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Fruit deformity in papaya: field screening, nutrient composition and amelioration by boron application

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Boron deficiency is a major production constraint of papaya under alkali (light) soils of India. Fruit deformity is an emerging physiological anomaly in developing papaya fruits. Systematic field screening was conducted in eighteen papaya germplasm to observe the severity of this disorder under spring transplanted crop. The disorder severity, fruit yield and economic losses due to physiological disorders were also observed. Germplasm, Pune Selection-3 was most sensitive (67.02 %) for the disorder, while PL (13/96), PN (13/86), Pusa Selection Red, Pusa Nanha and FPL-6 were most tolerant (≤4.46%) under agro-climatic conditions of India. The nutrient analysis of leaf and fruits of papaya plants indicated that the fruit deformity was caused due to boron deficiency. Basal application of borax @ 5 g/plant was most effective in increasing the B level in leaf and fruits (73.6 and 49.1 ppm, respectively) without any toxicity.

Keywords: Alkali soil, Boron deficiency, *Carica papaya*, Leaf toxicity

Papaya (*Carica papaya* L.) is one of the most important fruit cultivated throughout the tropical and subtropical regions of the world[1]. The natural habitat of papaya lies in tropical, central and South America. In order to effectively counter the demand as well as good source for returns, this crop will play an even more critical role in determining the productivity and food security. Papaya has gained more importance owing to its high palatability, early fruiting, highest productivity per unit area and multifarious uses, such as food, medicine and industrial input[2]. Papaya flourishes in the frost-free and humid areas of the tropics and subtropics. An average temperature of 25°C is optimum for this fruit crop. The plant requires rainfall between 1500-2000 mm, which needs to be spread throughout the year. Fertile, light to medium hard alluvial and volcanic earth with a pH-value of 6-7 makes an ideal site. Because papayas develop only a flat root system and a medium depth of soil with high soil fertility is sufficient. Fertility of soil, the pH and organic carbon coupled with availability of nutrients especially boron play major role for this crop in India. Quality fruit production, market value and export of papaya fruit suffer from several limiting factors including physiological disorders[3].

Nutrient deficiencies cause several physiological disorders such as bumpy fruit which may lead to deformed/discoloured seeds. Fruit deformity was identified as a new physiological disorder of papaya under diverse agro-climatic conditions of India[3]. Deformity first starts in young fruits, but symptoms become more severe over fruits close to physiological ripening. The bumpiness begins in areas on the fruit epidermis and is due to boron deficiency, arresting the fruit growth[4,5]. In addition, infected tissue continues increasing in size and end up forming a protuberance or “bump”, similar to a ball.

High incidence before maturity has also been a serious concern in papaya fruit production. Keeping above facts in mind, the present study was conducted on the varietal screening against fruit deformity, nutrient content and development of management module for farmers.

Materials and Methods

The investigations were carried out at Indian Agricultural Research Institute Regional Station, Pusa-848 125, Samastipur (Bihar), India (elevation 52 m; latitude 25.98°N and longitude 85.67°E). The details of different experiments conducted under this study are given as under.

Field screening of papaya germplasm

Field screening of different papaya germplasm was carried out during 2011-12 for taking an account of physiological disorders *i.e*., fruit deformity in papaya orchard. Uniformly aged papaya plants were selected for this study. In the orchard, three blocks of each germplasm were marked and ten plants in each block were randomly chosen for observations for this disorder at fruit maturity stage. Each plant represented a replication. Eighteen lines were studied for fruit deformity incidence. Each tree of different selected lines was observed carefully and number of deformed fruits was recorded at fruit maturity. These fruits were recorded by counting the number of normal and deformed fruits to get the incidence. The values of different observations obtained from these plants were worked out to get the mean value. The experiment was conducted for two consecutive seasons (spring and autumn seasons). The data presented are the pooled mean of two consecutive seasons. The statistical analysis of the data was carried out using standard statistical procedures.

Nutrient composition of papaya cv. Pune Selection-3

Owing to the severity of the fruit deformity problem in Pune Selection-3, the status of nutrients in different plant parts of normal and malady plants were worked out. The recently mature leaf and fruit samples of Pune Selection-3 were collected in the first week of October for two consecutive years, 2012 and 2013. The leaf and fruit sampling procedure as described by Nishima[6] was followed. Tissue concentration of nitrogen was determined by Kjeldhal's methods, phosphorous by vanadomolybdate method[7] and potassium by flame photometer[8]. The concentration of zinc, iron, manganese and copper were determined with the help of atomic absorption spectrophotometry. The content of boron was estimated by Azomethine-H method[9].

Effect of boron application in papaya cv. Pune Selection-3

This experiment was carried out during 2012 and 2013 in Pune Selection-3 as this is most susceptible to fruit deformity disorder. The treatments were applied during autumn sown crop. Representative soil samples were collected from experimental orchard on 1st October of 2012 and 2013 prior to the implication of treatments. The pH of the soil was determined in 1:2.5 soil water extract, organic carbon by Walkley and Black's titrimetric method and boron was estimated by Azomethine-H method[9]. Boron treatment was given through soil application. There were four treatments replicated ten times in randomized block design. The treatments were: T_1- control, T_2- soil application of borax @ 5 g/plant, T_3- soil application @ 10 g/plant, T_4- soil application @ 15 g/plant. Boron was applied through disodium octaborate tetrahydrate containing 13% boron. The soil application was given each year during first week of April on the soil surface, 30 cm away from the main trunk of plant (four months old) followed by earthing up. The incidence of fruit deformity on each plant was recorded by counting the number of deformed and healthy fruits at maturity as described earlier. The plants selected were of uniform age. In the orchard, ten plants in each treatment were randomly chosen for observations at fruit maturity. Other yield related traits *viz.*, plant height (cm), stem girth (cm), number of nodes at 1st fruiting, number of fruits/ plant, number of leaves/ plant, fruit diameter (cm), fruit weight (kg), fruit yield/plant (kg) and fruiting zone (cm) were measured as per standard procedures. The tissue concentration of boron in leaf and fruit was determined by Azomethine-H method[9].

Results and Discussion

Field screening of papaya germplasm

The field screening results had divulged that among the selected germplasm, the fruit deformity was significantly higher in Pune Selection-3 (67.02%) followed by Co-7 (50.07%) and Red Lady (49.67%), while PL (13/96) (3.26%) and PN (13/67) (3.38%) was least affected (Table 1 and Fig. 1). Saran *et al*.[10] reported that the susceptibility of Pune Selection-3 to bumpiness. It may be because of their higher boron requirement than other germplasm, the field screening studies revealed that out of 18 germplasm of papaya, Pune Selection-3 was most susceptible to this physiological disorder, while cv. PL (13/96) and PN

Table 1 — Field screening of different papaya germplasm for fruit deformity

Germplasm	Severity of deformity (%)	Fruit yield/plant (kg/tree)	Economic loss (Rs. ha^{-1})
Pusa Dwarf	18.97	43.60	110479
Pusa Nanha	4.28	31.30	17883
Pusa Selection Red	4.20	61.10	34253
Farm Selection	8.33	46.10	51265
PN (13/86)	3.38	59.80	26984
PS-5	22.26	48.02	142704
Pusa Majesty	10.17	33.10	44940
Co-7	50.07	42.90	286761
PS-1	42.23	53.40	301051
PS-2	47.20	49.20	310020
PS-3	67.02	63.70	321580
PL-2	39.25	46.36	242920
Red Lady	49.67	21.10	139917
Pusa Delicious	27.04	36.30	131033
PL-4	17.73	47.01	111273
FPL-6	4.46	45.03	26870
Vinayak	48.79	37.50	244245
PL (13/96)	3.26	53.40	23393
C.D.	16.43	3.01	92.81

(13/86) were most tolerant. The symptoms of fruit deformity in Pune Selection-3 are shown in Fig. 1. The susceptibility of Pune Selection-3 to fruit deformity may be because of their higher boron requirement than Pusa Dwarf[3]. This might be due to the effects of boron (B) on membranes and cell walls. It is also well documented that B helps in maintaining membrane stability. It has been reported that when B is deficient, plant cell walls tend to swell, split and to result in weakened intercellular space[11-13]. The highest economic loss (Rs. 3, 21580 ha^{-1}) was observed in Pune Selection-3 due to highest incidence of this disorder as compared to other germplasm under fruit production. Similarly, the highest economic loss (Rs. 11, 21580 ha^{-1}) was recorded during spring transplanted papaya under seed production[3].

Nutrient composition of papaya cv. Pune Selection-3

There was significant difference in normal and deformed fruit affected samples of leaf and fruit for N content in papaya plants. The N content in normal leaf (1.75%) and fruit (1.36%) was significantly higher than those of affected samples (deformed) of leaf (1.56%) and fruit (1.12%) as shown in Table 2. The P content of leaf and fruit were at par in normal (0.52 and 0.35%, respectively) and deformed samples (0.49 and 0.31%, respectively). K content in normal leaf (4.21%) and fruit (4.72%) was significantly higher than those of affected samples (deformed) of leaf (4.02%) and fruit (4.44%). However, significantly higher amount of Zn was noticed in leaf and fruit of deformed samples (69.60 and 22.60 mg kg^{-1}, respectively) as compared to normal samples (65.85 and 20.00 mg kg^{-1}, respectively). The Zn deprivation did not affect plant growth[14]. B, N, P, Mo, S and K are essential to obtain higher yield in papaya. Similarly, Fe content in leaf and fruit samples of deformed plants (9.25 and 4.30 mg kg^{-1}, respectively) was significantly increased compared to normal samples (5.70 and 2.06 mg kg^{-1}, respectively), while Mn content in normal leaf and fruit (70.20 and 45.50 mg kg^{-1}, respectively) was significantly higher than those of deformed samples (59.85 and 33.30 mg kg^{-1}, respectively). Similar trend has been reported for Mn deficiencies in mango[15]. Similarly, Cu content was also higher in normal samples (655.42 and 23.90 mg kg^{-1}, respectively) as compare to deformed sample (539.35 and 21.20 mg kg^{-1}, respectively) of leaf and fruit. The B content in normal samples of leaf (73.60 mg kg^{-1}) and fruit (49.10 mg kg^{-1}) were significantly higher compared to deformed samples of leaf (24.55 mg kg^{-1}) and fruit (16.10 mg kg^{-1}), affected plants had low concentrations of B in leaf and fruit indicating that deficiency of only B is responsible for deformity in Pune Selection-3. Papaya has high nutritional requirements, and boron was found to be limiting factors to plant growth and yield under agroclimatic conditions of Bangladesh[14].

Fig. 1 — (A) Most susceptible (Pune Selection-3); and (B) tolerant [PL (1-97)] cultivar.

Effect of borax application in papaya cv. Pune Selection-3

The soil analysis data of the experimental field are presented in Fig. 2. The Zn, B and S were lower in amount. The light soil was considering 0.5 mg kg^{-1} as the critical level of B in soil for most of the crops[10], the experimental soil was deficient in B.

The control plants of Pune Selection-3 showed highest incidence (66.78%) of fruit deformity as shown in Table 3 and Fig. 3 A. The soil application of borax @ 5, 10 and 15 g to each plant decreased fruit

Table 2 — Average nutrient status in different parts of normal and deformed plants of papaya cv., Pune Selection-3

Plant part		Average nutrient concentration							
		N (%)	P (%)	K (%)	Zn (mg kg^{-1})	Fe (mg kg^{-1})	Mn (mg kg^{-1})	Cu (mg kg^{-1})	B (mg kg^{-1})
Leaf	Deformed	1.56 (±0.03)	0.49 (±0.02)	4.02 (±0.01)	69.60 (±0.23)	9.25 (±0.14)	59.85 (±0.09)	539.35 (±0.14)	24.25 (±0.14)
	Normal	1.75 (±0.03)	0.52 (±0.01)	4.21 (±0.02)	65.85 (±0.03)	5.70 (±0.12)	70.20 (±0.11)	655.42 (±0.11)	73.60 (±0.35)
Fruit	Deformed	1.12 (±0.07)	0.31 (±0.01)	4.44 (±0.02)	22.60 (±0.35)	4.30 (±0.17)	33.30 (±0.17)	21.20 (±0.69)	16.10 (±0.06)
	Normal	1.36 (±0.02)	0.35 (±0.01)	4.72 (±0.01)	20.00 (±0.58)	2.06 (±0.04)	45.50 (±0.29)	23.90 (±0.58)	49.10 (±0.23)
C.D. (P=0.05)		0.14	0.05	0.06	1.28	0.33	0.67	69.04	0.88

Table 3 — Effect of borax application on different traits under autumn transplanted crop of papaya cv., PS-3

Borax doses (g/ plant)	Plant height (cm)	Stem girth (cm)	No. of nodes at I[st] fruiting	No. of fruits/ plant	No. of leaves/ plant	Fruit			Fruiting Zone (cm)	Fruit Deformity (%)
						Diameter (cm)	Weight (kg)	Yield/ plant (kg)		
Control	212.23 (±1.36)	29.65 (±0.61)	28.63 (±0.38)	36.20 (±1.14)	37.97 (±0.47)	42.63 (±0.18)	1.91 (±0.44)	69.14 (±2.23)	156.31 (±0.83)	66.78 (±0.38)
5	208.98 (±0.35)	31.59 (±0.05)	25.61 (±0.14)	38.29 (±0.30)	50.47 (±0.21)	44.99 (±0.27)	1.92 (±0.50)	73.51 (±1.84)	166.11 (±0.11)	0.00 (±0.00)
10	208.05 (±0.10)	31.01 (±0.09)	25.88 (±0.37)	39.04 (±0.23)	47.91 (±1.36)	42.84 (±0.20)	1.90 (±0.51)	74.18 (±2.20)	166.45 (±0.88)	0.00 (±0.00)
15	201.13 (±2.88)	30.64 (±0.20)	26.39 (±0.08)	38.63 (±0.84)	45.52 (±0.17)	43.09 (±0.23)	1.89 (±0.50)	73.01 (±1.15)	166.69 (±1.33)	0.00 (±0.00)
C.D. (P=0.05)	6.42	1.28	1.11	2.97	1.09	0.82	0.55	1.78	3.49	2.25

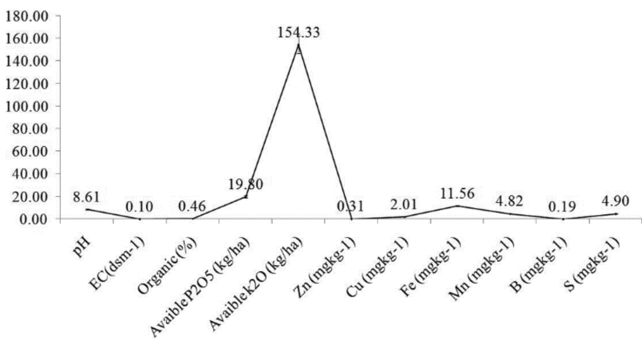

Fig. 2 — Some chemical properties of the orchard soil of experimental site.

deformity up to zero per cent. The stem girth (31.59 cm), number of leaves (50.47/plant), fruit diameter (44.99 cm), fruit weight (1.92 kg/fruit), fruit yield (73.51 kg/plant) and fruiting zone (166.11 cm) was observed significantly higher in soil application of borax @ 5 g/plant during autumn season crop as compare to control treatment (29.65 cm, 37.97/plant, 69.1451 kg/plant and 156.31cm, respectively). However, minimum plant height (208.98 cm) and number of nodes at I[st] fruiting (25.61) was also observed in soil application of borax @ 5 g/plant as compare to control treatment (212.23 cm and 28.63, respectively). The number of fruits per plant was at par in application of borax @ 5, 10 and 15 g to each plant as compare to control. The B, N, P, Mo, S and K are essential to obtain higher yield in papaya[14]. However, B deficiency symptoms in crop plants are interruption in flowering and fruiting[17] and poor yields, with deformed fruits or discolored grains[9].

The effect of different borax doses in papaya plants and toxicity symptoms of boron on leaf margins was also observed critically. Soil application of borax @ 5 g/plant have no any toxicity on leaves, while soil application of borax @ 10 and 15 g/plant were causing toxicity symptoms as burning of leaf tips and leaf tips along with margin, respectively (Fig. 3D). Boron accumulation follows a pattern from leaf base to tip in many plants and this leads to typical toxicity symptoms on older leaves which appear as marginal or tip chlorosis or both and necrosis[18,19]. The ameliorative effect of borax @ 5g/ plant was observed in increasing yield and yield contributing traits, reducing the incidence of fruit deformity along with no toxicity in papaya (Fig. 3 B and C). The toxicity in papaya was also reported in Bihar[5]. This treatment was also effective for economic point of view.

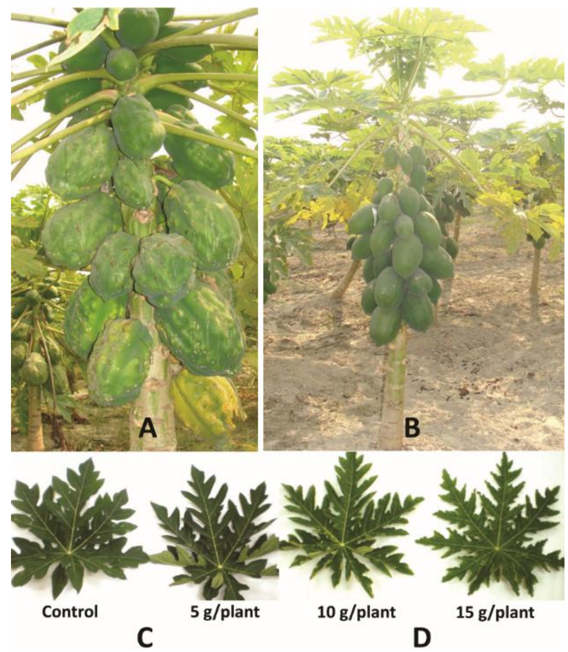

Fig. 3 — Effect of borax treatment on papaya fruits and leaves cv., Pune Selection-3 (A) Control; (B) 5 g/plant; (C) No toxicity; and (D) Toxicity.

Boron content was significantly higher in leaf samples as compared to fruit samples (Fig. 4). The concentration of boron in leaf and fruit samples

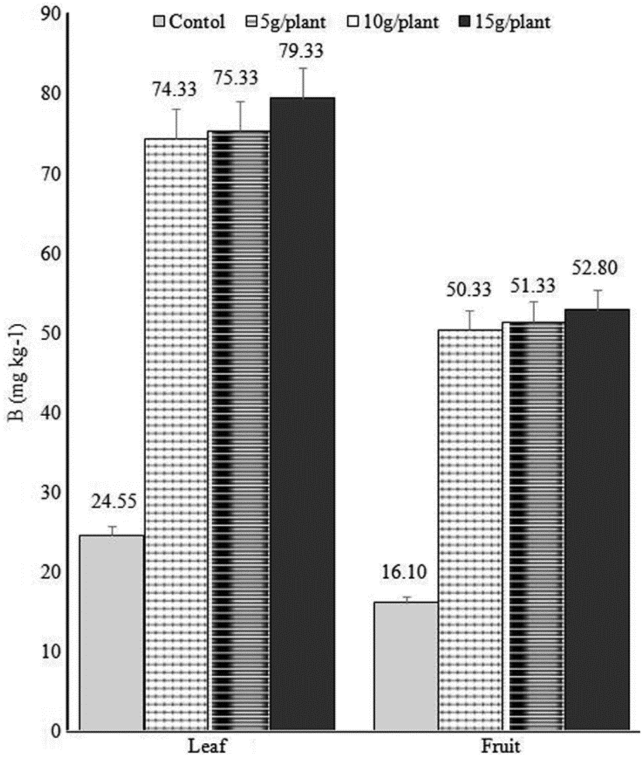

Fig 4 — Effect of borax application on the concentration of B in leaf and fruit of papaya cv. Pune Selection-3. Vertical bars show standard error.

significantly increased with soil application of borax @ 5 g/plant (74.33 and 50.33 mg kg^{-1}, respectively). The maximum increase of B concentration in leaf was found with soil application of boron @ 15 g/plant which was 79.33 mg kg^{-1} higher than the control followed by soil application @10 g/plant (75.33 mg kg^{-1}). The maximum increase of B concentration in fruit was found with soil application of boran @ 15 g/plant which was 52.80 mg kg^{-1} higher than the control (16.10 mg kg^{-1}) followed by soil application @10 g/plant (51.33 mg kg^{-1}). The B concentration (25-30 ppm) was necessary in fruit petiole of papaya to avoid deficiency symptoms under Hawaii conditions (acidic soils)[6]. In mango leaf, 50 to 100 mg kg^{-1} B is the satisfactory range under light soils of Doon Valley[12] and B in leaves above the concentration of 50 mg kg^{-1} is considered adequate[20-22].

In conclusion, among the screened germplasm, Pune Selection-3 was most sensitive to fruit deformity. The ameliorative effect of B as disodium octaborate tetrahydrate application @ 5g/plant is more effective and economic. Therefore, balanced application of macronutrients and micronutrients along with proper B management is imperative for quality production in B deficient sandy loam soils of papaya growing regions.

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