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Influence of Boron on Yield of Okra and Soil Microbial Activities in *Inceptisols*

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Abstract: The study entitled "Influence of boron on yield of Okra and soil microbial activities inInceptisols" was carried out at E Block of Central Farm, Regional Research & Technology Transfer Station (RRTTS), OUAT, Bhubaneswar during January to April, 2021 with the objectives of studying the effect of foliar spray of boron on yield of Okra and the soil microbial activities. The experiment was laid out in RBD with ten treatments replicated thrice.
The treatments included one on B control (only soil test dose NPK), NPK + 1.0 KgB/ha soil application and eight treatments of foliar application of B @ 0.25, 0.5, 0.75, and1.0% borax sprayed once or twice at 25 and/or 50 DAS. Plant and soil samples were collected one week after 1st and 2nd spraying for analysis of biometric and microbiological parameters including enzyme activities. The bacterial, fungal and actinomycetes population of soil in different treatments measured one week after 1stand 2ndfoliar spray of Brecordeda significant increase in number of count in all treatments including the one applied with B as basal in soil over that in control. A reduction in population of fungus (2-16%) and actinomycetes (9-43%) measure done week after 2nd spray was observed over that recorded after 1st spray. In contrast, an increase in population of bacteria (0-28%) measured one week after 2nd spray was observed over that recorded after 1st spray. The urease activity of soil due to different boron treatments varied significantly among the treatments from 25.2 to 38.6 µg $NH^{4+}Ng^{-1}$soil/2h. The dehydrogenase activity of soil due to different boron treatments varied significantly among different treatments from 0.7 to 46.6 µg $TPFg^{-1}$soil /24h. The urease and dehydro genase activities of soil measured after 2nd foliar spray of B increased with application of B to okra irrespective of dose and application methods.

I. INTRODUCTION

Over the coming decades, a changing climate, growing global population, rising food prices and environmental stressors will have significant yet uncertain impacts on food security. Adaptation strategies and policy responses to global change, including options for handling water allocation, land use patterns, food trade, post harvest food processing, and food prices and safety are urgently needed. IFPRI's (International Food Policy Research Institute) work on food security includes analysis of cash transfers, promotion of sustainable agricultural technologies, building resilience to shocks and managing trade-offs in food security, such as balancing the nutritional benefits of meat against the ecological costs of its production.

Okra (*Abelmoschus esculentus* L.) is an annual shrub that is cultivated mostly with in tropical and subtropical regions across the globe and represents a popular vegetable crop, commonly known as Lady's finger, as well as by several vernacular names, including bhindi,okura, quimgombo, bamia, gombo, and lai longma, in the different geographical regions of its cultivation . It is one of the important vegetables cultivated for its edible green fruit which can either be eaten raw or cooked. Okra plays a critical role in tropical diet because the soft immature pods contain a glutinous sticky substance that is used as soup thickener. It is a good source of vitamins and minerals and it also contains substantial amount of protein, carbohydrate and fat (Anisa*etal.*, 2016).

Keeping the above facts in view, the present study entitled 'Influence of boron on yield of Okra and soil microbial activities in *Inceptisols*' was carried out at Department of Soil Science and Agricultural Chemistry, OUAT, Bhubaneswar and the field experiment was conducted in E Block of Central Farm**,** Regional Research & Technology Transfer Station (RRTTS), OUAT, Bhubaneswar during the *rabi* season of the year 2021-22.withthefollowingobjectives:

1) To study the effect of foliar spray of boron on yield and yield attributing characters of Okra
2) To study the microbial activities in soil under foliar spray of boron on Okra

II. REVIEWOFLITERATURE

An attempt has been made in this chapter to briefly review the available literature on the importance of boron and other micronutrients in crops, especially different vegetables, efficiency of different application methods of nutrients in crops on yield, yield attributing characters, post harvest soil nutrient status and soil microbial activities under the following sections.

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A. Okra as an Important Vegetable Crop

Okra *[Abelmoschus esculentus* (L.) Moench], a member of the Malvacea family, is a widely cultivated vegetable crop and very important in the diet of Africans (Omotoso andShittu, 2008). It is also called synonymously as lady's finger or bhindi. It is a valuable crop that provides an excellent income and generates other opportunities for small-scale farmers (Selleck and Opena, 1985). Indeed, it is one of the important nutritional vegetable crops cultivated in Nigeria, covering an estimated land area of 1-2 million hectares (FMAWR&RD,1989). The leading bhindi growing states are Karnataka, Andhra Pradesh, Odisha, Bihar and West Bengal. The production and productivity of the crop is being adversely affected in different areas due to deficiencies of micronutrients (Boseand Tripathi, 1996).

B. Health Benefits of Okra

Okra is more a diet food than staple (National ResearchCouncil, 2006).Okra has been called "a perfect villager's vegetable" because of its robust nature, dietary fiber, and distinct seed protein balance of both lysine and tryptophan amino acids (unlike the proteins of cereals and pulses) (Holser & Bost, 2004; Sanjeet et al., 2010). Okra seeds are source of oiland protein. It can be also used as non-caffeinated substitute for coffee. Okra seeds may be roasted and ground to form a caffeine-free substitute for coffee (Calisir, & Yildiz, 2005).Okra, which is grown mainly as a vegetable crop, has potential for cultivation as an essentialoilseedcrop because okra seeds contain high amount of oil varying from20% to40%depending on the extraction method (Sorapong, 2012; MEF, 2013).

The importance of micronutrients in agriculture is well recognized and their uses have significantly contributed to the increased productivity of several crops (Tirpathi *et al;* 2015).Micronutrients are essentially as important as macronutrients to have better growth, yield and quality in plants (Yadav *et al;* 2018).The requirement of micronutrients (boron, iron, copper, zinc, manganese, chloride and molybdenum) is only in traces, which is partly met from the soil through chemical fertilizer or through other sources.

C. Micro Nutrients Deficiencies in Soil

Zinc is the most deficient micronutrient in Indian soils (52%), followed by boron (33%) (ISSS, 2009). It is reported that among micronutrients Zn and B have occupied unique position in enhancing the yield of potato (Trehanand Grewal, 1989).Micro nutrient deficiency can limit the crop growth and production. Furthermore, micronutrients also help to increase the use efficiency of macronutrients.

D. Boron Deficiencies in Plants

Borondoesnoteasilymovearoundtheplantandtherefore,thedeficiencyappearsfirstinyoungtissues,growingpoints,roottipsanddevelopingfruits.Sinceboronisrelativelyimmobileinplants,theearlycasualtiesofborondeficiencyoccurinthereproductiveprocessofplants,anditsinadequacyisoftenassociatedwithsterilityandmalformation of reproductive organs (Katya *et al.,2000).* Its deficiency may cause sterility, poor fruit set, small fruit size and ultimately lower yield.

The shortening of the terminal growth due to boron deficiency results in rosseting. Leaves may have thick coppery texture and sometimes curled and become brittle with scorched appearance. Growth is also ceased at the growing points (Bubarai *et al.,* 2017).

Boron deficiency has been reported in 132 crops in80 countries (Shorrocks, 1997) and is a major cause of crop yield loss in China, India, Nepal and Bangladesh (Anantawiroon et al., 1997).

Firoz *et al;* (2009) observed the effect of boron application on the yield of broccoli. A result revealed that application of boron @1kg/ha produced the highest yield (512.3g/plant) and the lowest (445.4g/plant) was observed in control.

E. Foliar Application of Micronutrients

Foliar application of micronutrients is widely used that reduces loss due to fixation in soil. Moreover, the uptake and assimilation of micronutrients through foliar application will be faster. It has been observed that the foliar spray of zinc, iron, copper, molybdenum and boron are often more effective than soil application because these elements are not highly soluble in the soil. It has also been proved that foliar feeding of nutrients is many time more effective and economical than soil application (Shanmugavelu, 1989).

Foliar fertilization, in relation to balanced plant nutrition, appeared to be the part and parcel of modern sustainable vegetable production during recent past.

This mode of applying fertilizers to the crops has been considered a precious supplement to the application of nutrients to soil system (Fageria*etal*.,2009).

F. Ecological Balance Between Plant and Microbes

Microbial metabolism accelerates the decomposition of organic matter, promotes the mineralization of nutrients, and stimulates nutrients absorbed by plant. Carbon dioxide efflux from the soil derived from two distinct aspects, including rhizosphere respiration that contains root and microbial respirations, and microbial decomposition of soil organic matter(Cheng et al., 2005).

The decomposer activity of soil microbial biomass is an important ecosystem trait to maintain the recycling and stabilization of nutrients. The curious relationship between plant and microbe is helping and competing based on ecological balance level.

III. MATERIALSANDMETHODS

The present study entitled ‘Influence of boron on yield of Okra and soil microbial activities in *Inceptisols’* was carried out at Dept. of Soil Science and Agricultural Chemistry, OUAT, Bhubaneswar and the field experiment was conducted in E Block of Central Farm**,** Regional Research & Technology Transfer Station (RRTTS), OUAT, Bhubaneswar during the year 2021.The techniques of investigation and the materials used for conducting the experiments have been described in this chapter.

A. Field Experiment

1) Experimental Site

WeekNo	Days	Rainfall (mm)	Temp(^{0}C)		RH (%)		BSH (hrs)	No of rainy days	Wind speed (kmph)	Evap (mm)
			Max	Min	7hrs	14hrs				
1	1-7Jan	0.0	29.4	13.5	92	36	6.2	0	2.1	3.5
2	8-14Jan	0.0	32.8	17.9	90	40	5.4	0	1.8	3.6
3	15-21Jan	0.0	29.8	16.9	93	45	2.7	0	3.3	3.6
4	22-28Jan	0.0	30.6	16.8	94	35	3.4	0	3.4	3.6
5	29Jan-4Feb	0.0	29.1	13.6	94	36	4.8	0	2.7	3.6
6	5-11Feb	0.0	31.0	13.2	92	29	8.1	0	2.2	3.8
7	12-18Feb	0.0	33.6	16.7	92	29	6.4	0	3.7	3.9
8	19-25Feb	0.0	33.4	16.9	89	28	5.8	0	2.9	4.0
9	26Feb-4Mar	0.0	38.1	20.2	95	25	7.8	0	3.7	4.5
10	5-11Mar	0.0	37.1	22.3	95	36	6.5	0	5.7	4.7
11	12-18Mar	0.0	36.3	22.7	92	33	7.1	0	4.7	5.6
12	19-25Mar	0.0	38.5	23.5	92	30	4.1	0	3.7	6.2
13	26Mar-1Apr	7.5	39.7	24.6	93	35	6.3	1	5.9	7.3
14	2-8Apr	3.5	37.6	25.5	92	46	6.8	1	6.9	7.6
15	9-15Apr	3.7	37.0	24.8	89	50	4.6	1	6.6	7.8
16	16-22Apr	0.0	38.8	26	90	42	8.0	0	6.2	8.6
17	23-29Apr	0.0	39.9	26.6	89	37	7.3	0	7.1	8.0
18	30April-6 May	5.6	37.3	25.0	87	47	7.6	2	7.5	7.9
19	7-13May	58.2	37.4	25.5	85	60	8.1	4	6.7	7.9
20	14-20May	31.2	37.1	27.3	91	51	8.1	1	6.7	8.5

The field trial was conducted during January to April, 2021 in E Block of Central Farm**,** Regional Research & Technology Transfer Station (RRTTS), OUAT, Bhubaneswar located at $20^0$29’61’’N, 85082’45’’E longitude latitude.

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2) Soil of Experimental Site

The soil is sandy loam and located at East and South east coastal plain of Odisha .

3) Treatmentdetails

Numberoftreatments:10 Number of replications: 3 Design: RBD

Plotsize:20m x20m Spacing:60cmx 30cm

Treatment numbers	Details	Abbreviated
T1	NPK(STD)	NPK(STD)
T2	NPK +B@1.0 Kg/ha soilapplicationasborax	NPK + 1.0 kg B/ha soilapplication
T3	NPK+FoliarSpray@0.25%Boraxonce	NPK+0.25%Borax 1 spray
T4	NPK+FoliarSpray@0.5%Boraxonce	NPK+0.5%Borax1 Spray
T5	NPK+FoliarSpray@0.75%Boraxonce	NPK+0.75%Borax 1spray
T6	NPK+FoliarSpray@1.0%Boraxonce	NPK+1.0%Borax 1spray
T7	NPK+FoliarSpray@0.25%Boraxtwice	NPK+0.25%Borax 2spray
T8	NPK+FoliarSpray@0.5%Boraxtwice	NPK+0.5%Borax 2spray
T9	NPK+FoliarSpray@0.75%Boraxtwice	NPK+0.75%Borax 2spray
T10	NPK+FoliarSpray@1.0%Boraxtwice	NPK+1.0%Borax 2spray

STD=Soil test dose of fertilizer

4) Preparation of Experimental Plots

a) Lay Out of Experiment: Thefieldwasploughedandlevelled.Theexperimentalplotswerelaidoutinstatistically laid out field with randomized block design with 10 treatments replicated three times. The treatments were assigned to different plots in each replication as per lay out plan (Fig.1).

R3 R2 R1

T7	T10	T9	T5	T1	T6
T9	T8	T10	T4	T2	T7
T6	T1	T7	T2	T3	T8
T2	T5	T8	T3	T4	T9
T4	T3	T6	T1	T5	T10

Fig 1. Lay out of the experimental plot in E Block of Central Farm, RRTTS, OUAT, Bhubaneswar.

b) *Application of Manures, Fertilizers, Micronutrients:* FYM was applied to the plot and incorporated in the soil thoroughly. The recommended fertiliser dose for okra is 80:40:40 kg N, P_2O_5, K_2O / ha). Required amount of fertilizers i.e. urea, DAP,MOP applied to soil are168g ,104g, 80g,respectively per plot.

c) *Intercultural Operation and Plant Protection Measures:* Intercultural operations like hoeing, weeding, thinning, irrigation and plant protection measures like application of Monocrotophos were carried out. The first and second sprays of borax were undertaken as per treatments at 25and 50 DAS.

B. Analysis of Soil Samples

1) *Sample Collection:* Initial soil samples were collected before sowing (12 January) and then composited properly for analysis of chemical and physical properties. Subsequently, after1st and 2ndspray of boron soil samples were collected from each plot separately for analysis of microbial population and enzyme activities of soils. After harvest of crop, composite soil samples were collected again from each plot for physico-chemical analysis and microbiological properties.

IV. RESULTS

The results of the investigation on "Influence of boron on yield of Okra and soil microbial activities in *Inceptisols"* conducted at the E-block of central research station, OUAT during *rabi* season of 2021 are presented systematically in the following paragraphs.

A. Initial Soil Characteristics

The composite experimental soil sampled before sowing was analyzed for different parameters and the data presented in table 2. The data from the above table showed that the soil is acidic with low in available nitrogen and potassium but sufficient phosphorus status. The status of available boron was found to below.

Table2.Therecordedpropertiesof initial soil

Properties	Value	Remark
pH(1:25)	4.56	Acidic
EC(dS/m)	0.05	Normal
Organic C(%)	0.45	Low
Available N(kg/ha)	195	Low
Bray-IP(kg/ha)	50.5	High
NH4O Acextractable K(kg/ha)	95	Low
Hot water soluble B (mg/kg)	0.35	Low

B. Periodic Changes in soil pH and Organic Carbon Content

The soil pH and organic carbon content are very important fundamental properties which influence chemical, physical and biological properties of soil. The nutrient availability and microbial growth and performance are largely influenced by soil pH and soil organic carbon. To know the periodic changes of these parameters after foliar spray of boron, samples were collected and analyzed for pH and organic carbon content and presented in table 3. It was found that the pH of the treatment plots of experiment one week after 1st spray varied from 4.76 to 5.22. There was an increase in pH of the treated plots over the initial value of4.56; however, there was no significant change in pH was observed within the treatments. One week after 2nd spray, the pH of treated plots varied from 4.66 to 5.11.There was slight decrease in soil pH recorded after 2nd spray compared to that recorded after 1st spray. But, no significant changes in soil pH were observed among the plots receiving one and two sprays. It was found that the organic carbon content of the treatment plots one week after 1stspray varied from 0.41 to 0.52% and those after 2nd spray varied from 0.35 to 0.44%. There was no significant change in organic carbon content of the treated plots over the initial value of 0.45% and also among the treatments; however, there was slight numerical decrease in organic carbon content was observed in the values recorded after2nd spray over the corresponding values recorded after 1st spray.

Table3. Changes in soil pH and Org.C with application of boron

Tr.nos	Treatment details	pH(1:2.5)		Org.C(%)	
		after1st spray	after2nd spray	after1st spray	after2nd spray
T1	NPK(STD)	4.76	4. 66	0.48	0.42
T2	NPK+1.0 kg B/ha Soil application	5.11	5.02	0.52	0.41
T3	NPK+0.25%Borax 1spray	5.22	5.05	0.43	0.41
T4	NPK+0.5%Borax 1Spray	5.10	4.98	0.41	0.37
T5	NPK+0.75%Borax 1spray	5.12	5.02	0.46	0.43
T6	NPK+1.0%Borax1 spray	4.92	4.81	0.44	0.44
T7	NPK+0.25%Borax 2spray	5.18	5.05	0.48	0.45
T8	NPK+0.5%Borax2 spray	5.21	5.11	0.49	0.35
T9	NPK+0.75%Borax 2spray	5.12	5.01	0.48	0.37
T10	NPK+1.0%Borax2	5.11	5.02		0.44
	spray			0.48	
Initial soil		4.56		0.45	

C. Yield attributing characters of okra under boron treatments

The different yield attributing characters of okra like mean emergence count (MEC), plant population, plant height and leaf area are presented in table4.

5) Mean Emergence Count

The test crop Okra (variety LILY) was sown with 2-3 seeds per hole. The seedling emergence was counted after 8 days of sowing. The percentage of emergence is depicted in fig 1. It was observed from the data that the emergence count on the 1st date (27th January)variedfrom71.8to75.5% with maximum value in the treatment receiving NPK +1.0%Borax 2 sprays and the minimum value being recorded with the treatment receiving only soil test dose of NPK fertilizers (Fig 1).

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Table4.Changes in yield at tributing characters of okraunderboron treatments

Treatment nos.	Treatment details	MEC(%)	Plant population per plot		Plant height(cm)		Leaf area/plant (cm^2)	
			30 DAS	60 DAS	30 DAS	60 DAS	30 DAS	60 DAS
T1	NPK(STD)-Noboron	72.8	82.3	73.3	15.3	48.8	685	2171
T2	NPK+1.0kg B/ha soil appln	74.8	84.6	74.3	16.9	56.7	779	3393
T3	NPK+0.25%Borax 1 spray	73.3	83.3	74.6	17.1	52.6	677	2581
T4	NPK+0.5%Borax 1 Spray	74.8	84.0	73.3	16.0	53.2	780	3106
T5	NPK+0.75%Borax 1spray	72.4	80.3	72.3	16.4	55.2	722	3333
T6	NPK+1.0%Borax 1spray	75.2	85.6	73.3	16.5	53.9	715	2556
T7	NPK+0.25%Borax2 sprays	71.8	81.3	72.3	17.3	54.5	731	3088
T8	NPK+0.5%Borax2 sprays	73.8	83.6	75.3	17.6	59.3	772	3081
T9	NPK+0.75%Borax2 sprays	73.3	82.3	74.6	17.4	56.1	738	3220
T10	NPK+1.0%Borax2 sprays	75.5	85.6	72.3	17.3	55.1	744	3135
	Sem	1.62	0.85	1.29	1.76	2.12	1.02	1.60
	CDat5%	3.14	2.74	NS	1.28	1.04	3.03	4.77

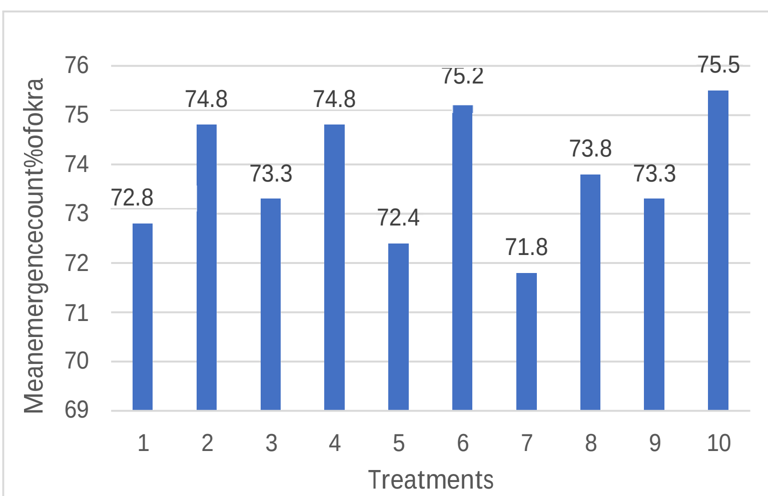

Fig.1.Meanemergence count (%) of okra plants under varying boron application

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Treatment nos.	Treatment details	Enzymeactivity	
		Urease activity ($\mu g NH^{4+} N\ g^{-1}$ soil/2h)	DHA ($\mu g TPF g^{-1}$soil/24h)
T1	NPK(STD)-Noboron	25.2	0.7
T2	NPK+1.0 kg B/ha soil appln	38.2	46.6
T3	NPK+0.25%Borax 1 spray	25.6	23.3
T4	NPK+0.5%Borax 1 spray	26.6	44.0
T5	NPK+0.75%Borax 1spray	28.2	38.6
T6	NPK+1.0%Borax 1spray	35.2	36.2
T7	NPK+0.25%Borax 2sprays	36.5	33.1
T8	NPK+0.5%Borax 2sprays	37.4	38.8
T9	NPK+0.75%Borax 2sprays	38.4	38.5
T10	NPK+1.0%Borax 2sprays	38.6	31.9
	SEm	0.24	0.68
	CDat5%	0.72	2.02

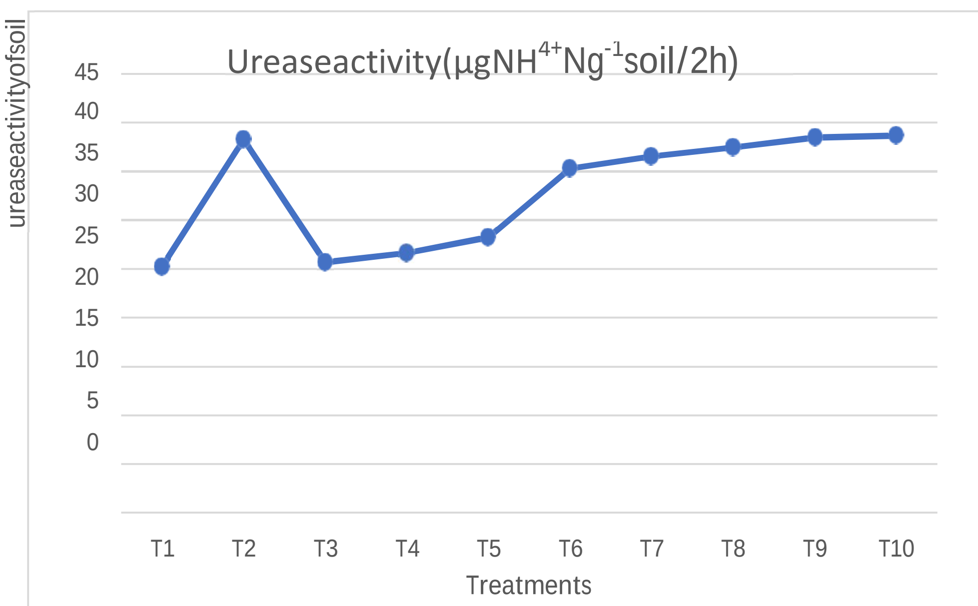


Fig.11. Urease activity of soil after 2nd foliar spray of boron in okra

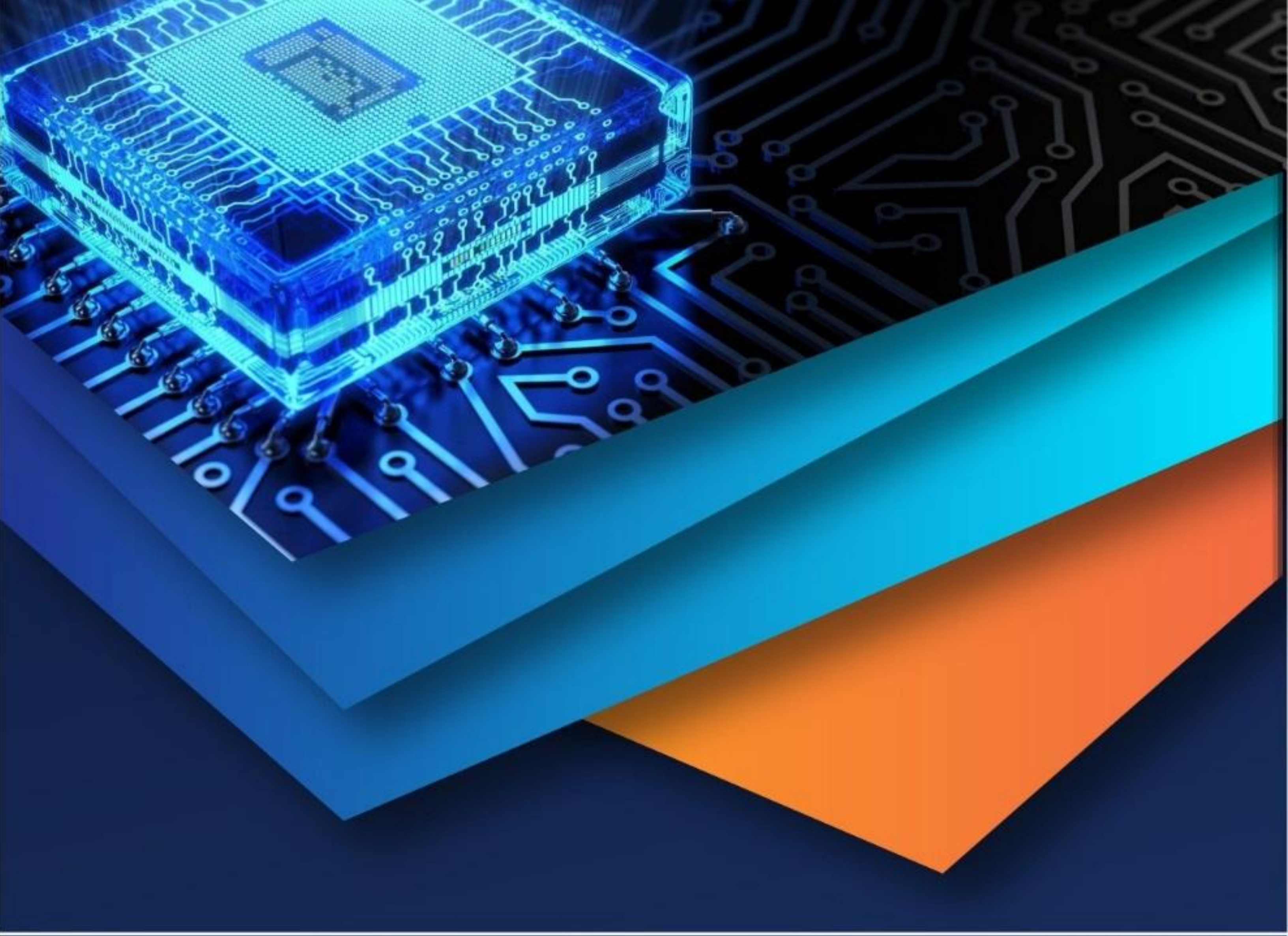
V. CONCLUSION

The results the present study entitled "Influence of boron on yield of Okra and soilmicrobial activities in *Inceptisols"* carried out with the objectives of studying the effect of foliar spray of boron on yield of Okra and the soil microbial activities are discussed in this chapter in the following paragraphs.

The experimental soil was acidic with low organic carbon, nitrogen and boron due to lateritic origin, high rainfall, high temperature, and light texture. Soil pH and soil organic carbon directly influence the soil microbial population (Bradyand Weil, 2013).The experimental soil was acidic and there no visible change in soil pH and organic carbon content among the various treatments after 1st spray except T2, where boron was applied as borax in soil and rest others were similar in nature. One week after 2nd foliar spray, slight drop in soil pH was noted, might be due to uptake of cationic nutrients by growing okra crop. The soils were acidic because of acidic parent material and the climate.

There was slight increase in soil organic carbon content in different treatments one week after1st spray compared to initial soil organic carbon, might be due to application of FYM common to all treatments and incorporation of more root biomass through growth enhancements during active growth stage of crop (Das *et al*., 2017). The soil organic carbon value one week after 2nd spray were diminished compared to that after 1st spray. It was due to subsequent decomposition and oxidation of organic matter in soil used by organisms present in soil.

The number of seeds sprouted was counted after 8 days of sowing and expressed in percentage. There was no significant difference due to boron application on emergence count but there was a significant difference within the date of sowing due to lower temperature13.6°C.Themaximum temperature was 29.1°C.



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