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Research Article

Effect of biofertilizer, zinc and boron on growth and yield of okra under the agro climatic conditions of Swat

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Abstract

The experiment titled "Effect of biofertilizer (*Trichoderma harzianum*) and micronutrients zinc and boron on growth and yield of okra" was conducted in (ARI) Agriculture Research Institute North Mingora Swat, during 2017. Research work was performed in a Randomized Complete Block Design with split plot arrangement in three replications. Two factors were used in the experiment i.e. Trichoderma (0, 10, 20 kg ha^{-1}) and micronutrients; zinc and boron (0, zinc 10 kg ha^{-1}, boron 5 kg ha^{-1}, zinc+boron). The analyzed data showed that Trichoderma significantly enhanced all the growth parameters. Minimum days to emergence (5.85), days to flowering (39.88), number of days to first picking (46.69), maximum plant height (131.60 cm), number of leaves plant^{-1} (35.82), pod length (15.96 cm), pod weight (24.33 g) and fresh pod yield (14.50 tons ha^{-1}) were recorded in plots treated with 20 kg ha^{-1}trichoderma. Zinc and boron combination significantly affected the growth and yield of okra. Plants treated with zinc + boron resulted in minimum days to emergence (5.63), days to 50 % flowering (39.45), number of days to first picking (47.12) maximum plant height (131.25 cm), number of leaves plant^{-1} (35.71), pod length (15.63 cm), pod weight (24.98g) and pod yield (14.73 tons ha^{-1}). It was found that Trichoderma is the best biofertilizer and should be used at the rate of 20 kg ha^{-1}, while micronutrients (Zinc 10 kg ha^{-1} and Boron 5 kg ha^{-1}) should be utilized for good growth and yield of okra in swat climate.

Keywords: Biofertilizer; Boron; Okra; Zinc

Introduction

Okra *(Abelmoschusesculentus* L.*)*, locally called bhindi, its family is Malvaceae. The origin of okra is tropical Africa. In India and Mediterranean, the wild forms of okra are found. Young pods of okra are the consumed parts of the plant, which are cooked, stewed and used in soaps. Okra contains minerals, protein, iodine and the basic three vitamins (A, B and C). Its seeds are used as a substitute for coffee when matured. From its stem, fiber is extracted that has multiple uses in paper industries **[1, 2]**.

Total production of okra in Pakistan was recorded as 123 thousand tones and cultivated on an area of 14.9 thousand ha. In

KP gross production of okra was 16 thousand tons and total area under cultivation was 2 thousand hectares, Production of okra in Punjab was 62.5 thousand tons, having area under cultivation was 5.6 thousand hectares, Baluchistan produced 16.5 thousand tons of okra having area under cultivation was 2.6 thousand hectares, while Sindh have cultivated area for okra 4.6 thousand hectares with the total production of 18.2 thousand tons **[3]**.

Okra has creamy flowers having 5-9 stamens. It is a self-pollinated crop **[4]**. Okra has a hard seed coat which does not absorb water easily. Seeds of okra are sowed 3 – 4 cm deep in soil on proper ridges with a distance of 50-70 cm. It can be also sown on raised bed. Plant to plant distance is kept 20 to 30 cm, while seed rate is kept 20 to 30 kg ha^{-1}**[5]**. In summer season, the crop is irrigated on the interval of six or seven days according to the need of the crop. 3 to 5 inches fresh pod of okra is considered fit for market and consumption. Pickings are done 2 to 3 times in a week **[6]**. It is best to pick the pods 6-7 days after flower opening depending on the variety and seasons. Usually, the simple method of picking is hand picking. Wearing of gloves is an important factor during okra picking otherwise, it causes irritation to hands. Irregular picking affects growth and production of okra. 9 to 11 tons ha^{-1} is the average yield of okra crop **[7]**. In order to produce the seed, pods are allowed to dry on the plant, and then dry pods are harvested to avoid the shattering of seeds. Seeds are dried and preserved in a cool dry storage. In normal storage condition, seeds are viable up to 2 years **[8]**.

Usually, okra crops are cultivated on a wide range of soil. The soil having organic matters, adequate amount of micronutrients and well drained is better for the production of okra. The pH which is required for the best production of okra varies from 6.0 to 7.0. In moist soil various cultivars do not show their actual performance and somewhat it tolerates acidity of soil. Malvaceae family does not tolerate frost condition and grow best in warm seasons. Approximately all of the okra cultivars are tolerent to excessive warm temperature. The favourable condition for seed germination of okra is warmer soil, because at the temperature below 16^{0}C the germination becomes unsuccessful. For suitable development of all growth stages of okra, the monthly average temperature range 21-30 ^{0}C is required **[9, 10]**. Seeds are sown in March or early April in plain areas while in hilly areas seeds are sown in April. Germination is a major problem of okra to prevent this, different methods of priming are used to break the hard seed coat of okra seeds for easy and better germination **[11, 12]**.

Okra requires excessive land preparation because it has deep root system. Before planting, seed is treated with priming techniques, soaking of seed is done for 24 hours in order to break the hard surface of seed to enhance the germination and growth rate of okra seeds. In order to get early crop of okra, it is cultivated on ridges. At interval of six or seven days the spring or summer crop should be irrigated **[13]**. Immature pods of okra are harvested at interval of two or three days **[4]**.

Plants need macro and micronutrients for their growth and development. Zinc is an important micronutrient of plant. Significant role of zinc is to activate different enzymes i.e protease, peptidase, amylase and phosphohydrolases. Zinc develops the ribosome, RNA and auxin and activates phosphate protein and carbohydrates **[14]**. Likewise, Boron is the fundamental minerals in all micronutrients which are necessary for growth of plant. Boron is related to cell wall strengthening, cell division and fruit and seed development. It also helps in pollen tube formation. Boron is one of the basic micronutrients that enhance major cellular functions and metabolic actions which positively affect many plants characters and which enhances growth and development of vascular plant **[15]**. Plants take it from soil in the form of boric acid **[16]**. Excess application of boron causes toxicity which may result in considerable loss in yield of many plants **[17, 18]**. It controls various physiological processes in plants like RNA, carbohydrates metabolism and cell wall elongation **[19]**.

Trichoderma is a saprophytic fungus. It builds up various antifungal metabolites containing many enzymes and antibiotics. it contains organic acids which reduce pH of soil due to which solubilization of micronutrients, phosphates and minerals such as manganese, magnesium and iron occur, which is the key step for plant metabolism **[20]**, *Trichoderma* discharges many antibiotics such as gilotoxin, trichodermine and virindin which were demonstrated to have antifungal activity for controlling different soil borne pathogenslike *Rhizoctonia solani pythium plant spp. Fusarium*, *Sclerotium rolfsii*etc **[21]**.

Trichoderma species, utilize different organic matters for food purpose. This fungus makes close association with roots of the plants in the surrounding soil. Trichoderma helps in the decomposition of organic matter making insoluble nutrients soluble. Trichoderma activate certain nutrients like phosphorous and iron. Some types of *trichoderma* improve growth and yield of different crops like bean, cucumber and pepper **[22]**.

The study was design to investigate the effect of trichoderma, zinc, boron on okra with the following objectives; to find out the effect of *Trichoderma* on growth and yield of okra, to sort out the best level of micro nutrients (boron and zinc) for maximum growth and yield of okra and to investigate the interactive effect of *Trichoderma* and micro nutrients.

Materials and methods

An experiment entitled "Effect of biofertilizer, boron and zinc on the growth and yield of okra under agro climatic conditions of Swat" was arranged in (ARIM) Agriculture Research Institute Mingora, Swat in April, 2017.

Experimental design

The factorial experiment was laid out in Randomized Complete Block Design (RCBD) with split plot arrangements. Each treatment was replicated three times. There were 36 experimental units (Table 1).

Table 1. Shows factors

Factor A Trichoderma	Factor B Zinc sulphate and Boric acid
T_1: Control	M_1: Control
T2: 10 kg ha^{-1}	M_2: $ZnSO_4$(10 kg ha^{-1})
T3: 20 kg ha^{-1}	M_3: H_3BO_3(5 kg ha^{-1})
	M4:$ZnSO_4$ (10 kg ha^{-1}) +H_3BO_3 (5 kg ha^{-1})

Soil analysis

Before treatment application, soil analysis was done to determine the current status of micro and macro nutrients in the soil. Soil sample was randomly collected using auger 10 cm deep. With the coordination of Agriculture Research Institute Mingora, Swat, laboratory the soil sample analysis took place.

Land preparation and sowing method

Field was prepared on 2nd April 2017. Before sowing of seeds, the field was properly ploughed and thoroughly prepared. The recommended doses of macronutrients NPK (90:45:45) were equally applied to experimental plots before sowing of seeds. The seeds of okra were sown on flat bed. Treatments combinations were assigned in the divided plots of the field. P to P distance was set aside 30 cm and R to R was kept 60 cm. The seed of okra cv. Swat green was sown in first week of April. All the culture practices were done uniformly.

Trichoderma and micronutrients (zinc sulphate, boric acid) application

Different doses of *Trichoderma harazianum*were mixed with sand and were broadcast to the main plots having some moisture before sowing of seeds. Agriculture research institute Mingora swat purchased trichoderma from Adalat Khan Agro services Swat. Different levels of zinc and boron were mixed with sand and applied to sub plots during seed sowing time.

Parameters studied

Following mention parameters were studied during the experiment.

1. Germination percentage
2. Days to emergence
3. Number of days to flowering
4. Number of days to first picking
5. Plant height (cm)
6. Number of leaves plant^{-1}
7. Pod length (cm)
8. Pod weight (g)
9. Pod yield (tons ha^{-1})
10. Benefit cost ratio

Statistical analysis

Data collected on various growth and yield parameters were subjected to analyse of variance using STATISTIX-8.1 and significance means were separated where appropriates by the least significance difference test at 0.05 probability levels.

Results and discussion

Germination percentage

The data related to days to emergence are shown in (Table 2), analysis of variance represented that Trichoderma, micronutrients and their interactions had non-significant affect on germination percentage, Maximum germination percentage (62.39%) was found in the plots treated with 20 kg ha^{-1} of trichoderma, followed by (61.76%) in plot treated with 10 kg ha^{-1} of trichoderma, while minimum germination percentage (60.52%) was obtained in control plot. In case of micronutrients, highest germination percentage (62.07%) was observed in the plant received combination of zinc sulphate and boric acid, followed by (61.79%) that was found in plants received 5 kg ha^{-1}boric acid whereas, minimum germination percentage (60.94%) was obtained in control plants. Trichoderma directly reduces the efficiency of biological activities in the seeds which ultimately reduce the germination percentage. The seeds treated with bio pesticides are sometime become toxic which adversely affect seed characters **[23]**.The obtained results are closely similar to **[24]** he also said that trichoderma has no effect on germination percentage

Number of days to emergence

The data related to days to emergence are shown in (Table 3), statistical analysis of the data indicated that trichoderma and micronutrients significantly affected days to emergence, however, their interaction was found non-significant. According to the mean value of days to emergence, minimum (5.81) days to emergence was noted in plots received 20 kg ha^{-1} of trichoderma, while maximum days to emergence (6.46) were recorded in untreated plot. Whereas in case of micronutrients, minimum (5.466) days to emergence were noticed in plants treated with combine application of zinc sulphate and boric acid, followed by days to emergence (6.11) in plants treated with 5 kg ha^{-1} boric acid, which was statistically similar with days to emergence (6.38) observed in plant treated with 10 kg ha^{-1} zinc sulphate, while maximum days to emergence (6.72) was recorded in control plant. Tremendous effect on growth of seedling and development has been observed in plants treated with trichoderma strain **[25]**. Our results are in close conformity with **[26]** who concluded that Trichoderma play vital role in improvement of soil performance by suppressing several types of soil pathogens. They also added that soil borne diseases are major constraints to emergence of crop plants. This can be controlled by application of Trichoderma as biological control having ultimate effect on days to emergence of seedlings and other characteristics of crops. Boron stimulates the concentration of carboxylic acid. The increased concentration of carboxylic acid stimulates cell division and elongation, which have direct effect on germination and ultimate response is emergence of crop plants **[27]** Furthermore, during early seed germination stages, zinc accumulates in seed when treated with zinc related soil application. Zinc is concentrated at aleurone layer and may help the seed to germinate early **[28]**. Early germination may lead to early emergence. Hence earlier emergence was recorded in plots treated with both boron and zinc.

Days to flowering

Data related to days to flowering are given in (Table 3), analysis of variance showed that Trichoderma and micronutrients significantly affected days to flowering, whereas their interactive result was found non-significant. Minimum days to flowering (64.95 days) was found in the plot received 20 kg ha^{-1} of Trichoderma, followed by (59.40 days) in plot supplied with 10 kg $ha^{-1}$of Trichoderma, while maximum days to flowering (55.48 days) were recorded in control plot. Likewise, minimum days (39.45 days) to flowering were observed in plants treated with combination of $ZnSO_4$ and H_3BO_3, followed by (41.37 days) plants treated with 5 kg ha^{-1} of boric acid, while maximum days to 50% flowering (44.46 days) were found in untreated plants. In case of Trichoderma, minimum days to flowering might be due to increased photosynthetic activity and uptake of food nutrients **[29, 30]**. **[20]** also stated that the Trichoderma is a rich source of organic acids which reduces the soil pH leading to solubilisation of phosphates, micronutrients, and minerals such as magnesium, manganese, and iron, which enhance the plant metabolism leading to early flowering and better yield of okra crop. The minimum days to flowering could be due to the facts that certain biological activities are activated by zinc which initiates flowering in okra as reported by **[31]** similarly, **[32]** also stated that optimum application of boron increased phosphorus uptake by plants roots. The increased phosphorus uptake initiated and promoted the formation of flowers in okra **[33]**. **[34]** stated that combine application of micronutrients Zinc and boron enhanced the synthesis and transport of assimilates from source tissues to sink which caused early flowering and fruiting in okra. Related results were also stated by **[35]** in tomato. Plant hormones are synthesized due to the application of zinc which improves shoots maturity to emerge early flowering **[36]**.

Number of days to first picking

The data relevant to the number of days to first picking are placed in (Table 3), mean table shows the replicated data. Trichoderma and micronutrients have significant affect on number of days taken to first picking. The interactive was found non-significant. Mean values show that the minimum number of days to first picking (46.69) was observed in the plots applied with Trichoderma at 20 kg ha^{-1}, followed by number of days to first picking (48.99) noted in those plots where 10 kg ha^{-1} of Trichoderma was applied, whereas maximum (50.22) number of days taken to first picking was noted in the control plots. In case of micronutrients, minimum (47.12) days to first picking were recorded in the plants treated with combination of zinc sulphate and boric acid, followed by number of days to first picking (48.10) recorded in the plants treated with 5 kg ha^{-1} of boric acid, whereas maximum (50.24) number of days to first picking were noted in untreated plants.

Minimum days to first picking were noticed in case of Trichoderma. It might be due to production of more carbohydrates and improved nutrients uptake in those plants which were treated with Trichoderma due to the reason that their chlorophyll swell up in leaves which increased photosynthates resulting in enlarge fruit length, fruit diameter which ultimately reduced number of days to picking in okra plants. Our results are further supported by **[37, 38]** as they studied that application of Trichoderma enhancedsucrose synthatase which helped in early fruit maturity. Same result also explains by **[26]** as they noticed that Trichoderma treated plants absorb more nutrients from root zone to plants, thus plants improved their growth and reproductive parameters. For early picking, boron is important because it may result in faster vegetative growth and then switch very quickly to reproductive growth leading to early flowering and fruit setting, which ultimately give early picking. These are in line with **[39]** who reported that combination of NAA and boron promoted early picking in bitter gourd plant. Likewise, application of $ZnSO_4$ also reduces days to first flowering. It might be due to formation of plant hormones which convert shoots to flower that lead to early fruit formation as reported by **[40]**. Same results are in conformity with **[41]** as he studied that zinc application reduced days to first flowering and enhanced emergence of early flowering in okra plant. **[42]** observed early days to first picking by the combined application of zinc and boron as they enhanced metabolic and photosynthetic activities which results in the production of more assimilates leading to increased cell division and early maturity of the okra. **[43]** Also reported that increased photosynthesis rate by combine application of zinc and boron led to early picking and maturity of the crop.

Plant height (cm)

In (Table 3) shows the mean data related to plant height. The statistical analysis of the data indicated that Trichoderma and micronutrients significantly affected the plant height, while their interaction was found non-significant.

Maximum plant height (131.60 cm) was obtained in plots apply with 20 kg ha^{-1} of Trichoderma, followed by (128.59 cm) plant height noted in plots supplied with 10 kg ha^{-1}Trichoderma, while lowest plant height (125.76 cm) was noted in untreated plots. In case of zinc and boron application, the highest plant height (131.25 cm) was observed in plants treated with combination of zinc sulphate and boric acid, followed by plant height (129.55 cm) supplied with 5 kg $ha^{-1}$of boric acid, which was statistically at par with plant height (127.60 cm) noticed in plants obtained with 10 kg ha^{-1} zinc sulphate, whereas the minimum plant height (126.21 cm) were noticed in untreated plants. Maximum plant height noted in case of boron and zinc treated plants are attributed to the role of boron in cell division, tissue differentiation and enhanced uptake of nitrogen which enhanced the growth of plant. These results are supported by **[44]** who observed increase in seedling height due to the application of boron. In case of boron and zinc, taller plants were recorded in plots applied with boron and zinc together. In general, boron is observed to inhibit the growth and development in excess amount. Studies have shown that sole application of boron has overall reduced the plant performance. But the studies on combined application of boron and zinc indicated that they show antagonistic effect in some aspects, but also have synergistic effect on the other side. Overall zinc diminishes the toxic effect but improves overall performance of boron in crops and hence results in enhanced growth and development performance **[45]**. These finding have similarity with **[46]** they observed that response of tomato plant have significant variation in terms of Trichoderma to control nematode and soil born pathogen. It may be due to the fact that Trichoderma excretes solubilising minerals and phytohormones which lead to significant plant height and is also used as bio agent against pathogens. The results are also in agreement with **[47]** who reported that Trichoderma treated plants improved microbes amount in the soil which helped in breakdown of organic matters and the nutrients became readily available that increased plant height.

Number of leaves plant^{-1}

Mean data regarding number of leaves plant^{-1} are given in (Table 3), the statistical analysis of variance shows that Trichoderma and micronutrients significantly affected the number of leaves plant^{-1}, while the interactive effect of both Trichoderma and micro nutrients was non-significant. Plots apply with 20 kg ha^{-1} Trichoderma resulted in maximum number of leaves plant^{-1} (35.83), followed by number of leaves plant^{-1} (33.10) recorded in plots treated with 10 kg ha^{-1}Trichoderma, while the least number of leaves plant^{-1} (31.44) was recorded in untreated plants.

In case of Zinc sulphate and boric acid application, the maximum number of leaves (35.71) was recorded in plants treated with combination of zinc sulphate and boric acid, followed by number of leaves (34.13) observed in plants received 5 kg ha^{-1} boric acid, which was statistically similar with number of leaves (32.76) noticed in plants received 10 kg ha^{-1} zinc sulphate, whereas the minimum number of leaves (31.21) was noticed in untreated plants. Trichoderma increased the uptake of nutrients by enhancing the root growth of the plants resulting in improving growth parameters of the plant including the number of leaves **[26]**. **[48]** Also reported that number of leaves increased with application of Trichoderma in tomato crop. Our results are further supported by **[49]** who reported that due to the application of Trichoderma, the insoluble minerals are converted into soluble form and uptake essential nutrients which are required for plant resulting in better vegetative growth and more number of leaves. **[50]** Reported that boron had significant effect on plant growth parameters like number of leaves plant^{-1} and fruit weight. It may be due to increase in photosynthetic and metabolic activities which are responsible for cell division and elongation. For photosynthesis, the leaves number and size are considered as important factor which determines the photosynthesis rate. Similarly, **[51]** stated that both zinc and boron application enhanced the uptake of nutrients and chlorophyll contents which resulted in increased vegetative growth including number of leaves plant^{-1} in tomato crop. Zinc is an important micronutrient which plays an important role in plants by activating many enzymes. **[52]** Stated that zinc increased the number of leaves in flax. **[53]** Recorded more number of leaves in gladiolus through the combine application of zinc and boron.

Pod length (cm)

Mean related to pod length are given in (Table 3), Trichoderma and micronutrients significantly affected pod length, whereas its interaction was non-significant. In case of Trichoderma, the highest (15.96 cm) pod length was noted in the plots apply with 20 kg ha^{-1} of Trichoderma, followed by pod length (14.62 cm) recorded in the plots treated with 10 kg ha^{-1}of Trichoderma. While the minimum pod length (13.29 cm) was noted in control plants. The highest pod length (15.63) was observed in case of micronutrients in the plants treated with combination of zinc and boron, followed by pod length (14.96) recorded in the plants treated with alone application of boron, while smallest pod length (13.70) was noticed in untreated plants. The increase in pod length might be due to bio fertilizers which encourage nutrients availability in the soil due to which the plant easily uptake all the essential nutrients which are the basic needs for the growth, nourishment and yield of plants **[54]**. Trichoderma sets off certain molecules and enzymes which facilitate the expansion and enlargement of fruit cells, due to this process increase occur in fruit volume. The obtained results are in agreement with **[55]** who noticed that due to many type of enzymes, Trichoderma activate cell elongation in plants. Our results are further supported with the work of **[56]** as they studied that the longest pod in chilli was noted with Trichoderma spp *harzianum*. The increase in pod length was associated with increased in size of pod and was probably due to boron and zinc that help in photosynthesis and translocation of food materials. Similar observation was reported by **[57]** similarly, **[58]** reported that application of zinc and boron promotes growth regulators activity which helps in sucrose assimilation related results were also reported by **[59]** they stated that combination of zinc and boron significantly increased pod length in lentil crop.

Pod weight (gm)

The data related to pod weight is given in (Table 3), Trichoderma and micronutrients application significantly influenced pod weight of okra while their interaction was found non-significant. Maximum pod weight (24.34 g) was noted in those plots which were treated with 20 kg ha^{1} of Trichoderma, followed by pod weight (21.96 g) plots which treated with 10 kg ha^{-1} of Trichoderma, whereas minimum pod weight (19.44 g) was observed in the control plot. In case of micronutrients maximum pod weight (24.98 g) was recorded in the plants treated with both zinc sulphate and boric acid combination followed by pod weight (22.79 g) in plants treated with boric acid and (21.45) was observed in plants treated with zinc sulphate, While minimum pod weight (18.44) was noted in control plants. In plants, boron and zinc might stimulated better utilization of minerals which might played prominent role in enhancing photosynthetic activities, metabolic mechanism and ultimately provision of assimilates to sinks. Similar findings were reported by **[60]** in bitter gourd. The optimum application of boron and zinc together has synergistic effect on other nutrients. They increase the utilization efficiency of different nutrients. Hence, nitrogen availability and its proper utilization help in improvement of vegetative growth like number of branches, number of leaves and plant height. Improved vegetative growth results in luxurious reproductive growth that showed ultimate effect on reproductive parts. Studies also have indicated that potassium utilization is also improved by combined application of boron and zinc. Improvement in potassium performance helps plant in enhanced physiological aspects like transpiration. The increased transpiration helps plant fix more CO_2, which can be converted to assimilate by translocation. Phosphorus use is also triggered by micro nutrients specifically zinc and boron which is the part of energy production and translocation system **[61]**. Our result is supported by **[62]** who concluded that due to the combine effect of zinc and boron, pod weight of mung bean crop was increased significantly. Trichoderma enhances the microbial population in soil which releases some exudates (organic substances) and increases the uptake of nutrients by enhancing the root growth or promoting availability of necessary nutrients and solubilising a number of poorly soluble nutrients in the soil which enhance the growth and yield contributing parameters including the fruit weight **[63, 64]**

Yield (tons ha^{-1})

Mean data regarding pod yield (tons ha^{-1}) are presented in (Table 3), Trichoderma and micronutrients significantly affected pod yield (tons ha^{-1}), whereas interaction was found non-significant. Maximum yield (14.50 tons ha^{-1}) was noted in the plots treated with 20 kg ha^{-1} of Trichoderma, followed by yield (13.06 tons ha^{-1}) in the plots treated with 10 kg ha^{-1} of Trichoderma while minimum yield (11.22 tons ha^{-1}) was observed in untreated plots. In case of micronutrients, maximum yield (14.73 tons ha^{-1})was obtained in the plant treated with the combine application of zinc sulphate and boric acid, followed by yield (13.39 tons ha^{-1}) recorded in the plants received only boric acid while minimum yield (11.26tons ha^{-1}) were obtained in untreated plants. The increase in yield may be attributed to the reason that Trichoderma enhances the production of various types of organic acid, which reduces the pH of the soil and enhances the solubilisation of micronutrients, phosphates, and mineral cations like manganese, iron, and magnesium which may improve the growth and yield of okra **[20]** Under different stress condition, Trichoderma induces defence mechanism and improves the performance of crops, which led to better yield **[65]**. **[66]** Reported that atmospheric nitrogen is converted into nitrates form by the addition of Trichoderma and also various types of phyto hormones are released by Trichoderma which causes maximum yield and yield related parameters. **[47]** Reported that the application of Trichoderma increased in the microbes decomposition process, which increased the availability of nutrients in the soil increases and maximum phothsynthates produced in the plants resulted in higher production of plants. Zinc and boron in combination are involved in enzymatic activities, which are important for protein synthesis, germination of pollen grain, fruit and seed development and consequently improved yield **[67, 68]**. Similar results were also observed by **[69]** who reported that application of Zn, Mn, and B increased the yield of okra. The obtained results are further supported by **[70]** who reported that crop yield increased due to the fact that zinc and boron had significant effect on photosynthesis, respiration, morphological activity and nitrogen metabolism which had synergistic effect on growth and yield.

Benefit cost ratio

In (Table 4) shows the data related to benefit cost ratio. The price of micronutrients and Trichoderma application at various levels were considered to calculate the benefit cost ratio. For all treatments, the cost of all cultural practices was similar, which have fixed cost. In case of Trichoderma, the maximum benefit cost ratio was observe in those plots which received 20 kg ha^{-1} of Trichoderma (11.16), followed by plants (9.66) which received 10 kg ha^{-1} of Trichoderma. The benefit cost ratio of 11.16 it means that if farmer spend Rs. 1 rupee on Trichoderma, he will get return Rs 11.16 in those plot which were treated with Trichoderma. In case of micronutrients zinc and boron treated plants the greatest benefit cost ratio (20.54) was observed in those plants which received combination of zinc sulphate and boric acid, followed by (18.44 Rs) in plants which were treated with 5 kg ha^{-1} of boric acid. (20.54 Rs) benefit cost ratio in plants treated with combination of zinc sulphate and boric acid means that if a farmer spends Rs 1 on buying zinc sulphate and boric acid he will earn Rs. 20.54.

Table 2. Soil analysis of the experimental site at Agriculture Research Institute Mingora, Swat (ARI) laboratory

Zinc	3.238 mg/kg
Boron	<0.5mg/kg
Sand	14.0%
Silt	68.0%
Clay	18.0%
Nitrogen	0.028%
Phosphorus	12.91%
Potassium	115.5%
Soil Texture	Silt loam
pH	6.4

Table 3. Germination (%), Days to emergence, No. of days to flowering, No. of days to first picking, Plant Height (cm), No. of leaves /plant, Pod length (cm), Pod Weight (g), Pod Yield (tons/hec)

Treatments	Germination %	Days to emergence	No. of days to flowering	No. of days to first picking	Plant Height (cm)	No. of leaves /plant	Pod length (cm)	Pod Weight (g)	Pod Yield (tons/hec)
Micronutrients									
Control	60.94	6.72a	44.66 a	50.24 a	126.21 b	31.21 c	13.70 b	18.44 c	11.26 c
$ZnSO_4$ (10kg ha$^{-1)}$	61.42	6.44ab	42.60 b	49.08 b	127.60 ab	32.76 bc	14.19 b	21.45 b	12.33 bc
H_3BO_3(5kg ha^{-1})	61.79	6.17b	41.37 b	48.10 bc	129.55 ab	34.13 ab	14.96 ab	22.79 ab	13.39 b
$ZnSO_4$(10 kg ha^{-1}) +H_3BO_3(5kg ha^{-1})	62.07	5.63c	39.45 c	47.12 c	131.25 a	35.71 a	15.63 a	24.98 a	14.73 a
LSD (0.05%)		0.46	1.31	1.06	4.37	2.29	1.41	2.41	1.21
Trichoderma (kgha^{-1})									
Control	60.52	6.58a	43.84 c	50.22 a	125.76b	31.44 b	13.29 c	19.44 b	11.22 b
10	61.76	6.29a	42.34 b	48.99 a	128.59 ab	33.10 ab	14.62 b	21.96 ab	13.06 ab
20	62.39	5.85b	39.88 c	46.69 b	131.60 a	35.82 a	15.96 a	24.33a	14.50 a
LSD (0.05%)		0.33	0.98	1.94	4.04	3.59	1.11	2.95	2.42

Table 4. Benefit to cost ratio ha^{-1} of okra crop as influenced by Trichoderma and micronutrients

Factor A *Trichoderma harzianum* (kgha^{-1})	Yield (kg ha^{-1})	Total incom (Rs)	Additional income	Additional cost of Trichoderma	BCR
20	145042	2320667	637917	57142.86	**11.16**
10	130592	1958875	276125	28571.43	**9.66**
Control	112183	1682750			
Factor B (Zinc and boron kg ha^{-1})					
10+5	147322	2018314	554514	27000	**20.54**
5	133878	1740411	276611	15000	**18.44**
10	123289	1602756	138956	12000	**11.58**
Control	112600	1463800			
Price of 1 kg *Trichoderma* spp powder in RS= 1000 Price of 1 kg zinc sulphate in Rs = 850 Price of 1 kg boric acid = 2800 Price of 1 kg okra = 40					

Conclusion and recommendation

After the experimental results, the following conclusions can be concluded, Maximum yield, plant height, pod length, pod weight, number of leaves, number of branches and minimum days to emergence, days to flowering, days to first picking were obtained with the application of Trichoderma at the rate of 20 kg ha^{-1}, In case of micronutrients all the growth and reproductive parameters were significantly enhanced by the combine application of zinc sulphate and boric acid., interactive effect of Trichoderma and micronutrients were non-significant for all the studied attributes. It is recommended that *Trichoderma harzianum*at the rate of 20 kg ha^{-1} is good for maximum growth and yield of okra, hence recommended for general cultivation of okra under the agro climatic condition of swat. The combination of $ZnSO_4$ and H_3BO_3 at the rate of 10 and 5 kg ha^{-1} is recommended for the good growth and yield of okra. Further research should be carried out to study different *Trichoderma species* with different micronutrients.

Authors' contributions

Conceived and designed the experiments: S Akbar & N Ara, Performed the experiments: S Akbar, MN Khan & S Sattar, Analyzed the data: S Akbar, R Khan, R Ali & Dawood, Contributed materials/ analysis/ tools: A Zeb & S Sattar, Wrote the paper: S Akbar & MN Khan.

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