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Effect of seaweed extract on the growth and yield of radish cultivars (*Raphanus sativus* L.)

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ABSTRACT

A field research was carried out to study the effect of foliar applied seaweed extract on the growth and yield of radish cultivars. Research was conducted at horticulture research farm, the university of Agriculture, Peshawar, in winter during radish growing season, 2021. Experiment was laid out in Randomized Complete Block Design (RCBD) with split plot arrangement having two factors and three replications. Two factors included levels of seaweed extract (0, 5 mlL^{-1}, 10 mlL^{-1} and 15 mlL^{-1}) in main plot and radish cultivars (Mino early, green neck, red long and forty days) in subplot were studied. Analysis of variance revealed that foliar application of seaweed extract significantly affected growth and yield attributes of radish cultivars while their interaction was observed non-significant for all the studied parameters. Maximum vegetative growth and the highest root yield were observed for radish crop when 15 mlL^{-1} of seaweed extract was sprayed on plants. However, most of the growth and yield attributes at 15 mlL^{-1} were at par with those recorded at 10 mlL^{-1} of seaweed extract. Radish plants sprayed with 15 mlL^{-1} of seaweed extract produced the highest number of leaves $plant^{-1}$ (15.93), leaf length (37.71 cm), leaf area (301.67 cm^2), leaf chlorophyll content (37.7 SPAD), root length (39.41 cm), root diameter (6.20 cm), root weight (465.34 g), TSS (6.350 Brix) root moisture content (95.16%) and root yield (29.98 tons ha^{-1}). Seaweed extracts application also reduced days to harvest. Minimum days to harvest (51.44 days) were observed at 15 mlL^{-1} of seaweed extract. All attributes, however, were observed inferior for the crop of radish in the control plots. Among radish cultivars, maximum number of leaves $plant^{-1}$ (15.60), leaf area (298.05 cm^2), leaf chlorophyll content (37.7 SPAD), root length (38.01 cm), root diameter (5.93 mm), root weight (462.47 g), root moisture content (96.10%) and root yield (29.55 tons ha^{-1}) were recorded for cultivar Mino early which were at par with those recorded for green neck and red long while maximum TSS (6.300 Brix) was recorded for cultivar red long. Cultivar, forty days took minimum days to harvest (47.23 days) among all other studied cultivars of radish. Considering the stimulatory effects of seaweed extract on plant growth, yield and high benefit cost ratio, 15 mlL^{-1} of seaweed extract as a natural plant growth stimulant could be sprayed to improve vegetative growth and root yield of radish crop. Further, radish cultivar Mino early, is recommended for obtaining high yields and maximum profit under the agro climatic conditions of Peshawar.

Keywords: Growth; Radish cultivars; Seaweed extract; Yield; Radish growing season

Introduction

Radish (*Raphanus sativus* L.) is an annual and cool-season root vegetable crop belongs to *Brassicaceae* family. The genus has originated in Central and Western China and in the Indo-Pakistan subcontinent. It is a root vegetable grown and consumed all over the world and is considered part of human diet. Radish has also been used in naturopathic medicine as a laxative, stimulant and digestive aid, as well as in the treatment of stomach disorders. Red radish cultivars are potential source of natural colorants due to the presence of anthocyanin's. Anthocyanin's

have well-known health benefits, including the ability to scavenge free radicals, inhibit cancer and diabetes, prevent neuronal and cardiovascular diseases and suppress inflammation. The red color of root skin is due to the presence of anthocyanin pigment. Root contains an adequate amount of vitamin C, glucosinolates, sulforaphane, polyphenolic compounds, sulfur, calcium, potassium and phosphorus. Vegetables belong to *Brassicaceae* family have been connected with valuable health benefits effects [1].

Radish is a favorite crop for kitchen gardening, because it is ready for use in three to six weeks after sowing. It is grown for its fleshy edible roots, which are eaten as salad in raw from or cooked as a vegetable. Its leaves are cooked as leafy vegetables in different forms and are very rich in minerals and vitamins A and C. Radish has a cooling effect, prevents constipation, increases appetite and is tasty. Radish contains mostly protein, sugar, vitamin C and other important nutrients. It is recommended to patients suffering from piles, liver trouble, enlarged spleen and jaundice [2].

Radish can be grown on all soil types, but grows well in light and moist soils. As compared to other countries, production of radish is lower in Pakistan. Average yield of radish decreases yearly, as the production of radish in Pakistan was 160582 tons in 2015-2016 which reduced to 157648 tons in 2018-19. Khyber Pakhtunkhwa (KP) shares its production of 12463 tons with cultivated area of 1051 hectares. Radishes have different skin colors but mostly white pulp. Major Asian radish has a white thick root and is called East Asian big long radish, white radish or daikon whereas European small radish is commonly called radish. Root surface of some landraces in Asia are red although the red part develops from a hypocotyl. There are also purple, green, and black colors on the root surface in other landraces. Some cultivars of China are red or green inside the roots. Young plants removed by thinning are used as a leafy vegetable [3].

Various parts of radish plant including roots, seeds and leaves have been used for medicinal purposes. In Unani medicine, radish is used as a household remedy for the treatment of many diseases such as jaundice, gallstone, liver diseases, rectal prolapse, indigestion and other gastric pains. Radish contains unique bioactive compounds that have potential health benefits to humans. Main bioactive compounds in radish are gluco and isothiocyanates (sulforaphene and indole-3-carbinol). Dry matter content of radish affects quality for processing. Crude fiber of radish plays an important role in human health by decreasing the risks of constipation and diabetes. Radish is a good source of ascorbic acid which has been shown to have major role in curing asthma because of its anti-inflammatory properties [4].

Seaweed extracts are derived from marine brown algae and marketed for use in agriculture and horticulture. In Europe and North America, the most commonly utilized alga is Ascophyllum nodosum. Seaweed extract is applied on different crops for improving growth and yields due to the presence of organic matter, micronutrients, vitamins and growth regulators such as auxins, cytokinens and gibberellins. Seaweeds do not only remediate soils but also serve as bio-fertilizers and bio-stimulants for both soils and plants. Seaweed is biodegradable, non-polluting, non-toxic and non-hazardous to humans and other animals including birds [5].

Seaweeds have plant growth hormones (auxins and cytokinens) which promote the growth and development of plants. Plant growth regulators in seaweed are present in very small quantities. However, auxins in seaweed extract stimulate the development of roots and buds. While cytokinins help in plant growth. When it is applied as foliar spray, leaves rejuvenate which stimulate photosynthesis. Seaweed extract, therefore, results in higher yields.

Brown seaweeds are good organic fertilizers but the cost of collection, drying and transportation restrict their widespread use. Major biologically active compounds of seaweed extract are plant growth regulators such as auxins and cytokinins. Moreover, minerals, carbohydrates and antibiotics are also active ingredients of seaweed extract. An aspect worth considering is that seaweed extract is a rich source of cytokinin which improves resistance of plants to diseases [6].

More than 15 million metric tons of seaweed products are used annually as nutrient supplements and biostimulants in agriculture and horticultural crop production. Further, a variety of seaweeds are used as soil conditioners to improve organic matter and preserve moisture and mineral content of soil. Seaweed extract plays major role for boosting tolerance in plants against extremes of temperature, salt and other environmental factors. It has positive effects on root growth when applied to the rhizosphere or as a foliar spray. In agriculture seaweed extracts are used for improving soil properties, plant growth and crop yield. Seaweed extracts because early seed germination and establishment, improve yield and resistance to biotic and abiotic stresses. Stimulatory effects of seaweed extract were found to be

more pronounced when applied at the early stage of plant growth [7].

Keeping in view the importance of seaweed extract in vegetable production, the present research was conducted with the following objectives:

- To find out the optimum dose of seaweed extract for the growth and yield of radish cultivars.
- To identify the best cultivar of radish for the agro-climatic conditions of Peshawar.
- To find out whether there is any interaction between seaweed extract and radish cultivars for growth and yield attributes of radish.

Materials and Methods

A research entitled "effect of seaweed extract on the growth and yield of radish cultivars (Raphanus sativas) was conducted at horticultural research farm, the university of agriculture, Peshawar during November, 2021 Jan, 2022. The details of the experiment are given below:

Experimental design

Experiment was conducted in a Randomized Complete Block Design (RCBD) with split plot arrangement having two factors and three replications. There were four main plots in each replication and four subplots (ridges) in every main plot. Experimental field was divided into twelve main plots. Number of plants per treatment were eight. Total number of treatments were forty-eight in the experimental field. Total number of plants were three hundred and eighty-four. Levels of seaweed extract was assigned to main plots while radish cultivars were allocated to sub-plots [8].

Factors

Two factors were used in the experiment, which are as under;

FACTOR A (Main plot):

Levels of seaweed extract (mlL^{-1})

S1=0

S2=5

S3=10

S4=15

FACTOR B (Subplots):

Radish cultivars

V1=Minoe

V2=Green neck

V3=Red long

V4=Forty days

Soil analysis: Before sowing, of three samples were collected randomly from the field of experimental site by using auger at two depths *i.e.* 0 cm -10 cm and 10 cm-20 cm for soil analysis. Sample were packed in polythene bags, labeled and analyzed for soil texture, Electrical Conductivity (EC), pH, lime, Nitrogen (N), Phosphorus (P), Potassium (K) and Organic Matter content (OM). Soil analysis was performed at the soil science laboratory, department of soil sciences, the university of Agriculture Peshawar [9].

Preparation of seaweed extract for foliar spray: Seaweed extract was obtained from the market in stock solution form with the composition of 600 g of seaweed (Ascophyllum nodosum) dissolved in 1L of water. For the preparation of foliar spray of seaweed extract 5 ml, 10 ml, 15 ml of seaweed extract were taken and each was dissolved in one litter of distilled water.

Seaweed extract is mainly made by collecting seaweed material from coastal regions. Sample are collected in netted baskets for the drainage of seawater and brought to the laboratory where seaweed is washed with fresh water in order to remove the sand and other contaminations. In the laboratory seaweed are air dried, grind with electric grinder to homogenous powder. The powder is mixed with one liter of water to prepare solutions of different concentrations [10].

Field preparation: Before sowing seeds of radish cultivars *i.e.* Mino early, green neck, red long and forty days, soil was properly prepared and all debris were removed. Recommended dose of nitrogen was used at 60 $Kgha^{-1}$ with phosphorus and potassium each at 75 Kg ha^{-1}. Full dose of phosphorus and potassium and half dose of nitrogen were used as basal dose at the time of field preparation, in the form of di-ammonium phosphate and potassium sulphate, respectively. While, remaining half dose of nitrogen was applied after one month of seed sowing. Seeds were sown on prepared ridges in rows spaced 30 cm apart, keeping 15 cm distance between plants. All cultural practices were performed uniformly from germination till harvest of the crop as and when required. Plot area for each treatment (sub-plot area) was 0.813 m^2.

Application of seaweed extracts: Radish plants were sprayed twice by seaweed extract at the rates of 5 ml L^{-1}, 10 ml L^{-1} and 15 ml L^{-1}. Plants were sprayed 20 days after germination and then spray was repeated 10 days after the first application. A few drops of detergent as a surfactant agent was added to the spraying solutions of seaweed extract, all applications were done early in the morning using hand sprayer and covering the whole plant with spraying solution (Table 1).

Table 1: Variables and their values.

Variable	N (%)	P (mg kg^{-1})	K (mg kg^{-1})	OM (%)	EC (dms^{-1})
Values	0.037	8	146	0.75	0.2

Studied parameters: A sample of 5 radish plants from each sub-plot was randomly selected. Plants were uprooted carefully from the soil to avoid damage to the root. Excess soil around the roots was carefully removed by washing with plenty of water. After that harvested plants were used to measure vegetative and yield attributes. Then data were recorded using selected plants on the following parameters.

Number of leaves $plant^{-1}$: Number of leaves plant-1 was recorded by counting leaves per plant from five selected plants in each sub plot and their average was calculated.

Length of leaf (cm): Leaf length was measured through measuring tape for each treatment of all replications and mean leaf length was recorded.

Leaf area $plant^{-1}$ (cm^2): Leaf area plant-1 of each treatment of all replication was calculated through leaf area meter and their average was recorded.

Leaf chlorophyll content (SPAD): For chlorophyll content, total chlorophyll was determined through SPAD meter by collecting leaf samples from five randomly selected plants in each sub plot and average was calculated.

Root length (cm): Length of radish root collected from randomly selected five plants in each sub plot was measured with the help of measuring tape and their average was calculated.

Root diameter (cm): Diameter of each radish root was measured at the upper, middle and lower portion of root collected from randomly five selected plants in each treatment with the help of Vernier caliper and their mean was taken.

Fresh root weight (g): For root weight, roots of five selected plants were taken and rinsed with water until all visible soil and sand particles were washed. Their weight was then recorded with the help of digital balance and average fresh root weight was calculated and noted.

Total soluble solvents (TSS) (Brix): Data for TSS were obtained by means of refractometer for five randomly selected samples. Mean data were then recorded and analyzed.

Root moisture content (%): Moisture content of radish was determined through hot air oven method described by AOAC.

$$\text{Moisture content} = \frac{W_1 - W_2}{W_2} \times 100$$

Where,

W_1 =weight of sample before drying

W_2 =weight of sample after drying

Days to harvest: Days were counted from date of sowing till harvest for each treatment of all replication. Their average was then worked out and noted.

Root yield (tons ha^{-1}): For yield data, roots of each cultivar were harvested and weighed to estimate total yield. Root yield for each cultivar was then converted to tons ha^{-1} using the following formula.

$$Root\ yield\ \left(tons\ ha^{-1}\right) = \frac{\text{Root yeild per plot (kg)}}{Are\ of\ plot\ \left(m^2\right) \times 1000}$$

Benefit Cost Ratio (BCR): BCR was found by dividing the total benefit on total cost. The income from plot for each treatment was obtained. The total cost on each treatment was also worked out. Then the total benefit in term of income was divided by total cost and their ratio was worked out using the following formula.

$$BCR = \frac{\text{total income}}{\text{total cost}} \times 100$$

Statistical analysis: Data were analyzed statistically using statistical software STATISTIX 8.1. Differences among treatments were separated through Least Significance Difference test (LSD) at 5 and 1 percent levels of significance.

Results and Discussion

In the light of previous findings all the results of the study were discussed below.

Number of leaves plant^{-1}: Data regarding number of leaves plant^{-1} are mentioned in Table 2 revealed that radish cultivars and levels of seaweed extract significantly affected number of leaves plant^{-1} while their interaction was found non-significant. Data concerning foliar application of seaweed extract showed that maximum number of leaves plant^{-1} (15.93) was recorded when 15 mlL^{-1} of seaweed extract was sprayed on radish plants, which was statistically similar to number of leaves plant^{-1} (15.69) at 10 mlL^{-1} level of seaweed extract. However, minimum number of leaves plant^{-1} (13.95) was observed for plants in control treatments. Among radish cultivars, maximum number of leaves plant^{-1} (15.60) was recorded for cultivar Mino early which was statistically similar to those noted for cultivar green neck (15.29) while minimum number of leaves plant^{-1} (14.84) was produced by cultivar forty days. Differences among radish cultivars for number of leaves plant^{-1} might be due to genetic makeup of each cultivar and its adaptability to the soil and environmental conditions. Such type of variations in number of leaves plant^{-1} was also observed which support the results of present study. Concerning the effect of seaweed extract on leaf number of radish plants, there was increase in the number of leaves plant^{-1} with increasing levels of seaweed extract. Increase of leaves with spraying seaweed extract is related with plant growth promoting hormones in the extract. Obtained findings are in agreement with the results reported in tomato crop, chilli crop. They also observed more number of leaves in plants that were sprayed with seaweed extract [11].

Table 2: Number of leaves plant^{-1}, length of leaf (cm), leaf area (cm^2) and leaf chlorophyll content (SPAD), root length (cm) of radish cultivars as influenced by different levels of seaweed extract.

Seaweed extract (mlL^{-1})	Number of leaves $plant^{-1}$	Length of leaf (cm)	Leaf area (cm^2)	Leaf chlorophyll content (SPAD)	Root length (cm)	Root diameter (cm)
Control	13.95	35.77	285.72	35.7	32.28	4.94
5	15.18	35.93	287.05	35.9	34.94	5.37
10	15.69	37.13	296.48	37.1	36.35	5.73
15	15.93	37.71	301.33	37.7	39.41	6.20
Radish cultivars						
Mino early	15.60	37.44	298.05	37.7	38.01	5.93
Green neck	15.29	37.44	296.48	36.7A	36.34	5.64
Red long	15.10	36.53	287.05	36.52	34.76	5.53
Forty days	14.84	35.52	285.72	35.5	33.87	5.14
Interaction						
Seaweed extract radish cultivars	NS	NS	NS	NS	NS	NS

Length of leaf (cm): Data pertaining to leaf length showed that radish cultivars and levels of seaweed extract significantly affected the length of leaf while their interaction was found non-significant. Data regarding the effect of seaweed extract revealed that when 15 mlL^{-1} of seaweed extract was sprayed, radish plants produced the longest leaves (37.71 cm) compared to other treatments. However, it was statistically similar to the length of leaf (37.13 cm) obtained at 10 mlL^{-1} level of seaweed extract. Minimum leaf length of 35.77 cm was recorded for plants in control treatments. While mean data regarding radish cultivars showed that maximum leaf length (37.44 cm) was recorded for cultivar Green Neck which was at par with cultivars Mino Early and Red Long while minimum leaf length (35.52 cm) was noted for cultivar forty days. Significant variations among radish cultivars for leaf length could be attributed to their inherent traits. Moreover, the genetic potential of developing plants of different cultivars for utilizing nutrients, which might have forced the plants of those cultivars to increase the length of leaf. Similar results were also recorded in radish crop. Potential of seaweed extract to improve length of leaf might be attributed to the presence of nutrients and phytohormones. Moreover, hormones in seaweed extract could be attributed to delay of leaf senescence, allowing leaves to grow and attain length [12].

Leaf area (cm^2): Data pertaining to leaf area shows that radish cultivars and levels of seaweed extract significantly affected leaf area while their interaction was found non-significant. Data for seaweed extract revealed that the largest leaf area (301.33 cm^2) was recorded for radish plants when they were sprayed with 15 mlL^{-1} of seaweed extract which was statistically similar to leaf area (296.48 cm^2) at 10 mlL^{-1} level of sea weed extract. The smallest leaf area (285.72 cm^2), however, was noted for plants in control treatments. However, mean data regarding radish cultivars showed that maximum leaf area (298.05 cm^2) was recorded for cultivar Mino early which was at par with that of cultivar green neck (296.48 cm^2). However, minimum leaf area (285.72 cm^2) was noted for cultivar forty days which was statistically similar to cultivar red long. Differences in leaf area of radish cultivars are greatly dependent upon variations in their inherent characters. Moreover, growth traits of plants are mostly expressed according to their genetic makeup

and their growing environment. Also supported findings of the present study in radish crop. Concerning the effect of foliar application of seaweed extract, growth triggering property of seaweed extract might have increased leaf area of radish plants. This might be attributed to the presence of endogenous hormones in the extract. Seaweed extract contains growth hormones, namely indole acetic acid and cytokinins. These organic compounds are known to stimulate growth due to synthesis of proteins, activation of cell division and metabolism of nutrients, thus, promoting plant growth by enhancing leaf area [13].

Leaf chlorophyll content (SPAD): Data regarding leaf chlorophyll content shown in Table 1 showed that radish cultivars and levels of seaweed extract significantly affected leaf chlorophyll content while their interaction was found non-significant. Data regarding levels of seaweed extract showed that the highest chlorophyll content in radish leaf (37.7 SPAD) was recorded when 15 mlL^{-1} of seaweed extract was sprayed on the plants. It was statistically same to leaf chlorophyll content (37.1 SPAD) that was noted for 10 mlL^{-1} level of seaweed extract. Minimum leaf chlorophyll content (35.57 SPAD) was recorded for plants in control treatments. The mean data pertaining to radish cultivars revealed that maximum chlorophyll content in leaves (37.7 SPAD) was recorded for cultivar Mino Early which is statistically similar to cultivar Green Neck and Red Long. Minimum chlorophyll content (35.5 SPAD), however, was noted for cultivar forty days. Differences in leaf chlorophyll content among cultivars might be genetic and probably because of their adaptability to the agro climatic conditions available during the growing season of the crop. Similar findings were reported by Kopta and Pokluda while studying variations in radish varieties. Similarly, Mapari, recorded that chlorophyll content of leaf has direct relationship with leaf area and leaf type and it is also genetic character. Seaweed extracts being bio-stimulant significantly increased leaf chlorophyll content of plants. Plants treated with seaweed extract could be considered an appropriate mean by which its application promoted nitrogen uptake efficiency and therefore resulted in enhancement of chlorophyll in leaves. They reported that the use of seaweed extract increased leaf chlorophyll content consequently enhancing photosynthetic capability of plants. Enhancement of leaf chlorophyll content might also be attributed to low degradation of leaf pigments and delay in leaf senescence, such positive effects are possibly because of the presence of plant growth hormones in seaweed extract, mainly cytokinins [14].

Root length (cm): Data in Table 1 regarding root length revealed that radish cultivars and levels of seaweed extract significantly affected the root length while their interaction was found non-significant. Concerning the effect of levels of seaweed extract, it is observed that maximum root lengths of (39.41 cm) was recorded for radish plants which received 15 mlL^{-1} of seaweed extract which is statistically similar to root lengths of (36.35 cm) when 10 mlL^{-1} of seaweed extract was applied. However, minimum root length (32.28 cm) was noted for plants in control plots. While data showing the effect of radish cultivars revealed that maximum root length (38.01 cm) was recorded for cultivar Mino early. Minimum root length (33.87 cm) was recorded for cultivar forty days. Root length of radish crop is considered main character of quality and yield. Variations were noted for this trait in the studied cultivars which might be due to genetic diversity among cultivars as well as environmental conditions. Similar results were recorded by Chapagain, in radish crop. The increment of root length with application of seaweed extract might be associated with plant hormones in the extract. This is possibly due to the involvement of phytohormones in absorption and mobilization of nutrients. Further, improvement of vegetative characters (leaf number, leaf area) with seaweed extract led to improvement in root length [15].

Root diameter (cm): Data presented in Table 3 showed that radish cultivars and levels of seaweed extract significantly affected root diameter while their interaction was found non-significant. Data concerning seaweed extract levels revealed that maximum root diameter (6.20 cm) was recorded when 15 mlL^{-1} of seaweed extract was sprayed on the plants, which was statistically similar to root diameter (5.73 cm) at 10 mlL^{-1} level of seaweed extract. However, minimum root diameter (4.94 cm) was measured for plants in the control plots. The mean data pertaining to radish cultivars showed that maximum root diameter (5.93 cm) was observed for cultivar Mino early. It was statistically similar to root diameters of cultivar green neck (5.64 cm). Minimum root diameter (5.14 cm), however, was recorded for cultivar forty days. Variations were observed in root diameter for different radish cultivars. Those cultivars that were having large leaf area had maximum root diameter. This attribute could be possible because of genetic variations among cultivars. Also better adaptability to the growing environment and soil conditions led to improvement in root diameter. Sea weed extract increased root diameter because it has not only macro and micro nutrients, antibiotics and vitamins but also contains good quantity of growth hormones. All these components are active plant growth promoting substances. These compounds enhance plant growth by triggering protein synthesis, cell division and cell

differentiation. Hormones also play important role in the uptake of nutrient dissolved water, distribution of nutrients and sugars in plant body. This in turn enhanced the diameter of treated plants. Findings of this study are in agreement with those of Craigie [16].

Table 3: Root diameter (cm), root weight (g), total soluble solids (^{0}Brix), root moisture content (%) and days to harvest of radish cultivars as influenced by different levels of seaweed extract.

Seaweed extract (mlL^{-1})	Root weight (g)	Total soluble solids (0Brix)	Root moisture content (%)	Days to harvest	Root yield (tons ha^{-1})
Control	412.13	5.78	94.16	59.41	26.30
5	435.56	6.03	94.47	57.17	27.67
10	450.37	6.26	94.79	52.53	28.61
15	465.34	6.35	95.16	51.44	29.98
Radish cultivars					
Mino early	462.47	6.09	94.76	57,77	29.55
Green neck	450.71	5.89	95.10	59.22	28.79
Red long	436.37	6.30	94.60	56.33	2760
Forty days	413.85	6.13	94.12	47.23	26.62
Interaction					
Seaweed extract* radish cultivars	NS	NS	NS	NS	NS

Root weight (g): Data pertaining to root weight showed that radish cultivars and levels of seaweed extract significantly affected root while their interaction was found non-significant. Data concerning levels of seaweed extract revealed that maximum root weight (465.34 g) was recorded when 15 mlL^{-1} seaweed extract was sprayed on radish plants, which was observed statistically similar to root weights at 10 mlL^{-1} (450.37 g) of seaweed extract. Minimum root weight (412.13 g), however, was recorded for plants in control treatments. Mean data regarding radish cultivars showed that among cultivars, maximum root weight (462.47 g) was recorded for cultivar Mino early which was at par with cultivar green neck (450.71 g). However, minimum root weight (413.85 g) was noted for cultivar forty days. Differences were noted among radish cultivars for root weight which might be possible because of genetic variations among cultivars. Further, radish cultivars which attained optimum root weight seemed to be more adapted to the growing environmental and soil conditions. Sea weed extract increased root weight because it contains nutrients, antibiotics and growth hormones (auxins, cytokinins, gibberellin). All these compounds are active plant growth promoting substances. Such substances enhanced plant growth by triggering protein synthesis, cell division and cell differentiation. Hormones in the extract also facilitated translocation of sugars and other nutrients, establishing better source sink relationship in the plant. All such conditions might have increased dry matter content in the root which led to increase in root weight [17].

Total soluble solids (^{0}Brix): Data regarding Total Soluble Solids (TSS) presented showed that radish cultivars and levels of seaweed extract significantly affected the total soluble solids (^{0}Brix) while their interaction was found non-significant. Among cultivars, maximum TSS (6.300 Brix) was recorded in cultivar red long, followed by cultivar forty days (6.13 ^{0}Brix). Minimum TSS (5.89 ^{0}Brix) was observed in cultivar Green Neck. According to seaweed extract, maximum TSS (6.35 ^{0}Brix) was recorded when seaweed extracts was sprayed at the rate of 15 mlL^{-1}, which is statistically similar to 10 mlL^{-1} concentration (6.26 ^{0}Brix). Minimum TSS (5.78 ^{0}Brix), however, was noted for plants in

the control plots. Variation among radish cultivars for total soluble solids could be due to genetic differences among cultivars and might be due to suitable climatic conditions during the growing period of the crop which increased root mass and ultimately resulted in higher Total Soluble Solids (TSS) in it. Such differences in TSS content in root of different radish varieties were also reported by Panwar. Seaweed extract might have enhanced the rate of photosynthesis in treated plants which in turn enhanced the accumulation of sugars compared to untreated radish plants. It might be possible because, seaweed extract contains several bio active compounds and plant growth hormones. Seaweed extract enhances stress tolerance and uptake of nutrient uptake and it also enhances root growth, flowering, fruit quality and taste. Similarly, Khan reported an increments of 28% of total sugars in vegetables by applying Ascophyllum nodosum. Our findings are also in agreement with the findings who reported that seaweed extract significantly increased total phenols and TSS content in different root vegetables [18].

Root moisture content (%): Data showed that radish cultivars and levels of seaweed extract significantly affected dry matter content while their interaction was found non-significant. Data concerning levels of seaweed extract revealed that maximum root moisture content (95.16%) was recorded when 15 mlL^{-1} seaweed extract was sprayed on radish plants, which was observed statistically similar to root moisture content at 10 mlL^{-1} of seaweed extract (94.79%). Minimum root moisture content (94.16%), however, was recorded for plants in control treatments. Mean data regarding radish cultivars showed that among cultivars, maximum root moisture content (95.10%) was recorded for green neck which was at par with Mino early (94.76%) and red long (94.60%). However, minimum root moisture content (94.12%) was noted for cultivar forty days. Variation among radish cultivars for root moisture content might be due to differences in genetic makeup of particular cultivar. It probably could be the result of suitable climatic conditions during the growing period of the crop which increased root mass and ultimately resulted in high moisture content in it. Kopta and Pokluda favor the findings of this study. Seaweed extract increased moisture content of root in treated plants compared to untreated radish plants. It might be possible because, seaweed extract contains several bio active compounds and plant growth hormones. Other researchers also stated that seaweed had favorable effect on the quantitative and qualitative traits of root crops. They further reported that improvement in root growth and root moisture content could be a result of the presence of small amount of phytohormones in the extract like auxins and the activation of various stimulatory processes within plant upon treatment with these extracts. Further, foliar spraying of seaweed extract proved to increase crop yield by improving the uptake of water and nutrients [19].

Days to harvest: Data regarding days to harvest are presented. Analysis of variance revealed that radish cultivars and levels of seaweed extract significantly affected days to harvest while their interaction was found non-significant. Among cultivars, maximum days to harvest (59.22) were recorded in green neck cultivar, followed by Mino early (57.77). However, minimum days to harvest (47.228) were taken by cultivar, green neck. Data pertaining to seaweed extract showed that maximum days to harvest (59.41) were recorded for plants in the control plots while minimum days to harvest (51.44) were recorded for plants when they were sprayed with seaweed extract at the rate of 15 mlL^{-1}. Significant variations among radish cultivars for days to harvest could be attributed to their genetic make. Our results are in agreement with Chapagain who reported that variations were noted in cultivars for days to harvest which might be due to genetic diversity among cultivars as well as environmental conditions. Potential of seaweed extract to reduce days to harvest might be attributed to the presence of nutrients and phytohormones which might have promoted growth of plants and reduced days to maturity. The application of seaweed extracts has been reported to promote earliness in cucumbers. Our findings are also supported by Ashour who reported that seaweed extract as foliar spray have currently gained much significance because it can induce speedy growth and therefore reduces days to harvesting in vegetable crops.

Root yield (tons ha^{-1}): Data presented showed that radish cultivars and levels of seaweed extract significantly affected root yield while their interaction was found non-significant. Data regarding levels of seaweed extract revealed that the highest root yield (29.98 tons ha^{-1}) was recorded for treatments where plants were sprayed with 15 mlL^{-1} of seaweed extract which was statistically similar to root yield (28.61 tons ha^{-1}) obtained at 10 mlL-^{1} of seaweed extract. However, minimum root yield (26.30 tons ha^{-1}) was recorded for control plots. Mean data concerning radish cultivars showed that among cultivars, the highest root yield (29.55 tons ha^{-1}) was recorded for cultivar Mino early cultivar which was statistically similar to root yield of green neck (28.79 tons ha^{-1}). However, the lowest yield (26.62 tons ha^{-1}) was observed for cultivar forty days. Improvement in root yield might be due to proper translocation of food from source to sink. Those radish cultivars which have shown better performance in root yield had significantly more

number of leaves, large leaf area and high chlorophyll content, that led to more food synthesis and translocation of that food to the roots. This might have increased diameter and weight of roots and ultimately resulted in higher root yield in those cultivars. These results are close inconformity with the findings of Singh and Taj in radish crop. Seaweed extract improved root length, enhanced the uptake and translocation of nutrients and then boosted root yield. This might be possible due to the fact that seaweed extract is a good source of many essential minerals from marine water needed by plants. Seaweed also has growth-enhancing hormones, which increased root yield in root crops. Seaweed extract contains proteins and macro nutrients such as iron, copper and zinc. It is also a rich source of polysaccharides and unsaturated fatty acids. The extract has good biological activity and regulates balance of endogenous hormone balance. All such stimulating compounds might have increased root yield of radish cultivars [20].

Benefit Cost Ratio (BCR): Data regarding benefit cost ratio of cultivars presented in Table 4 shows that highest benefit cost ratio (8.98) was recorded for cultivar Mino early which was followed by cultivar forty days (8.90). While, the lowest BCR (7.89) was recorded for cultivar Green Neck. In case of seaweed extract data presented in Table 5 shows that highest benefit cost ratio (10.72) was obtained when 15 mlL^{-1} was applied. However, the lowest BCR (5.11) was recorded for 5 mlL^{-1} of seaweed extract application.

Table 4: Benefit Cost Ratio (BCR) for radish cultivars.

Varieties	Mino early	Green neck	Red long	Forty days
Root yield (Kg)	29795	29045	27853	26955
Income Kg^{-1} (Rs)	35	32	35	38
Yield ha^{-1} (Rs)	1042825	929440	974855	1024290
Labor (Rs)	58800	58800	58800	58800
Seed price (Rs)	4500	3500	3500	5500
Tractor (Rs)	4000	4000	4000	4000
Fertilizer (Rs)	25000	25000	25000	25000
Irrigation (Rs)	12150	13200	1200	10200
Total expenditure (Rs)	104450	104500	103300	103500
Net income (Rs)	938375	824940	871555	920790
Benefit Cost Ratio (BCR)	8.98	7.89	8.44	8.9

Table 5: Benefit Cost Ratio (BCR) for different levels of seaweed extract.

Seaweed extract	0 mlL^{-1}	5 mlL^{-1}	10 mlL^{-1}	15 mlL^{-1}
Root yield (Kg)	26301	27672	28613	31063
Income Kg^{-1} (Rs)	20	20	30	35
Yield ha^{-1} (Rs)	526020	553440	858390	1087205
Labor (Rs)	58800	58800	58800	58800

Seaweed extract price (Rs)	0	1150	2300	3450
Tractor (Rs)	4000	4000	4000	4000
Fertilizer (Rs)	25000	25000	25000	25000
Irrigation (Rs)	1500	1500	1500	1500
Total expenditure (Rs)	89300	90450	91600	92750
Net income (Rs)	436720	462990	766790	994455
Benefit cost ratio (BCR)	4.89	5.12	8.37	10.72

Conclusion

It was concluded from the experiment that with the foliar application of 15 mlL^{-1} of seaweed extract, maximum vegetative growth and the highest root yield was observed for radish plants. However, most of the growth and yield parameters of the sprayed plants at 15 mlL^{-1} were at par with those recorded at 10 mlL^{-1} of seaweed extract. Among radish cultivars, Mino early, green neck and red long have shown superior performance by producing maximum number of leaves, leaf area, leaf chlorophyll content, root length, root weight, root diameter, dry matter content, root yield. In case of cultivars, the highest benefit cost ratio was recorded for cultivar Mino early which was followed by cultivar forty days (8.90). In case of seaweed extract the highest benefit cost ratio was obtained when 15 mlL^{-1} was applied. Interaction of seaweed extract and radish cultivars was found non-significant for all the studied attributes.

Recommendation

From the findings of the present study it could be recommended that radish cultivar Mino early, is recommended for obtaining optimum growth, high yield and maximum profit under the agro climatic conditions of Peshawar. Considering the stimulatory effects of seaweed extract on plant growth and yield, 15 mlL^{-1} of seaweed extract could be sprayed to get the highest root yield and maximum profit from radish crop. Future research should be conducted to assess the effect of seaweed extract on root and other vegetable crops.

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