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Enhancing yield and economic returns of lemon (*Citrus Limon*) cv. pant lemon-1 through optimized foliar application of micronutrients under western Uttar Pradesh conditions

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Abstract
The experiment was conducted in a Randomized Block Design with 12 treatments *viz* T_1- Control, T_2 - $ZnSO_4$ (0.2%), T_3 - $ZnSO_4$ (0.5%), T_4 – Borax (0.2%) T_5 – Borax (0.4%) T_6 – $CuSO_4$ (0.2%), T_7 - $CuSO_4$ (0.5%) T_8 - $ZnSO_4$ (0.5%) + Borax (0.4%) T_9- $ZnSO_4$ + $CuSO_4$ T_{10} - Borax + $CuSO_4$ T_{11} - $ZnSO_4$ + Borax + $CuSO_4$ (0.2% each), T_{12} - $ZnSO_4$ (0.5%) + Borax (0.4%) + $CuSO_4$ (0.5%) and 3 replications, during 2022. Yield parameters i.e., number of fruits per tree, fruit yield per tree (kg), yield per hectare (tonnes) and economic parameters i.e., cost of cultivation, net return, gross return and cost-benefit ratio were recorded during the experimental period. There was a significant effect of foliar application of zinc, boron and copper on yield attributes and economic feasibility of lemon cv. Pant Lemon-1. This study revealed that optimum yield and maximum benefit-cost ratio were obtained by spraying a combination of zinc (0.5%), boron (0.4%) and copper (0.5%). It can be concluded that foliar spray of zinc sulphate (0.5%), borax (0.4%) and copper sulphate (0.5%) performed best when applied twice in the month of June and July under western Uttar Pradesh conditions.

Keywords: Zinc, boron, copper, lemon, yield, economics, cost-benefit ratio

Introduction
Citrus fruits belong to the family Rutaceae. They hold an important place among the world's most popular fruits. In 2020, citrus fruit production across the world was 158 million tonnes (Anonymous, 2021) [2]. These fruits can be grown in tropical, sub-tropical and even in temperate regions, as they have greater adaptability to different climate conditions. In India, commonly grown citrus are mandarins, sweet oranges, limes and lemons. Among all the species of citrus, lemons (*Citrus Limon* Burm.) with chromosome no. 2n = 18, occupying 10% of the total area among the citrus group in India (Radha and Mathew, 2007) [15]. Lemons are commonly cultivated in regions having warm climates (tropical regions) but can also be grown in sub-tropical regions at the commercial level. India is the highest producer of lemons in the world. These are grown both for domestic consumption as well as for export to countries like the United Arab Emirates, Nepal, and Bangladesh. Lemon cultivation is primarily done through traditional farming practices in India, with many small and marginal farmers involved. However, there has been a growing interest in lemon cultivation among commercial farmers in recent years, with modern techniques and technology being used to increase production and efficiency. Lemon production in India is a significant source of income and livelihood for many farmers, as well as an important component of the country's agriculture sector.

Citrus fruits like lemon are sensitive to micronutrient deficiencies. Agronomic practices like unbalanced N, P, K application, intensified agricultural practices, growing crops in saline or alkaline soils etc. worsen the micronutrient deficiency which led to fruit drop, flower drop and fruit cracking in citrus plants (Jeyakumar and Balamohan, 2013) [11]. So, an optimum level of nutrients should be provided to citrus. Some of the important micronutrients are Zinc, Boron and copper.

Zinc is essential for the growth and development of citrus trees. Citrus trees require trace amounts of zinc to carry out essential physiological processes. Zekri and Thomas (2021) [22] explained that zinc is necessary for plants because it improves water uptake and is a component of the enzyme system.

It is a necessary component in the production of proteins, the synthesis of chlorophyll. It acts as a cofactor for many enzymes involved in metabolic processes in citrus trees, including DNA synthesis and carbohydrate metabolism.

Boron is an essential micronutrient for citrus trees, as it is involved in a variety of physiological processes. It is required for the formation and maintenance of cell walls, which are essential for plant growth and structure. It promotes cell elongation and division and also plays a role in the formation of vascular tissue (Gupta and Solanki, 2013) [8]. It is essential for the flowering and fruit development of citrus trees. It aids in the regulation of sugar and other nutrient transport to the developing fruit; facilitates the absorption and utilization of other vital nutrients like calcium, potassium, and magnesium. It plays an important role in carbohydrate metabolism and starch formation (Zekri and Obreza, 2013) [22]. It also helps in pollen tube growth, which influences seed/fruit set and thus yield.

Copper is an important nutrient in citrus production because it is required for the healthy growth and development of citrus trees. Copper is required for photosynthesis and is involved in the production of chlorophyll in citrus (Yruela, 2009) [21]. Chlorophyll is responsible for transforming solar energy into chemical energy that the citrus tree can use to grow and develop. Without enough copper, chlorophyll production is inhibited, resulting in growth retardation, poor fruit quality, and lower yields. Copper is needed for the synthesis of enzymes involved in carbohydrate metabolism. Copper is essential for disease control in citrus. Copper aids citrus trees in the uptake and utilization of iron. It aids in the regulation of iron transport to the chloroplasts of plants, where it is required for photosynthesis.

Micronutrients like zinc, boron and copper are very essential for optimum development, and physiological and metabolic pathways in citrus cultivation (Mohammed, 2022) [14]. Foliar spraying of micronutrients boosts photosynthetic chemicals inside plant tissue, which minimizes leaf loss and strengthens their persistency when compared to soil application. Foliar application of micronutrients is an excellent method for addressing nutrient availability issues and supplementing soil fertilizers. It is a safe method of applying nutrients for maximum absorption and availability. Keeping the above points in view, the importance of foliar spray of micronutrients for improving the fruit yield, the present research entitled "Enhancing yield and economic returns of lemon (*Citrus limon*) cv. Pant Lemon-1 through optimized foliar application of micronutrients under western Uttar Pradesh conditions" was carried out at Horticultural Research Centre, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut.

Materials and Methods

Experimental site and location

The present investigation was carried out to investigate at Horticultural Research Centre, Sardar Vallabhbhai Patel University of Agriculture and Technology, Modipuram, Meerut from June 2022 to October 2022.

The University is located at Meerut – Roorkee road (near Modipuram), about 11 Km away from Meerut City. Geographically, the experimental field is located at 29°.08' North latitude, 77°.45' East longitude and at an altitude of 237.35 meters above the main sea level.

Experimental details

The investigation was carried out on 5 years old trees of lemon cv. Pant Lemon - 1 which were planted at a 5 m x 5 m distance in the square system of planting and maintained under uniform cultural practices. There were twelve treatments which consisted of foliar sprays of different concentrations of zinc (0.2% and 0.5%), boron (0.2% and 0.4%), copper (0.2% and 0.5%) and their combinations with a total of twelve treatments including control. Each treatment was replicated thrice. Total of 36 plants were marked for the experiment. The spray was done twice in the month of June and July.

Details of treatment with their symbols

S. No.	Treatment details	Concentrations	Symbols
1.	Control (Distilled water)	-	T_1
2.	Zinc sulphate	0.2%	T_2
3.	Zinc sulphate	0.5%	T_3
4.	Borax	0.2%	T_4
5.	Borax	0.4%	T_5
6.	Copper sulphate	0.2%	T_6
7.	Copper sulphate	0.5%	T_7
8.	$ZnSO_4$ + Borax	(0.5%) + (0.4%)	T_8
9.	$ZnSO_4$ + $CuSO_4$	(0.5%) + (0.5%)	T_9
10.	Borax + $CuSO_4$	(0.4%) + (0.5%)	T_{10}
11.	$ZnSO_4$ + Borax + $CuSO_4$	(0.2%) + (0.2%) + (0.2%)	T_{11}
12.	$ZnSO_4$ + Borax + $CuSO_4$	(0.5%) + (0.4%) + (0.5%)	T_{12}

Observations Recorded

Yield attributes

Number of fruits per tree: The number of fruits per plant was physically counted after maturity and then harvested.

Fruit yield per tree (Kg/tree): The number of lemons per tree was multiplied with the average fruit weight obtained per tree.

Yield per hectare (tonnes): The yield per hectare was computed by multiplying the yield per plant with the no. of plants that can be accommodated in one hectare and was expressed in tonnes per hectare.

Economic Analysis

Cost of cultivation: The cost of cultivation refers to the total expenses incurred in cultivating one hectare of a crop. It was worked upon, considering both input and operational expenses incurred in the cultivation of lemon. It was calculated based on various input costs, such as the value of hired human labour, seeds, fertilizers, manures, irrigation charges etc.

Gross income: The gross income was worked out based on the prevailing market price of lemon fruits.

Net income: The net income per hectare was calculated by using the following formula.

NI = Gross income – The cost of cultivation

Cost-benefit ratio: The cost-benefit ratio for different treatments was worked out based on the price of inputs used for cultivation and the price of marketable produce in the local market by using the following formula and it is expressed in ratio.

$$\text{Cost benefit ratio} = \frac{\text{Net income (Rs./ha)}}{\text{Cost of cultivation (Rs./ha)}}$$

Results and Discussion

Yield attributes

The results of data pertaining to the number of fruits per tree, fruit yield (kg) and fruit yield (t ha^{-1}) were found statistically significant. The maximum number of fruits per tree and fruit yield (t ha^{-1}) were found in T_{12} [$ZnSO_4$ (0.5%) + Borax (0.4%) + $CuSO_4$ (0.5%)] which was at par with T_{11} [$ZnSO_4$ (0.2%) + Borax (0.2%) + $CuSO_4$ (0.2%)] while a minimum number of fruits per tree was recorded in (control) T_1. Maximum fruit yield per tree (kg) was found in T_{12} [$ZnSO_4$ (0.5%) + Borax (0.4%) + $CuSO_4$ (0.5%)] which was at par with T_{11} [$ZnSO_4$ (0.2%) + Borax (0.2%) + $CuSO_4$ (0.2%)], T_9 [ZnSO4 (0.5%) + CuSO4 (0.5%)], T_7 (Copper sulphate – 0.5%) and T_{10} (Borax (0.4%) + CuSO4 (0.5%). This result is supported by Boaretto *et al.* (2002) [6], Meena *et al.* (2014) [13] in Nagpur mandarin, Bhoyar and Ramdevputra (2016) [5] in guava, Kumar *et al.* (2018) [12] in lime, Al- Obeed *et al.* (2018) [1], Throat *et al.* (2018) [19] in Nagpur Mandarin, Zoremtluangi *et al.* (2019) [23] in Khasi mandarin and Jangid *et al.* (2019) [10] in aonla. Ilyas *et al.* (2015) [9] observed similar findings that the foliar spray of zinc, copper and boron had a significant influence on fruit yield with regard to a number of fruits and fruit weight and they also observed a significant improvement of photosynthesis in *Citrus reticulata* Blanco var. Kinnow. Similarly, Singh *et al.* (2018) [18] observed that the combined influence of different concentrations of Zn + B + Cu resulted in a maximum number of fruits per plant, fruit weight and estimated yield in sweet oranges.

Copper is involved in the production and stability of chlorophyll which is involved in food production needed for the growth and development of fruits. Bastakoti *et al.* (2022) [4] reported the significant effect of copper on yield. The reason behind this was due to its association with fruit weight. Awasthi *et al.* (1975) [3] reported that zinc plays a major role to increase the flowering, fruit set, and fruit size, control the fruit drop and eventually increasing the yield and also increasing the source and sink relationship. Ganie *et al.* (2013) [7] observed that fruit set, retention and yield increased in guava as a result of boron's role in pollen germination and pollen tube elongation which resulted in improving fruit set percentage and eventually increased yield. Razzaq *et al.* (2013) [17] reported that the significant influence of zinc and boron are related with increased fruit number because of increased fruit set and reduced fruit drop. Venu *et al.*, 2014 [20] revealed that B and Zn facilitate better photosynthesis and accumulation of starch in fruit as both nutrients help in increasing in chlorophyll content and leaf area which ultimately improves fruit weight consequently improving yield. Zoremtluangi *et al.* (2019) [23] found that an increase in fruit number and yield might be due to a reduction in fruit drop.

Table 1: Show Treatments, Symbol, Fruit yield per tree (kg), No. of fruits per tree and Fruit yield (tonnes/ha)

SN	Treatments	Symbol	Fruit yield per tree (kg)	No. of fruits per tree	Fruit yield (tonnes/ha)
1	Control (Distilled water)	T1	6.67	89	2.66
2	Zinc sulphate- 0.2%	T2	10.00	126	4.00
3	Zinc sulphate- 0.5%	T3	10.55	129.67	4.22
4	Borax – 0.2%	T4	10.87	127.66	4.34
5	Borax – 0.4%	T5	11.04	120.66	4.41
6	Copper sulphate – 0.2%	T6	10.24	121.66	4.09
7	Copper sulphate – 0.5%	T7	12.58	126.66	5.03
8	ZnSO4 (0.5%) + Borax (0.4%)	T8	11.97	135	4.78
9	ZnSO4 (0.5%) + CuSO4 (0.5%)	T9	12.66	133	5.06
10	Borax (0.4%) + CuSO4 (0.5%)	T10	12.27	132.33	4.90
11	ZnSO4 (0.2%) + Borax (0.2%) + CuSO4 (0.2%)	T11	13.97	138.33	5.58
12	ZnSO4 (0.5%) + Borax (0.4%) + CuSO4 (0.5%)	T12	14.24	139	6.10
	SE(m) ±		0.69	0.712	0.383
	C.D. at 5%		2.05	2.103	1.131

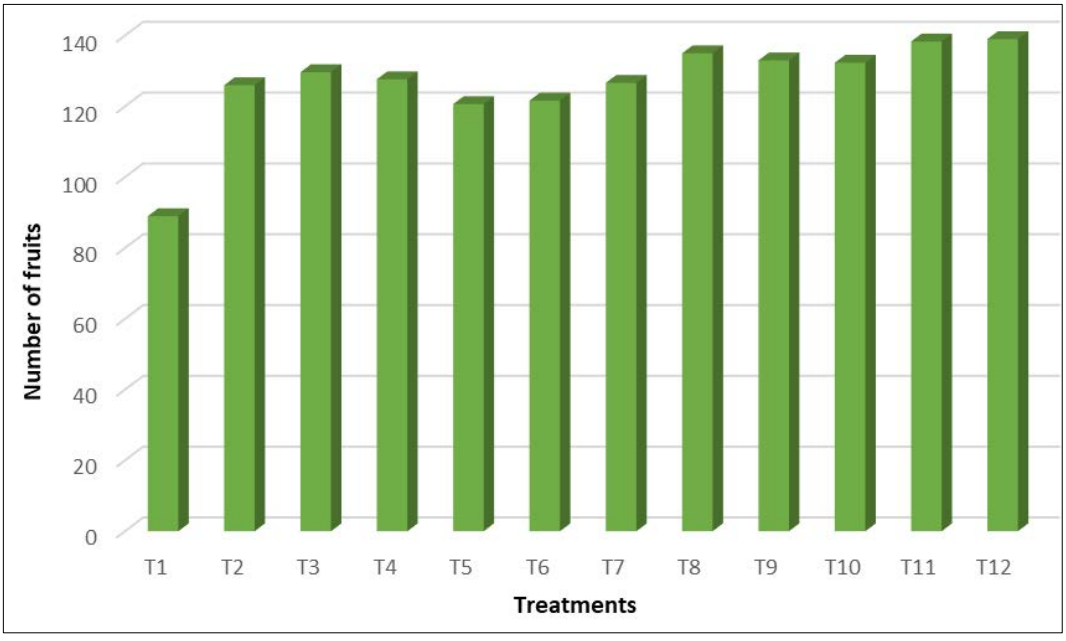

Fig 1: Effect of Zn, B and Cu on number of fruits.

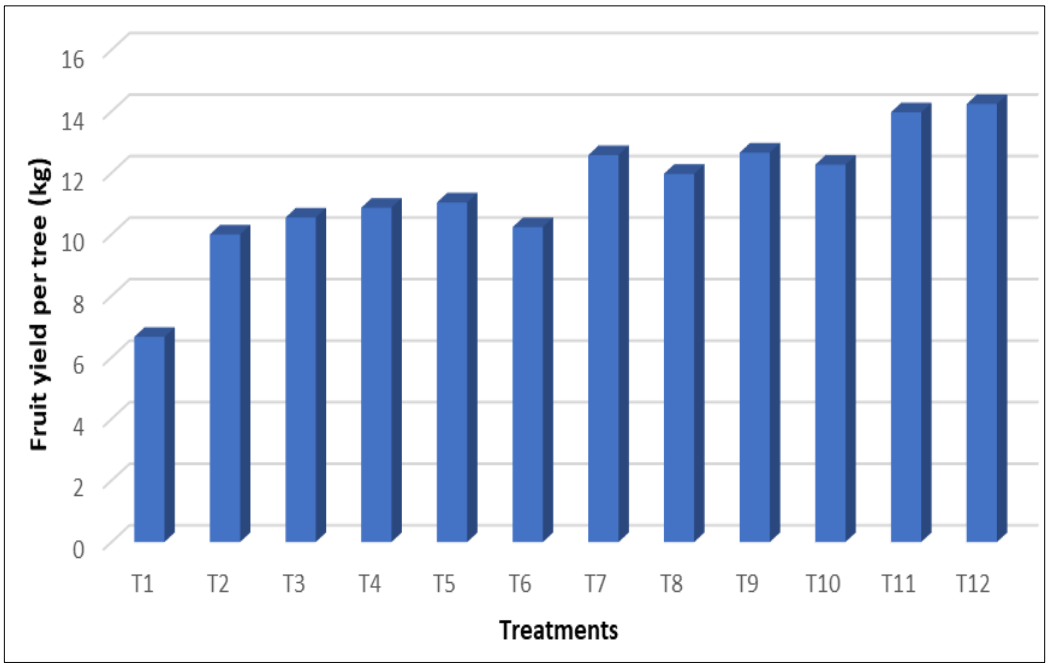

Fig 2: Effect of Zn, B and Cu on fruit yield per tree (kg).

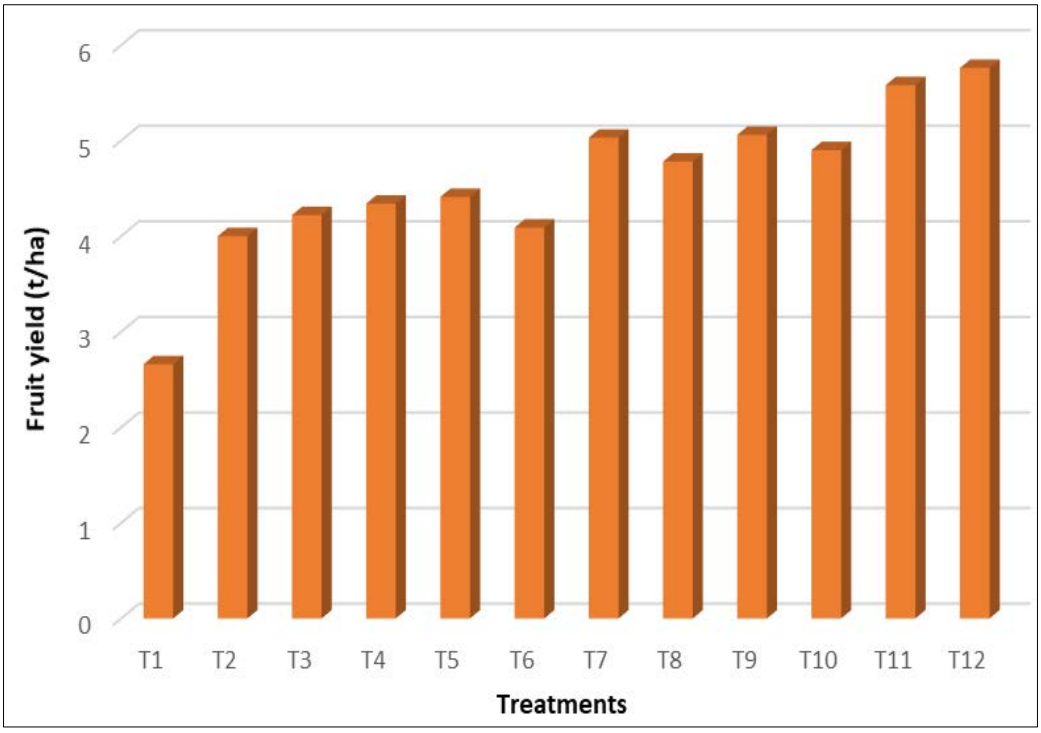

Fig 3: Effect of Zn, B and Cu on fruit yield (tonnes ha^{-1})

Economics

The highest gross income was obtained in treatment T_{12} [$ZnSO_4$ (0.5%) + Borax (0.4%) + $CuSO_4$ (0.5%)] (Rs. 155550/Ha) followed by T_{11} [$ZnSO_4$ (0.2%) + Borax (0.2%) + $CuSO_4$ (0.2%)] (Rs. 142290/Ha) while minimum was obtained in control (Rs. 67830/Ha). The highest net income was obtained in T_{12} [$ZnSO_4$ (0.5%) + Borax (0.4%) + $CuSO_4$ (0.5%)] (Rs. 113145.3/Ha) followed by T_{11} [$ZnSO_4$ (0.2%) + Borax (0.2%) + $CuSO_4$ (0.2%)], (Rs. 103053.3/Ha) while minimum was obtained in control (Rs. 31113.32/Ha). T_{12} [$ZnSO_4$ (0.5%) + Borax (0.4%) + $CuSO_4$ (0.5%)] (2.67) resulted in a maximum cost-benefit ratio followed by T_{11} [$ZnSO_4$ (0.2%) + Borax (0.2%) + $CuSO_4$ (0.2%)] (2.63). Maximum gross income, net income and the cost-benefit ratio was recorded as highest in a combination of zinc (0.5%), boron (0.4%) and copper (0.5%) followed by a combination of zinc, copper and boron with a concentration of 0.2% each. This might be due a maximum number of fruits per tree and maximum yield. This result is in accordance with Rajamanickam *et al.* 2022 [16] in acid lime and Singh *et al.* 2018 [18] in sweet orange.

Table 2: Economics of different treatments in lemon

Treatments	Cost of cultivation (Rs. ha^{-1})	Gross income (Rs. ha^{-1})	Net income (Rs. ha^{-1})	Cost-benefit ratio
T_1	36716.68	67830	31113.32	0.84
T_2	37316.68	102000	64683.32	1.73
T_3	38216.68	107610	69393.32	1.82
T_4	37940.68	110670	72729.32	1.92
T_5	39164.68	112455	73290.32	1.87
T_6	37412.68	104295	66882.32	1.79
T_7	38456.68	128265	89808.32	2.34
T_8	40664.68	121890	81225.32	2.00
T_9	39956.68	129030	89073.32	2.23
T_{10}	40904.68	124950	84045.32	2.05
T_{11}	39236.68	142290	103053.3	2.63
T_{12}	42404.68	155550	113145.3	2.67

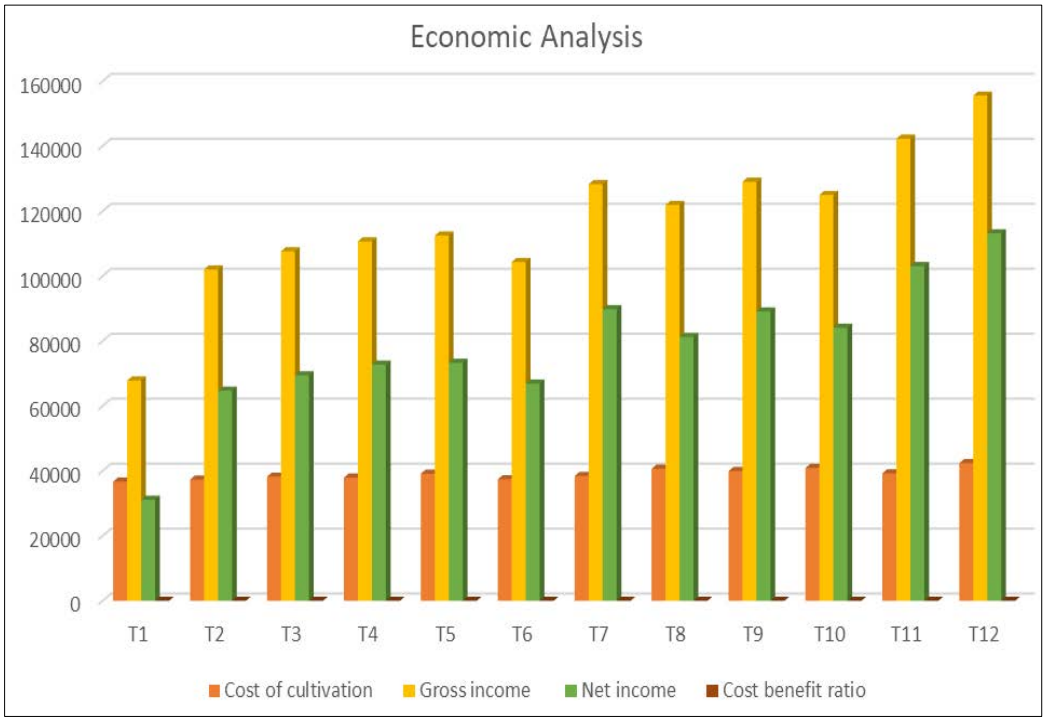

Fig 4: Economics of different treatments in lemon

Conclusion

Based on the above investigation, it was observed that there was a significant effect of foliar application of zinc, boron and copper on the yield and economic feasibility of lemon cv. Pant Lemon – 1. It could be concluded that maximum yield per tree (kg), number of fruit per tree, yield (tonnes/ha), maximum cost of cultivation, net return, gross return and maximum benefit-cost ratio was obtained by spraying a combination of zinc (0.5%), boron (0.4%) and copper (0.5%) followed by a combination of zinc (0.2%), boron (0.2%) and copper (0.2%). Therefore, it can be recommended that under conditions of western Uttar Pradesh, lemon growers should spray trees with combinations of zinc sulphate (0.5%), borax (0.4%) and copper sulphate (0.5%) twice during the month of June and July.

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