CORRELATES OF STUDY ON DIRECT AND RESIDUAL EFFECT OF BORON ON RICE-TOMATO CROPPING SYSTEM IN *INCEPTISOLS*

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***Abstract*— A field experiment was conducted in Central Research Station of O.U.A.T, Bhubaneswar, to study the direct and residual effect of Boron on Rice-Tomato cropping system in *Inceptisols*. Rice crop (Cv. Lalata) was transplanted in sandy loam *Inceptisols* with a design of RBD, with five levels of Boron (0, 0.5 ,1, 1.5, 2 Kg B/ha) and four replications with recommended dose of NPK. After harvest of Rice, Tomato (Cv. Utkal Kumari) was grown. Rice grain yield and tomato fruit yield was recorded. The samples were collected for nutrient and quality study. Post-harvest soil samples were collected, processed, and analysed for nutrients. The results revealed that rice crop responded to B application by producing more yield in all B treated plots than recommended dose of fertilizer. Highest rice grain yield of 49.44 q/ha was obtained when B was applied @ 1Kg/ha., Whereas residual effect of Boron on succeeding crop tomato was promising with yield response up to 1.5 Kg B/ha. Highest tomato yield 22.14 (t/ha) was obtained in the treatment receiving Boron @ 1.5 Kg/ha with recommended dose of NPK. Boron uptake by rice grain ranged from 10.19 to 52.38 g/ha. Highest Boron uptake in rice grain was found 52.38 g/ha in the treatment of 1Kg B/Ha. Similar trend was also observed in straw. Total Boron uptake increased significantly with increasing dose of B up to 2 Kg/ha., while Boron uptake by Tomato plant was much higher than uptake by fruits. Highest B uptake (336.70 g/ha) by fruit was obtained in the treatment receiving Boron @ 1.5 Kg/ha with recommended dose of NPK. Overall boron uptake was in increasing trend with increase dose of Boron. The quality parameters like Lycopene, Ascorbic acid, TSS and Crude protein were improved in tomato fruits significantly with increasing dose of B application**

I. INTRODUCTION

Boron belongs to metalloid group of elements which includes silicon and germanium. These elements are intermediate in properties between metals and non-metals, and also share many features in common in plants. The atom is small (Ionic radius, $0.23A^{0)}$ and has only three valencies. Boric acid is very weak and in aqueous solution at pH < 7, it occurs mainly as un-dissociated boric acid, at higher pH boric acid accepts hydroxyl ions from water thus forming a tetrahedral borate anion (Shelp, 1993).

$$\mathbf{B(OH)_3 + 2H_2O \leftrightarrow B(OH)^-_4 + H_3O^+}$$

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Boron is unique among the essential micronutrient for plant growth and is needed in small amount. Its deficiency is much more common in crops that are grown in soil that have higher amount of free carbonates, low organic matter, and high pH (Lindsay,1991 and Rashid, 1996). Occurance of Boron deficiency, by and large, has been reported from acid soils of eastern part of the country covering the states of Assam, Odisha, West Bengal and Jharkhand (Sarkar and Singh, 2003). About 80% of the soils of Odisha are mixed red and yellow, alluvial, red, laterite soils (Alfisols, Inceptisols, Entisols), which are mostly acidic in nature as developed under intense weathering. About 44% of soil profiles of Odisha were deficient in Boron (Jena *et al.,* 2008). As the crop plants are removed from the field, hardly any crop residue gets recycled back to the soil resulting in decreasing nutrient pool including B. In addition, abundant soil moisture (because of torrential monsoon rains during July-August, in flooded rice fields etc.) also causes B leaching, beyond the root zone (Keren and Bingham, 1985). On the other hand, the dry surface soil layers, because of dry spells during the growing season, inhibit root absorption of boron (Shorrocks, 1997). Crop yields and crop intensification have risen and, hence, increased amounts of B are being removed from soils, year after year.

It is a micronutrient or trace element but it plays macro role in crop production and crop quality. Boron plays an important role in stimulating a number of physiological processes in vascular plants, important in carbohydrate metabolism, translocation and development of cell wall and RNA metabolism (Siddiky *et al*., 2007).Boron has been found to play a key role in flowering, pollen germination, pollen longer viability, fruit setting and in development of bold seed size ensuring higher yield (Marten and westermann, 2003) and better quality by avoiding fruit cracking. Boron nutrition of crops has assumed greater importance in view of low B status of soils of intensive agricultural areas coupled with use of high analysis fertilizers. B nutrition of vegetable crops regarding the growth, quality and yield. Tomato (*Lycopersica esculentum* L.) is most important protective food crops in odisha and with an estimated global production of over 120 million metric ton (FAO, 2007).While production of tomato in Odisha is 1367.2,000 tonnes and 16826,000 tonnes in India(National Horticulture Board, 2011). Odisha shares around 8.13% of total production. Tomato has many uses in our daily diet starting from morning snacks , salads, curries, purees ,ketchups, pickles and sauce etc.

The low available B status of vegetable growing tract is attributed to the low organic matter status, unfavourable pH, low native B and fixation of applied B. Tomato is rich source of mineral, protein and vitamin(A,C), K and fibre in the human diet. Tomato response significantly to B by producing good quality tomato with good economic return and market values. Many researchers have been conducted experiments on direct effect of Boron on yield as well as seed/fruit and quality of crop plants less work has been done on cropping system in Odisha with these views an experiment was laid out to study the 'Direct and residual effect of boron on Rice-Tomato cropping system in *Inceptisols*'' with the following objectives.

1. To study the effect of boron on yield and yield attributing characters.
2. To study the effect of boron on nutrient uptake of crops.
3. To study the effect of boron on fruit quality.
4. Post-harvest soil properties.

II. REVIEW OF LITERATURE

Boron plays an important role for sustainable production of rice along with vegetables. Boron is important for various plant physiological functions such as nucleic acid, carbohydrate, protein, indole acetic acid, and phenol metabolism. Fertilizers uses in rice mostly macronutrients thus one main cause of low rice production is imbalanced nutrient application. Micronutrient deficit is one of the major reasons of decreasing production trends in rice growing countries. Boron deficiencies occur over a much wider range of soils and crops in comparison to deficiencies of any other micronutrient elements.

Boron deficiency has been reported in many crops. Boron stress affects the vegetative as well as economic yield of several plant species and quality of the product. Yield and Yield components of crops are positively and negatively affected by boron. Adequate supply of nutrient can increase the yield, fruit quality, fruit size keeping quality, color and taste of tomato. Among micronutrients boron and zinc play an important role in improving the yield and quality of tomato in addition to checking various disease and physiological disorder. Keeping in this view, literature pertaining to availability of nutrients in soils, response of B to rice and vegetable yield and yield attributing characters, nutrient uptake, quality parameters and post-harvest soil properties are listed below.

2.1 Distribution of boron in soil

Boron is unique among the essential mineral elements because it is the only element that is normally present in soil solution as a non- ionized molecule over the pH range suitable for the plant growth.

Occurrence of Boron deficiency by and large, has been reported from acid soils of eastern part of the country covering the states of Assam, West-Bengal and Jharkhand (**Sarkar and Singh, 2003**). The range between B deficiency and B toxicity being narrow; poses difficulty to maintain appropriate B levels in soil solutions .Available B content in Indian soils ranges from traces to 12.2 mg Kg^{-1} (**Das, 2000**).In Punjab available B content of the surface soils has been reported to vary from 0.40 to as high as 7.49 $mgKg^{-1}$ (**Katyal and Agarwal**, **1982**).Boron toxicity has also been reported in soils of Punjab and its effect on crop (**Arora and Chahal ,2007b**).

2.1.1 Effect of pH on Boron availability in soil

Soil pH affects plant growth and nutrient availability, therefore B at high pH is less available to plant specially cotton and wheat **(Rashid**, **2005; Communar and Keren, 2006**). Soluble B content in soils was significantly correlated with solution, pH (**Elrashidi and O'Connor, 1982).** In Pakistan, the pH value of most soils is more than 7.0 therefore; a widespread B deficiency was noted (**Sillanpaa, 1990; Rashid, 2005).**Some studies showed that pyrophyllitic soils and different ions played a significant role in B adsorption in relation to pH (**Keren and Sparks**, 1994a; **Communar and Keren, 2006**). Moreover, B adsorption-desorption kinetics and equilibrium in soil solution in association with pyrophyllitic soils has been reported by **Keren *et al.* (1994b). Keren *et al.* (1981**) revealed that pH had a specific role in adsorption of B in sodium montmorilonitic clay soils. In a most recent study, few researchers revealed that calcite is typically utilized to raise pH of soil however it maximized soil B fixation (**Chen *et al.*, 2009**). They further investigated that adsorption of B straight forwardly amplified with elevation in pH and soil pH had certain impacts on adsorption and desorption hysteresis of soils. **Rodriguez *et al.* (2001**) revealed that pH had certain impacts on B removal in de-salination and reverse-osmosis reactions or processes. Some researchers revealed that B retention by hydroxy Al and Fe was absolutely pH reliant and greatest retention was occurred at alkaline pH **(Sims and Bingham, 1968a).** Moreover, aging considerably decreased B retention by these materials (**Evans, 1987**). It was accomplished that the hydroxyl ions in these solutions encouraged hydrolysis of the precipitates of hydroxy-Al and –Fe. Consequentially B (as borate ions) released from the precipitates.

Several reports showed that pH directly controlled the B availability to higher plants and B adsorption on primary soil particles (sand, silt or clay) enhances with pH (particularly at pH 5 - 9). Necessarily this means that the greater the pH, the more firmly adsorbed the B to soil. Consequently, with each unit rise in pH, B turns into gradually more available to the plants (**Albion, 2003**). Soil pH has specific impacts on B availability more in terms of sorption reactions than by formation of fewer soluble compounds. **Mortvedt *et al.* (1999**) reported that at pH range of 5.5 – 7.50, the ability of B is highest. Boron is sorbed to Fe and Al oxides in soils and its availability is lowest at pH range 6-9. Numerous studies explained that there were relationships amongst the existence of Ca ions and B availability and higher Ca levels at elevated pH lessen the B uptake in plants. This is the clear reason/fact that high B levels in calcareous soils do not produce B toxicity in crops which might be toxic in other than calcareous conditions. Boron application significantly affects the sugar beet and bitter orange in calcareous sandy soils (**Hagin and Tucker, 1982).**

2.1.2 Effect of organic matter on B availability in soil

Boron availability decreased with increasing pH and most of the total soil B is unavailable to plants (**Borax,1998; Kubota *et al.*, 1948**).Poor organic matter and coarse texture are responsible for leaching loss of borate ions from surface which caused development of B deficiency in upland topo sequence. Low status of available B of upland in chotnagpur was reported by (**Kumar *et al*, 1994)** . Its deficiency in plants is most widespread in coarse textured, low organic matter, high pH and $CaCO_3$ soil (**Gupta *et al*,1985**).

Arora and Chahal (2009) reported that total desorbable B was negatively correlated with clay, CEC, Organic carbon while positively associated with sand content. A small quantity of Boron is gradually complexed within organic matter **(Yermiyahu *et al.,* 1995; Gu and Lowe,1990**) adsorbed on clays (**Bingham 1971; Keren *et al*., 1972**) and to some extent it is precipitated with $CaCO_3$ and is quite unavailable for plant growth (**Shorrocks, 1997**)

Sarkar *et al,* (2008) reported that a decrease in organic carbon, clay, and amorphous iron oxide content was responsible for the decrease in extractable B along depth of soil profile. The hot calcium chloride showed more efficiency than Potassium Di-hydrogen Phosphate and Tartaric acid for extracting B in soils high in organic carbon. Multiple regression equations explained 21, 57, and 59% of the variability in PDP-, HCC- and TA- extractable B content in soils by the soil properties analyzed, of which organic C and were the most important.

Abid Niaz *et al*, (2007) reported the effect of different soil characteristics like pH, $CaCO_3$, Organic matter and clay content on boron status in calcareous soils of Punjab. They found that correlation analysis exhibited that soil B is positively correlated with CaCO3 content and pH.

Mathur and Sudan (2011) reported the distribution of soil boron and its relationship with some soil properties. They found that a significant correlation was found among boron content and E.C, pH and Organic Carbon.

2.2 Effect of Boron on yield, yield attributing characters and uptake by crops.

Rashid *et al.* (2007) found that an increase of 14-23% in rice yield occurred with boron application in different areas of Punjab and Sindh, Pakistan. **Liew et al. (2010)** reported that some special fertilizers comprising of formulated mixtures of K, Mn, Zn, Cu, Mg and B were distributed with recommended manures resulted in the increase in rice production by 27%, from 4.62 tones/ha to 5.87 t/ha.

Shimpei Uraguchi & Toru Fujiwara (2010) reported analysis of B distribution among different parts in rice grain, demonstrated that the endosperm contained 92% of total B in brown rice and husk contains twice as much B as brown rice. **Shah *et al.* (2011)** revealed that Boron application @ 0.75 and 1 kg/ha significantly enhanced the straw yield of Khusboo-95, whereas the straw yield of Mehek was significantly increased at 1kg B/ha.

Pal and jena (2012) found that the application of B @ 1kg/ha rice in inceptisols of Bhubaneswar gave significant and higher rice yield 46.84q/ha.

Hyder *et al.* (2012) observed that with the application of different doses of boron (0, 0.5,1, 1.5, 2.0kg $ha^{-1)}$ straw yield of rice and paddy yield increases with the increase in boron application.

Sarki *et al*. (2013) reported that the application sodium pentaborate (SP) and powder colemanite (PC) @ 2 & 3kg Bha^{-1} significantly increased B concentration in paddy grain compared to the 0 and 1 Kg Bha^{-1}.

Pal and Jena ,(2012) conducted an experiment on interactive effect of K and B produced highest rice grain yield of 45.17 q/ha in the treatment receiving K @ 40 Kg/ha & B @ 1 Kg/ha in *inceptisols***.**

Jena (2005) reported that application of 5kg granubor per hectare gave 34% higher rice and sunflower yield over equal dose of borax on boron equivalent basis in rice-sunflower cropping system in coarse textured sandy loam soils of Bhubaneswar**.**

Hossain *et al.* (2001) revealed the effects of micronutrients (Zn, B, Mo) fertilization on the growth, yield, and nutrient uptake by transplanted aman rice (CV. BRRI Dhan-30). They observed that a significant positive effect of micronutrients on yield of Aman rice. The highest grain yield (4.8t/ha) was obtained in the treatments where all the 3 micronutrients were applied.

Islam *et al.* (2012) reported that the grain and straw yield of aman rice significantly influenced due to application of secondary nutrients, micronutrients and organic amendments. Grain yield of aman rice varied from 3410 kg to 3937 kg ha^{-1}, with the highest yield recorded in the treatment of N P K+ (PM) and lowest in N P K (control).

Chaturvedi (2006) observed the effects of micronutrients (Zn, B, Mn) alone or in combination on the yield and nutrient uptake by hybrid rice. Application of Mn+B+Zn significantly increased no. of grains/ear and 1000 grain wt by 29.39 and 16.60 respectively over control. Application of Mn+B+Zn to rice crop improved its seed and straw yield of (47.59 and 47.43%) of hybrid rice.

Rahmatullah *et al*. (2006) reported that paddy yield is significantly affected by boron application, which ranged from 3.51 to 6.11 t ha^{-1} . The highest yield was obtained from 2kg B ha^{-1} when applied to both rice and wheat crops. The direct application of 1 and 2 kg B ha^{-1} resulted an increase in yield 59.6 and 62.1%. Cumulative application of 1 & 2 kg B ha^{-1} increased the paddy yield 61.1 & 74.1% respectively, while on residual the yield of wheat increased by 36.8 & 48.8% over control.

Hussain and Yasin (2003) observed that wheat yield was increased by 13% over control with the application of 1 kg B ha^{-1}, similarly 16% yield increase of paddy over control. **Rashid** (2006) suggested in his long term research on rice-wheat system in four major soil types in Punjab province that the average Boron application (1kg B ha^{-1}) significantly affected wheat grain yield that ranged from 2.70 to 3.49 t ha^{-1}, recording the highest increase of 19.9% over the control.

Ahmed *et al.* (2012) reported that the interactive effects of silicon and boron in form of aqueous solutions that is 1.5% Si & 1.0% B performed well. It resulted in increasing biological yield (20.09 t /ha) and kernel yield 5.63tha^{-1} in case of maize.

Khan *et al.* (2006) found that the B concentration in the leaves of wheat and rice was significantly affected by the application of boron that ranged 10.37- 14.91 and 3.52 – 5.81mg kg-1, respectively. Similarly the boron concentration in soil was significantly affected by boron concentration in wheat and rice and ranged from 0.18-0.51 and 0.17- 0.61 mg kg^{-1}, respectively. The highest concentration in leaf and soil in wheat was found from 2 kg ha-1, while the cumulative application of 2 kg ha-1 proved to be highest in both the crops.

Hussain & Yasin, (2004) conducted field experiments to study the residual effect of Zn and B in rice-wheat system. Wheat grain yield ranged from 3.45to 3.53 t ha^{-1}. Highest yield of 3.53t/ha was found from the treatment of 5kg Zn+2kg B ha. Cumulative application of boron gave a yield increase by 10% over control; direct application gave an increase of 9% over control. However, residual effect of B increased paddy yield by 4% over control.

Hussain (2006) observed that the highest yield of wheat (3.21 t ha $^{-1}$) giving an increase of 27.4 % over control with the application of 5 kg B ha $^{-1}$.

Boron application @1kg ha-1produced the highest paddy yield of 4285 kg ha-1, which is significantly higher than NPK+Zn, NPK and control reported by **Motior Rahman *et al* .(2009**).

Quddus *et al*. (2011) showed that the combination of Zn @1.5 Kg/ha and B @1.0 Kg/ha produced significantly cumulative higher yield 2845 Kg/ha in Mungbean over control.

Hamsa et al., (2012) studied the residual effect of Zinc and Boron on rice - frenchbean cropping system at Karnataka state. They found that application of RDF+Zn (Zinc sulphate) @ 18 Kgha^{-1}+ Boron (boric acid) at 4 Kg ha^{-1} brought about significantly highest residual impact on growth(Plant height, number of leaves/plant, branches/plant) and yield(number of pods/plant, pod length, pod yield/ha) of French bean and on par with application of RDF+Zinc (Zinc sulphate) at 12 Kg ha^{-1}+ boron(boric acid)at 4 Kg/ha as compared to other treatments.

Ali *et al.* (2011) observed that the foliar application of Zn and B @ 0.75+1.00 kg proved as the best balanced fertilizer dose for higher seed cotton yield (2183.68 kg/ha) along with recommended dose of 170-57-62 kg NPK per hectare with higher number of bolls (26.7/plant) and boll weight (2.97g).

Yang *et al*. (2009) found that boron application increases 46.1% seed yield of rape seed mustard in light textured soil. **Devi *et al*. (2012)** studied the effect of sulphur and boron fertilization on yield, quality and nutrient uptake by soybean under upland condition. The result revealed that application of 30 kg S/ha and 1.5 kg B/ha were found to be the optimum levels of S and B for obtaining maximum yield attributes, yield, oil, protein content, total uptake of S and B.

FLD on yield of Ground nut to B application showed that foliar spray of B increased Rabi Ground nut yield between 18-22% & incurring a net profit of Rs. 1300 to 2100/ha in alluvial soil at Pipli Block(Annual report 1998-99).

Tomato *(Lycopersica esculentum* Mill) is a major horticultural crop with an estimated global production of over 120 million metric ton (FAO, 2007). Salad tomato must have a flavour, colour and texture that satisfy the consumers preference. At the same time they must be suitable for post-harvest handling and marketing.

Boron deficiency in fresh market tomatoes is a wide spread problem that reduces the yield and fruit quality (**Davis *et al*,2003**). **Smit and Combrick (2004),** reported that too low B levels in the root zone, the leaves of tomato are brittle and pale-green, a considerable fraction of flowers abscises and the fruits lack firmness, a problem that is worsened during storage (**Combrink, 2004)**. Further substantial B supply may considerably reduce fruit set, specially no other means of pollination eg. Vibration were applied (**Smit and Combrink, 2005**).

In another study, it was shown that an enhanced B supply(B foliar spray at 300 mgL^{-1}) was associated with a less frequent incidence of physiological disorder shoulder check crack (**Huang & Snapp 2004a**). **Davis *et al*, (2003)** reported that foliar spraying (1.87mgL^{-1}) of B chelated with mannitol, to tomato grown in river sand, was associated with increased plant growth and tissue K, Ca & B concentration. In the above study, foliar spray with Boron significantly enhance fruit B and K concentration In comparison with no B supply, which indicates B is translocated from the leaves to fruits & increased in K translocation with in the plant. Enhance uptake of Ca, Mg, Na, Zn, & B with high B levels in the root zone has been reported by **(Smit and Combrink, 2004**).

Experiments were carried out on tomato crop to application of B with or without different forms of organic manures on laterite sandy loam soil (Aeric Haplustalf) with pH 5.6, O.C 0.45% and HWS-B 0.48 ppm under AICRP on micro and secondary nutrient (1999-2000).The results revealed that application of 1KgB/ha significantly increased fruit yield of tomato (48.4%), B at 2Kgha^{-1} has a depressing effect on yield alone or in combination with the manures. Application of B along with FYM 5t/ha yielded 19.03t/ha of tomato fruit whereas with Vermicompost @ 2.5t/ha yielded 18.40t/ha.

Jyolsna and Mathew (2008) found that application of 0, 0.5, 1.0, 1.5 kg B ha^{-1} with recommended doses of fertilizers RDF (75:40:25:: kg N, P_2O_5, K_2O ha-1; RDF) and RDF+ FYM (FYM 25tha-1) resulted in an increase in growth and yield of tomato. It also reduced the days to flowering and increased fruit set (12.5 to 20% more at highest level) both with or without FYM.

Sathya *et al* (2010) revealed that the highest yield of tomato i.e 33 tonnes ha^{-1} was obtained due to the soil application of borax@ 20kg ha^{-1} which recorded 33.6% increase over control.

Patil *et al*. (2008) revealed that application of boric acid @ of 100ppm resulted in maximum number of primary branches(18.30), yield/plant (2.07 kg) and fruit yield of tomato (30.50 t/ha).Best treatment obtained by the mixture of micronutrients(B, Zn, Mn & Fe @ 100ppm and Mo @ 50ppm) recorded fruit yield 27.98 t/ha and differed significantly from control.

Muazzam Naz *et al*. (2012) found that the different doses of boron (0, 0.5, 1.0, 2.0, 3.0, 5.0 kg ha^{-1}) with N: P: K was incorporated @ of 150, 100, 60 kg ha^{-1} resulted significant growth and yield of tomato. Application of B 2kg B ha^{-1} resulted significant number of flower cluster/plant and fruit yield.

Pal and Jena (2012) conducted FLD on cabbage to B application as two foliar spray @ 0.3% produced higher yield of 270q/ha with a net return of Rs 36,165/ha in laterite soils of Dhenkanal. FLD on cauliflower to B application @1Kg/ha produced higher yield of 229.1 q/ha with a net return of RS 34150/ha in red and lateritic soils of Kandhamal.

FLD on onion to B application showed application of 2 Kg/ha through Borax with RDF recorded highest yield of 78% over farmers practice**. (Pal and Jena, 2012).**

(**Jena *et al*, 2009**). reported that liming and boron application has significant effect on cabbage yield, which varied between 39.9 to 62. t ha-1. Highest significant yield of 62.11 t ha-1 was obtained with 0.2 lime requirement (LR) + B @ 2 kg ha-1).It was found that pod yield of okra was increased by 5-10% under residual lime and 2-6% under residual B treatment over control.

Chander *et al.* (2010) reported that nutrient content in Cauli flower increased due to applied B & FYM in B deficient soils of Bajaura and Junga and nutritional quality of the produce got improved.

2.3 Effect of Boron on fruit quality and Biochemical parameters

Colour is a major quality characterstics in all fruits and vegetables since the deposition of carotenoid pigments are responsible for the characterstics colour of ripe tomato (**Fraser *et al*., 2001**). During fruit ripening, maximum concentration of α and β carotene occur at turning to breaking stage (**Meredith and Purcell, 1966**), after which lycopene accumulates (**Davis and Hobson, 1981**). Phytochrome has also been implicated in the induction of lycopene accumulation (**Alba *et al*, 2000**).

The antioxidant potential of tomato is derived from a mixture of antioxidant biomolecules, including lycopene, Ascobic, Phenolics, flavonoids of vitamin E and is especially high in cherry tomato (**Kaur *et al*, 2004**). Lycopene content increased from rose to red colour stage **(Brandt *et al*,2000 ;Helyes *et al*, 2006).** Mature green plant have lower lycopene content.52% of total antioxidant(48% lycopene, 43% ascorbic acid,53% phenolics) are located in the epidermis of the fruit (**Toor and Savage, 2005).**

Sathya *et al.* (2010) reported that the lycopene, ascorbic acid, crude protein, and total soluble sugars of tomato PKM-1 are significantly increased due to the soil application of borax @ 20 kg ha^{-1} recorded a value of 3.99 mg 100 g^{-1}, 23 mg 100 g^{-1}, 10.13%, 9.20^0 brix respectively. The crude fibre and titrable acidity were found to be highest in control that received RD of NPK alone, whereas the lowest value obtained in soil application of borax @ 20 kg ha^{-1}.

Sinha *et al.* (2006) found that in B deficient tomato leaves, the specific activity of peroxidase, ribonuclease, polyphenol oxidase increased and that of acid phosphatase and phenyl alanine ammonialyase decreased. In fruits, the concentration of starch, ascorbic acid and lycopene decreased in low B(0.0033 mg B/l) and that of ascorbic acid accumulated and lycopene content increased in excess B (3.3 mg B/l).

Salam *et al*. (2011) reported the integrated effect of B, Zn, and cow dung on quality of tomato. The results reflected that the highest pulp weight (90.24%) , dry matter content (5.82%), ascorbic acid (11.2mg/100g), lycopene content (147 micro gram/100 gram), marketable fruits at 30 days after storage (74%) and shelf life (17 days) were recorded with the combination of 2.5 kg B/ha + 6 kg Zn/ha and 20t/ha cow dung.

Jyolsna and Mathew (2008) found that the application of recommended doses of B (0, 0.5, 1.0, 1.5 kg B ha-1) along with RDF (75:40:25 kg N P K) and RDF+ FYM(25 t/ha) resulted in the improvement of reducing sugars, total sugars, vitamin C, and Lycopene content of tomato.

Johann S. Buck *et al* (2008) reported reported that the quality parameters like T.S.S was reported to be highest in HE treatment (continuous high EC, 4.7 dSm-1) and smallest in LE treatment (2.8dSm-1) are 12.9 or 17.6 kg. m^{-2} and 1.4 or 12.1 kg m-2 respectively.

Dorais *et al*. (2001) reported that the fruit quality of cherry tomato was improved when the EC treatment is in between the range of 3.5 to 9.0 dSm^{-1}.

Santamaria *et al.* (2004) reported that TSS of Naomi cherry tomato fruit treated with constant nutrient solution EC of 2 dSm^{-1} was significantly lower than that of fruit treated with a day EC nutrient solution of 2 dS.m-1.

Siddique *et al* (2010) found that the highest pulp content (88.14%), T.S.S(4.50%), acidity (0.47%), ascorbic acid (10.95mg/100g), lycopene content (112 micro gram/100 gram) were recorded with the combination of 2.5 kg B+ 6 kg Zn/ha and recommended doses of NPK(N=253, P=90, K=125 kg/ha).

Dube *et al.(*2004) recorded the highest ascorbic acid content in tomato with the soil application of Zinc sulphate and borax @ 10 and 20 kg/ha respectively.

III. MATERIALS AND METHODS

The particulars relating to the geographical set up of study area, collection and preparation of soil sample and analytical methods adopted in investigation are briefly presented in this chapter. Under this investigations rice and tomato were taken as test crop.

3.1 Experimental site

The experiment was conducted during *kharif* season of the year 2012-13 at E block of central research station, O.U.A.T, Bhubaneswar, which is situated at 20^0 15'' N latitude and 85^0 52 '' E longitude, elevation of 25.9 m above MSL (Mean sea level) and 44 Km west of Bay of Bengal. The soil of experimental field was sandy loam in texture.

3.2 Climate and Weather conditions

Bhubaneswar experiences a warm and moist climate with hot and humid summer and a mild winter.

3.3 Experimental details

The experiment was laid out in simple Randomized Block Design comprising of 5 treatments and 4 replications. Rice-Vegetable cropping system was taken.

Details of field experiment for *kharif* Rice

Design: Randomised Block Design
Plot size: 12 x 2.5 sq. m
Spacing: 20 x 10 cm
No. of replications: 4
No. of treatments: 5
Variety: Lalata
Duration: 120 days
Seed rate: 60kg/ha
Fertiliser dose: 60:30:30 Kg/ha :: N:P:K

Details of field experiment for tomato

Variety: Utkal kumari
Spacing: 60 x 45 cm
Duration: 80 days
Seed rate: 500gm/ha
Fertiliser dose: 125: 150: 100 Kg/ha :: N:P:K

Fertilizer Source

N: Urea, DAP

P_2O_5: DAP
K_2O: MOP
B: Borax $Na_2B_4O_710H_2O$(10.5% B)

3.4 Treatment details

T1	No B (control)
T2	B @ 0.5 $kgha^{-1}$
T3	B @ 1 $kgha^{-1}$
T4	B @ 1.5$kgha^{-1}$
T5	B @ 2 $kgha^{-1}$

Recommended doses of N: P: K remaining same in all the treatments.

3.5 Preparation of soil samples

Soil samples are collected from individual plot from 0-15 cm depth, dried in shade. The air dried soil samples were ground with a wooden pestle and passed through 2mm sieve to separate the coarse fragments (>2mm) . The fine earth samples were stored in separate containers and used for various analysis.

3.6 Preparation of plant samples

After harvest, the rice plant samples were collected from the field, washed with running water. The plants were dried in air and then in oven at 60^0 C. The dried plants were cut into small pieces by stainless steel scissors and ground thoroughly to have uniform sampling. The samples were levelled and kept for further analysis. Representative plant samples were digested in AR grade di-acid mixture (3:2 :: HNO_3:$HClO_4$) as described by Jackson. Boron was determined by spectrophotometer (Systronix) at 450 nm. Tomato fruit of adequate size and in ripen condition were taken. Fruits were chopped into pieces and required amount was taken and macerated in mortar and pestle. Fruits were extracted with acetone for the biochemical analysis of lycopene and for Ascorbic acid it was extracted with oxalic acid.

3.7 Soil physical analysis

Bulk density of soil

Bulk density of soil was determined by core method.

3.8 Soil Chemical analysis

Soil reaction

The pH of soil samples were determined in Soil: Water of 1: 2.5 using digital pH meter (Backsman pH meter) Jackson (1973).

Electrical conductivity

The electrical conductivity of soil samples were determined in soil: water suspension of 1:2.5 after equilibrium for half an hour with intermittent stirring using conductivity bridge (Jackson 1973).

Organic carbon

The organic carbon content of soil samples were determined by wet digestion procedure of Walkley and Black as described by Jackson 1967.

Available potassium

Available potassium in soil was extracted by neutral normal ammonium acetate and subsequent estimation was done by flame photometer Jackson (1973).

DTPA extractable micronutrients (Zn, Cu, Fe, Mn)

Micronutrients were extracted from soil with DTPA (0.005M) solution by shaking the mixture in mechanical shaker for 2 hrs. After filtration the concentration of extract was estimated using atomic absorption spectrophotometer AAS GBC model following the model described by Lindsay and Norvell (1978).

Hot Water extractable Boron

The boron from the soil was extracted from soil with water (1:2) by refluxing for 5 minutes on hot plate (Berger and Trough 1939). The extractant was determined by spectrophotometer (systronics) at 450 nm using azomethine-H as indicator. The procedure was followed as per (Page *et.al* 1982).

3.9 Biochemical analysis

Method of analysis

Lycopene

The lycopene content of tomato was determined by extracting the carotenoids in acetone and then it was taken in petroleum ether .The pulp of tomato (10g) was repeatedly extracted using acetone and then the extractant was taken in petroleum ether. Then phase separation was done, the lower aqueous phase was re extracted with petroleum ether till the solution becomes colourless. The extactant was kept in a brown bottle for 30 minutes. Extractant was then decanted to a 100ml volumetric flask, volume was made up and absorbance was measured in a spectrophotometer at 503 nm. Lycopene content was determined by adopting the method of Sadasivam and manickam (1992).

Ascorbic acid

The ascorbic acid content of tomato was determined by extracting the tomato sample (0.5 to 5 g) in 4% oxalic acid and the volume was made up to 100ml and then centrifuged. 5ml of supernatant was pipetted out and then 10ml of oxalic acid was added to it and it was titrated against dye solution. The amount of dye consumed was equivalent to amount of ascorbic acid. The method followed was described in Association of official Agricultural chemists (1962) and expressed in mg $100g^{-1}$ fruit sample.

Total soluble solids of fruit juice

Total soluble solids of tomato were obtained by taking the pulp of tomato in hand refractometer.

Total Nitrogen

For the estimation of total N, samples were digested with Concentrated. H_2SO_4 in presence of digestion mixture till it turn colourless. The digested samples were distilled by Kjeldahl method (page *et al.*1982). The Crude protein was estimated by multiplying Total N by 6.25.

$$mg.\,of\ lycopene\ in\ 100g\ sample\ = \frac{31.206\ \times Absorbance}{Weight\ of\ sample\ (g)}$$

Absorbance 1 unit = 3.1206 µg lycopene/ml.

$$Amount\ of\ Ascorbic\ acid\ mg/100g = \frac{0.5mg}{V1\ ml} \times \frac{V2}{5ml} \times \frac{100ml}{weight\ of\ the\ sample} \times 100$$

Amount of Crude protein (%) = Total Nitrogen x 6.25

3.10 Statistical analysis

The data obtained on various characters were averaged, tabulated, and analysed statistically as per randomized block design analysis as suggested by Gomez and Gomez (1984).

IV. RESULTS AND DISCUSSIONS

4.1 Soil Properties of the Experimental Site.

An experiment was conducted in 'E' block of Central Research Farm, OUAT, Bhubaneswar. Soil samples were collected from 0 to 15 cm soil depth, air dried and processed for physic-chemical analysis of the soil which are presented in Table 1 .Soils of experimental site was *Inceptisols*, acidic in reaction and pH was found to be 5.4. Electrical conductivity of soil was non saline, sandy loam texture. The bulk density was 1.68 Mg/M^3, The soil was low in organic carbon, low in Available K and medium in $CaCl_2$ extractable sulphur status. Zinc content was above critical limit whereas Copper content was below critical limit and Iron content was high. Hot water soluble Boron was 0.3 mg/kg.

Table.1 Physico-chemical properties of Initial Soil.

Properties	Depth (0-15 cm)
pH	5.4
EC(dSm^{-1})	0.06
OC(gKg^{-1})	3.2
Textural class	Sandy Loam
B.D (Mg M^{-3})	1.68
Av. K ($Kgha^{-1}$)	29.1
Av. S ($Kgha^{-1}$)	26.85
Hws-B ($mgkg^{-1}$)	0.30
DTPA Zn($mgkg^{-1}$)	0.79
Fe($mgkg^{-1}$)	118.2
Mn($mgkg^{-1}$)	20
Cu($mgkg^{-1}$)	0.068

4.2 Direct Effect of Boron on Grain and Straw yield of Rice.

Direct effect of Boron on grain and straw yield of rice are presented in Table 2. The results showed that Rice grain yield ranged from 40.33 to 49.44 q/ha due to various treatments. Lowest yield was produced in control plot which is only due to recommended dose of fertilizer (NPK). Grain yield of rice was found to increase with increase in Boron dose. The grain yield of rice was 45.44q/ha when 0.5 kg of Boron was applied. The increase was 13% over control. Highest rice grain yield of 49.44 q/ha was obtained when Boron was applied @ 1 Kg B/ha i.e 22% yield increase over control. There was significant increase in rice yield due to treatment over control. However no significant difference among the treatment (Fig. 1) was found. The increase in yield of rice may be due to increase in RNA and DNA content in reproductive tissue in presence of Boron which enhance flower bud initiation, fruit setting and filled grain development which resulted higher grain yield. Similar findings were reported by Khan *et al*., (2006), Shah *et al*., (2011) and Hyder *et al* ., (2012).

Similarly Straw yield of rice varied from 42.67 to 61.11 q/ha due to various treatments. The straw yield increased significantly over control as Boron dose increased from 1.0 Kg/ha to 2 Kg/ha. However no significant straw yield difference was observed at 0.5 Kg B/ha over control.

Table .2 Effect of graded dose of B on Grain and straw yield of Rice.

Treatments	Rice Grain Yield (q/ha)	Increase over Control (%)	Rice Straw Yield(q/ha)
Control	40.33	-	50.67
B @ 0.5 kg/ha	45.44	12.68	54.22
B @ 1 kg/ha	49.44	22.60	59.56
B @ 1.5 kg/ha	47.89	18.74	60.89
B @ 2.0 kg/ha	48.22	19.57	61.11
C.D.(0.05)	4.84	-	5.46

4.2.1 Effect of Boron on concentration of Rice

The effect of Boron on concentration of rice is presented in table.3. It was found that concentration of rice grain varied from 2.5 to 10.9 ppm. As compared to control the concentration of Rice grain was on decreasing with the increase in added B dose, while in case of Rice straw Boron concentration ranged from 2.9 to 32.5 ppm. (Fig.2). Boron concentration in straw was increased with increase in Boron dose as reported by Khan *et al*., (2006).

Table 3 Effect of Boron on concentration (ppm) of rice.

Treatments	Concentration(ppm)	
	Rice	
	Grain	Straw
Control	2.5	2.9
B @ 0.5	10.9	6.5

Kg/ha		
B @ 1 Kg/ha	10.5	15.3
B @ 1.5 Kg/ha	8.2	31.8
B @ 2 Kg/ha	9.7	32.5
C.D (0.05)	4.80	11.04

4.2.2 Effect of Boron on Boron uptake by Rice

Boron uptake by direct rice is presented in table 4. It was found that boron uptake by grain was less compared to straw indicating less mobility of boron with in plant to growing tip or to grains as Boron requirement of cereals are low. Boron uptake by grain was ranged from 10.19 to 52.38 g/ha with recommended dose of NPK. Boron uptake was 10.19 g/ha which increased to 49.49 g/ha due to application of 0.5 Kg B/ha Boron with recommended dose of NPK. Boron uptake was significantly increased to 52.38 g/ha as Boron dose increased to 1 Kg/ha over control (Fig.3).It was also found that with increase in Boron dose, Boron uptake decreased which is mostly due to decrease in yield.

Boron uptake by rice straw was ranged from 14.54 to 200.70 g/ha due to different treatments. Lowest B uptake (14.54 g/ha) was in control. B uptake increased to 35.06 g/ha when B @ 0.5 g/ha was applied with recommended dose of NPK indicating B application is supplementing growth of plants. With further increase in B dose uptake was increased significantly up to 2 Kg/ha (Fig.3).This may be due to Boron accumulation in older leaves for its less mobility. Total B uptake was increased with increase in B dose.

Table 4 Effect of Boron on boron uptake (g/ha) by Rice.

	Rice (*kharif)*		
Treatments	Grain (g/ha)	Straw (g/ha)	Total B Uptake (g/ha)
Control	10.19	14.54	
B @ 0.5 kg/ha	49.49	35.06	84.55
B @ 1 kg/ha	52.38	90.96	143.35
B @ 1.5 kg/ha	39.18	193.39	222.95
B @ 2.0 kg/ha	46.58	200.70	247.29
C.D.(0.05)	15.78	68.67	-

4.3 Effect of Boron on Fruit and Stover yield of Tomato

Residual effect of Boron on fresh fruit yield and stover yield of tomato are presented in table 5. Tomato fresh fruit yield was varied from 10.94 to 22.14 t/ha due to various treatments. Tomato yield obtained in control plot was 14.94 t/ha which was mostly due to recommended dose of NPK only. Increase in residual boron dose significantly affected tomato fruit yield. The increase was observed progressively up to 1.5 Kg B/ha treatment after which fruit yield decreased (Fig .1). Highest significant fresh fruit yield of 22.14 t/ha was found by the application of 1.5 Kg residual Boron treatment over control. The yield response was 7.2 t/ha over control (14.94 t/ha). Since Vegetable like tomato require Boron hence unutilized Boron from first crop is being utilized by tomato. Bose and Tripathi (1996) reported that the yield of tomato significantly increased besides, reducing the fruit cracking. The improvement in plant growth might be due enhancement in photosynthetic and other metabolic activity. Boron increased RNA and DNA content in reproductive tissue which enhanced the flower bud initiation and fruit setting as a result, increases the yield of tomato. Similar results were reported by Kumari, (2005), Sathya *et al*., (2010), Salam *et al*., (2010), Oyinlola and chube (2004), Patil *et al*.,(2008).

Tomato biomass or Stover yield was varied from 15.4 to 25.46 t/ha (table 5). Biomass yield was followed similar trend as that of tomato fruit yield. Lowest biomass yield of 15.4 t/ha was obtained in control. Biomass yield significantly increased due to residual effect of boron. It was found that stover yield was 20.13 t/ha due to residual effect of 0.5Kg B whereas stover yield increased to 25.46 t/ha on residual B of 1.5 Kg B/ha. Beyond that it did not produce any significant stover yield of tomato. Stover yield reduction was observed at higher residual boron treatments, indicating higher dose of boron applied to Cereal-Vegetable cropping system may give benefit to the second crop.

Table 5 Effect of Boron on Fruit and Stover yield of Tomato

Treatments	Fresh Fruit yield (t/ha)	Yield response over control (t/ha)	Stover Yield (t/ha)
Control	14.94		15.4
B @ 0.5 kg/ha	17.51	2.57	20.13
B @ 1 kg/ha	21.08	6.14	24.25
B @ 1.5 kg/ha	22.14	7.2	25.46
B @ 2.0 kg/ha	18.78	3.84	24.22
C.D.(0.05)	1.81	-	2.70

4.4 Effect of Boron on concentration of Tomato.

The residual effect of Boron on concentration of Tomato is presented in table 6. It was found that concentration of Boron in tomato fruit ranged from 9.9 to 15.3 ppm and Boron concentration of stover ranged from 24.6 to 45.2 ppm. It was found that with the increase in dose of Boron, concentration of Boron in fruit significantly increases up to 1.5 Kg B/ha.

Table 6 Residual effect of Boron on Concentration (ppm) in Tomato.

Treatments	Concentration (ppm)
	Tomato

	Fruit	Stover
Control	9.9	24.6
B @ 0.5 Kg/ha	10.3	45.2
B @ 1 Kg/ha	15.1	42.6
B @ 1.5 Kg/ha	15.3	42.6
B @ 2 Kg/ha	13.3	41.1
C.D (0.05)	3.40	10.97

4.5 Effect of residual Boron on Boron uptake by Tomato.

Residual effect of boron on B uptake by Tomato fruit and Stover are presented in Table 7. It was found that Boron uptake by fruit varied between 147.76 to 336.70 g/ha due to residual B treatments. Though Tomato was grown on residual Boron, uptake was much higher than direct crop rice. Lowest B uptake 147.76 (g/ha) was in control where only recommended dose of NPK was applied. Boron uptake significantly increased over control above 1.0 Kg B/ha residual Boron treatment. Highest significant Boron uptake (336.70 g/ha) was obtained in the residual treatment of B 1.5 Kg/ha. There was significant difference in B uptake among the treatments (Fig 5).

Boron uptake by tomato stover was much higher than the uptake by fruits, may be due to translocation of Boron to fruits is less because of immobility or less mobility of B from leaves/stems to fruits as reported by Sinha *et al*., (2006). However uptake showed an increasing trend with increase in residual Boron treatments. Stover Boron uptake was 386.52 g/ha in control (no B) treatments (Fig.5).

Table 7 Boron uptake by Tomato Fruits and Stover.

Treatments	Tomato(Rabi)		
	Fruit(g/ha)	Stover (g/ha)	Total B Uptake (g/ha)
Control	147.76	386.52	534.28
B @ 0.5 kg/ha	181.09	775.46	956.55
B @ 1 kg/ha	318.19	932.75	1250.94
B @ 1.5 kg/ha	336.70	1006.17	1342.86
B @ 2.0 kg/ha	255.29	870.08	1125.37
C.D.(0.05)	59.7	228.56	-

4.6 Residual Effect of Boron on Quality parameters of Tomato.

Boron plays an important role in improving quality of Tomato. The colours, sourness, TSS of tomato are important in determining quality tomato. Though many works on direct effect of Boron on Tomato quality is known but little is known about tomato quality influenced by residual Boron. The quality parameters like Lycopene, Ascorbic acid, T.S.S and Crude protein (%) are presented in table 8.

Lycopene:

It was found from (table 8) that pigment lycopene content was increased significantly with the increasing dose of Boron. Lycopene content varied from 1.053 to 1.975 mg/100g of pulp with different doses of residual Boron. Lowest lycopene content of 1.053 1 mg/100g of macerated pulp was found in control plot. Though lycopene content was found to increase in residual Boron treatments but no significant increase was observed. Lycopene content (1.708 and 1.975 mg/Kg) was significantly increase over control at higher residual Boron dose i.e 1.5 and 2.0 Kg B/ha. Lycopene content was positively related with B content (Fig. 10).Similar Findings was reported by Paithankar *et al.* (2004).

Ascorbic Acid

Ascorbic acid or vitamin–C is an important parameter of tomato fruits which increases to its market value. Tomato was grown on residual Boron have some effect on ascorbic acid. Ascorbic acid content ranged from 11.53 to 16.17 mg/100g of pulp due to various residual Boron treatment (table 8). Highest Ascorbic acid content (16.13 mg/100g) was found in control. With the residual Boron treatment, ascorbic acid content decrease over control indicating sourness of tomato fruits (Fig .10).

Total Soluble Solids

Total Soluble solids contents of Tomato fruits produced due to residual B ranged from 4.53 to 6.4 % (table 8). T.S.S content was 4.53 % In control. No definite trend was observed due to residual effect of Boron on TSS of fruits. TSS content was found to increase with increase in Boron dose except at 1.5 Kg residual Boron. Highest TSS of 6.4% was recorded at 2 Kg residual Boron treatment. Such increase in TSS may be due to involvement Boron in regulation of Carbohydrate balance and helped to increase TSS content (Uziak and Nurznski (1964), Salam *et al*., (2010), Mahajan & Sharma (2000), Naz *et al*., (2012).

Crude Protein

The Crude Protein content of tomato fruits varied from 0.99 to 1.34% due to graded dose of residual Boron (table 8). Highest Crude Protein 1.34 % was obtained in the residual treatment of Boron @ 2.0 Kg/ha. It had a positive relation with the residual Boron (Fig. 12).

Table 8 Effect of Boron on quality parameters of Tomato.

Treatments	Lycopene (mg/100g)	Ascorbic (mg/100g)	TSS (%)	Crude protein (%)
Control	1.053	16.17	4.53	0.99
B @ 0.5 kg/ha	1.284	11.53	4.67	1.25
B @ 1 kg/ha	1.285	11.71	5.50	1.05
B @ 1.5 kg/ha	1.708	12.91	4.87	1.14
B @ 2.0 kg/ha	1.975	16.13	6.40	1.34
C.D.(0.05)	0.56		1.26	

V. Effect of Boron on Post- harvest Boron soil Status

After harvest of two crops (Rice-Tomato) soil samples were collected, processed and analysed for various nutrients which are presented in (Table 9).

pH and EC

No change in soil pH was observed due to various B doses after harvest of two crops. pH in post -harvest soils ranged 5.14 to 5.63 (table 10). There was a positive relation with Boron (Fig. 10). Whereas EC in Post-harvest soil increased considerably than the initial value of 0.07 dS/m may be due to upward movement of salts/fertilisers during Rabi season.

Organic Carbon

Organic carbon status of soil increased from a low initial value (3.2 g/Kg) to medium status but no definite trend was observed synchronous to B application (table 9). However it had linearly positive relation with residual B (Fig 8) Such increase in Organic carbon was mostly due to FYM applied to both crops and crop residues which raised the Organic Carbon of Post-harvest soil.

Hot water Soluble Boron

There was considerable increase in B content in post- harvest soil. Initial soil hot water soluble B was 0.3 mg/kg. Boron content of post- harvest soil ranged from 0.21 to 0.41 mg/kg due to different treatments (table-9). Decrease in B content in control plot was observed than initial status may be due to uptake of B by two crops. Hsw-B content in all the treatments were above the initial value. (Fig7).

Table 9 Post Harvest Soil Analysis after harvest of two crops

Treatment	pH	EC (dS /m)	Organic carbon (g/Kg)	Hot water soluble B (mg/kg)
Control	5.39	0.24	6.2	0.21
B @ 0.5 kg/ha	5.50	0.21	6.6	0.37
B @ 1 kg/ha	5.14	0.30	7.9	0.40
B @ 1.5 kg/ha	5.63	0.24	7.1	0.41
B @ 2.0 kg/ha	5.45	0.21	6.5	0.47
Initial	5.4	0.06	3.2	0.30

VI. SUMMARY AND CONCLUSION

A field experiment was conducted at the 'E' block of Central Research Station, O.U.A.T, Bhubaneswar, during *Kharif* 2012 and *Rabi* 2012-13, to study the direct and residual effect of B in enhancing the yield of Rice – Tomato Cropping system with the following objectives.

1. To study the direct effect of B on grain & straw yield of Rice and residual effect on biomass yield of tomato.
2. To study the nutrient uptake by Rice –Tomato Cropping system.
3. To study the quality parameter of Tomato fruit.
4. To study the post- harvest soil status.

The field experiment was laid out in Sandy loam *Inceptisols* of 'E' block of Central Research Station, O.U.A.T, Bhubaneswar on Rice Var. 'Lalata' and tomato var. 'Utkal Kumari'. The experiment was designed in Randomised Block Design. The treatments were Boron at five levels (0, 0.5, 1.0, 1.5, and 2.0 Kg/ha) and four replications of totally twenty treatments. After harvest of *Kharif* Crop, rice grain and straw yield was recorded. The plant samples were collected from each treatment of each replication. After proper processing plant samples were digested and analysed by following the standard procedure. After harvest of Rice crop, Tomato was grown as Rabi crop. The fruits were recorded after every plucking, after final plucking, the total yield was recorded. Biomass yield was also recorded. Fruit, plant and soil samples were collected. After proper processing, the soil and plant samples were analysed following the standard procedure, which was indicated in Materials and Methods. Tomato fruits were analysed for fruit quality study. The Silent findings resulted from the experimental studies are given as under.

Highest rice grain yield of 49.44 q/ha was obtained when Boron was applied @ 1.0 Kg B/ha with the recommended dose of NPK fertilizer i.e 22.6% increase over control (as NPK fertilization).

Whereas on residual effect of Boron on tomato, it was found that the fruit yield of 22.14 t/ha was obtained in the treatment receiving Boron @ 1.5 Kg B/ha with the recommended dose of NPK fertilizer. The increase was 48% over only NPK fertilization.

Boron uptake by rice grain varied from 10.19 to 52.38 g/ha. Higher uptake (52.38 g/ha) was found in the treatment of Boron @ 1.0 Kg/ha with recommended dose of fertilizer.

Similarly, uptake by Straw/Stover was in increasing trend with the increasing dose of Boron. The total uptake by Rice was in increasing trend with the increase in Boron dose.

Higher Boron up take (336.70 g/ha) by Tomato fruit was obtained in the treatment receiving Boron @ 1.5 Kg/ha with recommended dose of NPK fertilizer. However, total uptake of Boron was increased up to Boron applied @ 1.5 Kg/ha.

The quality of Lycopene was enhanced by increasing Lycopene content (1.975mg/100g). The increase was 87% over control. It was found that lycopene content was positively correlated with the increasing doses of boron.

The Ascorbic acid content was decreased over control indicating the sourness of tomato fruit. Ascorbic acid content of tomato was positively correlated with increasing doses of boron.

The TSS and Crude protein content were increased over control with the increasing dose of Boron, T.S.S and Crude protein content of tomato also showed positive correlation with increasing dose of boron.

CONCLUSION FROM THE FINDINGS

Application of Boron @ 1.0 Kg/ha increased the yield of rice in *Kharif* season with the RDF.

Highest uptake of Boron by rice was in the treatment of Boron application @ 1.0 Kg B/ha with the RDF.

The quality of the fruit was improved significantly with the increasing dose of Boron over control.

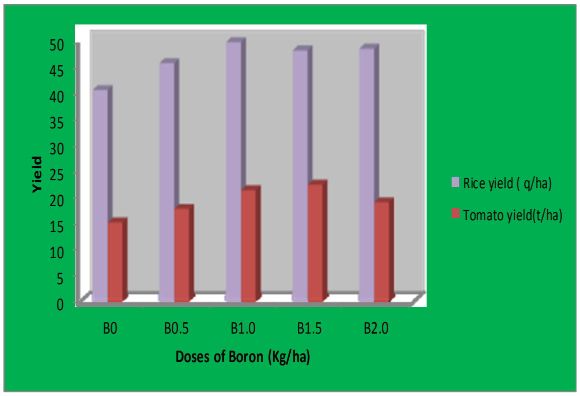

Fig.1 Effect of different doses of Boron on the yield of Rice-Tomato cropping system.

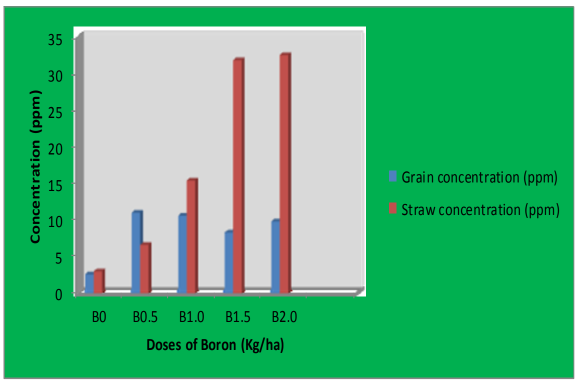

Fig. 2 Effect of different doses of Boron on Rice grain and straw concentration

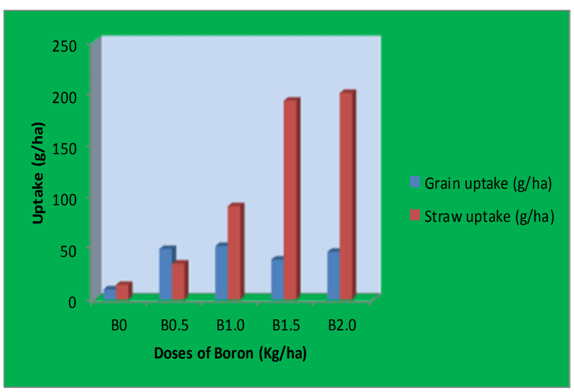

Fig .3 Effect of Doses of Boron on Boron uptake in Rice grain and straw.

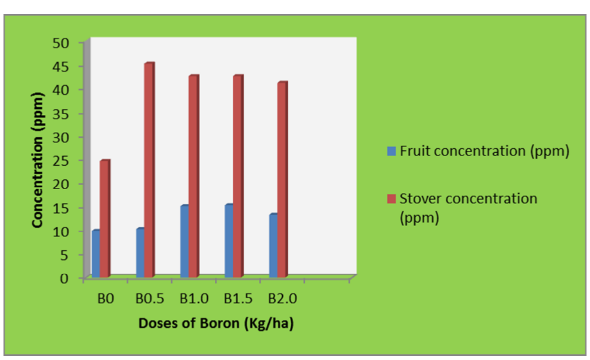

Fig 4 Effect of different doses of Boron on fruit and stover concentration of tomato.

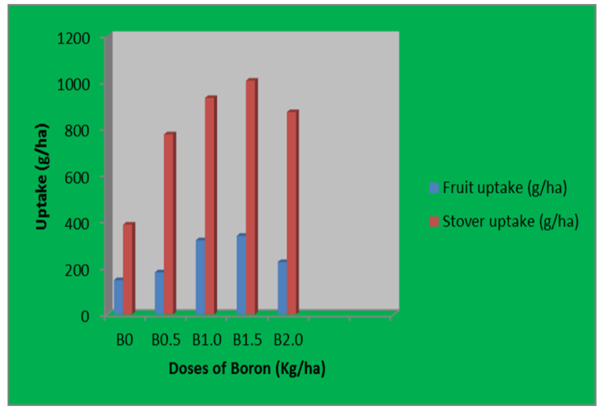

Fig 5 Effect of doses of Boron on Fruit and Stover uptake in Tomato

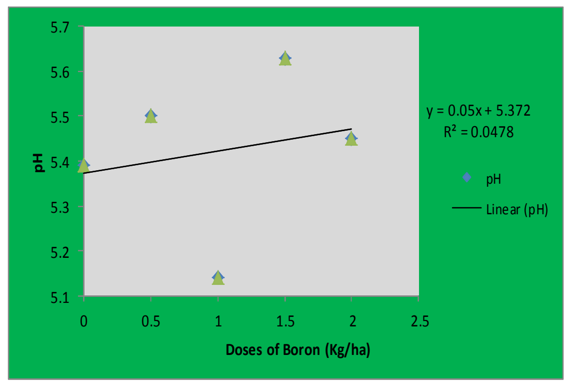

Fig6. Correlation between doses of Boron and pH of Post-Harvest soil.

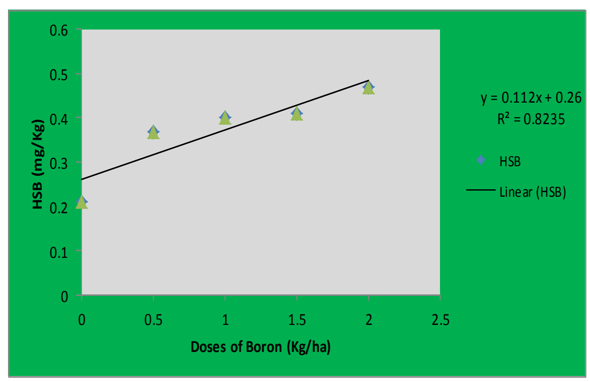

Fig. 7 Correlation between doses of Boron and HWS-B in Post-Harvest soil.

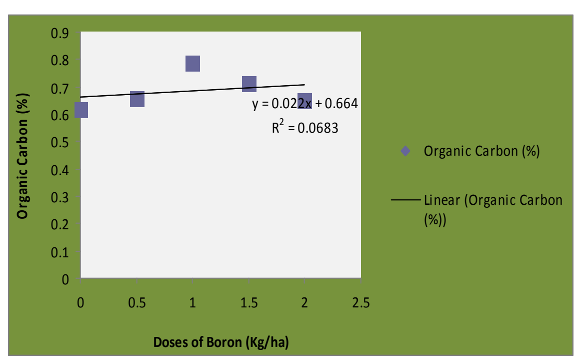

Fig 8 Correlation between doses of Boron and organic Carbon content in Post-harvest soil.

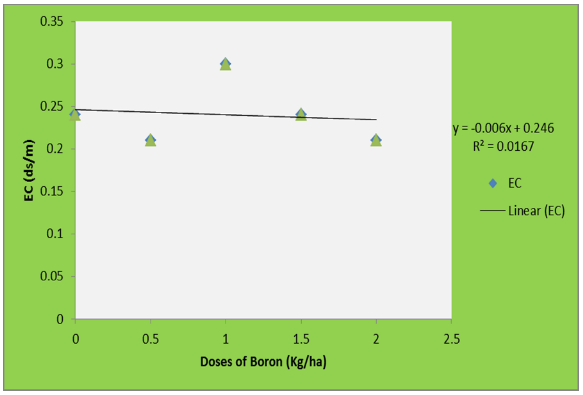

Fig 9. Correlation between doses of Boron and EC of Post-harvest soil.

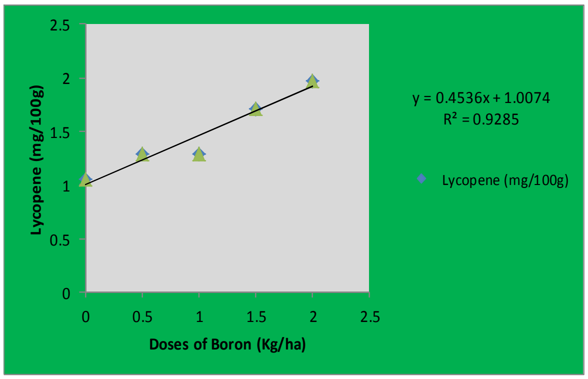

Fig 10 Correlation between doses of Boron and Lycopene content of Tomato.

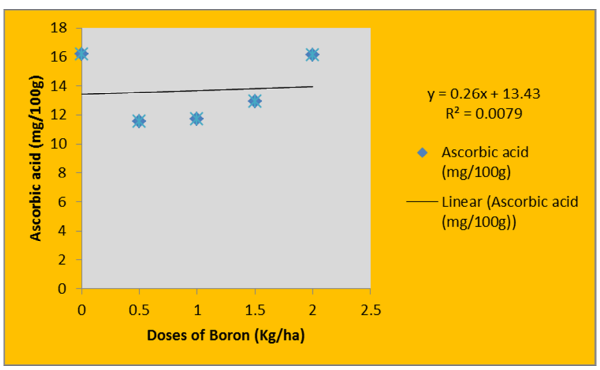

Fig10. Correlation between doses of Boron and Ascorbic acid content of Tomato

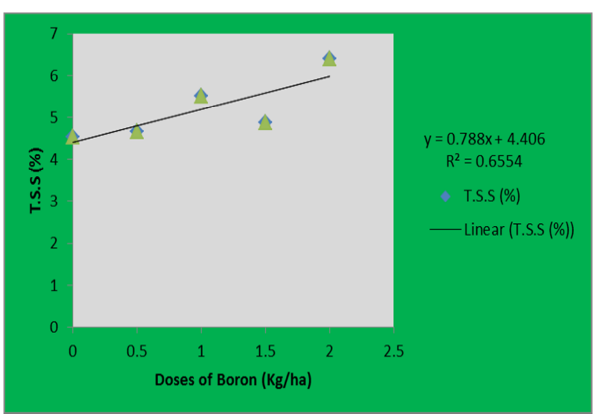

Fig 11 Correlation between doses of Boron and T.S.S of tomato.

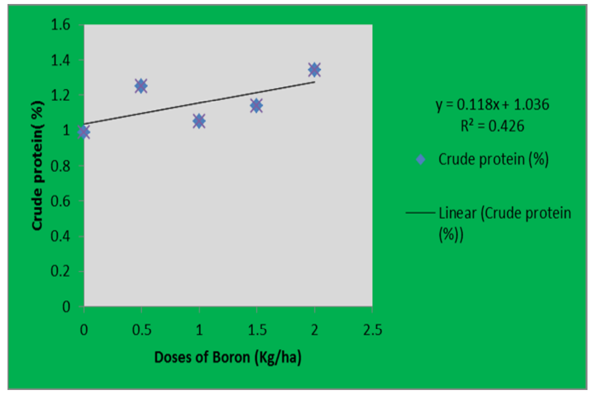

Fig 12 Correlation between doses of Boron and Crude protein content of tomato

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