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RESEARCH ARTICLE

Iodine Biofortificationin Tomato with a Strategy to Prevent Iodine Deficiency

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ABSTRACT

A field experiment was conducted to investigate the potential of iodine biofortification in tomato fruits by fertilizing potassium iodate in soil, foliar form and chitosan complex forms. While foliar spray alone increases iodine content in leaves (95%), chitosan iodate complex alone and soil application alone increased iodine contentin roots (11% and 16%) and stems (19% and 27%). However, higher iodine accumulation (3%) in tomato fruits was achieved through the combination of foliar and iodine chitosan forms, as electrostatic interaction between chitosan and iodate prevents volatilization and gradually increases the bioavailability of iodine from soil to fruits. The transfer factor was higher for iodate and chitosan complex from soil to plant. Further, the average and relative distribution of iodine in plants revealed that the chitosan iodate complex and foliar spray combination is proven to be the most effective, as it keeps adequate amounts of iodine in roots, stems, and leaves while also increasing iodine content in final fruit. Biofortifying iodine through iodate chitosan complex increases iodine content in tomato fruit and introducing it in our daily diet may help to reduce iodine deficiency.

Keywords*: Biofortification:Chitosan:Deficiency:Electrostatic, Iodine and Tomato*

INTRODUCTION

The earth's iodine (as iodide) is extensively spread but unevenly distributed because iodine is a rare element primarily found as a salt and referred to as iodide rather than iodine. Iodine is an essential micronutrient for a person's mental and physical development. Iodine is a component of thyroid hormone, which is essential for human health and plays an indispensable function in metabolism (Miller, 2017). Recommended daily allowance (RDA) of iodine is 120 µg for children 6 to 12 years old, 150 µg for adults over 12 years old, and 200 µg for pregnant and nursing women. Iodine deficiency occurs when iodine levels in the soil are inadequate, resulting in limited crop uptake and as a result, a population with insufficient iodine intake. The universal fortification of salt with iodine is one technique to treat Iodine Deficiency Disorder (IDD). This strategy, however, will not be sufficient to treat iodine deficiency disorder (Santos *et al*., 2019). This is because since iodine in table salt is unstable and exposed to increased volatilization (Yan *et al*., 2016). Biofortification is the technique of enhancing the nutrient content of edible plants and it has become widely recognized as a cost-effective method of giving micronutrients to the public. Iodine is nota required mineral for higher plants, although it can be absorbed from soil (Abid*et al*., 2016). The selection of appropriate fertilizer concentrations for a certain crop plant is a fundamental challenge inbiofortifying plants with iodine. Agricultural biofortification has made great progress in improving human micronutrients like Fe, Zn, and Se, among others (Buturi*et al*., 2016).Although it has been proven that applying exogenous iodine to soil can raise iodine levels in agricultural products (Gonzali*et al*.,2017), the majority of this research focused on grain crops and employed inorganic iodine (e.g., I, IO_3) as the exogenous iodine fertilizer (Kumar *et al*., 2017). Vegetables are essential nutrients that are ingested in large numbers. Although studies have shown that vegetables absorb more iodine than grain crops, little is understood about the translocation, transformation, and transport of iodine from the soil to diverse vegetables (Gonzali*et al*., 2017 and Nath*et al*., 2018). Iodine in foods is highly absorbable (up to 99 percent) and readily available (Petroski*et al*., 2020). Biofortifying commonly consumed crops with iodine can avoid iodine deficiency. Iodine biofortification by foliar spray and soil application resulted in higher iodine stability during various cooking techniques, whereas iodine provided in the form of iodized salt to non-biofortified vegetables resulted in significant iodine losses duringthe boiling process(Bouis*et al*., 2020). Chitosan (Cs) is a biological polymer that acts as metal, traces metal complexing agent, and is biodegradable. If iodine applied as a chitosan-iodate complex, the absorption of iodine will be boosted (Kanmani*et al*., 2017). The objective of the present study was to assess the potential for biofortifying tomato fruits with iodine. Tomato was chosen for the research since it is having the capacity to store excess iodine in vegetative tissues and fruits at levels that are more than adequate for human consumption. It is also a widely produced and consumed crop in every household. It is a desirable target crop for a fortification study because of its extensive distribution and fresh consumption. Furthermore, the ability to consume fresh fruits reducesthe risk of iodine loss caused by specific cooking procedures.

MATERIALS AND METHODS

To know the effect of biofortified iodine inthe soil and different plant parts of tomatoes a field experiment was carried out during the year 2020 in viraliyur village of thondamuthur block of Coimbatore district of Tamil Nadu (GPS value: 10°.9′99.284′′′N; 76.7′82.652″E). Iodine was biofortified through the soil and foliar application using and chitosan iodate complex mechanism.Chitsoan has purchased from the kerala marine hydrocolloids company, which has a molecular weight of 501.486 g/mol and more than 75%deacetylation. Potassium iodate having 59% iodine and 18% potassium was purchased from sigma aldrich company.The experiments were performed in randomized block design with three replications in palaviduthi soil series using hybrid tomato “Shivam”. Each plot had a gross size of 7m X 4m. The treatments were T_1- KIO_3-Soil Application(SA)- 5 Kg ha^{-1}, T_2- KIO_3- Soil Application(SA)- 10 Kg ha^{-1}, T_3- Chitosan-KIO_3 Complex-5 Kg ha^{-1}, T_4- Chitosan-KIO_3 Complex-10 Kg ha^{-1}, T_5- Foliar Application (FA)-KIO_3-0.2% @ 60 and 90 DAT , T_6- Foliar Application (FA)-KIO_3-0.3% @ 60 and 90 DAT , T_7- KIO_3- Soil Application(SA)- 5 Kg ha^{-1} + Foliar Application (FA)-KIO- 0.2% @ 60 and 90 DAT, T_8- KIO_3- Soil Application(SA)- 10 Kg ha^{-1} + Foliar Application (FA)-KIO_3- 0.2% @ 60 and 90 DAT, T_9- Chitosan-KIO_3 Complex-5 Kg ha^{-1} + Foliar Application (FA)-KIO_3-0.2% @ 60 and 90 DAT,

T_{10}-Chitosan-KIO_3 Complex-10 Kg ha^{-1} + Foliar Application (FA)-KIO_3-0.2% @ 60 and 90 DAT, T_{11}-KIO_3- Soil Application(SA)- 5 Kg ha^{-1} + Foliar Application (FA)-KIO_3- 0.3% @ 60 and 90 DAT, T_{12}-KIO_3- Soil Application(SA)- 10 Kg ha^{-1} + Foliar Application (FA)-KIO_3- 0.3% @ 60 and 90 DAT. T_{13}-Chitosan-KIO_3 Complex-5 Kg ha^{-1} + Foliar Application (FA)-KIO_3-0.3% @ 60 and 90 DAT, T_{14}-Chitosan-KIO_3 Complex-10 Kg ha^{-1} + Foliar Application (FA)-KIO_3-0.3% @ 60 and 90 DAT, T_{15}-Chitosan Spraying (control) and T_{16}- Water Spraying (Absolute Control).The plants were grown in medium black clay loam soil, low in nitrogen and medium in organic carbon, phosphorous and potassium. The soil is neutral in pH and non saline in EC. The initial water soluble iodine content in the sample was 1.68ppm. Tomato hybrid seedlings were transplanted at a spacing of 45 cm x 30 cm when they were around 25 days old. Potassium iodate was administered both as soil and as foliar application. For foliar application of potassium iodate, the solution was prepared in the laboratory with pure potassium iodate salts and stored in polyethylene bottles for further use. The chitosan and potassium iodate complexThe chitosan and potassium iodate complex was complexed in the ratio of 1% chitosan and 0.01% potassium iodate. The foliar fertilization was done using a backpack sprayer. Fruit, soil and plant samples were collected during green, pink, and red ripen harvest stages of tomato and processed for further analysis. The iodine concentration was measured using inductively coupled plasma–optical emission spectrometry by following procedure of (Knapp *et al.*, 1998).A 0.5g of plant/root/ fruits samples were added with 1mL of 25% Tetramethyl Ammonium Hydroxide and 10mL of double distilled water and maintained at 900°C for 3 hours. The sample was chilled and the final volume increased to 25mL and measured.For water-soluble iodine content modified procedure of (Weng*et al.*, 2014) was followed. A 2.5g of soil sample was transferred to a centrifuge tube and 25 mLof distilled water was added. The tube was shaken for 1 hour, centrifuged and the clear supernatant liquid was filtered and measured. The data obtained from soil, root, stem, leaves, and fruit iodine content, were subjected to one-way ANOVA. The program IBM SPSS® Statistics, version 25 was used to run all statistical tests.

RESULTS AND DISCUSSION

The availability of water-soluble iodine at different stages of tomato was given in table 1. The water-soluble iodine content in soil was highest for treatment T_{12}- KIO_3 SA-10 Kg ha^{-1} +FA-KIO_3-0.3% @ 60 and 90 DAT in green (143.02ppm) stage. At pink (116.83ppm) and red ripen (82.46ppm) stages the treatment T_{14}- Chitosan-KIO_3 Complex-10 Kg ha^{-1} + FA-KIO_3-0.3% @ 60 and 90 DAT recorded higher iodine in soil. The highest mean -soluble iodine content was recorded when chitosan KIO3 complex was applied as foliar applications were applied together. This might be because there is an electrostatic interaction between positively charged amino group (NH_2) and negatively charged iodate ion (IO_3^-). The amino group present outside in macromolecule helical conformation physically adsorbs iodine molecule (Moulay, 2019). The uptake of iodine in the roots and stems of tomato plant was higher in T_{12}-KIO_3 SA-10 Kg ha^{-1} +FA-KIO_3-0.3% @ 60 and 90 DAT in green (3.19 and 5.35ppm), pink (2.94 and 5.10ppm) and red ripen stages (2.81 and 4.70) of tomato (Figure 1 and 2) which was followed by T_{14}-Chitosan-KIO_3 Complex-10 Kg ha^{-1} + FA-KIO_3-0.3% @ 60 and 90 DAT. When potassium iodate was applied to soil there will be high surface adsorption of iodine due to the presence of root hairs in soil solution (Duborska*et al.*, 2018). Roots tend to adsorb iodide (I-) in more amounts than iodate (IO_3). Whatever forms of iodine are supplied to plants it always prefers the iodide form. So IO_3 is reduced to I^- before its uptake by plants (reduction mediated by iodate reductase enzyme). The reduction process takes a much longer time when iodate is complexed with chitosan rather than iodate as free salt (Davila rangel*et al.*, 2020). The root absorbed iodine mainly accumulated in the cytoplasm. Iodine is also preferably stored in the xylem parenchyma cells of stems as plant nutrients. The partitioning of iodine in the leaves and fruits ranged from 0.12ppm to 24.64ppm and 0.001ppm to 0.99ppm (Table 2 and Table 3). The treatment T_{14}-Chitosan-KIO_3 Complex-10 Kg ha^{-1} + FA-KIO_3-0.3% @ 60 and 90 DAT recorded higher uptake in leaves and fruits. The uptake of iodine in leaves and fruits were higher in chitosan iodate complex supplied treatments because there was no leaching and volatilization of iodate ion due to the strong interaction between cationic amino group of chitosan and iodateion(Pisoschi*et al.*, 2020). The major iodine species complexed by chitosan was I_3^-. The movement of iodine from roots is mainly through xylem vessels via mass flow driven by transpiration of leaves (Budke*et* *al.*, 2020). Hence,iodine accumulation is higher in leaves when compared to roots and stems for chitosan-supplied treatments. The greater degree of the complexing capacity of chitosan is directly related to the content of the amino group and indirectly related to the degree of deacetylation.

The foliar application of iodine increased iodine content in the leaves when compared to soil alone and chitosan iodate complex alone treatments. The cuticular waxes of leaves serving as an entry point for foliar-applied iodine. The crucial factor for enriching tomatoes with iodine was the foliar potassium iodate treatment timing. If time gap is larger between sprays and harvest date, less iodine was found in fruits. In the present study, two foliar sprayswasgiven. One was before green stage and another was before pink stage, which increased iodine content in the leaves and fruits of tomatoes at green and pink stages.

Further, the reduction of iodine in leaves and fruits in the red ripen stage is due to the lack of foliar spray of iodine. As plants prefer long-distance transport of iodine, the mobility of iodine in the xylem is consideredhigher than in phloem (Cakmak*et al.*, 2017). So normally, iodine content is more in leaves as they have higher transpiration than in phloem preferred low transpiring fruits. From the results of the current study, it is clear that as the growth ofthe plant progresses, iodine tends to be concentrated increasingly in leaves.

Conclusion

When potassium iodate is supplied entirely through the soil, a significant amount of iodine is discovered in roots and stems. When potassium iodate is supplied entirely through foliar application and also in the form of chitosan iodate complex, the leaves contain a large amount of iodine. The chitosan iodate complex and foliar application combination enhanced iodine content in leaves and fruits, while the soil and foliar application combination raised iodine content in roots and stems. We are concerned with increasing the iodine content in the fruits, so it is better to go with chitosan iodate complex and foliar application rather than the other treatments. As the chitosan-supplied iodine tretaments will maintain the levels of iodine throughout plant parts by inhibiting volatilization and gradually transferring it slowly from roots to fruits, the foliar supplied iodine will take care of the immediate translocation of iodine from leaves to the fruit. The low translocation rate of root adsorbed iodine limited the efficacy of soil fertilization practice. Further, the stability and solubility of chitosan molecule making it a valuable product for biofortifying iodine in crops. The stability of the chitosan is governed by its electrostatic interaction with iodate and its complexing capacity whereas the solubility is governed by the extent of deacetylation and degaree of crystallinity

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Ethics statement

No specific permits were required for the described field studies because no human or animal subjects were involved in this research.

Consent for publication

All the authors agreed to publish the content.

Competing interests

There were no conflict of interest in the publication of this content

Data availability

All the data of this manuscript are included in the MS. No separate external data source is required. If anything is required from the MS, certainly, this will be extended by communicating with the corresponding author through corresponding official mail; mageshsmart2@gmail.com.

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Table1.Effect of potassium iodate and iodine chitosan complex on soil water soluble iodine at different harvest stages of tomato

Treatments	Green Stage	Pink Stage	Red Ripen Stage	Treatment Mean
T_1- KIO_3-SA- 5kgha^{-1}	92.45±1.41^{d}	71.21±1.08^{h}	56.28±0.85^{h}	73.31
T_2- KIO_3-SA- 10Kgha^{-1}	125.03±3.30^{b}	93.53±2.47^{d}	76.03±2.01^{cd}	98.19
T_3- Chitosan-KIO_3 Complex-5Kgha^{-1}	90.97±3.27^{d}	78.34±2.82^{gh}	66.96±2.41^{g}	78.75
T_4- Chitosan-KIO_3 Complex-10Kgha^{-1}	132.63±5.02^{b}	104.88±3.97^{c}	72.98±2.76^{def}	103.49
T_5- FA-KIO_3-0.2% @ 60 and 90 DAT	5.66±0.08^{f}	5.32±0.08^{i}	4.95±0.07^{i}	5.31
T_6- FA-KIO_3-0.3% @ 60 and 90 DAT	6.79±0.17^{f}	6.46±0.16^{i}	6.15±0.15^{i}	6.46
T_7- KIO_3- SA- 5Kgha^{-1} + FA-KIO- 0.2% @ 60 and 90 DAT	103.24±3.31^{c}	84.87±2.72^{efg}	67.24±2.16^{g}	85.11
T_8- KIO_3-SA-10Kgha^{-1} + FA-KIO_3-0.2% @ 60 and 90 DAT	129.98±2.70^{b}	89.39±1.86^{de}	69.53±1.44^{efg}	96.30
T_9- Chitosan-KIO_3 Complex-5Kgha^{-1} + FA-KIO_3-0.2% @ 60 and 90 DAT	100.61±2.09^{c}	86.26±1.79^{def}	74.03±1.54^{de}	86.96
T_{10}-Chitosan-KIO_3 Complex-5Kgha^{-1} + FA-KIO_3-0.3% @ 60 and 90 DAT	132.29±3.50^{b}	112.28±2.97^{ab}	91.27±2.41^{a}	111.94
T_{11}- KIO_3- SA- 5Kgha^{-1} + FA-KIO_3- 0.2% @ 60 and 90 DAT	96.99±1.48^{cd}	80.9±1.23^{fg}	68.05±1.03^{fg}	81.98
T_{12}- KIO_3 SA-10Kg/ha^{-1} + FA-KIO_3-0.3% @ 60 and 90 DAT	143.02±5.15^{a}	105.13±3.79^{bc}	81.48±2.93^{bc}	109.87
T_{13}- Chitosan-KIO_3 Complex-5Kgha^{-1} + FA-KIO_3-0.3% @ 60 and 90 DAT	94.23±2.87^{cd}	84.36±2.57^{efg}	76.62±2.34^{cd}	85.07
T_{14}- Chitosan-KIO_3 Complex-10Kgha^{-1} + FA-KIO_3-0.3% @ 60 and 90 DAT	142.41±5.75^{a}	116.83±4.72^{a}	82.46±3.33^{b}	113.90
T_{15}- Chitosan Spraying	2.9±0.07^{f}	2.58±0.06^{i}	2.38±0.05^{i}	2.620
T_{16}- Water Spraying	1.98±0.05^{f}	1.72±0.04^{i}	1.64±0.04^{i}	1.780
Mean	87.57	70.25	56.13	71.32
S.Ed	4.44	3.57	2.78	
C.D(0.05)	9.08	7.29	5.69	

Table2. Effect of potassium iodate and iodine chitosan complex on partitioning of iodine at different harvest stages in leaves

Treatments	Green Stage	Pink Stage	Red Ripen Stage	Treatment Mean
T_1- KIO_3-SA- 5kgha^{-1}	5.33±0.08^{h}	5.52±0.07^{h}	5.04±0.06^{h}	4.93
T_2- KIO_3-SA- 10Kgha^{-1}	9.67±0.25^{g}	8.91±0.23^{g}	8.32±0.22^{g}	8.97
T_3- Chitosan-KIO_3 Complex-5Kgha^{-1}	10.26±0.36^{g}	10.03±0.36^{g}	9.69±0.35^{g}	9.99
T_4- Chitosan-KIO_3 Complex-10Kgha^{-1}	13.27±0.50^{f}	13.01±0.49^{f}	12.64±0.47^{f}	12.97
T_5- FA-KIO_3-0.2% @ 60 and 90 DAT	13.35±0.20^{f}	13.98±0.21^{f}	12.45±0.19^{f}	13.26
T_6- FA-KIO_3-0.3% @ 60 and 90 DAT	15.56±0.39^{e}	16.96±0.42^{e}	15.38±0.39^{e}	15.97
T_7- KIO_3- SA- 5Kgha^{-1} + FA-KIO- 0.2% @ 60 and 90 DAT	16.86±0.54^{de}	17.72±0.56^{e}	16.24±0.52^{de}	16.94
T_8- KIO_3-SA-10Kgha^{-1} + FA-KIO_3-0.2% @ 60 and 90 DAT	17.15±0.35^{d}	18.02±0.37^{e}	16.79±0.35^{d}	17.32
T_9- Chitosan-KIO_3 Complex-5Kgha^{-1} + FA-KIO_3-0.2% @ 60 and 90 DAT	19.55±0.40^{c}	20.67±0.43^{cd}	20.12±0.41^{c}	20.11
T_{10}-Chitosan-KIO_3 Complex-5Kgha^{-1} + FA-KIO_3-0.3% @ 60 and 90 DAT	21.25±0.56^{b}	22.86±0.60^{b}	21.54±0.57^{b}	21.88
T_{11}- KIO_3- SA- 5Kgha^{-1} + FA-KIO_3- 0.2% @ 60 and 90 DAT	16.86±0.25^{de}	18.34±0.28^{e}	17.02±0.26^{d}	17.41
T_{12}- KIO_3 SA-10Kg/ha^{-1} + FA-KIO_3-0.3% @ 60 and 90 DAT	19.31±0.69^{c}	20.02±0.72^{d}	19.64±0.70^{c}	19.66
T_{13}- Chitosan-KIO_3 Complex-5Kgha^{-1} + FA-KIO_3-0.3% @ 60 and 90 DAT	21.48±0.65^{b}	21.87±0.66^{bc}	20.99±0.64^{bc}	21.45
T_{14}- Chitosan-KIO_3 Complex-10Kgha^{-1} + FA-KIO_3-0.3% @ 60 and 90 DAT	24.39±0.98^{a}	24.83±1.00^{a}	24.72±0.99^{a}	24.65
T_{15}- Chitosan Spraying	0.160±0.004^{i}	0.146±0.004^{i}	0.134±0.003^{i}	0.147
T_{16}- Water Spraying	0.132±0.003^{i}	0.122±0.003^{i}	0.113±0.002^{i}	0.122
Mean	14.05	14.53	13.75	14.11
S.Ed	0.67	0.70	0.67	
C.D(0.05)	1.38	1.43	1.37	

Table3. Effect ofpotassium iodate and iodine chitosan complex on partitioning of iodine at different harvest stages in fruits (ppm)

Treatments	Green Stage	Pink Stage	Red Ripen Stage	Treatment Mean
T_1- KIO_3-SA- 5kgha^{-1}	0.136 ± 0.002^{i}	0.173 ± 0.002^{h}	0.150 ± 0.001^{j}	0.153
T_2- KIO_3-SA- 10Kgha^{-1}	0.220 ± 0.005^{i}	0.310 ± 0.004^{h}	0.280 ± 0.002^{j}	0.270
T_3- Chitosan-KIO_3 Complex-5Kgha^{-1}	0.230 ± 0.012^{h}	0.350 ± 0.011^{g}	0.310 ± 0.010^{h}	0.297
T_4- Chitosan-KIO_3 Complex-10Kgha^{-1}	0.290 ± 0.017^{g}	0.490 ± 0.016^{f}	0.410 ± 0.015^{g}	0.397
T_5- FA-KIO_3-0.2% @ 60 and 90 DAT	0.018 ± 0.006^{h}	0.025 ± 0.007^{f}	0.021 ± 0.001^{ij}	0.021
T_6- FA-KIO_3-0.3% @ 60 and 90 DAT	0.024 ± 0.012^{fg}	0.030 ± 0.014^{e}	0.028 ± 0.004^{i}	0.027
T_7- KIO_3- SA- 5Kgha^{-1} + FA-KIO- 0.2% @ 60 and 90 DAT	0.430 ± 0.017^{f}	0.570 ± 0.018^{e}	0.510 ± 0.016^{f}	0.503
T_8- KIO_3-SA-10Kgha^{-1} + FA-KIO_3-0.2% @ 60 and 90 DAT	0.530 ± 0.013^{d}	0.590 ± 0.014^{cd}	0.530 ± 0.013^{d}	0.550
T_9- Chitosan-KIO_3 Complex-5Kgha^{-1} + FA-KIO_3-0.2% @ 60 and 90 DAT	0.650 ± 0.014^{d}	0.730 ± 0.015^{c}	0.670 ± 0.014^{c}	0.683
T_{10}-Chitosan-KIO_3 Complex-5Kgha^{-1} + FA-KIO_3-0.3% @ 60 and 90 DAT	0.883 ± 0.022^{b}	0.976 ± 0.023^{b}	0.910 ± 0.021^{b}	0.923
T_{11}- KIO_3- SA- 5Kgha^{-1} + FA-KIO_3- 0.2% @ 60 and 90 DAT	0.490 ± 0.009^{e}	0.660 ± 0.009^{d}	0.570 ± 0.009^{e}	0.573
T_{12}- KIO_3 SA-10Kg/ha^{-1} + FA-KIO_3-0.3% @ 60 and 90 DAT	0.622 ± 0.027^{c}	0.701 ± 0.030^{b}	0.662 ± 0.025^{cd}	0.662
T_{13}- Chitosan-KIO_3 Complex-5Kgha^{-1} + FA-KIO_3-0.3% @ 60 and 90 DAT	0.650 ± 0.025^{bc}	0.980 ± 0.025^{b}	0.730 ± 0.025^{bc}	0.697
T_{14}- Chitosan-KIO_3 Complex-10Kgha^{-1} + FA-KIO_3-0.3% @ 60 and 90 DAT	0.940 ± 0.038^{a}	0.002 ± 0.040^{a}	0.990 ± 0.040^{a}	0.970
T_{15}- Chitosan Spraying	0.002 ± 0.000^{j}	0.001 ± 0.000^{i}	0.001 ± 0.000^{k}	0.002
T_{16}- Water Spraying	0.001 ± 0.000^{j}	0.001 ± 0.000^{i}	0.001 ± 0.000^{k}	0.001
Mean	**0.500**	**0.523**	**0.440**	**0.487**
S.Ed	0.026	0.026	0.024	
C.D(0.05)	0.053	0.054	0.050	

https://doi.org/10.29321/MAJ.10.000692 (online first draft)

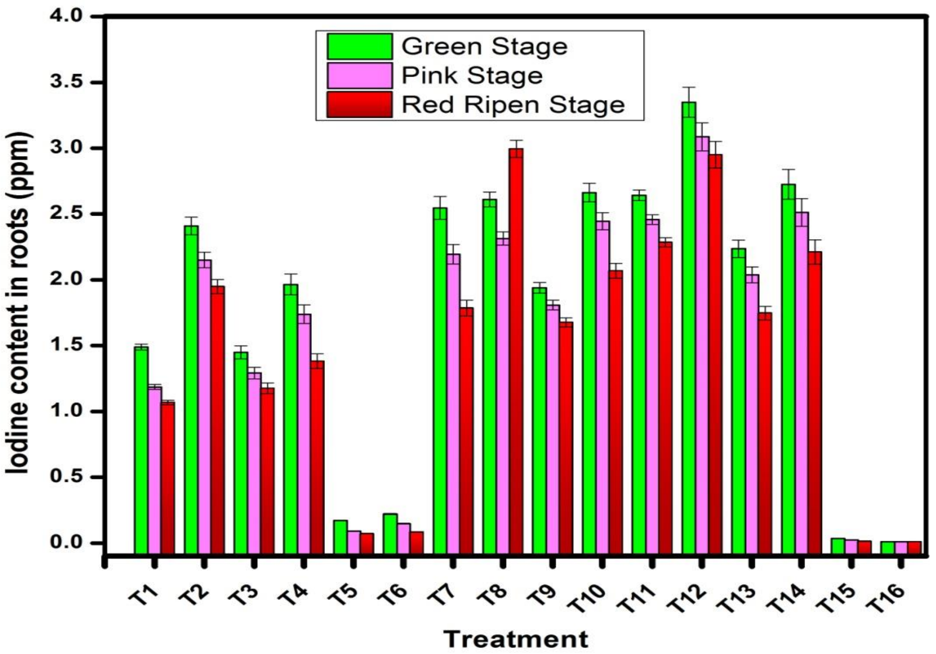

Fig 1.Partitioning of iodine in roots of tomato plant at different harvest stages

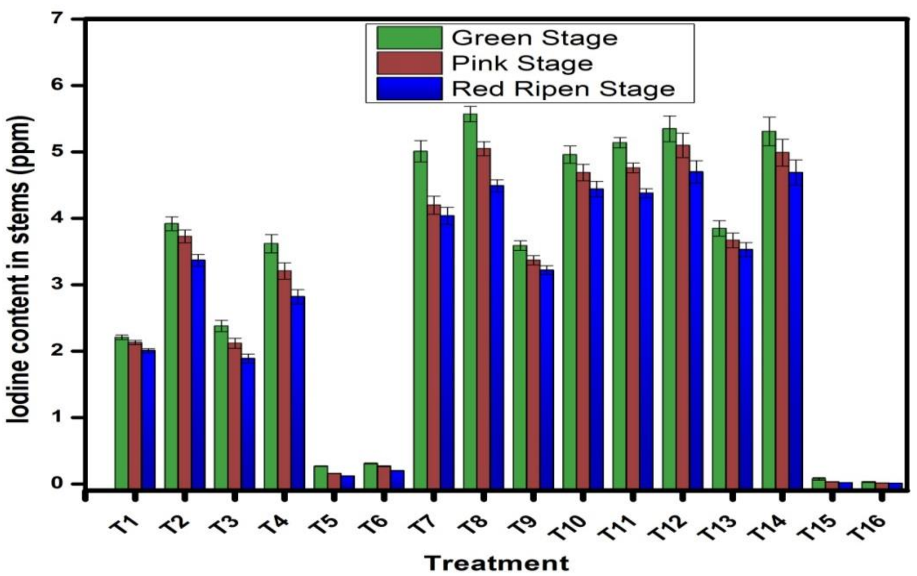

Fig 2.Partitioning of iodine in stems of tomato plant at different harvest stages