruit and yield characteristics

At each picking time, a representative sample of three fruits was selected for evaluating the following parameters: fruit length (cm), fruit diameter (cm), and fruit pH.

Yield and its components

Fruits on each plant were harvested at the full-ripe (maturity) stage, and then, counted and weighed; the following measures were calculated: number of fruits/plant, fruit weight, individual plant yield, and total yield/experimental unit. Early fruit-set time and the time of complete fruit maturity were recorded.

Statistical analysis

All results were statistically analyzed using a one way analysis of variance where $P < 0.05$ [10].

Results and Discussion

Germination percentage

The germination percentage of the tomato seeds treated with 0.1 g/100 ml aqueous *C. gerloffii* extract showed a higher significant increase ($P = 0.001$) compared with the control (Table 1).

Parameter	Aqueous C. gerloffii extract	Mean	Standard error	One-way ANOVA	LSD test	Significance
Germination percentage	0	68.3	1.8	0.049	-	-
	0.025	73.3	1.6		0.78	Insignificant
	0.05	66.9	1.3		0.41	Insignificant
	0.075	73.5	1.6		0.78	Insignificant
	0.1	100	1.03		0.001***	Highly significant

***Table 1**: Germination percentage of tomato seeds treated with aqueous C. gerloffii extract at different concentrations.*

Seaweed extracts have a benefit effect on plants, for instance, promoting seed germination, early seed germination, enhanced yield and resistance in several crops [11-15]. The aqueous extract of *C. gerloffii* was observed to promote seed germination by up to 0.1%. The same result was reported by [16], who clarified that an extract of green algae increased germination percentage in the analyzed plants. Results presented in this study showed that concentrated *C. gerloffii* extract found to be more efficient than the diluted extracts in promoting seed germination. The effect of seaweed on germination percentage may be either due to high levels of moisture around seeds after drying as proposed by [17], or leakage of inhibitors, such as abscisic acid from the seeds [18]. Blunden [19] and Jeannin., *et al.* [20] illustrated that the value of seaweed extracts as biofertilizers was due to the presence of macro and micro elements, and growth regulators, such as cytokinins, gibberellins, and auxins; amino acids and vitamins. Thus, seaweed extract when irrigated to seed, stimulate seed germination.

Vegetative growth

Data on the morphological characters of tomato cv. peto 111 as affected by the foliar application of seaweed extract at different concentrations are presented in table 2. The investigated morphological parameters included plant height (cm), leaf area (cm^2), compound leaves developed/plant, and stem diameter.

Parameter	Concentration	Mean	Standard error	One-way ANOVA test	LSD	Significance
Total length (cm)	0.000	94.33	1.88	0.589 Insignificant	-	-
	0.025	91.33	1.15		0.839	Insignificant
	0.050	83.33	0.88		0.462	Insignificant
	0.075	74.33	0.41		0.194	Insignificant
	0.100	94.66	0.62		0.982	Insignificant
Stem diameter	0.000	09.52	0.24	0.094 Insignificant	-	-
	0.025	09.35	0.27		0.777	Insignificant
	0.050	10.26	0.27		0.245	Insignificant
	0.075	10.76	0.33		0.066	Insignificant
	0.100	10.86	0.29		0.049	Insignificant
Leaf area (cm^2)	0.000	231.00	1.66	0.026 significant	-	Insignificant
	0.025	169.00	1.73		0.055	Insignificant
	0.050	215.00	2.05		0.092	Insignificant
	0.075	150.00	0.67		0.050	Significant
	0.100	173.00	1.94		0.029	Significant
Leaf number	0.000	35.00	1.20	0.030 significant	-	-
	0.025	62.00	0.77		0.015	Significant
	0.050	53.00	1.45		0.052	Significant
	0.075	51.00	0.95		0.053	Significant
	0.100	69.00	1.02		0.003	Highly significant

***Table 2:** Morphological characteristics of tomato cv. peto 111, aged 160 days, as affected by the foliar application of seaweed extract at different concentrations.*

Data presented in table 2 showed that most vegetative characters of the tomato plants were significantly affected by the foliar spray of *C. gerloffii* extract at a different concentration, compared with the control. Treatment with the extract at 0.1% resulted in the development of plants with the highest leaf number, and the largest leaf area and stem diameter, followed by treatment with the extract at 0.075%, which resulted in significant increase in the area and number of the leaves. Treatment with the *C. gerloffii* extract at low concentrations (0.025% and 0.05%) resulted in a significant increase only in leaf number. The control plants had the lowest values for all parameters. The stimulation of plant growth by the extract of the green alga, *C. gerloffii* may due to its components, such as macro- and microelements, amino acids, vitamins, cytokinins, auxins, and abscisic acid (ABA). These growth regulators affect cell metabolism in treated plants, resulting in enhanced growth [21-23]. As mentioned previously, the treatment of tomato with the foliar spray of *C. gerloffii* extract at 0.1% and 0.075%, stimulated plant growth, while that at other concentrations (0.025% and 0.05%) did not. Crouch and van Staden [4] proposed that seaweed extracts at low concentrations function as bioactive substances. Therefore, in this study, the suitable concentrations of the *C. gerloffii* extract promoting plant growth were 0.1% and 0.075%. At these concentrations, the extract may contain many nutrients acting synergistically to enhance tomato growth through hitherto unknown mechanisms [24,25].

Yield characters

Early fruit set and ripening

Treatment of the plants with the aqueous *C. gerloffii* extract at different concentrations promoted early fruit set. Tomato fruits were set after 13 weeks of seed sowing, whereas the control plants began to develop fruits after 14 weeks. Fruit ripening in the plants treated with 0.1% *C. gerloffii* extract began at 16 weeks of seed sowing, while the plants treated with 0.025%, 0.05%, and 0.075% extracts, began developing fruits at the same time as the control plants, after 16 weeks of seed sowing (Table 3). Thus, tomato fruit ripening began one week earlier in the plants treated with 0.1% extract than the control plants, suggesting that the aqueous *C. gerloffii* extract may contain higher amounts of nutrients, such as K, Ca, Mg, and S; these elements may enhance plant growth and photosynthetic efficiency, enhancing flowering and fruiting, and resulting in increased early fruit [26]. A study by Ramya., *et al.* [27] similarly reported that spraying plants with seaweed extracts at low concentrations promotes plant growth, and triggers early flowering and fruiting, as well.

	Control plant	Plants treated with aqueous C. gerloffii extract
Time of early fruit set	Fourteen weeks	Thirteen weeks (all plant treated with extract at different concentrations)
Time of early fruit ripening	Sixteen weeks	Fifteen weeks for plants treated with 0.1% extract. Sixteen weeks for plants treated with extract at 0.025%, 0.05%, and 0.075%

Table 3: *Effect of C. gerloffii extract on time of formation and ripening of fruit.*

Yield characteristics and fruit quality of tomato

The mean values of the yield parameters of tomato cv. peto 111, as affected by the foliar application of the seaweed extract at different concentrations are provided in figure 1 and table 4. The investigated parameters included number of pods/plant, number of seeds/plant, weight of 100 seeds (g), and yield of seeds (g)/plant.

Yield parameters	Control	Concentration of aqueous C. gerloffii extract (%)			
Concentration	0	0.1	0.075	0.05	0.025
Fruit number	15	**26	**27	*21	*21
Fruit Size	31	31	*40	31	38
Fruit weight (g)	47	*72	52	59	52
pH	5.77	5.75	5.77	5.74	5.74

Table 4: *Yield parameters and fruit quality of tomato treated with aqueous C. gerloffii extract at different concentrations.*

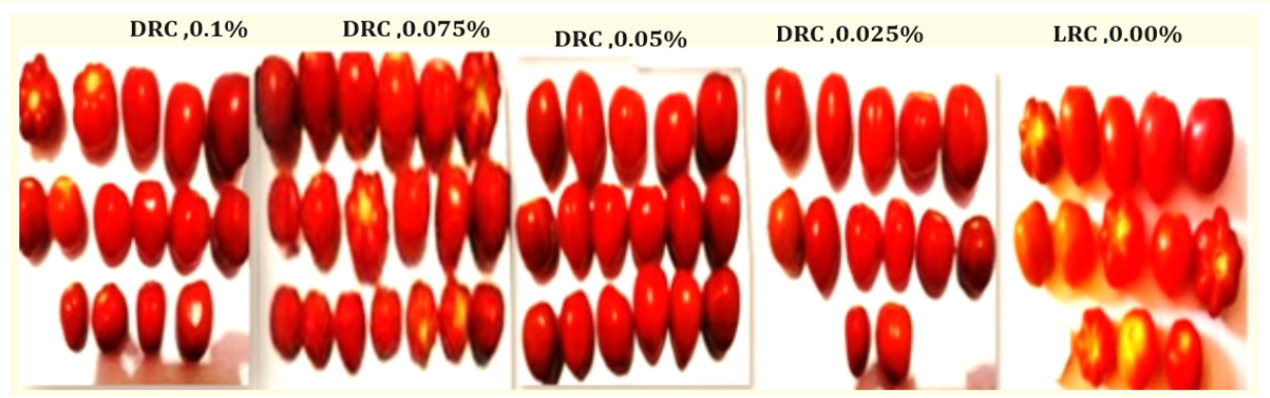

Figure 1: *Yield parameters and fruit quality of tomato treated with aqueous C. gerloffii extract at different concentrations. Light Red Color (LRC), Dark Red Color (DRC).*

Fruit number

Foliar spray of the *C. gerloffii* extract significantly enhanced the number of fruits per plant. The highest number of fruits was produced by the tomato plants treated with the extract at 0.075% and 0.1%. However, the control plants produced fewer fruits [28]. Regarding the tomato plants treated with the seaweed extract at low concentrations (0.025% and 0.05%), a significant difference was observed in fruit number per plant between the treated and control tomato plants.

Fruit Size

Regarding fruit size, only the tomato plants treated with the 0.075% aqueous *C. gerloffii* extract showed significant increase, while the tomato plants treated with the aqueous *C. gerloffii* extract at the other concentrations (0.025%, 0.05%, and 0.1%) showed insignificant differences in fruit size compared with the control plants.

Fruit weight

The tomato plants treated with the aqueous *C. gerloffii* extract at different concentrations showed increases in their fruit weights, and the highest weight (72g) was exhibited by the fruit of a plant treated with the seaweed extract at 0.1%.

pH of tomato fruit

This parameter was measured in both treated and untreated plants. The results of the study showed that the pH of the fruits of the treated plants did not change, compared with the control. Generally, the fruits of the treated plant showed improvements, especially in color. The fruits of the tomato plants treated with the *C. gerloffii* extract at different concentrations were dark red, which may indicate increased lycopene concentrations and improved fruit quality in the treated plants. The foliar spray with the aqueous seaweed extract enhanced the yield parameters, such as the weight, size and number of fruits in the tomato plants. A large increase in the number and weight of fruits was exhibited upon application of 0.1% *C. gerloffii* extract. The increase in fruit weight in the tomato plants sprayed with the seaweed extract may reflect its role in enhancing the number and area of leaves, total plant length, and stem diameter; therefore, improvement of plant-growth parameters may be a reason for increased fruit weight [28]. Additionally, the yield increase may be due to

cytokinins, as reported by [29]. Cytokinins play different roles during plant development. During the productive stage, they are related to nutrient partitioning, whereas, during the vegetative stage, cytokinins could be related to nutrient mobilization, and responsible for fruit ripening, which generally causes an increase in the transport of nutrient resources, as well [30]. Noodén and Leopold [31] supposed that photosynthetic products could be distributed, perhaps markedly, from vegetative parts (roots, stem, and young leaves) to the developing fruits, to be utilized in fruit development. Abd El Moniem [32] similarly reported that seaweed extracts contain macro- and micronutrients, and organic substances, such as amino acids, which improve nutritional quality, vegetative growth, and yield quality.

Conclusion

The results of this study demonstrated that the foliar spray of aqueous *Cladophoropsis gerloffii* extract enhanced the growth and yield parameters of tomato plant. Furthermore, it improved fruit quality. This study demonstrated that the optimum concentration of the aqueous *Cladophoropsis gerloffii* extract was 0.1%. At this concentration, the extract exerted desirable effects on growth parameters, productivity, and fruit quality, suggesting that aqueous *Cladophoropsis gerloffii* extract can serve as a fertilizer, and additionally, an ecofriendly approach to organic farming.

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