STUDIES ON BIOFORTIFICATION OF BYADGI CHILLIES (*Capsicum annuum* L.) WITH IODINE USING POTASSIUM IODATE (KIO_3) IN A VERTISOL

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Abstract: An experiment was conducted during *kharif* 2014-15 to study the "Biofortification of Byadgi chillies (*Capsicum annuum* L.) with iodine through soil and foliar application of potassium iodate (KIO_3) in a Vertisol". Experiment consisted of thirteen treatments and three replications laid out in Randomized Block Design. Application of potassium iodate to soil at 10 mg kg^{-1} on 45 DAT recorded highest fruit yield (10.40 q/ha) followed by treatment which received five mg kg^{-1} of KIO_3(10.35 q/ha) and control (9.70 q/ha). Treatments which received soil plus foliar application of KIO_3 recorded significantly lower fruit yield (average 7.86 q/ha) over control as well as soil applied and foliar applied treatments. Highest colour value (183.11 ASTA units) and oleoresin content (14.98 %) in red chilli fruits were recorded with soil application of KIO_3 at 10 mg kg^{-1} on 45 DAT. Soil plus foliar application of KIO_3 reduced significantly the colour value (124.13 ASTA units) and oleoresin content (12.87%) over control. Highest iodine content in green (7.47µg g^{-1}) and red fruits (12.39 µg g^{-1}) was noticed due to soil application of KIO_3 at 10 mg kg^{-1} on 45 DAT along with foliar sprays of 0.3 % KIO_3 on 60 and 90 DAT. Two foliar applications of KIO_3 improved iodine content in chilli fruits significantly (11.29 µg /g) over single spray (6.17 µg/g) in association with soil application of KIO_3. Foliar application increased iodine content in red chilli fruits over control, but colour value and oleoresin contents were affected. But in fresh green fruits application of KIO_3 enhanced iodine content significantly over control without altering vitamin-C content.

Key words: Biofortification, colour value, oleoresin, vitamin-C and potassium iodate.

Introduction : Biofortification is the process of increasing the natural content of nutrients in edible parts of crop plants. Halogens are a group of five chemically related elements: fluorine (F), chlorine (Cl), bromine (Br), iodine (I) and astatine (At). Concentrations in plants generally follow the order Cl > Br > F > I. Iodine is an essential micro-element and a component of thyroid hormones which are involved in a variety of physiological processes, including reproductive functions, preservation of central nervous system, energy conversion and maintaining normal metabolism. The low consumption of iodine rich foods, the paucity of this element in cultivated soils, absence of iodine in the drinking and irrigation waters, strong fixation of this element by the soil organic matter coupled with lack of adequate enrichment in finished foods (Zhang *et al.,* 2002) cause iodine deficiency disorders [IDD].

In order to counteract iodine deficiency, its supplementation through iodised table salt is an efficient way of introducing this micro element into human diet. Commercial table salt contains 0.003% of iodine supplemented through potassium iodate (KIO_3). But excessive consumption of salt may lead to increased occurrence of cardiovascular diseases. To meet daily iodine requirements of body, the recommended iodine intake as per World Health Organization is 150 µg for adults, for children 50 to 90 µg and for pregnant and lactating women is 200 µg.

To meet daily iodine requirement of body, the average salt intake should be around 10 gms/day/person. Human beings suffering from diabetes, cardiac disorders and blood pressure cannot consume salt in higher quantity. The iodine concentration in both soils and vegetables is usually too low to meet the need of the iodine in human body. The important carriers of iodine are potassium iodide (KI), potassium iodate (KIO_3) potassium per iodate (KIO_4) and iodoacetic acid (CH_2ICOO^-). Among them potassium iodate is most extensively used for the biofortification of vegetables. Iodised chilli powder can reduce salt intake to some extent and meet normal iodine requirement of body. Information on the content of iodine in chilli powder and its biofortification through foliar and soil application of iodine carriers is lacking. Hence the present investigation is undertaken to enrich chilli powder with iodine using soil and foliar application of potassium iodate.

Material and methods: A field experiment was conducted during *kharif* 2014-15 in the farmer's field. The soil of the experimental site was medium black with clay in texture, organic carbon 6.60 g/kg, neutral pH 7.20 and available N, P_2O_5 and K_2O were 175.6, 17.44 and 268 kg/ha. respectively. Water soluble iodine content in the sample was 1.68 mg/kg. The experiment was laid out in complete randomized design with 13 treatments and 3 replications. The treatment details are given in Table-1.

Table – 1: Treatment details:

T_1	Control (water spray at 60 and 90 DAT)
T_2	KIO_3 soil application @ 5 mg/kg at 45 DAT
T_3	KIO_3 soil application @ 10mg/kg at 45 DAT
T_4	KIO_3 0.2% foliar spray at 60 and 90 DAT
T_5	KIO_3 0.3% foliar spray at 60 and 90 DAT
T_6	KIO_3 soil application @ 5 mg/kg at 45 DAT + 0.2% KIO_3 foliar spray at 60 and 90 DAT
T_7	KIO_3 soil application @ 5 mg/kg at 45 DAT + 0.2% KIO_3foliar spray at 90 DAT
T_8	KIO_3 soil application @ 5 mg/kg at 45 DAT + 0.3% KIO_3 foliar spray at 60 and 90 DAT
T_9	KIO_3 soil application @ 5 mg/kg at 45 DAT + 0.3% KIO_3 foliar spray at 90 DAT
T_{10}	KIO_3 soil application @ 10mg/kg at 45 DAT + 0.2% KIO_3 foliar spray at 60 and 90 DAT
T_{11}	KIO_3soil application @ 10mg/kg at 45 DAT + 0.2% KIO_3 foliar spray at 90 DAT
T_{12}	KIO_3 soil application @ 10mg/kg at 45 DAT + 0.3% KIO_3 foliar spray at 60 and 90 DAT
T_{13}	KIO_3 soil application @ 10mg/kg at 45 DAT + 0.3% KIO_3 foliar spray at 90 DAT

Note: RDF 150:75:75 kg N, P_2O_5, K_2O /ha respectively + FYM (25t/ha) is common for all the treatments.

Potassium iodate contains 59 % iodine and 18% potassium. A foliar spray trial of potassium iodate was taken with five chilli plants at the concentrations of 0.5, 0.75 and 1.0 per cent. All the plants receiving 0.75 and 1.0 per cent solution showed yellowing of leaves along with wilting symptoms. Hence, 0.2 and 0.3 per cent concentrations were considered as safe limit to avoid adverse effects on plants.

Transplanting: One month old chilli (Cv. Dyavnur) seedlings were transplanted in the main field. Two seedlings were planted per hill at 75 cm x 75 cm spacing. Gap filling was done within a week after transplanting wherever necessary in all the plots.

Fertilizer application: Nitrogen was supplied partly through DAP and urea while the entire doses of P and K were supplied through DAP and muriate of potash respectively. Nitrogen was applied in two split doses, basal dose of 50 per cent at the time of transplanting and remaining half dose at 45 days after transplanting. The fertilizers were applied in ring method and mixed with soil.

Soil and foliar application of potassium iodate : Potassium iodate salt (KIO_3) was mixed with soil to get 5 mg kg^{-1} and 10 mg kg^{-1} dosage (53.33 mg and 106.66 mg of potassium iodate were mixed with 10 kg soil separately for each plot, respectively) a three days before application to soil. The potassium iodate mixed with soil earlier was applied in ring method on 45^{th} day after transplanting to each plot. Potassium iodate was dissolved in water to get 0.2 per cent (0.2 g /100 ml) and 0.3 per cent (0.3 g /100 ml) concentration and sprayed on 60^{th} and 90^{th} day after transplanting as per the treatment details.

Iodine analysis in chilli fruits.: Red chilli fruits were harvested periodically and plant samples were collected at harvest and analysed for water soluble iodine and other nutrients. Iodine content in fresh green fruits was analysed after extracting the fruit pulp with distilled water. Quantification of the extracted iodine was made by titrating the water extract of green fruits against 0.01 N sodium thiosulphate solution with starch solution as indicator given by Williams (2008). Similarly, red chilli fruits were finely powdered and extracted with water. The colored water extract of chilli powder was titrated against 0.01 N sodium thiosulphate solution with starch solution as indicator Williams (2008).

Quality parameters of chilli fruits: Ascorbic acid content in fresh green chilli fruits was determined as per the method out lined by Sadasivam and Manickam (1992). Color value of sun dried red chilli fruits was determined as per the procedure out lined by Mahindru (1987) while oleoresin content was determined by adopting Ethylene dichloride method as given by AOAC, (1997).

Soil and plant analysis: Soil and chilli plant samples were collected treatment wise at harvest and analysed for nutrients by adopting standard procedures and uptake of nutrients was calculated. Chilli fruit yield was recorded by pooling the yield recorded at different pickings.

Results and discussion

Dry fruit yield : Dry chilli yield was significantly influenced by potassium iodate application (Table 2). Soil application of KIO_3 at 10 mg kg^{-1} on 45 DAT without any foliar spray (T_3) produced highest yield (10.40 q ha^{-1}) closely followed by soil application of KIO_3 at 5 mg kg^{-1} (10.35 q ha^{-1}) and control (9.70 q ha^{-1}). Increased chilli yield in the former treatment was attributed to greater availability of potassium to plants applied through KIO_3 (18% K in KIO_3). The organic matter present in soil binds the iodate ion very strongly and prevents its absorption by plant roots which otherwise would have caused toxicity on plants. Kiferle *et al.* (2013) reported the negative role of organic matter on the mobility of iodine and clarified that, iodate anion could be retained stronger than iodide by organic matter fraction of soil. Further there existed synergistic relationship between iodate anion and nitrate anion. This might have resulted in increased uptake by nitrogen by plants leading to increased fruit yield. There was significant reduction in fruit yield due to foliar spray of potassium iodate at 0.2 and 0.3 per cent concentrations (T_4 and T_5 treatments) compared to control (T_1) as well those treatments which received only soil application of KIO_3. To enrich iodine content in red chilli fruits, foliar spray of KIO_3 at 0.2 and 0.3 per cent concentrations closely synchronising with fruiting and fruit development (60 and 90DAT) stages was taken. But there was toxic effect of iodine on plants which led to reduced yield. Umlay and Poel (1970) reported similar observations due to foliar spray of potassium iodide at 0.5 and 10 mg litre^{-1} on barley, tomato and pea crops. Further foliar spray of KIO_3 might has resulted in greater accumulation of iodine on leaf and fruit surfaces without being absorbed. This was due to preference of iodine translocation through xylem rather than phloem. Herrett *et al.* (1962) reported that iodine applied through foliar spray has little or no translocation downward through the phloem. This might has resulted in occurrence of iodine toxicity symptoms on leaves and chilli fruits leading to dropping of leaves, flowers and fruits.

Control (T_1) recorded higher fruit yield than treatments which received foliar and soil applied treatments. This was because absence of toxic symptoms of iodine in this control treatment. The beneficial effect of potassium present in KIO_3 (18% K) in influencing fruit yield might be obscured by high content of iodine (59%) present in KIO_3.

Table 2 : Effect of soil and foliar application of potassium iodate (KIO_3) on dry fruit yield & quality parameters of red chilli fruits

Treatments	Dry fruit yield (q/ha)	Ascorbic acid* (mg 100 g^{-1})	Colour value (ASTA units)	Oleoresin (%)
T_1- Control (water spray at 60 & 90 DAT)	9.70	121.33	174.63	14.06
T_2- KIO_3 soil application @ 5 mg/kg	10.35	147.77	180.73	14.19
T_3- KIO_3 soil application @ 10 mg/kg	10.40	158.30	183.11	14.98
T_4- KIO_3 0.2% foliar spray at 60 & 90 DAT	8.56	145.53	131.23	13.38
T_5- KIO_3 0.3% foliar spray at 60 & 90 DAT	8.43	146.30	127.19	12.63
T_6- KIO_3 soil application @ 5 mg/kg +0.2% KIO_3 foliar spray at 60 & 90 DAT	8.66	128.44	129.98	12.63
T_7- KIO_3 soil application @ 5 mg/kg +0.2% KIO_3foliar spray at 90 DAT	9.25	129.73	132.12	12.81
T_8- KIO_3 soil application @ 5 mg/kg + 0.3% KIO_3 foliar spray at 60 & 90 DAT	7.90	128.78	116.50	13.12
T_9- KIO_3 soil application @ 5 mg/kg + 0.3% KIO_3 foliar spray at 90 DAT	7.67	128.44	118.67	13.38
T_{10}- KIO_3 soil application @ 10 mg/kg +0.2%KIO_3 foliar spray at 60 & 90 DAT	7.55	140.60	130.61	12.81
T_{11}- KIO_3 soil application @ 10 mg/kg +0.2% KIO_3 foliar spray at 90 DAT	7.40	128.67	134.63	13.19
T_{12}- KIO_3 soil application @ 10 mg/kg +0.3% KIO_3 foliar spray at 60 & 90 DAT	6.95	144.06	114.02	12.33
T_{13}- KIO_3 soil application @ 10 mg/kg +0.3% KIO_3 foliar spray at 90 DAT	7.52	132.67	116.50	12.67
S. Em ±	0.56	4.96	2.61	0.15
CD (0.05)	1.64	14.46	7.61	0.45
CV %	11.40	-	-	-

Quality attributes (Table – 2)

Ascorbic acid: Application of potassium iodate at 10 mg kg^{-1} (T_3) to soil resulted in highest ascorbic acid content (158.30 mg /100gm) closely followed by application at 5 mg kg^{-1} (147.77mg/100gm) further followed by foliar spray of KIO_3 at 0.3 per cent on 60 and 90 DAT (146.30 mg/100gm) and 0.2 per cent spray (145.53 mg/100gm). Higher ascorbic acid contents in the soil applied treatments (T_2 and T_3) might due to increased uptake of potassium supplied through KIO_3. This absorbed potassium might catalyses the enzyme responsible for ascorbic acid synthesis in green chillies. Further, the iodate ion of KIO_3 and nitrate ion of added fertilizers have synergistic relationship. This might has resulted in increased uptake of nitrate nitrogen by plants. This nitrogen along with absorbed K increases the activity of ascorbic acid oxidase enzyme leading to enhanced vitamin-C content in green chillies. Osuna *et al.* (2014) reported that in *Opuntia Ficus- Indica* crop, application of both potassium iodide (KI) and potassium iodate (KIO_3) increased the ascorbic acid content by 45 per cent.

Colour value: Soil application of KIO_3 at 10 mg kg^{-1} (T_3) recorded highest colour value (183.11 ASTA units) which was on par with treatment (T_2) having KIO_3 at 5 mg kg^{-1} (180.73 ASTA units) but differed significantly from control (174.63 ASTA units) as well as other treatments [Fig. 5]. High colour value in the first two treatments was attributed greater uptake of potassium by plants supplied through KIO_3. Potassium plays a significant role in red colour synthesis in plants, particularly the capsanthins and capsorubins the vital constituents of red colour in chillies. The absorbed K by plant roots participates in the synthesis of these pigments. Somimol (2012) reported that split and foliar application of potassium nitrate resulted in enhanced colour value in byadgi chillies.

Foliar spray of KIO_3 either alone ($T_4$and T_5) or in combination with soil application (T_6 to T_{13}) recorded significantly lower value than the two treatments which received only soil application of KIO_3. Reduced colour value due to foliar spray KIO_3 was attributed to toxic effect of iodine on chilli fruits. The oxygen present in iodate radical might bring about oxidation of capsanthins and capsorubins leading to discolouration of fruits. Further, the beneficial effects of potassium supplied through foliar spray of KIO_3might have been reduced due to high content of iodine present in KIO_3 (59% iodine). Hence all the foliar applied treatments recorded low colour value.

Oleoresin : Highest oleoresin content (14.98%) in chilli fruits was noticed due to soil application of KIO_3 at 10 mg kg^{-1} (T_3) and differed significantly from all other treatments [Fig. 6]. This might be due to greater availability of potassium to plants applied through KIO_3 (18% K). Lesser oleoresin content in chilli fruits due to foliar spray was attributed to toxic effect of iodine. The iodate ion of the foliar spray might interfere with colour formation as well as seed development in fruits. This has led to reduced oleoresin contents in fruits.

Iodine uptake (Table – 3) : Treatment (T_{12}) that received soil application of KIO_3 at 10 mg kg^{-1} along with two foliar sprays (0.3 %) recorded highest uptake at 55, 70 and 100 DAT. This was attributed to greater supply of iodine to plants through soil and foliar spray which has resulted in greater availability and uptake by plants. Smolen and Sady (2012) reported that, potassium iodate applied through soil and foliar spray is better absorbed by spinach plants grown in sand culture.

Treatments which received two foliar sprays (60 and 90 DAT) recorded higher iodine uptake than those which received one foliar spray. This is because of increased iodine supply to plants through two sprays. Further these two sprays might have close synchronisation with fruit development, which has resulted in greater uptake. Particularly foliar spray of KIO_3 at 90 DAT, has close synchronisation with red colour synthesis in chilli fruits for which potassium is necessary at harvest, treatments (T_6 to T_{13}) which received soil + foliar application of KIO_3recorded higher iodine uptake than those treatments which received only soil or foliar soil application as well as control (T_1). Increased iodine uptake in the former treatments was due to greater iodine availability to plants because of combined application (soil + foliar spray). The time of soil application (45 DAT) and foliar spray (60 and 90 DAT) might have closely synchronisation with grand growth period in chilli, which has resulted in greater uptake. It can be inferred that, combined application of potassium iodate through soil and foliar spray resulted in greater uptake leading to toxicity of iodine on plants.

Table 3: Effect of soil and foliar application of KIO_3 on the uptake of iodine at 70, 100 DAT and at harvest by chilli crop

Treatments	Uptake of iodine (g /ha)				
	70 DAT	100 DAT	At harvest		
			Plant	Fruit	Total
T_1- Control (water spray at 60 & 90 DAT)	2.73	2.72	3.48	1.78	5.26
T_2- KIO_3 soil application @ 5 mg/kg	6.82	7.32	10.90	3.40	14.29
T_3- KIO_3 soil application @ 10 mg/kg	12.75	15.81	20.02	7.01	27.03
T_4- KIO_3 0.2% foliar spray at 60 & 90 DAT	17.38	39.01	47.53	14.92	62.45
T_5- KIO_3 0.3% foliar spray at 60 & 90 DAT	25.58	53.30	72.63	20.73	93.36
T_6- KIO_3 soil application @ 5 mg/kg + 0.2% KIO_3 foliar spray at 60 & 90 DAT	28.95	65.19	73.83	25.97	108.77
T_7- KIO_3 soil application @ 5 mg/kg + 0.2% KIO_3foliar spray at 90 DAT	9.68	25.93	35.68	11.18	46.86
T_8- KIO_3 soil application @ 5 mg/kg + 0.3% KIO_3 foliar spray at 60 & 90 DAT	30.26	74.94	96.36	27.52	123.89

T_9- KIO_3 soil application @ 5 mg/kg + 0.3% KIO_3 foliar spray at 90 DAT	7.97	32.57	47.45	12.24	59.69
T_{10}- KIO_3 soil application @ 10 mg/kg +0.2%KIO_3 foliar spray at 60 & 90 DAT	28.53	67.98	82.81	23.36	97.19
T_{11}- KIO_3 soil application @ 10 mg/kg + 0.2% KIO_3 foliar spray at 90 DAT	12.73	36.80	42.19	14.49	56.68
T_{12}- KIO_3 soil application @ 10 mg/kg + 0.3% KIO_3 foliar spray at 60 & 90 DAT	34.22	79.60	96.37	28.01	124.37
T_{13}- KIO_3 soil application @ 10 mg/kg + 0.3% KIO_3 foliar spray at 90 DAT	10.93	42.83	52.58	15.96	68.54
S. Em ±	0.14	0.42	0.69	0.11	0.68
CD (0.05)	0.40	1.23	2.00	0.33	1.98

Iodine content in fresh green fruits (Table – 4): Application of potassium iodate to soil at 5 and 10 mg kg^{-1} (T_2 and T_3) at 45^{th} day after chilli transplanting produced green chilli fruits having higher iodine content (2.99 and 1.79 g/g for T_3 and T_2 respectively) than control which did not receive KIO_3 application (0.77 g/g). This was attributed greater availability of iodine to plants supplied through KIO_3 (59% iodine in KIO_3). This applied iodine was absorbed by plant roots and translocated through xylem to aerial parts and accumulated in fruits. Landini *et al.* (2011) reported that, when iodine was applied to soil, root uptake and xylem transport of iodine takes place in tomato plants. This transported iodine gets accumulated in chloroplast present in leaves and green chilli fruits because water is a major agent to carry iodine. But due to transpiration and evaporation of water from these plant organs iodine gets accumulated and increased in its content. Treatments (T_4 and T_5) which received only foliar spray of KIO_3 recorded significantly higher iodine content in fruits (3.64 and 5.42 g/g for T_4 and T_5 respectively) than treatments which received soil application of KIO_3 (T_2 and T_3). Foliar spray of KIO_3 resulted in direct absorption and accumulation of iodine by canopy leading to high content of iodine in fruits. The quantity of KIO_3 applied to soil was equivalent to 0.0005 and 0.001 per cent for 5 mg kg^{-1} and 10 mg kg^{-1} respectively. But foliar spray concentrations were 0.2 and 0.3 per cent. Hence the amount of iodine supplied to plants through foliar spray was several folds higher than soil application.

Table 4: Effect of soil and foliar application of potassium iodate (KIO_3) on iodine content in chilli fruits (g/g).

Treatments	Fresh green fruit	Sundried red fruit
T_1- Control (water spray at 60 & 90 DAT)	0.77	0.85
T_2- KIO_3Soil application @ 5 mg/kg	1.79	1.98
T_3- KIO_3Soil application @ 10 mg/kg	2.99	3.21
T_4- KIO_3 0.2% foliar spray at 60 & 90 DAT	3.64	6.43
T_5- KIO_3 0.3% foliar spray at 60 & 90 DAT	5.42	10.01
T_6- KIO_3Soil application @ 5 mg/kg +0.2% KIO_3 foliar spray at 60 & 90 DAT	5.70	10.46
T_7- KIO_3Soil application @ 5 mg/kg +0.2% KIO_3foliar spray at 90 DAT	2.23	5.25
T_8- KIO_3Soil application @ 5 mg/kg + 0.3% KIO_3 foliar spray at 60 & 90 DAT	6.26	12.11
T_9- KIO_3Soil application @ 5 mg/kg + 0.3% KIO_3 foliar spray at 90 DAT	1.90	6.40
T_{10}- KIO_3Soil application @ 10 mg/kg +0.2%KIO_3 foliar spray at 60 & 90 DAT	6.65	10.19
T_{11}- KIO_3Soil application @ 10 mg/kg +0.2% KIO_3 foliar spray at 90 DAT	2.71	5.47
T_{12}- KIO_3Soil application @ 10 mg/kg +0.3% KIO_3 foliar spray at 60 & 90 DAT	7.47	12.39
T_{13}- KIO_3Soil application @ 10 mg/kg +0.3% KIO_3 foliar spray at 90 DAT	2.82	7.57
S. Em ±	0.03	0.05
CD (0.05)	0.09	0.15

Iodine content in sundried red chilli fruits (Table – 4) : Soil application of KIO_3 at 10 mg kg^{-1} along with two foliar sprays (0.3%) recorded highest iodine content (12.39 g/g) in fruits closely followed by treatment (T_8) which received 5 mg kg^{-1} of KIO_3 along 0.3 per cent foliar spray (12.11 g/g). This was due to greater availability of iodine to plants through soil as well as foliar spray. The two treatments (T_4 and T_5) which received only foliar spray of KIO_3 recorded significantly higher iodine content in fruits (6.43 and

10.01 µg/g) than treatments (T_2 and T_3) which received only soil application (1.98 and 3.21 µg/g). The latter treatments received only 0.0005 and 0.001 per cent KIO_3, indirectly indicating very low availability of iodine to plants from soil. This has led to reduced uptake of iodine by plants. Further the soil organic matter binds the iodate ion and prevents its absorption by roots. Kiferle *et al.* (2013) reported that, iodate ion applied to soil is strongly retained by organic matter and inhibits its absorption by tomato plant roots. Caffagni *et al.* (2012) stated that, at maturity leaves and stem contained more iodine than edible parts in tomato, plum and potato crops. Mackowiak and Grossl (1999) stated that, for leafy vegetables, iodine accumulation in the edible parts largely dependent on xylem transport. But in chilli crop, fruit is the edible part and accumulation of iodine in fruits is largely depends on phloem.

All the foliar applied treatments recorded higher iodine content in fruits. This was attributed to high concentration of spray solutions (0.2 and 0.3%) and increased availability of iodine leading to increased absorption by leaves and fruits. Foliar sprayed iodine first enters phloem vessels, where it is retained for long time and iodine prefers xylem vessels for transport. Based on the observations, it can be inferred that, iodine content in sundried red chilli fruits ranged from 1.98 to 12.39 µg g^{-1} (except control). In the present study, the amount of iodine present in red chilli fruits is far less than present in iodised salt. Hence, it can be concluded that, neither soil application nor foliar spray brings about biofortification of chilli fruits with iodine. Increased doses of KIO_3 application for the purpose of iodine biofortification in red chillies have marked adverse effects on yield as well as important quality parameters like colour value and oleoresin contents. Such chilli fruits loose market price.

Iodine content of whole plant (stem + leaves) Vs Iodine content of fruits (Table – 5) : In all the treatments iodine concentration in whole plants was higher than found in fruits Leaves and stem retain more iodine and small quantity gets partitioned to fruits. Herrett *et al.* (1962) reported that, iodine absorbed by roots gets transported upward through xylem but did not translocate out of leaves to fruits. Hence leaves and stem contained more iodine than fruits. Caffagni *et al.* (2012) studied the distribution of iodine in different organs of plum tree and potato as a function of iodine doses applied. They stated that, iodine was mainly accumulated in the leaves and only a small portion of absorbed iodine was transported to fruits. In the present study also more iodine content was noticed in whole plant (stem + leaves) than in fruits.

Table 5 : Effect of soil and foliar application of potassium iodate (KIO_3) on iodine content in whole plant* (µg/ g) at 70, 100 DAT & at harvest in chilli

Treatments	70 DAT	100 DAT	At harvest
T_1- Control (water spray at 60 & 90 DAT)	1.14	1.22	1.30
T_2- KIO_3Soil application @ 5 mg/kg	3.76	4.03	4.27
T_3- KIO_3Soil application @ 10 mg/kg	6.27	6.82	7.24
T_4- KIO_3 0.2% foliar spray at 60 & 90 DAT	8.30	15.83	16.80
T_5- KIO_3 0.3% foliar spray at 60 & 90 DAT	12.80	24.56	25.73
T_6- KIO_3Soil application @ 5 mg/kg +0.2% KIO_3 foliar spray at 60 & 90 DAT	13.10	25.80	27.38
T_7- KIO_3Soil application @ 5 mg/kg + 0.2% KIO_3 foliar spray at 90 DAT	4.64	11.47	12.18
T_8- KIO_3Soil application @ 5 mg/kg + 0.3% KIO_3 foliar spray at 60 & 90 DAT	14.34	31.40	32.99
T_9- KIO_3Soil application @ 5 mg/kg + 0.3% KIO_3 foliar spray at 90 DAT	4.05	16.04	17.02
T_{10}- KIO_3Soil application @ 10 mg/kg +0.2%KIO_3 foliar spray at 60 & 90 DAT	14.89	26.79	28.43
T_{11}- KIO_3Soil application @ 10 mg/kg +0.2% KIO_3 foliar spray at 90 DAT	5.68	13.09	13.89
T_{12}- KIO_3Soil application @ 10 mg/kg +0.3% KIO_3 foliar spray at 60 & 90 DAT	17.41	33.18	35.21
T_{13}- KIO_3Soil application @ 10 mg/kg +0.3% KIO_3 foliar spray at 90 DAT	5.74	19.15	20.32
S. Em ±	0.07	0.23	0.18
CD (0.05)	0.20	0.68	0.52

***Whole plant : Only stem +leaves**

Water soluble iodine in soil (mg kg^{-1}) and B:C ratio of experiment. (Table – 6): Treatments which received only soil application of KIO_3 (T_2 and T_3) as well as those treatments which received KIO_3 application through soil and foliar spray recorded higher residual iodine content in soil compared to initial value (1.68 mg/kg). Muramatsu *et al.* (1990) reported that, iodine uptake by plants is mainly dependent on the availability of iodine in the soil and this mechanism is mainly governed by adsorption desorption processes in soil. He also stated that, the decreased rates of available iodine in soil might be due to substantial iodine volatilization. Further, Whitehead (1978) reported that, other potential iodine sinks may be the microbial formation of organoiodides, the fixation of iodine into the soil organic matter as well as its adsorption on iron and aluminum oxides. Treatments which received combined application of KIO_3 (T_6 to T_{13}) recorded very low B:C ratios (0.55 to 1.30) over control (3.04). There was only marginal increase in B:C ratio over control (3.04) in treatments which received only soil application of KIO_3 at 5 and 10 mg kg^{-1} (3.22 and 3.21 for T_2 and T_3 respectively). But there was decreased B:C ratio over control in treatments which received only foliar sprays of KIO_3 (T_4 and T_5). Combined application of KIO_3 (soil + foliar spray) resulted in net negative income which indicated a loss. Hence, it can be concluded that, application of KIO_3 either through soil or foliar spray is not beneficial.

Table 6 : Effect of soil and foliar application of potassium iodate (KIO_3) on water soluble iodine in soil (mg kg^{-1}) at harvest and B:C ratio of experiment.

Treatments	I*	B:C ratio
T_1- Control (water spray at 60 & 90 DAT)	0.44	3.04
T_2- KIO_3Soil application @ 5 mg/kg	2.33	3.22
T_3- KIO_3Soil application @ 10 mg/kg	2.91	3.21
T_4- KIO_3 0.2% foliar spray at 60 & 90 DAT	0.61	1.52
T_5- KIO_3 0.3% foliar spray at 60 & 90 DAT	0.72	1.23
T_6- KIO_3Soil application @ 5 mg/kg + 0.2% KIO_3 foliar spray at 60 & 90 DAT	2.66	0.91
T_7- KIO_3Soil application @ 5 mg/kg + 0.2% KIO_3foliar spray at 90 DAT	2.48	1.30
T_8- KIO_3Soil application @ 5 mg/kg + 0.3% KIO_3 foliar spray at 60 & 90 DAT	2.80	0.62
T_9- KIO_3Soil application @ 5 mg/kg + 0.3% KIO_3 foliar spray at 90 DAT	2.63	0.85
T_{10}- KIO_3Soil application @ 10 mg/kg + 0.2%KIO_3 foliar spray at 60 & 90 DAT	3.19	0.79
T_{11}- KIO_3Soil application @ 10 mg/kg + 0.2% KIO_3 foliar spray at 90 DAT	2.97	1.04
T_{12}- KIO_3Soil application @ 10 mg/kg +0.3% KIO_3 foliar spray at 60 & 90 DAT	3.07	0.55
T_{13}- KIO_3Soil application @ 10 mg/kg + 0.3% KIO_3 foliar spray at 90 DAT	2.98	0.83
S. Em ±	0.03	-
CD (0.05)	0.09	-
Initial	**1.68**	**-**

Conclusions: Increased doses of potassium iodate applied either to soil or to plant canopy through foliar spray improve the iodine content in chilli fruits. Nevertheless iodine content of these fruits does not match with iodine content of iodised salt (30 mg I/kg). It is not expedient to apply potassium iodate to chilli plants either through soil or foliar spray to enrich red chilli fruits with iodine as colour value and oleoresin contents will be severely affected. This leads to reduced price of red chillies in the market. For fresh green chilli fruits iodine enrichment through KIO_3 application is a practically viable option.

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