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Effect of different sources of boron on flowering and yield of mango cv. Amrapali

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Abstract
The present investigation was carried out at Instructional Research Farm, School of Agricultural Sciences and Rural Development, Nagaland University, Nagaland during November 2017-August 2018. The experiment was laid out in Randomized Block Design with three replications and seven treatments of different boron sources *viz*., Agricol 2.5 g, Agricol 5g, Chemibor-P 2.5g, Chemibor-P 5g, Disodium Octaborate Tetrahydrate 2.5 g, Disodium Octaborate Tetrahydrate 5g and control (distilled water). The aqueous solution of boron was applied on the soil at two stages *i.e*., before flowering and at pea stage. Data were collected from N-E and S-W aspects of the tree canopy. Results revealed that the earliest panicle emergence, minimum number of days for 50% flowering (22.51 and 22.07), days to fruit set (57.27 and 56.82) and days to harvesting from panicle initiation (168.26 and 168.00) were obtained with Agricol (2.5 g) on N-E and S-W aspects of the canopy respectively. Maximum fruit yield (46.2 and 45.92 kg/tree) significantly increased with Agricol (2.5 g) application. The number of hermaphrodite flower/panicle (208.55 and 207.71), sex ratio/panicle (0.66 and 0.61) and least fruit drop (51.23 and 50.50) were found maximum with application of DOT (2.5g) The lower concentrations of boron from various sources performed better in the present study.

Keywords: Mango, mineral boron, flowering, fruit yield

Introduction
Mango (*Mangifera indica* L.) belongs to the family Anacardiaceae and originated in the Indo-Burma region. Mango the "King of fruits" is the main fruit of Asia and relished all over the world as dessert fruit which has been in cultivation in the Indian sub continent for well over 4000 years (De Candolle, 1904). The total annual production of mango in India is estimated to be 2,07,98,000 MT in an area of 22,93,000 ha land. The important mango producing states in India are Andhra Pradesh, Uttar Pradesh, Bihar, Karnataka, Tamil Nadu, Gujarat, Telangana where, Andhra Pradesh leads in its production (50001.2 MT) followed by Uttar Pradesh (4557.2 MT) (NHB data base 2018-19). Mango performs well under both tropical and subtropical climatic conditions. The crop has wide adaptability with respect to soil, climate and altitude for its successful cultivation. The trees can survive at 10 to 65 ˚C and the optimum range of temperature is 21 to 27 ˚C (Chadha, 2012) [6]. Inflorescence of mango is borne on large panicles grown terminally. Mango is andromonoecious *i.e.* each inflorescence bears both hermaphrodite and staminate flowers (Coetzer *et al.,* 1955) [4]. In western India, several mango varieties *viz.,* Alphonso, Kesar, Rajapuri, Pairi, Dashehari, Langra, Neelum, Amrapali and Mallika are commercially grown and accepted by consumers. Among this, Amrapali is one of the leading hybrid variety of mango developed at IARI, New Delhi through crosses between Dashehari x Neelum in the year 1971. It is precocious, famous for excellent quality fruit and has regular bearing habit. Fruits are medium sized, flesh is deep orange red in colour, fibreless, sweet in taste with high TSS and pulp content (75%) (Singh *et al.*, 2017) [25]. There has been several reports that application of only primary nutrients would not prove successful in producing high quality fruits in mango trees and there is need for application of micronutrients in order to improve the yield as well as fruit quality. Moreover, the macro nutrients are generally taken up and utilized by the tissues of the plants by the catalyzing effect of micronutrients (Phillips, 2004) [17]. Micronutrients also play vital role in various enzymatic activities and synthesis of assimilates and hormones. These micronutrients play an active role in the plant metabolism processes starting from cell wall development to respiration, photosynthesis, chlorophyll formation, enzymatic activity, hormone synthesis, nitrogen fixation and reduction etc. (Das, 2003) [7]. Quality production, market value and export of mango suffer from several limiting factors including nutritional deficiency.

The requirement of micronutrients are only trace, which is partly met from the soil or through chemical fertilizer or through other sources. The major causes of micro nutrient deficiencies are intensified agricultural practices, unbalanced fertilizer application including NPK, depletion of nutrients and no replenishment (Rajedran and Ramamurthy, 2009) [19]. Boron is involved in the transportation of carbohydrates in plant. It is also essential for cell division and cell development. Boron is necessary for calcium metabolism and it probably facilitates the translocation of sugar, pollination and fruit set. Generally in many crops boron deficiency symptoms first appear in the growing tips. This results in a stunted appearance (rosetting), barren ears due to poor pollination, hollow stems and fruit (hollow heart), brittle discolored leaves and loss of fruits (Chadha, 2012) [6]. Boron deficiencies are mainly found in soils, sandy soils in regions of high rainfall or under irrigation and those soils with low soil organic matter (Brown *et al*., 1995) [3]. Some organic boron sources like Agricol, Chemibor-P, Disodium Octaborate Tetrahydrate are recommended for soil application as they have higher solubility in the soils of acidic pH. In a trial on peanuts conducted in Department of Plant Sciences, UC Davis, it was reported to enhance pod filling thereby increasing the yield and the peanut productivity. In most of the crops, boron shows very poor phloem mobility because of this boron in leaf tissue cannot be easily transported nor sufficiently to the reproductive organs (*i.e.*, buds, flowers, seeds, etc.), therefore, application of boron in moist soils during all stages.

the laboratory for further analyses. All data were recorded in accordance with standard practices.

Results and Discussion

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads:

Panicle initiation and length

The data in table 1 depicts the date of panicle initiation and its growth on the different aspects of the tree canopy. Early emergence of panicle was observed with the application of Agricol (2.5 g) in the N-E aspect of the tree canopy followed by the S-W aspect and in the N-E aspects with application of DOT (2.5g). In general, trees applied with mineral boron showed advancement in panicle initiation as compared to control. There was significant variation on the length of panicle on all days of observation with the greatest length (36.66 cm and 36.27 cm) which was significantly highest over all other treatments was observed with Disodium Octaborate Tetrahydrate (DOT) (2.5 g) treatment on both aspects of canopy respectively. The boron sources and concentrations used also showed significant differences baring DOT in the later. The effect of boron on panicle length may be due to action of boron on photo assimilates and protein synthesis and translocation to the growing site which is the panicle on the terminal portion of the branches thereby increasing length of panicle. Similar results were observed by Sarkar *et al.,* (2015) [22] in mango cv. Alphonso where foliar application of 0.5% borax recorded maximum panicle length (36.48 cm). Singroul (2016) [27] reported that application of 100% RDF+0.1% B on mango cv. Amrapali showed the maximum panicle length (36.67 cm).

Flowering characteristics

There was significant influence on the flowering of mango with the application of mineral boron (Table 2). Application of Agricol (2.5g) resulted in 50% flowering in three weeks time of panicle initiation (PI) as compared to six weeks in control. This was followed by three and half weeks duration with the application of Agricol at 5g and DOT at 2.5g in both aspects of tree canopy. There was significant variations on the effect of boron sources on the days to 50% flowering while different concentrations of boron did not show any significant variations in the S-W canopy but varied significantly on the N-E aspect of the canopy. Boron regulates the RNA synthesis (Ram and Bose, 2000) [18] which might have played vital role in increasing physiological activities leading to early initiation of flowering in mango cv.

Alphonso. The present findings confirm the reports of Gurjar *et al.* (2015) [13] who reported that foliar application of 1% zinc sulphate, 1% iron sulphate and 0.5% borax in combination had influenced flowering in terms of minimum days (19.67) taken to 50% flowering. Patel (2016) [23] also reported that soil application of RDF+200 g zinc sulphate + 100g boric acid recorded minimum number of days (30.00) to 50% flowering in mango cv. Amrapali. A perusal of the data shows that the various treatments significantly influenced the days to full bloom. The number of days to full bloom (data not shown) also showed similar results with those of 50% flowering and influenced by the mineral boron applications.

A perusal on table 2 clearly shows that application of mineral boron caused a shift in number of male and hermaphrodite flowers in the inflorescence. Number of male flowers/panicle was found greater with the application of Chemibor-P in both concentrations and DOT at 5g in all canopy aspects of the plant. Further, these treatments showed a reciprocal lower number of hermaphrodite flowers/panicle. There was significant variations on the effect of boron sources on the number of male and hermaphrodite flowers per panicle, however, different concentrations failed to reach the level of significance.

Production of greater number of hermaphrodite flowers may be due to the boron activity in plants as it involves in the protein synthesis and enhances the production and utilization of amino acids. The present findings confirm the reports of Dutta (2004) [11] where application of 3000 ppm boric acid at the late bud swelling stage recorded the highest number of hermaphrodite flowers on mango cv. Himsagar. Negi *et al*. (2010) [16] also reported that foliar application of boric acid 200 ppm on mango cv. Dashehari recorded maximum number of hermaphrodite flowers. Boron is essential for reproductive growth as it involves in metabolisam and protein synthesis which might be the reason for greatest number of male flowers per panicle. These findings corroborates with those of Singh and Maurya (2004) [25] where foliar application of boric acid 0.2% on mango cv. Mallika recorded the maximum number of male flowers. The sex ratio per panicle was found to be least with the application of Chemibor-P with both concentrations followed by DOT at 5g application on all parts of the plant canopy.

Fruit setting characteristics

The days to fruit set and harvest from panicle initiation followed similar trend with days to 50% flowering where Agricol application at 2.5g minimized the time taken for fruit

set and harvest as compared to control. The various concentrations did not have much effect on these parameters. The reduction in time taken for harvest of fruits were at least about a month with the application of mineral boron. There was drastic reduction in number of fruits/panicle from pea stage to marble stage in all treatments. The treatments with DOT with both concentrations and Chemibor-P (2.5g) resulted in more number of fruits retained at marble stage. Foliar application of borax 0.5% recorded maximum number of fruit set at pea stage (13.54) which reduced to 6.83 at marble stage in mango cv. Alphonso (Gurjar *et al*., 2015) [13].
Sajid *et al.* (2010) also reported that foliar application of 0.05% zinc + 0.04% boron before flower initiation, after fruit set and 40 days interval of second spray increased fruit set in sweet orange cv. Blood Orange. The number of fruits/panicle at harvest also followed more or less a similar trend with DOT (2.5g) and Chemibor-P (2.5g) retaining the highest number of fruits/panicle. There was significant variations on the effect of boron sources on the fruits retained per panicle. These findings confirm the reports of foliar application of borax 0.4% on guava cv. Lucknow- 49 which recorded a maximum fruit retention percentage of 57.27% (Yadav *et al.*, 2011) and foliar application of 0.5% borox on mango cv. Alphonso recorded maximum number (1.5) of fruits per panicle (Gurjar *et al.*, 2015) [13].
There was maximum fruit drop% in plants where no boron was applied. The least fruit drop was recorded in plants treated with DOT (2.5g) closely followed by Chemibor-P (2.5g). There was significant variations on the effect of boron sources on the fruits retained per panicle. The concentration of boron from various sources did not vary significantly on fruit drop percentage on both aspects of tree canopy. The present findings confirm the reports of Banyal *et al.* (2011) where spraying of borax 0.4% on litchi cv. Dehradun in mid February and first week of May as a foliar application showed lowest fruit drop (77.42%). Abhijith (2018) also recorded less fruit drop % (45.60% as against 79.63% in control in aonla cv. NA-7 with the foliar application of micronutrients 0.5% zinc sulphate + 0.5% iron sulphate + 0.25% borax.
A perusal of the data shows that the various treatments significantly influenced the fruits per tree. The greatest number of fruits per tree (245.48 and 244.18) in north east and south west directions of canopy were obtained with application of DOT (2.5g) treatment which was significantly highest amongst the treatments. There was significant variations on the effect of boron sources on the fruits retained per tree. The number of fruits per tree increased about 60% to 100% with the boron application regardless of the source or concentration as compared to the control plants. The greatest yield (245.48 and 244.18 fruits/tree) on both canopy directions was obtained with application of DOT at 2.5g followed by 2.5g application of Chemibor-P (223.28 and 163.54 fruits/tree) while control plants produced significantly the least number of fruits on both canopy directions (104.38 and 104.04 plants/tree). The yield per plant was found to be significantly greater with the application of mineral boron as compared to control. The increase in the yield per plant as compared with control was fourfold in the plants treated with Agricol 2.5g from both aspects of the canopy. This was followed by the treatments of DOT (2.5g), Chemibor-P (2.5g), Agricol (5g). The treatments with DOT (5g) and Chemibor-P (5g) also brought about double the yield/plant when compared with control. Similar findings have been reported in sapota with soil application of borax (20 g/tree) during 50% flowering and pea stage of fruit development which recorded maximum yield (Shraswathy *et al.*, 2004).

Table 1: Influence of boron sources and canopy direction on the panicle initiation and length on Mango cv. Amrapali

Treatments	Date of Panicle initiation (PI)		Panicle Length after PI (cm)					
			10th day		20th day		30th day	
	N-E	S-W	N-E	S-W	N-E	S-W	N-E	S-W
Control	27/01/18	31/01/18	4.51	4.86	9.22	8.86	14.31	13.93
Agricol (2.5 g)	17/01/18	19/01/18	8.36	9.06	18.23	18.13	34.70	34.00
Agricol (5g)	20/01/18	23/01/18	5.38	5.06	13.82	12.51	25.99	25.56
Chemibor-P(2.5 g)	23/01/18	23/01/18	5.96	5.92	14.61	14.79	29.76	29.50
Chemibor-P(5 g)	23/01/18	26/01/18	5.17	5.08	13.65	12.95	26.30	25.96
D O T (2.5g)	19/01/18	22/01/18	7.63	7.08	19.01	18.42	36.66	36.27
D O T (5g)	19/01/18	22/01/18	6.34	5.76	11.65	11.79	23.75	24.21
S Em±			0.14	0.12	0.12	0.12	0.37	0.37
LSD (p=0.05)			0.50	0.44	0.42	0.44	1.32	1.34
Boron sources compared with control								
S Em±			0.15	0.13	0.13	0.13	0.40	0.40
LSD (p=0.05)			0.54	0.47	0.46	0.48	1.43	1.45
Concentration effect								
S Em±			0.08	0.07	0.07	0.07	0.21	0.21
LSD (p=0.05)			0.29	0.25	0.24	0.25	NS	NS

*DOT= Disodium Octaborate Tetrahydrate

Table 2: Influence of boron sources and canopy direction on the flowering characteristics of mango cv. Amrapali

Treatments	Days to 50% flowering		Male flowers/ panicle		Hermaphrodite flowers/panicle		Sex Ratio /panicle	
	N-E	S-W	N-E	S-W	N-E	S-W	N-E	S-W
Control	42.29	41.75	46.94	46.03	52.24	51.97	0.52	0.53
Agricol (2.5 g)	22.51	22.07	183.33	180.33	181.79	181.11	0.50	0.50
Agricol (5g)	25.23	25.20	151.69	147.97	176.95	175.60	0.54	0.54
Chemibor-P(2.5 g)	30.66	31.06	243.68	240.62	184.46	181.56	0.43	0.43
Chemibor-P(5 g)	31.76	32.34	262.08	259.13	151.76	151.78	0.37	0.37
D O T (2.5g)	25.99	26.29	162.03	157.92	208.55	207.71	0.56	0.57

D O T (5g)	26.96	27.33	223.42	221.46	184.6	184.60	0.45	0.45
S Em±	0.31	0.30	0.85	0.79	0.90	0.88	0.03	0.03
LSD (p=0.05)	1.12	1.05	3.51	3.46	3.25	3.18	NS	NS
Boron sources compared with control								
S Em±	0.33	0.31	1.04	1.04	0.97	0.94	0.03	0.03
LSD (p=0.05)	1.21	1.14	3.78	3.78	3.51	3.43	0.11	0.11
Concentration effect								
S Em±	0.18	0.17	0.56	0.56	0.52	0.51	0.02	0.02
LSD (p=0.05)	0.65	NS	NS	NS	NS	NS	NS	NS

*DOT= Disodium Octaborate Tetrahydrate

Table 3: Effect of different boron sources and canopy direction on fruiting behaviour of mango cv. Amrapali

Treatments	**Number of fruits at Pea stage Marble stage Harvest**						**Fruitdrop %**	
	N-E	**S-W**	**N-E**	**S-W**	**N-E**	**S-W**	**N-E**	**S-W**
Control	5.81	5.63	2.29	2.26	1.24	1.22	92.13	92.45
Agricol (2.5 g)	14.90	14.91	5.05	5.00	4.73	4.70	62.63	62.28
Agricol (5g)	8.96	8.95	4.22	3.97	3.53	3.49	67.76	66.14
Chemibor-P(2.5 g)	16.24	15.91	7.94	7.80	7.37	7.35	58.78	58.27
Chemibor-P(5 g)	9.91	9.86	5.18	5.19	3.42	3.37	75.29	75.25
D O T (2.5g)	16.20	15.94	8.60	8.30	7.67	7.64	51.23	50.50
D O T (5g)	12.68	12.59	8.04	7.97	6.49	6.25	75.88	75.19
S Em±	5.81	5.63	2.29	2.26	1.24	1.22	0.43	0.42
LSD (p=0.05)	14.90	14.91	5.05	5.00	4.73	4.70	1.54	1.53
Boron sources compared with control								
S Em±	0.46	0.44	0.31	0.31	0.33	0.32	0.43	0.42
LSD (p=0.05)	1.68	1.59	1.11	1.07	1.21	1.17	1.54	1.53
Concentration effect								
S Em±	0.24	0.23	0.17	0.17	0.18	0.17	0.23	0.22
LSD (p=0.05)	NS	NS	NS	NS	NS	NS	0.82	0.82

*DOT= Disodium Octaborate Tetrahydrate

Table 4: Effect of different boron sources and canopy direction on fruit setting of mango cv. Amrapali

Treatments	**Days from PI to Fruit set Harvest**				**Fruit /tree**		**Yield/plant (kg)**	
	N-E	**S-W**	**N-E**	**S-W**	**N-E**	**S-W**	**N-E**	**S-W**
Control	90.04	90.40	203.81	203.00	104.38	104.04	11.30	10.95
Agricol (2.5 g)	57.27	56.82	168.26	168.00	219.35	193.08	46.24	45.92
Agricol (5g)	63.41	63.13	170.93	170.14	192.38	222.11	41.22	40.72
Chemibor-P(2.5 g)	65.83	65.81	178.35	178.62	223.28	163.54	41.90	41.44
Chemibor-P(5 g)	67.69	67.37	179.43	179.12	189.53	189.12	25.87	25.39
D O T (2.5g)	61.66	60.93	173.53	173.09	245.48	244.18	42.24	41.80
D O T (5g)	63.98	63.33	173.56	173.20	189.53	189.62	31.36	31.04
S Em±	0.35	0.35	0.24	0.25	0.86	0.86	0.28	0.26
LSD (p=0.05)	1.26	1.27	0.88	0.99	3.11	3.12	1.02	0.95
Boron sources compared with control								
S Em±	0.38	0.38	0.26	0.27	0.86	0.86	0.30	0.28
LSD (p=0.05)	1.21	1.37	0.95	0.97	3.11	3.12	1.10	1.02
Concentration effect								
S Em±	0.20	0.20	0.14	0.15	0.46	0.46	0.16	0.15
LSD (p=0.05)	NS	NS	NS	NS	1.66	1.67	0.59	0.55

*DOT= Disodium Octaborate Tetrahydrate

Conclusions

This paper shows that soil application of boron from various mineral sources on mango cv. Amrapali clearly resulted in positive effect on the advancement of reproductive growth in mango as compared with control plants. The different aspects of tree canopy did not show much variations on the parameters studied. Soil application of boron sources at two stages i.e pre-flowering and fruit set at pea stage influenced the flowering and fruiting of mango with greatest number of flowers, greater yield and lowest fruit drop (%) of mango. That boron involves in reproductive physiology of plants *i.e.* pollen tube elongation, pollen germination and translocation of sugars and synthesis of carbohydrates is indicative from the results of this investigation. There was positive influence on the parameters under study with the application of lower concentration of boron on production of mango.

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