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Comparison of iodine application methods in Rocket Plant

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Abstract. Iodine is an essential trace element for human health and is involved in the production of the thyroid hormone. Recently, a new idea has emerged: to meet people's need for daily iodine by increasing the iodine content of vegetables with high iodine bioavailability and assimilation. This study was carried out with iodine foliar application and root application methods to determine which is more appropriate when attempting to increase iodine content. An experiment was conducted in a greenhouse with 4 doses of iodine in the form of potassium iodide (0, 2, 4, 8 mM), two application methods (foliar and root application) and three replicates. At the end of the experiment, the plants' fresh and dry weight, relative water content, membrane stability, chlorophyll a, chlorophyll b and total chlorophyll were determined. The results were subjected to analysis of variance according to the randomized blocks experiment design using the MINITAB 17.0 statistical package program. The applications did not show a statistical difference in plant fresh weight and dry weight. There was no statistical difference in the relative water content between the applications, while a statistical difference ($P < 0.05$) in the membrane stability was observed for the interaction of application type and application dose. Chlorophyll a, chlorophyll b and the total chlorophyll amount were also statistically affected ($P < 0.05$) by the application doses. Foliar and root application methods have not caused significant loss of yield. Both methods are also considered to be appropriate to use in practice.

Key words: Iodine, Rocket, Vegetable, Thyroid.

INTRODUCTION

Iodine is an essential element for humans and animals, while not necessarily a nutrient for plants. Iodine, which is involved in thyroid hormone production, is an essential element for normal growth and development and for brain and body functions (Erbaş, 2008).

The amount of iodine in rocks is generally low. Iodine concentrations are between 0.2 and 0.8 ppm in basic extrusive. In acid eruptive, metamorphic rocks and some sedimentary rocks, the amount of iodine varies from 1 to 2 ppm. The average iodine content of the soil surface is stated as 5 ug g^{-1}. The iodine content of the soil is more than 20–30 times that of rocks (Halilova, 2004). According to Whitehead (1984), the basic source of iodine in the soil is atmospheric iodine and the main sources of atmospheric iodine are seas and oceans (Tsukada et al., 2008). Iodine can easily evaporate under the influence of daylight and temperature. Iodine, which is mixed with the atmosphere, reaches land with rain (Halilova, 2004). The losses which occur during the process of the iodine reaching the soil cause a small amount of iodine to be found in the soil and in the crops grown in these soils. According to the WHO, ICCIDD (International Council for the Control of Iodine Deficiency Disorders), Global Network and UNICEF, the daily amounts of iodine that people should take are as follows: 0–6 years – 90 micrograms (µg), 7–12 years – 120 µg, over 12 years – 150 µg and pregnant and lactating women – 250 µg. When the daily iodine requirement is not satisfied, a series of developmental and functional diseases known as Iodine Deficiency Disorders can occur. The total amount of iodine in the human body is 15–20 mg (Erdoğan & Erdoğan, 1999). Although iodine deficiency can be cured, it remains a health problem for about 35% of the world's population (Pearce et al., 2004; Winger, 2008; Landini, 2011). According to recent WHO surveys, around 2 billion people in the world are still confronted with insufficient iodine intake. Compared with the WHO regions, the European continent has the highest rate of iodine deficiency, at 45% of the population (Anderson et al., 2012; Daum et al., 2013). In Turkey, iodine deficiency remains an important public health problem.

The visible sign of iodine deficiency is the goiter which is seen in all age groups. The total prevalence of goiter in Turkey is as high as 30.5% and the visible goiter rate is around 6.7% (Yordam et al., 1999). According to a study conducted by Koloğlu in 1984, 29 provinces, excepting the Aegean and Marmara regions, are endemic goiter zones (Aydın, 1989).

Iodine deficiency causes growth retardation, deafness, dwarfism and hypothyroidism in infants, growth retardation, school failure, difficulties in understanding and learning in children and adolescents, hypothyroidism, inadequate mental functioning, weakness and inefficiency in adults (Pekcan, 2008). At the same time, iodine deficiency was found to reduce IQ by 13.5 points (Pekcan, 2008; Zimmermann, 2012). There is an increased risk of death in newborns with a lack of iodine. The prevention of iodine deficiency in China and Zaire has been shown to reduce the risk of newborn mortality (Erbaş, 2008).

In the human body and animals, 80% of the iodine is naturally supplied by edible vegetables (Welch & Graham, 2005; Weng et al., 2013) and the bioavailability of iodine in these vegetables is about 99%. The concentration of iodine in the soil in which vegetables are grown is usually too low to supply the needs of the human body (Weng et al., 2013). The iodine content of the plant that grows in soil with a high amount of iodine is high. The iodine deficiency in the soil in Turkey affects the goiter rate more than drinking water. As consumption of vegetables, fruits and grain low in iodine content is common in our country, the total amount of iodine entering the body remains low (Aydın, 1989).

Diet is the only way to take iodine into the body (Vitti et al., 2001; Pekcan, 2008). The use of iodized salt is the most common approach for iodine supplementation (Delange & Lecomte, 2000; Andersson et al., 2005). However, during activities such as cooking, storage and transportation, it is difficult to control the loss of iodine and iodine supplementation causes many problems during food processing (Winger et al., 2008; Landini et al., 2011). The level of iodized salt usage in our country is inadequate to control iodine deficiency (Özkan et al., 2004). Increasing iodine levels in food with vegetables which have a high rate of bioavailability and assimilation is a more effective way of controlling iodine deficiency in a cost effective manner (Dai et al., 2004; Weng et al., 2009; White & Broadley, 2009; Landini et al., 2011).

Some studies show that iodine application to the soil increases iodine accumulation in the edible parts of vegetables (Dai et al., 2004). Umaly & Poel (1971) reported that plants could use iodate more than iodide. Whitehead (1973) reported that iodine is useful for many plants, even at very low concentrations, regardless of the form (Landini et al., 2011).

In a study carried out in lettuce, iodine (0.25 and 0.50 kg ha^{-1}) applied to the leaves increased the content of iodine in the edible parts of the plant without reducing the yield and quality of the product (Daum et al., 2013).

Food consumption in Turkey is largely composed of foods which are of cereal origin. In addition, leafy vegetables play an important role in the nutrition program. The rocket plant (*Eruca vesicaria*) is a vegetable with leaves consumed as a salad and recently its consumption has increased. The rocket plant is rich in vitamin C and also has antioxidant properties.

Considering that rocket production and consumption is increasing in Turkey, that it is consumed raw in salads daily, and that iodine can be accumulated in the leaves, this study aimed to determine which method is more appropriate to increase the iodine content of rocket plants, namely, spraying iodine on the leaves or applying it to the roots.

MATERIALS AND METHODS

The experiment was developed under greenhouse conditions at Canakkale Onsekiz Mart University in Turkey. The rocket plant was chosen as study material because of its consumption as raw leaves. The experiment was conducted with a randomized block design with 4 doses of iodine in the form of potassium iodide (0, 2, 4, 8 mM), two application methods (foliar and root application) and three replicates. The plants were grown with a Hoagland nutrient solution. At the end of the experiment, the plant's fresh and dry weight, relative water content, membrane stability, chlorophyll a, chlorophyll b and total chlorophyll were determined. After harvesting, the fresh weight (FW) of leaves was directly determined. For dry weight (DW) determination, the leaves were dried at 70 °C for 48 h and weighed.

Leaf tissue was used for Relative Water Content (RWC) determination, as follows. A composite sample of leaf discs was taken and the fresh weight was determined, followed by flotation on water for up to 4 hr. The turgid weight was then recorded, and the leaf tissue was subsequently oven-dried to a constant weight at about 60 °C for 48 h. RWC was calculated as

$$RWC\% = (FW - DW) \div (TW - DW) \times 100 \text{ (Weatherley, 1950)} \quad (1)$$

Membrane permeability was evaluated by the leaf relative electrolyte leakage (EL). Samples were washed three times with deionized water to remove surface-adhered electrolytes. Leaf disks were soaked in 10 ml distilled water at 40 °C for 30 minutes and then the initial electrical conductivity (ECi) was determined by measuring the electrical conductivity of the solution using a conductivity meter, whereas the final electrical conductivity (ECf) was obtained by boiling the same solution for 10 minutes. EL was calculated as a percent of the initial to the final conductivity.

$$\text{Electrolyte leakage\%} = (ECi \div ECf) \times 100 \quad (2)$$

Accurately weighted 0.5 g of a fresh plant leaf sample was taken, and homogenized with 10 ml of 80% acetone. The homogenized sample mixture was centrifuged at

4,500 rpm for 5 minutes. The supernatants were separated and analyzed for Chlorophyll-a, Chlorophyll-b and total Chlorophyll content in a spectrophotometer.

The results were subjected to analysis of variance according to the randomized block experiment design using the MINITAB 17.0 statistical package program and the averages of the data with significant differences between them were compared with the LSD.

RESULTS AND DISCUSSION

The fresh and dry weight data obtained from the soil and foliar iodine application to the rocket plant are given in Table 1. When Table 1 is examined, it can be seen that the highest fresh weight is 67.66 g and the lowest is 60.74 g. Although the highest and lowest data showed a numerical difference, there was no statistical difference. When the plant dry weight is considered, the situation is seen to be the same. Although there are numerical differences between the application form and the application doses, this is not statistically significant. The plant dry weight ranged from 11.90 g to 9.88 g.

Table 1. Fresh weight and dry weight (g) averages and multiple comparison results

Method of	Iodine application doses (mM)			
Application	0	2	4	8
	Fresh weight(g)			
Soil	67.66	65.98	62.66	63.27
Foliar	60.74	63.29	65.56	62.40
	Dry weight (g)			
Soil	11.90	11.20	9.88	10.37
Foliar	10.48	11.21	11.35	10.42

The Relative Water Content and Membrane Stability data obtained from the iodine application to rocket plants by soil and foliar application are given in Table 2. When Table 2 is considered, it can be seen that there is no numerical or statistical difference between the relative water contents. When analyzed, the results of the membrane stability data indicated that interaction between the application form and the doses created a statistically significant difference ($P < 0.05$) in membrane stability. Membrane stability reached the highest value at the level of 8mM iodine application to the soil, while the lowest value was reached in the control group with soil application.

Table 2. Relative water content and membrane stability (%) averages and multiple comparison results

Method of	Iodine Application Doses (mM)			
application	0	2	4	8
	Relative water content (%)			
Soil	72.56	72.13	74.05	70.60
Foliar	71.10	70.73	72.75	71.00
	Membrane stability (%)			
Soil	27.96 B	41.80 AB	40.21 AB	57.63 A
Foliar	37.30 B	29.98 B	33.68 B	39.70 AB

Mean values marked with the same letter in columns do not differ significantly ($P < 0.05$) from each other.

The Chlorophyll-a, Chlorophyll-b and total Chlorophyll content data obtained from the iodine application to rocket plants with soil and foliar application are given in Table 3. When Table 3 is examined, it can be seen that the doses of iodine application statistically affect ($P < 0.05$) chlorophyll a, chlorophyll b and total chlorophyll content.When compared with the control group, the highest dose of iodine application (8 mM) increased chlorophyll content.

Table 3. Chlorophyll-a, chlorophyll-b and total chlorophyll content averages and multiple comparison results

Method of application	Iodine Application Doses (mM)			
	0	2	4	8
	Chlorophyll-a			
Soil	4.46	4.50	4.21	4.53
Foliar	4.18	4.02	3.70	5.41
Average	4.32 AB	4.26 AB	3.95 B	4.97 A
	Chlorophyll-b			
Soil	4.83	5.08	4.46	5.08
Foliar	4.63	4.49	4.26	5.95
Average	4.73 AB	4.78 AB	4.36 B	5.51 A
	Total Chlorophyll			
Soil	9.30	9.58	8.67	9.61
Foliar	8.82	8.51	7.97	11.37
Average	9.06 AB	9.05 AB	8.32 B	10.49 A

Mean values marked with the same letter in columns do not differ significantly ($P < 0.05$) from each other.

CONCLUSIONS

It is important that no loss of yield occurred in applications to increase the iodine content of the vegetables. According to the results obtained from the experiment, foliar and root application methods have not caused significant loss of yield. Both methods used in the experiment are also considered to be appropriate to use in practice. In addition, considering the differences in membrane stability and chlorophyll content, the application dose should be selected carefully, so that it gives no harm to the plant.

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