Eco. Env. & Cons. 28 (October Suppl. Issue) : 2022; pp. (S391-S397)

ISSN 0971–765X

DOI No.: http://doi.org/10.53550/EEC.2022.v28i06s.066

Effects of Iron Fortification in Watercress under Soiless Culture System

Dewan Limboo, Sujata Upadhyay*, Laxuman Sharma, Rajesh Kumar, Suren Limbu and Obadiya Rai

Department of Horticulture, Sikkim University, 6th Mile, Tadong 737 102, Gangtok, Sikkim, India

(Received 20 December, 2021; Accepted 16 June, 2022)

ABSTRACT

An experiment was conducted to study the effect of iron fortification in morphology, minerals and antioxidant composition of watercress under organic soilless culture for testing the possibility of increase in iron content in its edible parts at Dept. of Horticulture, Sikkim University, Gangtok during 2017-2018. Plants were grown in a solution of 500 g vermicompost and 5 g citric acid in trays filled with cocopeat +coarse perlite (1:1). The experiment was laid out under the protected condition. Four different concentrations of $FeSO_4$@0.2%, 0.3%, 0.4% and 0.5% were used. All the morphological parameters like leaf length, number of leaves per plant, leaf thickness, plant height, plant fresh weight and plant dry weight showed significant increase at 0.5% concentration of $FeSO_4$ fortification. Minerals like Fe, Cu, Zn and Mn content in plant were also significantly increased at given concentration. In contrast, the maximum concentration of $FeSO_4$ showed the opposite effect on the antioxidant content in the watercress plant. Overall, the watercress plants grown in increased amount of $FeSO_4$ media were luxuriant in their growth with increased number of essential elements especially iron. Therefore, the findings suggest that $FeSO_4$ can be used in the growing media for iron fortification in watercress with yield enhancement.

***Key words** : Nasturtium officinale,* Fortification, Soilless culture, Treatment, Iron sulphate, Iron deficiency, Anaemia

Introduction

Watercress is botanically *Nasturtium officinale* R. Br. and is known by a variety of common names, such as eker, biller, bilure, rib cress, brown cress, teng tongue, long tails, well grass (Anjali *et al.,* 2015) and it belongs to the family Brassicaceae. The origin lands of the plant are western Asia, India, Europe, and Africa (Asensi-Fabado and Munne Bosch, 2010). It is a perennial plant grown for its leaves and young stems, which are suitable for garnishing, salads, as well as in culinary purposes due to its hot and sour taste (Beibel, 1960), grown in an aquatic and semi-aquatic nature, and prefers soil pH within the range of 4.3 to 8.3 and its production is heavier in the months of summer when more daylight promotes growth (Butler (2002). Commercially, it can be grown through seeds or cuttings in unshaded shallow pools of flowing clean water. Flowing streams, areas of running water adjacent to springs and riverbanks, or wet soil are the place where this plant is found often (Asensi-Fabado and Munne Bosch, 2010). Leaves and stems are partially submerged during growth. This plant is very light-sensitive, though it can acclimate to low-light regions by aug-

Abbreviations

mg = milligram, g = gram, cm = centimeter, mm = millimeter, $FeSO_4$ = Iron sulphate, Fe = Iron, Cu = Cupper, Zn= Zinc, Mn= Manganese, T = Treatment, L = Litre, STPR= software test procedures menting its physiology and morphology to increase photosynthetic efficiency.

Watercress is a good source of vitamin A, C, B_1 and B_2 (Anjali *et al.,* 2015 and Carrasco *et al.,* 2011) as well as vitamin E, gluconasturtine and minerals (especially iodine, iron, and phosphorus) (Cruz *et al.*, 2008). Watercress also contains good amount of macro minerals like potassium, calcium, sodium, and magnesium Carrasco *et al*. (2011).

It is a good source of vitamins, essential minerals and beneficial phyto-chemicals, such as lutein and zea-xanthin. Watercress consumption has strong potential to act as a source of anti-cancer drug (Engelen *et al.,* 2006). It is one of the most important herbal medicines used for the treatment of some diseases like diabetes in traditional treatment (Cruz *et al.,* 2008). Its supplementation in diet has shown to ameliorate the DNA damage and increased the blood antioxidant potential in human subjects (Gill *et al.,* 2007). It is the richest source of glucosinolatenasturtiin, which on hydrolysis produces phenethyl isothiocyante. This glucosinolate is an anticancer and used as standards in cell studies as well as for commercial purification and production of dietary supplements for use as nutraceuticals. This crop is a major source of phenethyl isothiocyante which can be called as a potential nutraceutical (H and FWD, 2019).

Due to various soil borne diseases and nematodes, soil may have limitations for the growth of plants (Habib, 2009). Moreover, soilless/hydroponics cultivation can employ in the production of this vegetable, because it is considered a useful technique for the development of leafy vegetables when early maturity is sought (Haro *et al.,* 2018). Soilless cultivation of watercress can have a significant effect on morphology of the plant and represents an alternative to traditional agriculture, showing several possible advantages, including higher water-use efficiency, lower production costs, higher nutrient use efficiency and reduced foliar disease and there will be no leaching of nutrients to the groundwater and this cultivation system can be suitable for improving nutrient content of edible leaves like watercress.

Iron is one of the essential components of the pigment haemoglobin and helps in carrying oxygen to all parts of the body (Heeht *et al.,* 1995). If iron intake is low, the amount of haemoglobin in the red blood cells can fall leading to iron deficiency anaemia. Iron deficiency is the most common and widespread nutritional deficiency in the world. At the global level, it is estimated that 1.62 billion people are affected by anaemia, corresponding to 24.8% of the world's population (Kim and Rees, 1992). Recommended dietary allowances (RDAs) varies from person's age, gender and non-vegetarian to vegetarian. According to report, the requirement of iron in infants (0-12 months) and children (1-8 years) ranges from 0.27 mg to 11 mg and 7-10 mg respectively. However, in case of adults, the females iron requirement was found to be more ranging from 8 mg to 27 mg in pregnant women as against male's iron requirement *i.e.,* 8 mg to 11 mg (Megan, 2018).

Iron deficiency is defined as a progressive loss of iron in the body resulting from dietary fibres, inadequate absorption, or iron losses. Other common symptoms of iron deficiency include reduced work capacity, impaired cognitive development, and increased rates of preterm delivery and low birth weight. In developing countries like India has direct and indirect effects on the state and national economy (Kim and Rees (1992). Likewise, the over prevalence of anaemia recorded in Sikkim was 51%. However, the female population (63%) recorded proportionately more as compared to male population (37%) in the state (Ranganna, 2004). This plant is consumed in every household of Sikkim which makes it a primary vegetable at its peak season, but the fact is that only 0.2mg/100g of iron is present in this vegetable, keeping the above ongoing facts in mind the present investigation was carried out to assess and validate the effects of iron fortification on morphology, minerals, and antioxidants in watercress.

Materials and Methods

The present experiment was carried out in the green house condition at Department of Horticulture, Sikkim University, Gangtok at an altitude of 1610m and with latitude and longitude as N°27°18.495' and E°88°35.307 during the year 2017-2018. Planting material was collected from Pakyong and Kartok in East Sikkim. Collected planting materials (20-30 days old and 2 leaf stage sapling) were planted in plastic trays of 5 litres capacity filled with fine cocopeat, coarse perlite, vermi-compost and citric acid supplemented with iron sulphate in various concentrations under organic hydroponics condition. The experiment was laid in Completely Randomized Design with five treatments and four replications. All the data obtained from various experiments were subjected to the analysis for their mean, standard error and critical difference (at 5) by using the STPR statistical computer package.

Treatment details:

- T_1 Coconut fibre + coarse perlite+ vermi-compost (½ kg) + Iron sulphate (0.2 %) + citric acid (0.2%)
- T_2 Coconut fibre + coarse perlite+ vermi-compost (½ kg) + Iron sulphate (0.3 %) + citric acid (0.2%)
- T_3 Coconut fibre + coarse perlite+ vermi-compost (½ kg) + Iron sulphate (0.4%) + citric acid (0.2%)
- T_4 Coconut fibre + coarse perlite+ vermi-compost (½ kg) + Iron sulphate (0.5%) + citric acid (0.2%)
- T_5 (Control) Coconut fibre + coarse perlite + vermi-compost (½ kg)

The data on leaf length, no. of leaf per plant, plant height, plant fresh weight and plant dry weight were recorded by using ruler. Leaf thickness was measured by an instrument viz., vernier calliper (make: Mitutoyo, digimatic calliper). Iron, zinc, copper and manganese content of plant was determined by atomic absorption spectrometry and vitamin A and C was determined by method suggested by Ranganna (2004).

Results

The effects of different levels of iron sulphate on morphological parameters and effects of different concentrations of iron sulphate on biochemical parameters of watercress under organic soilless system have been presented in Table 1 and 2 and discussed in this section.

Effects of different levels of iron sulphate on morphological parameters of watercress under organic soilless system

Leaf Length (cm)

There was a significant difference found among the treatments regarding leaf length of watercress. It was observed that plants with T_4[Coconut fibre + coarse perlite+ vermi-compost (½ kg) + Iron sulphate (0.5 %) + citric acid (0.2 %)] have recorded the maximum leaf length (2.85 cm) as compared to other treatments, which were found to be at par with each other.

Leaf thickness (cm)

However, there was no significant difference found in leaf thickness of the plant because of treatments. All the observations of the treatment were found to be at par with each other as signified by critical difference value. There was no substantial change in the leaf thickness by any of the treatments.

Number of leaves per plant

The amount of leaf per plant was significantly increased in T_4 [Coconut fibre + coarse perlite+ vermicompost (½ kg) + Iron sulphate (0.5 %) + citric acid (0.2 %)] as compared to other treatments. It has recorded maximum amount of leaf per plant (57.1).

Plant height (cm)

As shown in the Table 1, the increase in plant height seemed to be significant and distinct in T_4 as compared to other treatments. Remaining all treatments were at per with each other. T_4 being an exception which attained the highest plant height of 21.4 cm.

Plant fresh weight (g)

In comparison with all other treatments for plant fresh weight (as shown in Table 1), it was resulted those plants treated with $FeSO_4$@ 0.5% (T_4) achieved highest plant fresh weight (2.10 g) and found significantly different with all other treatments.

Plant dry weight (g)

Table 1 depicts that plant treated with Iron sulphate 0.5% (T_4) gave the highest plant dry weight (1.22 g) and were significantly different with all other treatments. The non-significant effects were observed for plant dry weight among other remaining treatments.

Effects of different concentrations of iron sulphate on biochemical parameters of watercress under organic soilless system

Fe content (mg/ 100 g)

With the application of increased Iron Sulphate level, there were increased in Iron content in plants (as shown in Table 2). Highest Fe was recorded (5.82 mg/100 g) in plant treated with Iron Sulphate @ 0.5% (T_4) and was significantly different with other treatments. T_2 and T_3were at per with each other. Lowest Fe content was recorded in control (3.07 mg/100 g).

Cu content (mg/ 100 g)

Table 2 showed that plant treated with Iron Sulphate @ 0.5% (T_4) had the highest Cu content i.e., 0.22 mg/100 g and found to be at par with T_1. Both

Table 1. Effects of different levels of iron sulphate on morphological parameters of watercress under organic soilless system

Treatment details		Morphological parameters					
		Leaf length (cm)	Leaf thickness (cm)	No. of leaf per plant	Plant height (cm)	Plant fresh weight (g)	Plant dry weight (g)
T1	Coconut fibre + coarse perlite+ vermicompost (½ kg) + Iron sulphate (0.2 %) + citric acid (0.2 %)	1.92	0.25	44.3	18.8	1.55	0.19
T2	Coconut fibre + coarse perlite+ vermicompost (½ kg) + Iron sulphate (0.3 %) + citric acid (0.2 %)	2.02	0.27	48.9	18.4	1.63	0.18
T3	Coconut fibre + coarse perlite+ vermicompost (½ kg) + Iron sulphate (0.4 %) + citric acid (0.2 %)	1.88	0.27	49.5	18.8	1.61	0.68
T4	Coconut fibre + coarse perlite+ vermicompost (½ kg) + Iron sulphate (0.5 %) + citric acid (0.2 %)	2.85	0.28	57.1	21.4	2.10	1.22
T5	Coconut fibre + coarse perlite + vermicompost (½ kg) + citric acid (0.2 %)	1.67	0.25	44.9	18.1	1.41	0.32
	G.M.	2.07±.221	0.26±0.023	48.9±1.63	19.2±0.62	1.66±0.09	0.52±0.16
	C.D. (5%)	0.7	0.07	5.14	1.95	0.27	0.49

Table 2. Effects of different concentrations of iron sulphate in biochemical parameters of Watercress under organic soilless system

Treatment details		Biochemical parameters					
		Fe (mg/l)	Cu (mg/l)	Zn (mg/l)	Mn (mg/l)	Vitamin-A (mg/100g)	Vitamin-C (mg/100g)
T1	Coconut fibre + coarse perlite+ vermicompost (½ kg) + Iron sulphate (0.2 %) + citric acid (0.2 %)	3.63	0.21	1.44	1.61	316	14.7
T2	Coconut fibre + coarse perlite+ vermicompost (½ kg) + Iron sulphate (0.3 %) + citric acid (0.2 %)	4.74	0.17	1.28	2.04	323	11.7
T3	Coconut fibre + coarse perlite+ vermicompost (½ kg) + Iron sulphate (0.4 %) + citric acid (0.2 %)	4.84	0.14	2.15	1.80	252	11.0
T4	Coconut fibre + coarse perlite+ vermicompost (½ kg) + Iron sulphate (0.5 %) + citric acid (0.2 %)	5.82	0.22	1.99	2.34	242	11.7
T5	Coconut fibre + coarse perlite + vermicompost (½ kg) + citric acid (0.2 %)	3.07	0.14	1.70	1.35	285	5.0
	G.M.	4.42±0.13	0.18±0.011	1.71±0.07	1.83±0.10	283±4.89	10.8±0.77
	C.D. (5%)	0.40	0.04	0.22	0.30	15.4	2.44

T_3 and T_5 recorded 0.14 mg/100 g Cu content, which was lowest among all the treatments and were at par with T_2.

Zn content (mg/ 100 g)

Highest Zn content (2.15 mg/ 100 g) was recorded in the plants treated with 0.4% (T_3) of Iron Sulphate and was at par with T_4 as shown in Table 2. Zn content was found lowest in the plant treated with 0.3 % iron sulphate (T_2) which is at par with T_1. T_5 (control) content 1.7 mg/ l of Zn.

Mn content (mg/ 100 g)

According to Table no. 02. the highest Mn (2.34 mg/ l) was found in plant treated with 0.5% iron sulphate (T_4) and found to at par with T_2. However, T_2 was at par with T_3 that contain 1.80 mg/l of Manganese. Plant grown without addition of iron sulphate contain minimum amount of Manganese which was at par with T_1.

Vitamin- A content (mg/100 g)

The amount of Vitamin- A recorded maximum (323 mg/100 g) and minimum (242 mg/ 100 g) in plants treated with iron sulphate @ 0.3% (T_2) and 0.5% (T_4) respectively as data available in Table 2. However, plant treated with 0.2% iron sulphate (T_1) contain second highest Vitamin- A and at par with T_2. 285 mg/100 g was recorded in plant which was untreated with iron sulphate.

Vitamin- C content

As shown in Table 2, highest amount of Vitamin- C (14.7 mg/100 g) was found in plant treated with minimum amount of iron sulphate (0.2 %) and found superior compared with other treatments. Lowest vitamin- C was found in T_5 (control). In T_2, T_3 and T_4, vitamin- C recorded were 11.7 mg/100 g, 11 mg/100 g and 11.7 mg/100 g respectively and shown at par with each other.

Discussion

As evident from the mean values of (Table 1), there were significant increase in the morphological parameters *viz.* leaf length (2.85cm), leaf thickness (0.28cm), no. of leaf per plant (57.1), plant height (21.4cm), plant fresh weight (2.10 g) and plant dry weight (1.22) by the fortification of plant with 0.5% of iron sulphate. These findings clearly indicate that iron played a significant role on growth parameters of watercress. Iron as a critical component of proteins and enzymes which is also associated with chloroplast, plays a significant role in basic biological processes such as photosynthesis, chlorophyll synthesis, respiration, nitrogen fixation, uptake mechanisms (Saleem *et al.,* 2017) and DNA synthesis through the action of the ribonucleotide reductase (Satpute *et al.,* 2013), which might help the better vegetative growth of watercress. Significant increase in plant morphology and production of more biomasses might be due to micro-nutrients supplement, avail and better uptake of nutrients in the soilless condition. Growth and yield parameters like maximum plant height, diameter of stem, longest leaf length, width of longest leaf, days taken to the appearance of first pod, weight of fresh pod and yield of green pods per plant were significantly increases on application of iron in okra (Seelig, 1974). Application of iron in okra significantly increases the number of leaves per plant (Shahrokhi *et al.*, 2009).

As evident from Table 2, the biochemical parameters pertaining to Fe, Cu, Zn and Mn also exhibited significant increment with iron supplied through iron sulphate in the organic soilless condition. T4 have significant effects on the biochemical parameters like Fe, Mn and Cu. However, Zn content was recorded highest in T_3, which is showed in (Table 2). Foliar application of iron on wheat has significant effect on yield, grain and Fe content (Singh *et al.*, 2007). Application of 0.4% of iron sulphate have sig-

Plate 1. Watercress plants at harvesting stage

nificant effect on Zn content of plant which is at par with T5 (0.5%) and it can clearly say that iron also have significant effect on Zn accumulation in plant. The $ZnSO_4$ plays synergetic effect for availability of iron (Stephens, 1994). Iron fortification with 0.05–2 g/l ferrous sulphate increased the iron concentration in germinated brown rice from 1.1 to 15.6 times in rice (Wei *et al*., 2013).

The amount of vitamin A recorded maximum (323 mg/100g) in plants treated with iron sulphate @ 0.3 % (T_2) and maximum amount of vitamin C (14.7 mg/100g) was found with the application of iron sulphate (0.2 %) T1, which is at par with control. It can be expected that production of vitamin A and vitamin C in watercress plant will increase only in certain or low concentration of Fe. Vitamins can be increased either through an optimization of growth conditions or through the process of biofortification (World Health Statistics, 2015).

Acknowledgement

The authors would like to thank Department of Horticulture, Sikkim University, Gangtok for laboratory and field (or polyhouse) facility and all cooperation. The authors also acknowledge the support extended by Mr. Saran Kumar Subba, Sikkim in sapling collection and in entire duration of research work.

References

Anjali, G., Marsonia, P. J. and Sakarvadia, H. L. 2015. Effect of zinc and iron on yield and yield attributes of okra (*Abelmoschus esculentus* L.). *Asian Journal of Soil Science*. 10: 104-107.

Asensi-Fabado, M. A. and Munné-Bosch, S. 2010. Vitamins in plants: occurrence, biosynthesis and antioxidant function. *Trends in Plant Science.* 15 : 582-592.

Beibel, J. P. 1960. Hydroponics-The Science of Growing Crops Without Soil. Florida Department of Agric. *Bull.*, p. 180.

Butler, B. J. 2002. Ironing out the Facts Why Plant Iron Is Best. *Small.* p. 1–6.

Carrasco, G., Moggia, C., Osses, I. J., Álvaro, J. E. and Urrestarazu, M. 2011. Use of peroxyacetic acid as green chemical on yield and sensorial quality in watercress (*Nasturtium officinale* R. Br.) under soilless culture. *International Journal of Molecular Sciences*. 12: 9463-947.

Cruz, R. M. S., Vieira, M. C. and Silva, C. L. M. 2008. Effect of Heat and Thermosonication Treatments on Watercress (*Nasturtium officinale*) Vitamin C Degradation Kinetics. *Innovative Food Science & Emerging Technologies*. 9 : 483–488.

Engelen-Eigles, G., Holden, G., Cohen, J. D. and Gardner, G. 2006. The effect of temperature, photoperiod, and light quality on gluconasturtiin concentration in watercress (*Nasturtium officinale* R. Br.). *Journal of Agricultural and Food Chemistry*. 54 : 328-334.

Gill, C. I., Haldar, S., Boyd, L. A., Bennett, R., Whiteford, J., Butler, M. and Rowland, I. R. 2007. Watercress supplementation in diet reduces lymphocyte DNA damage and alters blood antioxidant status in healthy adults. *The American Journal of Clinical Nutrition*. 85: 504-510.

H and FWD 2019. State Portal, Govt. of Sikkim (Health & Family Welfare Department | State Portal-Sikkim, https://sikkim.gov.in/departments/health-family-welfare-department)

Habib, M. 2009. Effect of foliar application of Zn and Fe on wheat yield and quality. *African Journal of Biotechnology*. 8.

Haro, G., Iksen, I., Rumanti, R. M., Marbun, N., Sari, R. P., and Gultom, R. P. J. 2018. Evaluation of antioxidant activity and minerals value from watercress (*Nasturtium officinale* R. Br.). *Rasayan Journal of Chemistry*. 11: 232-237.

Hecht, S. S., Chung, F. L., Richie, J. P., Akerkar, S. A., Borukhova, A., Skowronski, L. and Carmella, S. G. 1995. Effects of watercress consumption on metabolism of a tobacco-specific lung carcinogen in smokers. *Cancer Epidemiology and Prevention Biomarkers*. 4: 877-884.

Kim, J. and Rees, D. C. 1992. Structural models for the metal centers in the nitrogenase molybdenum-iron protein. *Science*. 257: 1677-1682.

Megan Ware, 2018. Iron; recommended intake, benefits and food sources., Medical News Today. 2018. (Retrieved from https//www.medicalnewstoday.com/articles/287228#recomended-intake)

Ranganna, S. 2004. *Handbook of Analysis and Quality Control for Fruit and Vegetable Products*, 2nd ed. Tata McGraw-Hill. New Delhi.

Reichard, P. 1993. From RNA to DNA, why so many ribonucleotide reductases? *Science.* 260 : 1773-1777.

Saleem Albermani, S., Albermani, A. and Jasim Altameme, H. 2017. Systematic Study of the Genus Nasturtium R. Br (Brassicaceae) in Iraq. *Journal of Chemical and Pharmaceutical Sciences*. 10 : 352-358.

Satpute, N. R., Suryawanshi, L. B., Waghmare, J. M. and Jagtap, P. B. 2013. Response of summer okra (cv. Phule Utkarsha) to iron, zinc and boron in inceptisol. *Asian Journal of Horticulture.* 8: 541-546.

Seelig, R. A. 1974. Watercress. United Fresh Fruit & Vegetable Association, Washington, DC.

Shahrokhi, N., Hadad, M. K., Keshavarzi, Z. and Shabani, M. 2009. Effects of aqueous extract of water cress on glucose and lipid plasma in streptozotocin induced diabetic rats. *Pakistan Journal of Physiology*. 5 : 6-10.

Singh, K.V., Singh, M.K. and Singh, B. 2007. Response of macro and micronutrient on growth and yield of okra (*Abelmoschus esculentus* (L.) Moench]. *Pro. Agric*. 7 : 63-65.

Stephens, J.1994. Watercress *Nasturtium officinale* R.Br. University of Florida Cooperative Extension Service, Institute of Food and Agriculture Sciences, EDIS, pp.1-2.

Wei, Y., Shohag, M. J. I., Ying, F., Yang, X., Wu, C. and Wang, Y. 2013. Effect of ferrous sulfate fortification in germinated brown rice on seed iron concentration and bioavailability. *Food Chemistry*. 138 : 1952-1958.

World Health Statistics, 2015 - World Health Organization - Google Books https://books. google.co. in/books?hl=en&lr=&id=Kl00DgAAQBAJ&oi=fnd&pg=PP1&dq=(WHO,+2015)&ots=8NsGosWQAg& sig=V1GItAOEJy7_Xr5T uDr1JP281gs&redir_esc=y#v=onepage&q=(WHO%2C%202015)&f=false (accessed 2021 -08 -09).