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Micronutrient content and yield of spinach (*Spinacea oleracea. L.*) as influenced by different sources and levels of iodine fertilization

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Abstract
A pot experiment was undertaken to study of the effect of different sources (Iodine & Iodates) the levels (0.0. 1.0 .2.5 & 5.0 mg $kg^{-1,}$) of iodine in combination of recommended dose of NPK and NPK + FYM on yield and micronutrient content in spinach *(spinacea oleracea. L.)*Yield of spinach leaf significantly influenced by various sources and levels of applied iodine at both statges of harvesting (45 and 60 Days after Sowing). Spinach yield was significantly higher with the application of recommended dose NPK +FYM as Compared with recommended dose of NPK alone at each levels of applied iodine Nutrients contents (Fe, Mn, Zn, & Cu).

Keywords: spinach, yield, nutrient content

Introduction

Spinach (*Spinacia oleracea* L.) is an important vegetable crop of Varanasi and gaining its popularity to all kinds of people due to its high carotene and vitamin C contents. In our country, most of the people, especially the children suffer from malnutrition tremendously, which affect theirnational life. According to WHO and FAO, an adult person's diet should contain 250 g vegetable per day. Vegetables are produced at present which are too low against our demand [1]. Fertilizers are essential part of modern farming system, about 50% of the world production being attributed to fertilizer use and it may be a source of the environmental and soil degradation [2].Minerals and vitamins are essential protective nutrients for maintenance of nutritional and health status of the body. They cannot be synthesized in the human body and, therefore, they must be obtained through diet.

Vegetables form a considerable part of an Indian diet, which is basically vegetarian. The composition of nutrient content of the vegetables varies widely depending on the part of the plant used as food [3]. Generally, vegetables are considered to contribute appreciable amounts of minerals and vitamins; but when compared with other groups of vegetables, green leafy vegetables are known to be exceptionally rich in minerals, β-carotene [4] and are also a good source of dietary fiber and antioxidants [5, 6]. Green leafy vegetables, in general, are inexpansive foods rich in minerals and vitamins. Specifically, it is also well known that nutrient elements in the leaves of spinach are always important to human health [7]. Spinach as a dietetic nutrient has long been the object of many investigators. Spinach is the commonly consumed green leafy vegetables in different parts of India.

In the recent years, there is growing concern regarding the nutritive value of foods and to nourish the ever increasing population and the inadequacy of essential nutrients can be improved through fortifications. The findings from various studies conducted by several groups of investigators revealed that content of minerals in plant foods can be altered by the application of fertilizers to the soil by balancing the macronutrients and with micronutrients [8, 9, 10]. However, most of this research was carried out with foods other than vegetable crops. Hence, the present study was undertaken to find the effect of addition of chemical fertilizers and in combination, chemical fertilizer and FYM to soil on mineral contents of most popular green leafy vegetable, spinach (*Spinacea oleracea* L.). In addition, the spinach was tried to fortify iodine by the application potassium iodide/potassium iodate in soil. Thus, iodine was applied in soil in addition chemical fertilizer/chemical fertilizer + FYM. Although iodine is not essential element to plant, but iodine is an important essential micronutrient element for human being and animals. It require for synthesis of thyroid hormones, thyroxins and triiodothyroxin which are iodinated molecules of the amino acid tyrosine. Consumption of crops and plants grown in iodine deficient soils leads to iodine deficiency. It is now established that iodine deficiency in human being and animal occurs only in the areas where vegetation is poor in iodine. Hence, iodine rich salt supplement is recommended to ward off iodine deficiency disorder. But during cooking with high temperature oil will result in the volatilization of Iodine [11]. The present study was undertaken to find the effect of iodine application through potassium iodide/potassium iodate in addition to fertilization on the yield and micronutrient contents of spinach.

Materials and Methods

The present investigation involved a pot experiment followed by laboratory analysis of the plant and soil at the Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, is situated at an altitude of 123.93 m above mean sea level and at 25°18' North latitude and -1 80°36' East longitudes.

The experimental soil was sandy loam with 2.25 mg kg^{-1} available iodine, 1.43 Mg m^{-3} bulk density, 2.56 Mgm^{-3} particle density, 45.40 % water holding capacity, 7.8 pH, 0.254 dS m^{-1} electrical conductivity, 6.21g kg^{-1} organic matter, 11.04 C mol (p+) kg^{-1} cation exchange capacity and 197.27, 19.09, 203.54, 19.77 kg ha^{-1} of available N, P, K, S, respectively and the soil was characterized by standard method [12].The pot experiment was planned in a greenhouse with temperature of 28 ± 3°C during the day and 18 ± 3°C at night. 1.0kg well pulverized soil was filled in each pot. The recommended doses of N, P, K (80:50:50) fertilizers were applied in each pot through urea, single super phosphate and muriate of potash, respectively with different levels and sources of iodine in combination with and without FYM (1% organic carbon). Potassium iodide and potassium iodate were used as an iodine fertilizer for iodine treatments. 100 mg I $L^{-1}$of potassium iodide and iodate were prepared as stock solution then 0.0, 1.0, 2.5 and 5.0 mg $kg^{-.1}$ iodine solution was applied at 20 DAS in respective pots. Full dose of phosphorus, potassium and 1/3 dose of nitrogen were applied at the time of pot filling through mixing and rest N was applied into two split doses at 20 and 30 days after seed sowing, respectively. The plants were grown in green house, keeping moisture level 50% of the field capacity with de-ionized water at regular interval. 5-6 healthy seeds of spinach were shown at proper depth in the month of December and after germination 3 plants in each pot was maintained at 15 days after sowing (DAS). Experimental samples were collected into two stages, 45 and 60 DAS. The fresh weight of edible portion of spinach was taken after harvesting at 45 and 60 DAS.

The micronutrient contents in plant samples were estimated after proper processing. The surface moisture of plant samples were air dried, after that samples demoistened in hot air oven (65°C) and the oven dried samples has been grinded. Micronutrients (Fe, Mn, Zn & Cu) in plant samples were extracted by diacid digestion with HNO_3: $HC10_4$ (9:4). The iron manganese, zinc& copper in plant samples were determined by atomic absorption spectrophotometer.

Results and Discussion

Yield and Spinach

The yield of leafy vegetable, spinach *(Spinacea oleracea L.)* grown with different sources and levels of iodine in combination with recommended dose of NPK and NPK + FYM are shown in (Table 1.), A perusal of the data revealed that yield of the edible portion of spinach leaf significantly influenced byvarious sources and levels of applied iodine at both the stages of harvesting (45 and 60 days after sowing). Spinach yield was significantly higher with the application of recommended dose of NPK+ FYM as compared with recommended dose of NPK alone at each level of applied iodine. Furthermore, yield of spinach improved at 60 DAS as compared to 45 DAS with the application of different sources and levels of iodine and recommended dose of NPK and NPK+FYM.

[13]Conducted some experiments to evaluate the iodine as a micronutrient for plants. In sand-culture experiments in pots it was shown that various crops react to minute applications (0.02 to 1.00 ppm) of iodide or iodate. The vegetative growth of spinach, white clover fodder beet, tomatoes, perennial ryegrass, turnips (aerial parts) barley, wheat andmustard was favorably influenced by iodine [14]. Studying six different types of plants classified according to their edible parts (root, tuber, aerial part and leaf), found that iodate concentration had a significant effect over biomass of plants only in those where the edible part was the leaf but for root vegetable, iodate concentration had nosignificant effect. [15].Working with spinach plants, observed a direct relationship between foliar biomass and the application of 10 and 100 ppm of iodide and iodate.

An enhance of spinach yield were recorded with increasing levels of iodine when applied with recommended dose of NPK + FYM at 45 DAS and the maximum spinach yield was obtained by the application of @ 5.0 $mgkg^{-1}$ of iodine (53.6 and 32.9%) at both the stages. However, in case of $IO3^-$ highest yield of spinach was obtained @ 5.0 mgkg-^{1} of iodine (43.3 and 39.4%) with recommended dose of NPK + FYM at 45 and 60 DAS. Iodine applied with recommended dose of NPK was not increase the yield as much increased by iodine applied with NPK + FYM. Iodine @ 5.0 mg kg^{-1} with NPK retarded the growth of plant and consequently the yield of spinach. Further examination of the data showed that the application of various levels of iodide (KI) and iodate (KIO_3) with recommended dose of NPK increased the yield of spinach significantly in comparison to control. Iodine applied @ 2.5 mg I kg-' increased 18.1 and 23.8 % of spinach yield was highest for iodide and for iodate it was 23.7 and 38.5% (Fig. 1) with recommended dose of NPK at 45 and 60 DAS, respectively. Thus, application of iodine as iodide and iodate significantly influenced the biomass of edible part of spinach at both the stages. It means that both I^- and IO_3^-uptake by the vegetables stimulated their biomass output. Moreover, species of iodine and their doses are most important for stimulation of biomass production. Among the sources of iodine, iodate was better responsive than iodide, to increase in yield of leafy vegetable spinach.

Table 1: Effect of Iodine Treatments on Yield of Spinach

Treatment	**Recommended dose of NPK**				**Recommended dose of NPK + FYM**			
(mg I kg^{-1}of soil)	**45 DAS**		**60 DAS**		**45 DAS**	**60 DAS**	**45 DAS**	**60 DAS**
Control	I^-	IO3$^-$	I^-	IO3$^-$	I^-	IO3$^-$	I^-	IO3$^-$
	18.76		19.50		20.16		23.67	
1.0	20.68	22.90	22.20	25.60	24.17	25.08	24.56	
2.5	22.16	24.90	24.15	27.00	28.94	26.69	28.63	29.50 29.84 32.99
5.0	21.00	19.70	22.01	21,20	30.96	28.88	31.46	
SEm	0.737		1.140		1.038		1.416	
CD (p=0.5)	2.237		3.358		3.147		4.294	

Iron (Fe) Content in Spinach

Iron content (mg kg^{-1}) in spinach corresponding to different treatments is presented in (Table 2). Fertilization had no effect on Fe content at initial stage (45 DAS). The iron content in spinach was found significantly higher (15.27%) in chemical fertilizer application over chemical fertilizer + FYM at 60 DAS. High organic carbon in FYM adsorbed or chelated (through organic acids) the native Fe in soil. In general, it was observed (Table 2) that, iron content were slightly increased (45 DAS) due to addition initial dose of iodine @ 1.0 mg kg^{-1} either through KI or KIO_3. But the iron content was severely affected with the increment (Fig.1) of the iodine doses (@ 2.5 and @ 5.0 mg kg^{-1}) at 45 DAS. The iron content was found increased (10.37 to 20.28%) with the addition of iodine at later stage (60 DAS). at initial stage. At 60 DAS manganese content was increased (12.16 to 14.06%) by the application of iodine through KI irrespective of doses, but only through @ 1.0 mg kg^{-1} KIO_3 (15.20%).The manganese content was increased (Table 2) significantly through application of chemical fertilizer + FYM and iodine @ 2.5 mg kg^{-1} through KI at initial stage (45 DAS) with the application of iodine @ 1.0 mg kg^{-1} through KIO_3 at 60 DAS.

Table 2: Effect of Fertilization & Iodine Application on Iron & Manganese Content in Spinach

Particulars	**Fe (mg kg^{-1})**		**Mn (mg kg^{-1})**	
	45 DAS	**60 DAS**	**45 DAS**	**60 DAS**
Nutrient source				
Chemical (NPK)	27.50	31.78	2.44	2.84
Chemical (NPK) + Organic (FYM)	27.34	27.57	2.28	2.94
SEm ±	0.076	0.366	0.030	0.026
CD (P= 0.05)	NS	0.880	0.070	0.060
Iodine sources/doses				
Control	28.75	26.03	2.36	2.63
KI – 1.0 mg kg^{-1}	29.23	30.38	2.45	2.95
KI – 2.5 mg kg^{-1}	27.35	30.11	2.90	3.20
KI – 5.0 mg kg^{-1}	28.40	31.31	2.25	2.98
KIO_3 – 1.0 mg kg^{-1}	29.48	31.15	2.46	3.03
KIO_3 – 2.5 mg kg^{-1}	26.55	30.03	2.08	2.71
KIO_3 – 5.0 mg kg^{-1}	22.20	28.73	2.03	2.73
SEm ±	0.143	0.685	0.056	0.050
CD (P= 0.05)	0.340	1.650	0.130	0.120

Table 3: Effectsof Fertilization and Iodine Application on Copper & Zinc Content in Spinach

Particulars	**Cu(mg kg^{-1})**		**Zn(mg kg^{-1})**	
	45 DAS	**60 DAS**	**45 DAS**	**60 DAS**
Nutrient source				
Chemical (NPK)	0.64	0.88	0.49	1.53
Chemical (NPK) + Organic (FYM)	1.15	1.25	0.34	1.40
SEm ±	0.032	0.032	0.039	0.032
CD (P= 0.05)	0.09	0.08	0.090	0.08
Iodine sources/doses				
Control	0.50	1.00	0.31	1.21
KI^- 1.0 mg kg^{-1}	1.01	1.03	0.48	1.36
KI^- 2.5 mg kg^{-1}	1.26	1.46	0.35	1.46
KI – 5.0 mg kg^{-1}	0.80	0.80	0.43	1.23
KIO_3^- 1.0 mg kg^{-1}	0.95	0.93	0.51	2.03
KIO_3^- 2.5 mg kg^{-1}	0.90	1.05	0.41	1.70
KIO_3^- 5.0 mg kg^{-1}	0.88	1.20	0.40	1.28
SEm ±	0.061	0.061	0.074	0.059
CD (P= 0.05)	0.150	0.150	NS	0.140

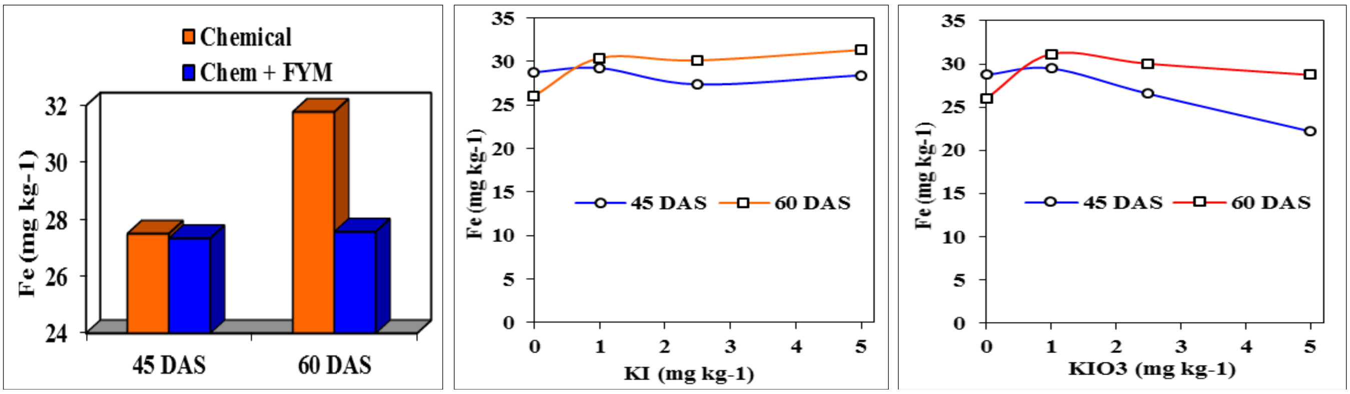


Fig 1: Effect of Fertilization and Iodine Application on Iron Content (Mg Kg^{-1}) in Spinach

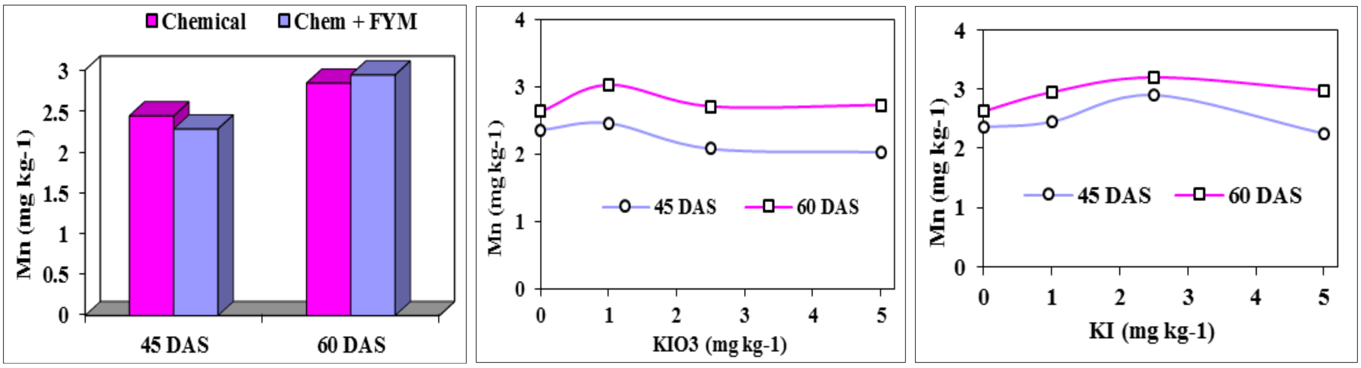


Fig 2: Effectsof Fertilization and Iodine Application on Manganese Content (Mg Kg^{-1}) In Spinach

Copper (Cu) content in spinach

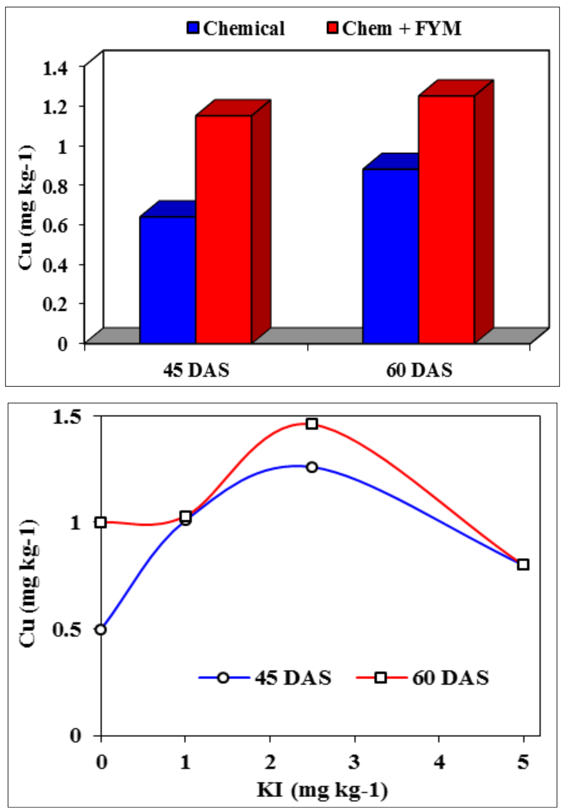
The copper content was significantly increased (Table 3) through the integration of FYM with chemical fertilizers (NPK) at 45 DAS (79.68%) and 60 DAS (42.04%). The plant available copper was released through the decomposition of FYM within two months. The Cu content initially (45 DAS) increased due to addition to iodine eitherthrough KI or KIO_3 (Fig.3). But, at later stages (60 DAS) significant difference (46% increment) in Cu content was observed particularly in iodine application @ 2.5 mg kg^{-1} of iodine through KIO_3.

The iodine application @ 2.5 mg kg^{-1} through KI along with chemical fertilizer + FYM improved maximum amount of Cu content at 45 DAS and 60 DAS, but @ 5.0 mg kg^{-1} and I^- through KI at 60 DAS severely affected the Cu content in spinach. There was a wide difference in Cu content between chemical fertilizer and chemical fertilizer + FYM with iodine application. The iodine application with integrated use of FYM + chemical fertilizer improved significantly the Cu content in spinach.

Zinc (Zn) content in spinach

The zinc content was significantly increased (44.11%) only at initial stage (45 DAS) due to application (Table 3) of chemical fertilizers. The zinc content was increased significantly by the application of iodine through KI and KIO_3(Fig. 4) at both stages 45 DAS and 60 DAS, but increment of Zn content was higher (12.90 to 64.51) at initial stage (45 DAS) than the later stage (60 DAS). Maximum increment (64.51 to 67.76%) was observed at both the stages 45 DAS and 60 DAS (Fig. 4) by the application of iodine through KIO_3. The Zn content was observed maximum at 60 DAS, when chemical fertilizers (Table 3) were applied with iodine @ 1.0 mg kg^{-1} through KIO_3.

A critical examination on fortification of iodine in spinach with recommended dose of fertilizers (NPK)/NPK + FYM revealed that iodine application either KI or KIO_3 affected the Fe and Mn content at initial stages (45 DAS) with higher doses, but at later stages (60 DAS) Fe and Mn content in spinach was improved. The significant improvement of Cu and Zn content due to application of iodine were observed at initial stage (45 DAS). Organic matter (FYM) adsorbed/chelated the native Fe, Mn and Zn and thus chemical fertilizers application improved the Fe, Mn and Zn content in spinach.



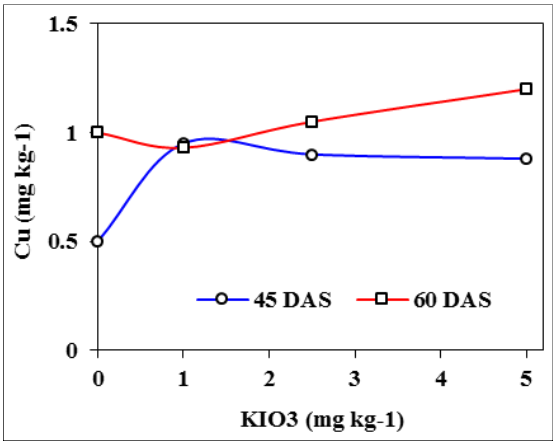


Fig 3: Effectsof Fertilization and Iodine Application on Copper Content (Mg Kg^{-1}) in Spinach

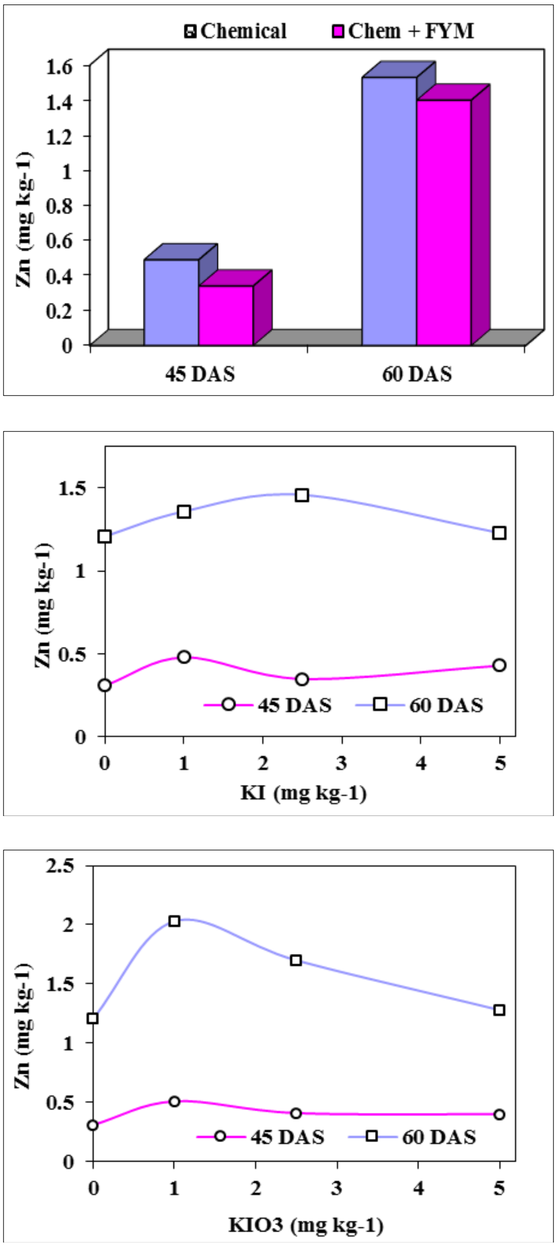


Fig 4: Effectsof Fertilization and Iodine Application on Zinc Content (Mg Kg^{-1}) In Spinach

Conclusion

The findings from various studies conducted by several groups of investigators revealed that content of minerals in plant can be altered by application of fertilizers to the soil by balancing the macronutrients and with micronutrients. However, most of this research was carried out with foods other than vegetable crops. Hence, the present study was undertaken to find the effect of addition of chemical fertilizers and in combination, chemical fertilizer and FYM to soil on micro nutrient contents of most popular green leafy vegetable, Spinach (*Spinacea oleracea* L.). Micronutrients (Fe, Mn, Cu and Zn) were analyzed by extracting separately with HNO_3 and $HClO_4$. The Iron, Magnesium, Copper and Zinc in leaves of spinach were estimated by atomic absorption spectrophotometer. Fortification of iodine with the application of potassium iodide/iodine in spinach significantly reduced the iron and manganese content in spinach at initial stages (45 DAS) particularly with higher doses of iodine, but at later stage (60 DAS) the iron and manganese content in spinach were improved. The significant improvement of copper and zinc content were observed at initial stage (45 DAS) due to application of iodine.

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