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INFLUENCE OF FOLIAR APPLICATION OF ZINC AND BORON ON SEEDLING GROWTH OF PAPAYA (*Carica papaya* L.)

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ABSTRACT

Papaya is one of the important nutrient rich tropical fruit that is preferred and cultivated almost in majority of the states of India. Choice of variety, proper nutrition and disease management are the key operations for successful commercial papaya cultivation. Micronutrient deficiency starting from the early stage of growth can cause poor growth and yield reduction. Thus a potted plant experiment was conducted to study the influence of zinc and boron as foliar application on seedling growth of papaya. The experiment was laid out in a completely randomized design with nine treatments comprising of zinc sulphate @ 0.2 and 0.4%, and borax @ 0.2 and 0.4% and their combinations along with a control treatment (distilled water spray). The seedlings were raised in polythene bags filled with growing media (soil: sand: FYM @ 4:2:1) and sprayed with the micronutrients as per treatment, adjusting neutral pH at 15 day's interval after germination. The application of $ZnSO_4$ @ 0.4% + borax @ 0.2% improved seedling growth of papaya in terms of height, girth, number of leaves and leaf size. Also, the fresh and dry weights of shoot and root also showed significant improvement. Thus the foliar application of $ZnSO_4$ @ 0.4% + borax @ 0.2% can be recommended for better seedling growth of papaya.

Keywords: Boron, papaya seedlings, growth, stress physiology, zinc

INTRODUCTION

Papaya (*Carica papaya* L.), a member of Caricaceae family, is a tropical fruit crop with remarkable capacity to thrive in subtropical environments like Punjab and Haryana. It is often called "melon tree" and "common man's fruit" (Lay *et al*., 2013). Earlier, it was grown as a filler crop in fruit orchards such as mango, but nowadays it considered a major crop due to its various health and benefits (Chawla and Sadawarti, 2022). It holds 2nd position on fruits in terms of vitamin A content (2020 IU) after mango, and contains good amount of vitamin C (85 mg 100 g^{-1} pulp) and essential minerals like iron, calcium and phosphorus along with good quantity of sugars (Rana *et al*., 2020). Papain, a protolytic enzyme extracted from the dried latex of immature papaya fruits, has industrial and medicinal value (Reena *et al*., 2022). Papaya is indigenous to the Caribbean coast of Central America and its cultivation is common in the countries across Asia, Africa, America and even in subtropical regions of Europe (Baiyeri, 2006; Reena *et al*., 2022). In India, papaya cultivation is popular in Tamil Nadu, Gujarat, Karnataka, Maharashtra, Uttarakhand, Bihar, Jharkhand, West Bengal, and Andhra Pradesh (Rao *et al*., 2023) and is used for both domestic consumption and commercial purposes.

Micronutrients particularly zinc, iron and boron play a vital role in papaya cultivation with respect to yield and quality. They are essential for various metabolic processes, enzymatic reactions and overall health of papaya plant. Optimum micronutrient levels ensure optimal growth, fruit development and nutritional content in papaya (Dahaiya, 2018). Zinc is required for the activation of various enzymes and plays a crucial role in metabolic processes, including the synthesis of growth hormones (Saini *et al*., 2019). Zinc also helps the plant to withstand abiotic stress such as drought and disease. It also aids in root development and nutrient uptake (Kumar *et al*., 2015). On the other hand, boron is vital for the formation and stability of plant cell walls, increasing the structural integrity of plant and influences the transport of sugars. Adequate boron is necessary for proper flower development, pollination, and fruit set in papaya (Modi *et al*., 2012). Although a few research works have been carried out to study the effect of micronutrients on yield and quality of papaya (Singh *et al*., 2005; Sekhar *et al*., 2010; Bhalerao and Patel, 2012; Sarathkumar *et al*., 2022), however, a few of them are related to the growth performance and expression of stress of papaya seedlings. Thus the present study was aimed to assess the growth and physiological expression of papaya seedlings under influence of zinc and boron as foliar application.

MATERIALS AND METHODS

The present experiment was carried out at Horticultural Farm, Department of Horticulture and Post-Harvest Technology, Institute of Agriculture, Visva-Bharti, Srinikatan, West Bengal (23°42’ N latitude and 87°40’30” E longitude, 40 m above the mean sea level) during February to June in the year 2020-2021 and 2021-2022. The climatic condition of the experimental site is sub-tropical and the area lies under the Red and Lateritic zone. The temperature falls at 10-12℃ or even low during winter months while in summer months it reaches as high as 42-48℃. Most of the rainfall is received in the middle of July to the end of September with mean annual quantity of 1476 mm.

Planting and aftercare

The experiment was conducted in polybags containing soil, well rotten farmyard manure and sand in 4:2:1 ratio. Apparently healthy papaya seeds were soaked overnight in water and two seeds were sown in each polybag after treating them with carbendazim and mancozeb mixture @ 2g kg^{-1} seeds. The germination took place after 15 days of sowing. The plants were fed with urea as a foliar spray @ 5 g L^{-1} water starting from 15 days after germination (DAG). The 2nd application was with urea10 granules $plant^{-1}$ followed by 3rd and 4th application of 10-26-26 mixture @10 granules $plant^{-1}$ at an interval of 15 days. Hand weeding and loosening of soil was done manually. Standard plant protection measures i.e. application of insecticides and fungicides for plant protection from pests and diseases were done at one month’s interval (Deb *et al*., 2008).

Application procedure and schedule of micronutrient treatments

The papaya seedlings were treated with different doses of zinc and boron and their combinations as per treatment. Zinc sulphate heptahydrate (21.0% Zn) was used as zinc source by dissolving in water and adjusting it to neutral pH by adding lime. Borax (11.36% boron) was used as the source of boron by dissolving in hot water. Borax spray was done 3 days after zinc sprays in the combination treatments to reduce the nutrient interaction which can reduce the absorption through stomata (Deb *et al*., 2008). The treatment comprised of T_1: $ZnSO_4$ @ 0.2%; T_2: $ZnSO_4$ @ 0.4%); T_3: borax @ 0.2%; T_4: borax @ 0.4%; T_5: $ZnSO_4$ @ 0.2% + borax @ 0.2%; T_6: $ZnSO_4$ @ 0.2% + borax @ 0.4%; T_7: $ZnSO_4$ @ 0.4% + borax @ 0.2%; T_8: $ZnSO_4$ @ 0.4% + borax @ 0.4% and T_9: control (distilled water spray). Micronutrients were sprayed at fortnight interval and in all 4 sprays were done.

Observations

Observations for different plant growth parameters *viz*., seedling height, number of leaves, and stem girth) were recorded 30, 60 and 90 days after germination. Stem girth was measured with the help of a digital Vernier calliper (Mitutoyo, Digimatic 500). The root characteristics (number of roots, length, and diameter) were observed only 90 days after seed germination. The fresh weight of three randomly selected seedlings (shoot and root) of each treatment per replication was measured by an electronic balance (Wensar, PGB 301). The plant samples were sun-dried, followed by oven drying at 65°C for 12 h. The plant dry weight (shoot and root) was measured by electronic balance**.**

Statistical analysis

The experiment was conducted in a completely randomized design with each treatment replicated three times. The data was analysed as per the analysis of variance using IBM SPSS version 29.0. The overall significance of treatments was tested by using critical difference (CD) at 5% level (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

The pooled data of both the years with respect to different plant growth parameters and physiological parameters are presented in Table 1 and 2 and the findings are elaborated as under.

Effect on shoot growth of papaya seedlings

The foliar application of Zn and B, and their combinations exhibited significant variations on papaya seedlings height with maximum height (7.81 cm) observed in $ZnSO_4$ @ 0.4% + borax @ 0.2% treatment at 30 days after germination (DAG) (Table 1). At 60 and 90 DAG, $ZnSO_4$ @ 0.4% + borax @ 0.4% treatment proved beneficial in terms of increasing the seedling height. In all cases of observations i.e. 30, 60 and 90 DAG the minimum plant height of papaya seedlings (5.44, 12.55 and 25.76 cm, respectively) was observed in control. The increased seedling height in Zn + B treatments may be attributed to the higher auxin synthesis, followed by the apical dominance that was promoted due to zinc and better anabolic metabolism helped by boron. The present findings are in conformity with Bhalerao and Patel (2012) and Dahiya (2018).

Table 1: Growth behaviour of papaya seedlings as influenced by the foliar application of zinc and boron

Treat-ments	Seedling height (cm)			Seedling girth (mm)			Number of leaves			Leaf length (cm)		
	30th day	60th day	90th day	30th day	60th day	90th day	30th day	60th day	90th day	30th day	60th day	90th day
T1	6.69	12.91	26.79	1.80	4.28	9.72	4.93	11.77	15.30	7.58	13.03	20.82
T2	6.75	12.02	29.34	1.92	5.28	9.51	5.00	12.57	16.63	7.38	14.86	21.03
T3	6.76	13.12	29.98	2.21	5.54	10.24	5.67	12.30	17.03	8.26	14.77	23.26
T4	7.12	14.63	30.86	2.39	6.42	11.46	6.03	14.40	17.60	9.82	16.11	22.05
T5	6.59	13.96	29.14	1.81	6.78	10.20	5.63	13.20	17.63	10.61	16.31	22.21
T6	6.50	14.07	32.32	1.95	4.64	11.65	5.47	12.80	18.30	10.30	16.70	24.82
T7	7.81	16.73	35.32	2.04	6.64	13.48	6.97	13.30	19.42	11.46	19.99	26.65
T8	6.67	18.54	37.99	2.82	6.12	12.29	6.15	11.60	18.50	10.27	18.92	23.17
T9	5.44	12.55	25.76	1.78	5.17	8.74	4.02	9.67	14.67	6.51	11.28	15.80
SE(m)	0.25	0.53	0.72	0.13	0.21	0.36	0.18	0.36	0.43	0.45	0.87	0.57
$CD_{0.05}$	0.74	1.61	2.17	0.39	0.63	1.07	0.53	1.10	0.79	1.32	2.60	1.70

T_1: $ZnSO_4$ @ 0.2%, T_2: $ZnSO_4$ @ 0.4%, T_3: Borax @ 0.2%, T_4: Borax @ 0.4%, T_5: $ZnSO_4$ @ 0.2% + borax @ 0.2%, T_6: $ZnSO_4$ @ 0.2% + borax @ 0.4%, T_7: $ZnSO_4$ @ 0.4% + borax @ 0.2%, T_8: $ZnSO_4$ @ 0.4% + borax @ 0.4%, T_9: Control

The highest stem girth of papaya seedlings (2.82 mm) was noticed in $ZnSO_4$ @ 0.4% + borax @ 0.4% treatment at 60 DAG that was closely followed by borax @ 0.4% (2.39 mm). The results differed at 60 DAG showing maximum stem girth (6.78 mm) in $ZnSO_4$ @ 0.2% + borax @ 0.2% treatment which was statistically *at par* with the stem girth of papaya plants as 6.64 and 6.42 mm in $ZnSO_4$ @ 0.4% + borax @ 0.2% and borax @ 0.4% treatments, respectively. On the other hand, the maximum stem girth of papaya seedlings (13.48 mm) was noticed in $ZnSO_4$ @ 0.4% + borax @ 0.4% treatment. Minimum stem girth was noticed in control treatment. The higher seedling girth of papaya in higher dose of zinc may be attributed to the increased rate of cell division and cell elongation by the action of auxin synthesized in abundant presence of zinc within the plant system (Rashid *et al*., 2004). Similar findings have also been reported by Jeyakumar *et al*. (2021) and Kumar and Saravanan (2017).

Papaya seedlings produced maximum number of leaves (6.97, 13.30 and 19.42) in all observation periods in $ZnSO_4$ @ 0.4% + borax @ 0.2% treatment at 30, 60 and 90 DAG, respectively. However, the number of leaves of papaya seedlings in $ZnSO_4$ @ 0.2% + borax @ 0.4% and $ZnSO_4$ @ 0.4% + borax @ 0.4% treatments were statistically *at par* with $ZnSO_4$ @ 0.4% + borax @ 0.2% in case of 90 DAG. This may be due to the promotion of new organ (leaves) development in such plants that was triggered by auxin and better translocation of assimilates to newly grown leaves with abundant presence of boron (Sharrocks, 1997). Xi *et al*. (2023) too found higher numbers of leaves in papaya when treated with zinc and boron.

Production of higher leaves followed the same trend throughout the experiment period in $ZnSO_4$ @ 0.4% + borax @ 0.2% treatment where the leaf length measured as 11.46, 19.99 and 26.65 cm at 30, 60 and 90 DAG, respectively. Minimum length of leaves of papaya seedlings were noticed as 6.51, 11.28 and 15.80 cm in control treatment at 30, 60 and 90 DAG, respectively. In present study the application of zinc and boron in combination, particularly the higher dose of zinc and moderate dose of boron showed increased leaf length which may be attributed to the higher auxin synthesis and better translocation of photosynthates that promoted by zinc and boron, respectively (Singh, 2001). Similar findings have been reported by Deb *et al*. (2008) and Dwivedi *et al*. (2015) as increase in leaf size of papaya by application of micronutrients as seed treatment.

Effect on root growth of papaya seedlings

The root characters of papaya seedlings were studied at 90 DAG by uplifting the seedlings from growth media. The length of papaya seedling roots in present study was significantly influenced by the application of zinc and boron (Table 2). Maximum root growth in terms of root length (20.51 cm) was noticed in $ZnSO_4$ @ 0.4% + borax @ 0.2% treatment, closely followed by $ZnSO_4$ @ 0.4% + borax @ 0.4% treatment (18.50 cm). Minimum root length (11.83 cm) was recorded in control. The thickness of root was also influenced by micronutrients. Similar trend of root girth was noticed in present study. Highest root girth (13.42 mm) was recorded in $ZnSO_4$ @ 0.4% + borax @ 0.2% treatment which was *at par* with $ZnSO_4$ @ 0.4% + borax @ 0.4% treatment (12.01 mm). Minimum

Table 2: Root and shoot characters of papaya seedlings as influenced by foliar application of zinc and boron at 90th day

Treatments	Root length (cm)	Root girth (mm)	Primary branches (No.)	Secondary branches (No.)	Fresh shoot weight (g)	Dry shoot weight (g)	Fresh root weight (g)	Dry root weight (g)
$ZnSO_4$ @ 0.2%	14.33	9.58	7.06	2.72	18.05	2.74	5.33	0.931
$ZnSO_4$ @ 0.4%	16.50	9.51	7.54	2.80	18.34	2.82	5.48	0.984
Borax @ 0.2%	14.67	10.17	8.67	3.11	16.67	2.60	4.35	0.793
Borax @ 0.4%	15.01	9.98	8.15	2.82	17.90	2.87	4.78	0.862
$ZnSO_4$ @ 0.2% + borax @ 0.2%	17.03	10.59	8.82	2.89	18.48	3.20	5.23	0.945
$ZnSO_4$ @ 0.2% + borax @ 0.4%	17.53	11.48	9.27	3.16	18.70	3.56	5.52	0.996
$ZnSO_4$ @ 0.4% + borax @ 0.2%	20.51	13.42	10.66	3.87	20.78	3.74	6.39	1.152
$ZnSO_4$ @ 0.4% + borax @ 0.4%	18.50	12.01	11.33	3.13	20.43	3.47	6.01	1.085
Control	11.83	8.74	6.48	2.45	15.12	2.71	4.85	0.872
SE(m)	0.69	0.48	0.34	0.16	054	0.08	0.14	0.031
$CD_{0.05}$	2.09	1.45	1.03	0.48	1.62	0.24	0.41	0.094

root girth (8.74 mm) was observed in control treatment which was *at par* with $ZnSO_4$ @ 0.2% and $ZnSO_4$ @ 0.4% treatments (9.51 and 9.58 mm, respectively). On contrary the maximum number of primary branches of roots was noticed in the papaya seedlings (11.33) in $ZnSO_4$ @ 0.4% + borax @ 0.4% treatment, closely followed by $ZnSO_4$ @ 0.4% + borax @ 0.2% treatment (10.66), and minimum (6.48) in control. Secondary branch production from the root of papaya seedlings was increased by use of zinc and boron. Significantly maximum number of secondary branches of root were recorded in the papaya seedlings in $ZnSO_4$ @ 0.4% + borax @ 0.2% treatment and minimum (2.45) in control. The application of zinc and boron to papaya seedlings as foliar spray in present study increased the value of different root morphological parameters. This may be attributed to the positive influence of auxin synthesis as influenced by sufficient availability of zinc in plant system as well as better translocation of food to the root from leaves (Gupta *et al*., 1985). Present findings are in conformity with Vasanthu*et al*. (2015), Veena and Lavania (1989) and Ahmed *et al*. (2023).

Effect on fresh and dry plant weight

The statistical analysis of data on fresh and dry weight of shoot and root of papaya in present study is presented in Table 2. Maximum fresh shoot weight (20.78 g) was noticed in $ZnSO_4$ @ 0.4% + borax @ 0.2% treatment which was statistically similar to the fresh shoot weight (20.43 g) in $ZnSO_4$ @ 0.4% + borax @ 0.4% treatment. Again, the dry shoot weight was highest (3.74 g) in $ZnSO_4$ @ 0.4% + borax @ 0.2% treatment, closely followed by $ZnSO_4$ @ 0.2% + borax @ 0.4% treatment (3.56 g). Minimum fresh and dry shoot weight of 15.12 and 2.71 g, respectively, was observed in control treatment. More or less similar trend in fresh and dry root weight has also been noticed in present study. Highest fresh and dry root weight of 6.39 and 1.152 g, respectively was observed in plants in $ZnSO_4$ @ 0.4% + borax @ 0.2% treatment; and in both cases it was *at par* with $ZnSO_4$ @ 0.4% + borax @ 0.4% treatment. Minimum fresh and dry root weight was noticed in control treatment. The higher fresh and dry weight of plants in zinc and boron foliar application may be attributed to the increased growth rate and greater suberization of plant organs in higher rate (Farooq *et al*., 2012). Similar findings have been reported by Sebastian *et al*. (2021), Preethi*et al*., (2017).

Conclusion: The application of micronutrients significantly improved the shoot growth and root characteristics of papaya seedlings. The present study clearly indicated that the application of zinc sulphate @ 0.4% + borax @ 0.2% proved beneficial in enhancing seedling height, seedling girth, number of leaves/seedling and leaf length. Similarly, the root morphological parameters were significantly influenced by the same treatment. Thus it can be concluded that the foliar application of zinc sulphate @ 0.4% + borax @ 0.2% can be applied for better seedling growth of papaya.

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REFERENCES

Ahmed, R., Uddin, M.K., Quddus, M.A., Samad, M.Y.A., Hossain, M.A.M. and Haque, A.N.A. 2023. Impact of foliar application of zinc and zinc oxide nanoparticles on growth, yield, nutrient uptake and quality of tomato. *Horticulturae*, **9**: 162. [*https://doi.org/10.3390/horticulturae9020162*].

Baiyeri, K.P. 2006. Seedling emergence and growth of pawpaw (*Carica papaya*) grown under different coloured shade polyethylene. *International Journal of Agrophysics*, **20**: 77-84.

Bhalerao, P.P. and Patel, B.N. 2012. Effect of foliar application of Ca, Zn, Fe and B on physiological attributes, nutrient status, yield and economics of papaya (*Carica papaya* L.) cv. Taiwan Red Lady. *Madras Agricultural Journal*, **99** (4-6): 298-300.

Dahaiya, R. 2018. *Response of Zinc and Boron Spray on Yield, Growth and Quality of Papaya (Carica papaya L.) cv. Red Lady*. M.Sc. Thesis, Department of Horticulture, Lovely Professional University, Ludhiana, Punjab, India.

Deb, P., Das, A., Ghosh, S.K. and Suresh, C.P. 2008. Improvement of seed germination and seedling growth of papaya (*Carica papaya* L.) through different pre-sowing seed treatments. *Acta Horticulturae,* **851**: 313-316.

Dwivedi, D.H., Singh, S., Singh, N. and Kumar, P. 2015. Effect of plant bioregulator and chemical treatment on germination of papaya (*Carica papaya* L.) cv. Pusa Nanha. *Progressive Horticulture,* **47**(2): 250-252.

Farooq, M., Wahid A., and Siddique, K.H.M. 2012. Micronutrient application through seed treatments – A review. *Journal of Soil Science and Plant Nutrition,* **12**(1): 125-142.

Gupta, U.C., Jame, Y.W., Campbell, C.A., Leyshon, A.J. and Nicholaichuk, W. 1985. Boron toxicity and deficiency: A review. *Canadian Journal of Soil Science,* **65**(3): 381-409.

Jeyakumar, P., Durgadevi, D. and Kumar, N. 2001. Effect of zinc and boron fertilization on improving fruit yields in papaya (*Carica papaya* L.) cv. CO-5, pp. 356-357. **In**: *Plant Nutrition, Food Security and Sustainability of Agro-ecosystems*. (eds. W. Horst, M.K. Schenk, A. Bürkert, N. Claassen, H. Flessa, W.B. Frommer, and L. Wittenmayer). Springer Science, Dordrecht, Netherlands.

Kumar, J., Kumar, R., Ratna Rai and Mishra, S. 2015. Response of pant prabhat guava trees to foliar sprays of zinc, boron, calcium and potassium at different plant growth stages. *The Bioscan*, **10**(2): 495-498.

Kumar, S. and Saravanan, S. 2017. Effect of pruning and different micronutrient on plant growth, fruit yield and quality of phalsa (*Grewia asiatica* L.) *cv*. Sharbati. *Journal of Pharmacognosy and Phytochemistry,* **6**(6): 65-69.

Lay, P., Basvaraju, G.V., Sarika, G. and Amrutha, N. 2013. Effect of seed treatments to enhance seed quality of papaya (C*arica papaya* L.) cv. Surya. *Global Journal of Biology, Agriculture and Health Sciences*, **2**(3): 221-225.

Modi, P.K., Varma, L.R., Bhalerao, P.P., Verma, P. and Khade, A. 2012. Micronutrient spray on growth, yield and quality of papaya (*Carica papaya* L.) cv. Madhu Bindu. *Madras Agricultural Journal*, **99**(7-9): 500-502.

Preethi, M., Prakash, D.P., Hipparagi, K., Biradar, I.B., Gollagi, S.G. and Ryavalad, S. 2017. Effect of quantity of soil application of zinc, boron and iron on growth and yield in papaya cv. Red Lady. *International Journal of Current Microbiology and Applied Science*, **6**(9): 2081-2086.

Rana, G., Deb, P., Dowrah, B. and Sushmitha, K. 2020. Effect of seed pretreatment on seed germination and seedling growth of papaya. *International Journal of Current Microbiology and Applied Sciences*, **9**(4): 1066-1071.

Rao, G.S.K., Krishna, V.N.P.S., Srinivasulu, B., Sivaram, G.T., Padmaja, V.V. and Arunodhyam, K. 2023. Effect of different pre-sowing seed treatments on germination and growth of papaya (*Carica papaya* L.) seedlings cv. Arka Surya. *International Journal of Environment and Climate Change*, **13**(10): 933-3953.

Rashid, A. and Rayan, J. 2004. Micronutrient constraints to crop production in soils with Mediterranean type characteristics: A review. *Journal of Plant Nutrition*, **27**: 959-975.

Reena, B., Kavitha, C., Pugalendhi, L., Kalarani M.K. and Manoranjitham, S.K. 2022. Effect of foliar application of nutrient formulation on growth, yield and PRSV incidence of papaya (*Carica papaya* L.). *Biological Forum – An International Journal,* **14**(2): 53-56.

Sebastian, K., Bindu, B. and Rafeekher, M. 2021. Performance of papaya variety 'Surya' under fertigation and foliar nutrition. *Plant Science Today*, **8**(3): 718-726.

Sharathkumar, K.H., Shivanna, M., Anil Kumar, S., Honnabyraiah, M.K., Swamy, G.S.K. and Rao, V. 2022. Effect of foliar spray of potassium and micronutrients on growth, flowering and fruiting characters of papaya (*Carica papaya* L.) cv. Red Lady. *The Pharma Innovation Journal*, **11**(7): 1834-1839.

Sharrocks, V.M. 1997. The occurrence and correction of boron deficiency. *Plant and Soil*, **193**: 121-148.

Shekhar, C., Yadav, A.L., Singh, H.K. and Singh, M.K. 2010. Influence of micronutrients on plant growth, yield and quality of papaya fruit (*Carica papaya* L.) *cv.* Washington. *Asian Journal of Horticulture*, **5**(2): 326-329.

Singh, D.K., Paul, P.K. and Ghosh, S.K. 2005. Response of papaya to foliar application of boron, zinc and their combinations. *Research on Crops*, **6**(2): 277-280.

Singh, M.V. 2001. Evaluation of micronutrient stocks in different agroecological zones of India. *Fertilizer News*, **42**: 25-42.

Veena, P. and Lavania, M.L. 1989. Effect of foliar application of iron, zinc and boron on quality of papaya fruits. *Progressive Horticulture*, **21**(1-2): 165-167.

Xi, D., Yap, S.L., Kumar, N.N., Toh, C.C., Ishikawa, K. and Hori, M. 2023. Plasma-assisted priming: im germination and seedling performance of papaya. *Sains Malaysiana*, **52**(2): 599-611.