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Effect of different micro-nutrients (B, Zn & Cu) on the growth, yield and tuber quality of Carrot (*Daucus carota* L.) under Teak based Agroforestry system

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Abstract
The carrot (*Daucus Carota* L.) is the most important crop of Apiaceae family. An experiment laid out in a Randomized Block Design (RBD) with nine treatments, each replicated three times and each plot size of $4m^2$ was conducted in the Forestry Research farm, Department of Silviculture and Agroforestry, Sam Higginbottom University of Agriculture, Technology & Sciences Allahabad, during the winter (Rabi) season of 2017-2018. The crop was applied with recommended dose of fertilizer i.e., N, P and K application of organic manure i.e., Farm yard manure along with the combination of different micro-nutrients of Boron, Zinc and Copper. The results concluded that the treatment T_8 (1.5% Zn + 2% B + 2% Cu t/ha) was found to be the best treatment followed by the treatment T_3 (1.5% Zn + 1.5% B + 1.5% Cu t/ha) which beneficially and significantly improved the growth parameters and tuber yield of carrot grown under teak based agroforestry systems in Allahabad Agroclimatic conditions. This treatment also showed maximum gross return, net return and benefit: cost ratio i.e. 1:2.46.

Keywords: agro-forestry, boron, copper, *Daucus carota* L., growth, tuber quality, yield, zinc

1. Introduction
Carrot (*Daucus Carota* L.) is the most important crop of Apiaceae family. Worldwide production of carrot is more than 24 million tons, which may be consumed fresh or processed in forms such as mini carrots, grated carrots, baby food and instant soups. Success in growing this crop for high yields involves the integration of various factors, such as soil tillage, the cultivar chosen, and climatic conditions, among others. Plant spacing, fertilization levels, irrigation, soil tillage, and other factors may interact in diverse manners, depending on the cultivar. Micronutrients play an important role in germination and seedling establishment. Different micronutrient like Zn, Mn, Cu, B and Mo are becoming deficient in soil with increasing cropping intensity Malakouti *et al*., (2009) [4]. These nutrients play a vital role in germination and healthy seedling establishment in carrot. Seed treatment with micro nutrients is an attractive and cost effective alternative to soil reserves of these elements Farooq *et al*., (2012) [2]. Micronutrients also play vital roles in the growth and development of plants, due to their stimulatory and catalytic effects on metabolic processes and ultimately on flower yield and quality. Micronutrients are to be necessarily taken up by the plants from soil or supplemented through foliar application for good growth and yield of crops and maximizing the efficient use of applied N, P and K. In the absence of micronutrients, the plants are known to suffer from physiological disorders which eventually lead to imbalanced growth and low yield of flower.

2. Materials and Methods
The present research was carried out at the Forestry research farm, Department of Silviculture and Agroforestry, Sam Higginbottom University of Agriculture, Technology and Sciences (SHUATS), Allahabad, 211007 (U.P) which is situated six kilometers away from Allahabad city on the right bank of Yamuna river, Allahabad is situated in the south-eastern part of Uttar Pradesh. Geographically, Allahabad is located at 25° 45' North latitude, 81°85'East longitude and at an altitude of 98m (322ft) above mean sea level (MSL). The climate in this part of the country has been classified as semi-arid with both the extent of temperature during winter and summer. During December to January, the temperature may drop down to as low as 2˚C, while it may exceed 47˚C during May-June. The experiment was laid out in a Randomized Block Design (RBD) with nine treatments, each replicated three times and each plot size of $4m^2$

conducted during the winter (Rabi) season of 2017-2018. The crop was applied with recommended dose of fertilizer i.e., N, P and K application of organic manure i.e., Farm yard manure along with the combination of different micro-nutrients of Boron, Zinc and Copper. The treatment combinations were laid out as T_1-Control, T_2-1 % Zn + 1% B + 1% Cu, T_3-1.5% Zn + 1.5% B + 1.5% Cu, T_4- 2% Zn + 2% B + 2% Cu, T_5- 2% Zn + 1.5 % B + 1.5% Cu, T_6- 2% Zn + 1% B + 1% Cu, T_7-1.5% Zn + 1% B + 1% Cu, T_8-1.5% Zn + 2% B + 2% Cu, T_9-1% Zn + 1.5% B + 1.5% Cu, respectively.

3. Results and Discussion

3.1 Plant height (cm)

At 30 DAS, the maximum plant height was recorded with the treatment T_8 (1.5% Zn + 2% B + 2% Cu t/ha) with (23.56 cm) followed by treatment T_3 (1.5% Zn + 1.5% B + 1.5% Cu t/ha) with (21.34 cm) whereas, the minimum recorded was (19.24cm) with the treatment T_1 (Control). At 60 DAS, the maximum plant height was recorded with the treatment T_8 (1.5% Zn + 2% B + 2% Cu t/ha) with (31.77cm) followed by T_3 (1.5% Zn + 1.5% B + 1.5% Cu t/ha) with (31.61cm) whereas, the minimum recorded was (28.71cm) with the treatment T_1 (Control). At 90 DAS, the maximum plant height was recorded with the treatment T_8 (1.5% Zn + 2% B + 2% Cu t/ha) with (41.9 cm) which was closely followed by (41.6 cm) with treatment T_3 (1.5% Zn + 1.5% B + 1.5% Cu t/ha) whereas, the minimum plant height recorded was (38cm) with the treatment T_1 (Control). The results obtained are in similarity with the findings of Mohanta *et al*., (2013) [5]

3.2 Number of leaves

At 30 DAS, the maximum no. of leaves was recorded with the treatment T_8 (1.5% Zn + 2% B + 2% Cu t/ha) with 4.8 followed by the treatment T_3 (1.5% Zn + 1.5% B + 1.5% Cu t/ha) with 4.7 and the minimum recorded was 4.2 with the treatment T_1 (Control). At 60 DAS, the maximum number of leaves was recorded with the treatment T_8 (1.5% Zn + 2% B + 2% Cu t/ha) with 6.89 followed by the treatment T_3 (1.5% Zn + 1.5% B + 1.5% Cu t/ha) with 6.88 and the minimum recorded was 5.5 with the treatment T_1 (Control). At 90 DAS the maximum no. of leaves was recorded with the treatment T_8 (1.5% Zn + 2% B + 2% Cu t/ha) with 8.33 followed by the treatment T_3 (1.5% Zn + 1.5% B + 1.5% Cu t/ha) with 8.22 and the minimum recorded was 6.5 with the treatment T_1 (Control). The results are in conformity with the findings of Munawar *et al*., (2013) [6], Deepika *et al*., (2015) [1]

3.3 Tuber length (cm)

The maximum tuber length was (17.27 cm) recorded with the treatment T_8 (1.5% Zn + 2% B + 2% Cu t/ha) followed by the treatment T_3 (1.5% Zn + 1.5% B + 1.5% Cu t/ha) with (15.33 cm) whereas the minimum was recorded in the treatment T_1 (control) with (9.28 cm). The maximum tuber length + shoot length was (59.17) recorded with the treatment T_8 (1.5% Zn + 2% B + 2% Cu t/ha) followed by the treatment T_3 (1.5% Zn + 1.5% B + 1.5% Cu t/ha) with (56.93 cm) whereas the minimum was recorded in the treatment T_1 (control) with (47.28 cm). The similar results were recorded in the findings of Munawar *et al*., (2013) [6] where the carrot seed priming with zinc (1.5%) solution was found to be most beneficial as it significantly improved mean tuber length and mean shoot length.

3.4 Diameter of tuber (mm)

The maximum tuber diameter recorded was (30.50 mm) in the treatment T_8 (1.5% Zn + 2% B + 2% Cu t/ha) followed by (29.53 mm) in the treatment T_3 (1.5% Zn + 1.5% B + 1.5% Cu t/ha) whereas, the minimum was recorded in the treatment T_1 (control) with (24.71 mm). The results of which are in consonance with the findings of Sultana *et al*., (2015) [9]; Mohanta *et al*., (2013) [5]

3.5 Tuber weight (g)

The maximum tuber weight recorded was (52.82 gm) in the treatment T8 (1.5% Zn + 2% B + 2% Cu t/ha) followed by (51.79 gm) in the treatment T3 (1.5% Zn + 1.5% B + 1.5% Cu t/ha) whereas, the minimum was recorded in the treatment T1 (control) with (48.95 gm). The results of which are in similarity with the findings of Sultana *et al*., (2015) [9].

3.6 Yield/plot (kg)

The maximum tuber yield per plot was (2.61kg) obtained with the treatment T8 (1.5% Zn + 2% B + 2% Cu t/ha) followed by (2.52kg) with the treatment T3 (1.5% Zn + 1.5% B + 1.5% Cu t/ha) whereas the minimum was recorded in the treatment T1 (control) with (1.33kg). The results of which are in consonance with the findings of Sultana *et al*., (2015) [9]; Mohanta *et al*., (2013) [5].

Table 1: Effect of different micro-nutrients (B, Zn & Cu) on growth parameters and yield of carrot (90 days).

Treatment combination	Plant height (cm)	Numbers of leaves per plant	Tuber length (cm)	Diameter of tuber (mm)	Tuber weight (g)	Yield (kg per plot)	Cost benefit ratio
T1	38.00	6.5	9.28	24.71	48.95	1.33	1:1.25
T2	38.63	6.67	10.08	24.79	49.95	1.41	1:1.33
T3	41.60	8.22	15.33	29.53	51.80	2.52	1:2.37
T4	40.12	8.00	14.07	29.35	51.12	2.50	1:2.35
T5	39.55	7.55	13.18	27.44	50.89	2.42	1:2.29
T6	39.18	7.55	12.32	25.18	50.26	2.20	1:2.07
T7	38.68	7.2	11.02	25.42	50.01	1.91	1:1.80
T8	41.90	8.33	17.28	30.50	52.82	2.61	1:2.46
T9	39.00	7.44	12.50	27.08	50.52	2.14	1:2.02
Mean	39.62	7.49	12.78	27.11	50.70	2.11	
F-test	S	S	S	S	S	S	
S. Em (±)	2.24	0.71	0.12	0.16	0.19	0.01	
C. D. at 5%	6.66	2.10	0.36	0.49	0.57	0.04	

4. Conclusion

On the basis of the above results and the experiment conducted, it is concluded that the treatment T8 (1.5% Zn + 2% B + 2% Cu t/ha) is the best treatment followed by the treatment T3 (1.5% Zn + 1.5% B + 1.5% Cu t/ha) which have proved to attribute to the studied parameters and found beneficial and significantly improved the growth parameters and root yield of carrot grown under teak based agroforestry

systems in Allahabad Agro-climatic conditions. This treatment also showed maximum gross return, net return and benefit: cost ratio i.e. 1:2.46. These findings were attributed on a one year research trial, further works to be required to sustain more information.

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