OPEN ACCESS J. Plant Environ. 05 (02) 2023. 171-179 DOI: 10.33687/jpe.005.02.4009

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Available Online at EScience Press
Journal of Plant and Environment
ISSN: 2710-1665 (Online), 2710-1657 (Print)
https://esciencepress.net/journals/JPE

Combine Application of Zinc and Boron Improves Pearl Millet (*Pennisetum glaucum*) Performance Under No Tillage and Plough Tillage

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ARTICLE INFO

Article History
Received: May 05, 2023
Revised: June 09, 2023
Accepted: September 11, 2023

Keywords
Tillage
Micronutrients
Zinc
Boron
Millet
Growth and yield

ABSTRACT

No-tillage (NT) and crop rotation with green manure crops is a best alternative to plough tillage because it sustains environmental health, conserves natural resources and also improves crop growth and yield Conventional tillage practices result in losses of soil, water, and nutrients in the field, as well as degraded soils with low organic matter content and unstable physical structures, resulting in low crop yields and inefficient water and fertilizer usage. Micronutrient deficiencies, such as zinc (Zn) deficiency, are becoming more common in various annual crops as a result of continuous tillage. Zn has specific and essential physiological functions in plant metabolism, influencing yield and quality. Boron (B) plays an important role in the physiological process of plants, such as cell elongation, cell maturation, meristematic tissue development, and protein synthesis. To evaluate the role of Zn and B this experiment was performed in College of Agriculture BZU Bahaddar Sub Campus Layyah. The experiment was comprised of two tillage systems (No tillage and plough tillage) and three treatments application including (Zn, B, Zn+B) compared with control. These treatments were arranged according to RCBD split plot arrangement with net plot size of 1.8×4m. Findings of this study revealed that combine application of Zn and B boosted pearl millet growth and yield under no-tillage. Maximum relative water contents (RWC), membrane stability index (MSI), chlorophyll pigment, plant height, tillers per plant, leaf area index (LAI), stem diameter, length of ear head, seeds per ear, grain mass, grain yield, biological yield and 1000 grains were recorded when combine application of Zn and B was done under no-tillage. From the results it was concluded that pearl millet growth and yield can be maximized through combine application of Zn and B under no tillage.

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INTRODUCTION

Pearl millet (*Pennisetum glaucum*) generally familiar as bajra has tolerance against water stress and also it is used as staple food for the poor people. It gives its desirable yield potential grown in the areas where average rainfall is below 200 to 250 mm that makes it highly adoptive cereal crop under arid and semi-arid regions (Bidinger and Hash, 2003). Its yield is negatively affected by the amount of annual rainfall. That's why it is necessary to overcome this negative impact of Pearl Millet yield due to irregular rainfall pattern by suitable moisture conserving techniques (Verma *et al.,* 2017). There are several such strategies that enhance the crop water use efficiency for long period of time under drought stress by ensuring the availability of water in crop root zone under arid climate. Tillage is the most important strategy to conserve soil moisture in the plant root zone. Various tillage practices including no tillage maximize the moisture availability to crop that positively improved the yield of cereal crops under an arid climate (Neema *et al.,* 2008; Sinha *et al.,* 2011). Cost of production is an important factor for our rainfed farmer community that can be minimized by the no tillage. On the basis of numerous reports, practice of zero/minimum tillage can understandably be incorporated owing to its positive effects in sustaining the soil fertility by maintaining the crop residues on soil surface and improving water use efficiency and physical conditions of soils that is ultimately reflected in the enhanced crop productivity under rainfed conditions (Dala and Chaan, 2001).

Conventional tillage practice results in loss of soil water and nutrients in the field, as well as it deprives soils organic matter contents and disrupts soil physical structure that ultimately minimizes soil water and nutrient use efficiency that ultimately results in low crop yields (Wang *et al.,* 2007). Conservation tillage is defined as any agricultural practice that reduces soil erosion by leaving at least 30% of crop residue on the soil surface during the growing season (Benites *et al.,* 1998). Many nations have introduced conservation tillage methods like as minimum soil disturbance, stubble to preserve soil cover, and straw blending into the soil (Omara *et al.,* 2019). Conservation tillage methods, such as decreased tillage and mulch tillage, have gained popularity in recent years as a way to keep soil healthy, encourage plant development, and protect the environment (Bartaula *et al.,* 2020). These outcomes can be ascribed to conservation tillage's improved nutritional quality and changes in soil bacterial community structure (Yang *et al.,* 2018).

Mineral nutrition of plants is important for controlling physiological and biochemical processes of plants (Ahmad, 2009). Micronutrients are essential elements for life (Malakouti, 2008), as they play key roles in the release of carbon dioxide and in optimizing the function of vitamin A and the immune system (Marschner, 1995). The amount of trace elements found in soil is sometimes so small that they are barely detectable, but without them, plants fail to survive (Carrol, 2015). Micronutrient deficiency can greatly affect plant yield and quality and the health of domestic animals and humans negatively (Welch, 2003). Application of micronutrients through foliage can be from 10 to 20 times as efficient as soil application (Zaman and Schumann, 2006). Boron (B) plays an important role in the physiological process of plants, such as cell elongation, cell maturation, meristematic tissue development, and protein synthesis (Mengel and Kirkby, 1982). The need for B application in plants is therefore, to increase the growth, development, and at the same time to increase the yield of crops. The application of B also promotes the absorption of N in legumes and increases the plant height, plant dry weight, and the total number of pods (Fing et al., 1994). Globally, zinc (Zn) is now recognized as the 5th major nutrient deficiency in human beings mainly due to its deficiency in the soil. Zn has specific and essential physiological functions in plant metabolism, influencing yield and quality (Suri et al., 2011). Zinc plays a key role in plants with enzymes and proteins involved in carbohydrate metabolism, protein synthesis, gene expression, auxin (growth regulator) metabolism, pollen formation, maintenance of biological membranes, protection against photo-oxidative damage and heat stress, and resistance to infection by certain pathogens (Alloway, 2008). Keeping in view above importance of zero tillage for moisture conservation and in improving crop growth and productivity as well as beneficial aspects of zinc and boron application the following study was conducted to evaluate the suitable tillage practice for millet production and also to explore the combine effect of zinc and boron on millet growth and yield.

MATERIAL AND METHODS

Site description

In the summer of 2020, an experimental study was conducted at the BZU Bahadur Sub Campus Layyah 151m above sea level and 30.9 N and 70.9 E Pakistan. A sandy loam texture soil with electrical conductivity of 1.05 ds/m, pH of 8.4, organic matter of 0.8 percent, available phosphorus of 8 ppm, and available potassium of 85 ppm was used in the experiment.

Weather data for the entire growth duration of crop is provided (Figure 1). Randomly 3 soil samples gathered selectively from the field before seeding, and a representative sample was created to identify the soil chemical characteristics. The results of the soil analysis are presented in the form of a report (figure 2).

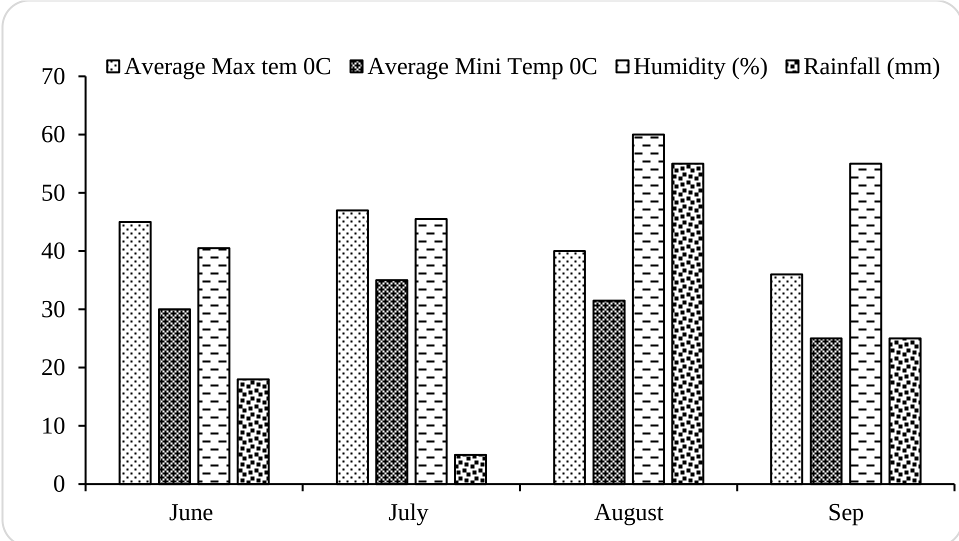

Figure1. Weather data for whole crop season.

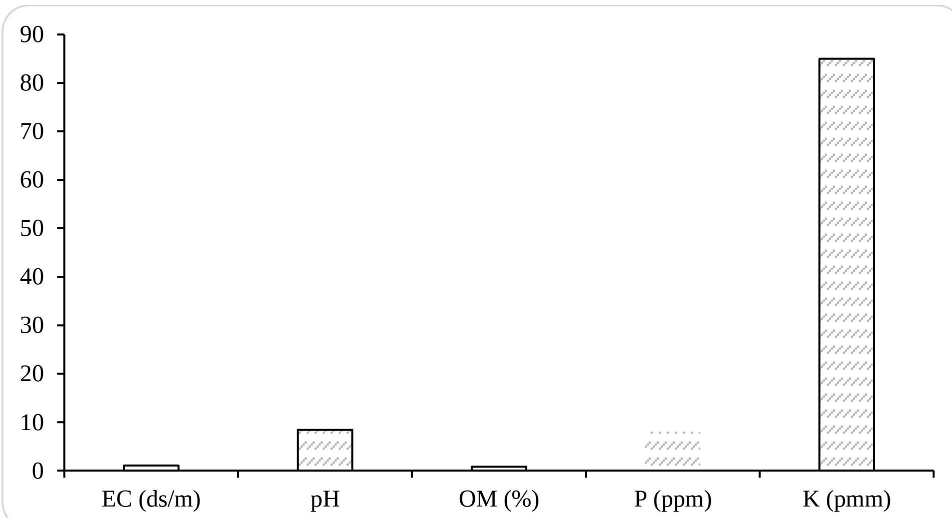

Figure 2. Soil analysis EC = electrical conductivity, OM = organic matter, P = phosphorus and K = potassium.

Experimental details

A tractor-drawn cultivator was used to prepare the soil, and seeds were sowed with a drill. There were two distinct aspects in the experimental treatments. Tillage systems and foliar sprays of zinc, boron, and zinc + boron, as well as a control application in various tillage systems, were used in this experiment. Two tillage systems are used in the trial. After harvesting the previously grown crop directly sowing with hand drawn drill was made in order to maintain the no-till practice, but seed bed was prepared through cultivator in order to maintain the conventional tillage practice, at sowing time zinc, boron, zinc + boron and control treatments were applied to each experimental unit. The treatments were split into three replications in an RCBD split plot layout. The net plot size remained the same at 1.8m × 3m.

Crop husbandry

The experimental field received 12 cm of pre-sowing irrigation. When the field was ready to sow after 6 days, it was prepared according to the experiment's requirements. The millet cultivar SGD.bajra-2011 was used in this study, and the seed was obtained from AARI (Ayoub agriculture research institute Faisalabad) in Punjab, Pakistan. On June 15, 2020, the crop was established. N with recommended dose of 50 kg ha^{-1} and P with recommended dose of 100 kg ha^{-1}were applied using diammonium phosphate (DAP) and urea.

Micronutrients such as zinc (zinc sulphate) and boron were applied at time of seed bed preparation with 2 kg ha^{-1} and 15 kg ha^{-1} respectively to the soil, but in control treatments no zinc and boron was applied.

Observations

Growth traits: Leaf area index was calculated by harvesting the plants from the bottom of plant from each experimental unit from the area of 1 feet square. Leaf area was determined by measuring the leaf length and leaf width of all harvested leaves from an area of 1 feet square. Using the area of the leaves it was multiplied by factor 0.68 as a criterion (Wasaya *et al*., 2017). The Leaf Area Index (LAI) was then measured from the ratio of harvested leaf area to area of from the harvested. The following formula was used to determine LAI:

$$\text{LAI} = \frac{\text{Leaf area}}{\text{Land area}}$$

Photosynthetic traits

Chlorophyll pigment: Five plants were selected randomly for chlorophyll contents measurement, and the chl value of each experimental unit was measured from the photosynthetic leaf of plants three times with a SPAD chlorophyll meter (SPAD-502Plus; Konica Minolta, Chiyoda) and then averaged.

Relative water contents: Five young fully grown leaves were collected from each sub-plot at 11-12 a.m. local time and stored in plastic bags in an ice tank before being transferred to the laboratory. 10 leaf discs of uniform size were provided, and the discs' fresh weight (Fw) was recorded. The leaf discs were then immersed in distilled water for 24 hours in the dark at 4°C. Prior to determining turgid weight, water on the leaf surface was rapidly and carefully dehumidified with tissue paper after soaking (Tw). Finally, drying of the leaf discs was made for 24 hrs at 80°C to acquire dried mass (Dw). The following equation was used to get the RWC value:

$$\text{RWC} = \frac{\text{FW} - \text{DW}}{\text{TW} - \text{DW}} \times 100$$

where, FW (fresh weight), DW (dried weight) and TW (turgid weight) (Soheila and Kazem, 2015).

Membrane stability index: According to (Sairam *et al*., 1997) leaf MSI was calculated. 100 mg of leaf material was taken in two sets of 100 mgs tubes beaker containing 10 ml of distillery water for MSI estimation. The EC of the absorbed solvent was noted through a bridge conductance (C1) after one set was heated in a water bath for 30 mins at 40^0C temperature (Elico, CM183EC-TDS analyzer, India). Another sample was heated for 10 minutes on a boiling water bath at 100 °C, then tested on a conductivity bridge (C2). The MSI was calculated as follows:

$$\text{MSI} = \left[1 - \left(\frac{\text{C1}}{\text{C2}}\right)\right] \text{ x } 100$$

Morphological and yield attributes

Random selected plants from each treatment were selected and plant height was examined through a meter rod. Plants were harvested from every treatment from an area of m^2 and their tillers were noticed manually to identify the tiller per m^2. After observing the tillers of each experimental treatment biomass yield of these harvested plants from an area of m^2 was measured by using a digital weighing balance. After the measurement of biomass of each experimental treatment spikes of these plants were detached from the plants and their length was observed by using the meter scale in cm. Afterward the measurement of spike size spikes of these random chosen plants, seeds of each spike were counted by using seed counter identify the grain the number per spike. The total yield of every experimental treatment was measured in grams and then changed into kg/ha after observing the spikelets per spike grain removed from these randomly selected plants. Using a electronic seed counter, thousands of grains were counted in each experimental unit and then weighed to determine the 1000 grain weight of every treatment of experiment. HI was calculated by ratio of economic yield to biomass yield by multiplying it with 100.

$$\text{HI} = \frac{\text{Economical yield}}{\text{Biomass yield}} \times 100$$

Statistical analysis

Statistix 8.1 was used to analyze the data, and LSD was used to compare treatment means at a 5% probability level (Steel *et al.,* 1997).

RESULTS

Results of this study indicated that various tillage practices, zinc and boron applications significantly affected the Relative water content of pearl millet. In case of tillage practices maximum relative water content were recorded in no tillage (76.2) where crop was sown directly after harvesting the previous crop without any disturbance in the soil while minimum Relative water content was notice in conventional tillage (63.7). In the case of zinc and boron application maximum Relative water content were recorded where zinc and boron were applied together (74.6) while minimum Relative water content were observed in control treatment (65.2) where nothing was applied. Interaction between tillage, zinc and boron application was found non-significant against Relative water content (Table 1).

Table 1. Effect of various tillage practices, zinc and boron application on pearl millet growth and photosynthetic traits.

Treatments		LAI	RWC	MSI	Chl-SPAD value
Tillage	ZT	4.7 A	76.2 B	78.0 A	52.5 A
	CT	4.2 B	63.7 A	67.5 B	44.5 B
LSD≤0.05		0.13	1.13	0.23	1.24
Z+B Application	Control	4.3 D	65.2 D	68.9 D	45.5 D
	Zn 2 kg ha^{-1}	4.4 C	68.4 C	71.5 C	47.5 C
	B 15 kg ha^{-1}	4.5 B	71.5 B	74.1 B	49.5 B
	Zn+B	4.7 A	74.6 A	76.7 A	51.5 A
LSD≤0.05		0.02	0.35	0.04	0.21
Interaction		ns	ns	ns	Ns

Membrane Stability Index of pearl millet was also significantly affected by various tillage practices, zinc and boron application. In case of tillage practices maximum Membrane Stability Index was recorded in no tillage (78.0) where crop was sown directly after harvesting the previous crop without any disturbance in the soil while minimum Membrane Stability Index was notice in conventional tillage (67.5). In case of zinc and boron application maximum Membrane Stability Index were recorded where zinc and boron were applied together (76.7) while minimum Membrane Stability Index was observed in control treatment (68.9) where nothing was applied. Interaction between tillage, zinc and boron application was found non- significant against Membrane Stability Index (Table 1).

Various tillage practices, zinc and boron application significantly affected the chlorophyll contents of pearl millet. In case of tillage practices maximum chlorophyll contents were recorded in no tillage (52.5) where crop was sown directly after harvesting the previous crop without any disturbance in the soil while minimum chlorophyll contents were notice in conventional tillage (44.5). In case of zinc and boron application maximum chlorophyll contents were recorded where zinc and boron were applied together (51.5) while minimum chlorophyll contents were observed in control treatment (45.5) where nothing was applied. Interaction between tillage, zinc and boron application was found non-significant against chlorophyll contents (Table 1).

Various tillage practices, zinc and boron application significantly affected the leaf area index of pearl millet. In case of tillage practices maximum leaf area index was recorded in no tillage (4.7) where crop was sown directly after harvesting the previous crop without any disturbance in the soil while minimum leaf area index was notice in conventional tillage (4.2). In case of zinc and boron application maximum leaf area index was recorded where zinc and boron were applied together (4.7) while minimum number of tillers were observed in control treatment (4.3) where nothing was applied. Interaction between tillage, zinc and boron application was found non- significant against leaf area index (Table 1).

Various tillage practices, zinc and boron application significantly affected the morphological traits like plant height, tillers, stem diameter, spike length and ear heads of pearl millet. In case of tillage practices maximum plant height, tillers, stem diameter, spike length and ear heads were recorded in no tillage (160.7 cm, 5.2, 7.6 cm, 21 cm, 26.7 m^{-2}) respectively where crop was sown directly after harvesting the previous crop without any disturbance in the soil while minimum plant height, tillers, stem diameter, spike length and ear heads were noticed in conventional tillage (140.5 cm, 2.9, 3.2, 5.1 cm, 14 cm and 25.1 m^{-2}) respectively. In case of zinc and boron application maximum plant height, tillers, stem diameter, spike length and ear heads were recorded where zinc and boron were applied together (168.4 cm, 4.9, 7.3 cm, 20.1 cm and 26.5 m^{-2}) respectively while minimum plant height, tillers, stem diameter, spike length and ear heads were observed in control treatment (140.7 cm, 3.2, 5.4 cm, 14.9 cm and 25.3 m^{-2}) respectively where nothing was applied. Interaction between tillage, Zn and B was found non-significant against plant height, tillers, stem diameter, spike length and ear heads (Table 2).

Table 2. Effect of various tillage practices, zinc and boron application on pearl millet morphological and yield attributes.

Treatments		Plant height	Tillers per Plant	Spike length (cm)	Earheads m^{-2}	Seeds per spike	Grain weight per earhead (g)	Grain yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Thousand grain weight (g)	HI (%)
Tillage	ZT	160.7 A	5.2 A	21.0 A	26.7 A	1248.7 A	20.1 A	1633.4 A	4208.4 A	16.5 A	48.9 A
	CT	140.5 B	2.9 B	14.0 B	25.1 B	916.5 B	18.4 B	1233.1 B	2964.9 B	9.3 B	38.8 B
LSD≤0.05		1.25	0.99	2.25	0.17	11.8	0.91	9.93	9.13	0.29	0.98
Z+B Application	Control	140.7 D	3.2 D	14.9 D	25.3 D	958 D	18.6 D	1283.2 D	3120.3 D	10.2 D	40.1 D
	Zn 2 kg ha^{-1}	148.0 B	3.7 C	16.6 C	25.7 C	1041 C	19.0 C	1383.2 C	3430.9 C	12.0 C	42.6 C
	B 15 kg ha^{-1}	145.2 C	4.3 B	18.4 B	26.1 B	1124 B	19.5 B	1483.3 B	3741.6 B	13.8 B	45.1 B
	Zn+B	168.4 A	4.9 A	20.1 A	26.5 A	1207.5 A	19.9 A	1583.4 A	4053.8 A	15.6 A	47.7 A
LSD≤0.05		0.93	0.16	0.31	0.02	2.28	0.03	1.62	1.63	0.07	0.13
Interaction		**	Ns	Ns	ns	ns	ns	ns	ns	ns	ns

Various tillage practices, zinc and boron application significantly affected the yield traits like seeds per earhead, grain weight per earhead, grain yield kg ha^{-1}, biological yield kg ha^{-1}, thousand grain weight and harvest index of pearl millet . In case of tillage practices maximum seeds per earhead, grain weight per earhead, grain yield kg ha^{-1}, biological yield kg ha^{-1}, thousand grain weight and harvest index were recorded in no tillage (1248.7, 20.1g, 1633.4 kg ha^{-1}, 4208.4 kg ha^{-1}, 16.5 g and 48.9) respectively where crop was sown directly after harvesting the previous crop without any disturbance in the soil while minimum seeds per earhead, grain weight per earhead, grain yield kg ha^{-1}, biological yield kg ha^{-1}, thousand grain weight and harvest index were noticed in conventional tillage (916.5, 18.4 g, 1233.1 kg ha^{-1}, 2964.9 kg ha^{-1}, 9.3 g and 38.8) respectively. In case of zinc and boron application maximum seeds per earhead, grain weight per earhead, grain yield kg ha^{-1}, biological yield kg ha^{-1}, thousand grain weight and harvest index were recorded where zinc and boron were applied together (1207.5, 19.9 g, 1583.4 kg ha^{-1}, 4053.8 kg $ha^{-1,}$ 15.6 g and 47.7) respectively while minimum seeds per earhead, grain weight per earhead, grain yield kg ha^{-1}, biological yield kg ha^{-1}, thousand grain weight and harvest index were observed in control treatment (958, 18.6 g, 1283.2 kg ha^{-1}, 3120.3 kg ha^{-1}, 10.2 g and 40.1) respectively where nothing was applied. Interaction between tillage, zinc and boron application was found non- significant against seeds per earhead, grain weight per earhead, grain yield kg ha^{-1}, biological yield kg ha^{-1}, thousand grain weight and harvest index (Table 2).

DISCUSSION

Pearl millet (*Pennisetum glaucum*) is the sixth most essential cereal crop worldwide and the fourth among important tropical cereals (Ismail *et al.,* 2012). Pearl millet adaptable grain that can be used for food, feed, and forage. Therefore, this crop is considered to be a first-rate element of the protection of the meals of the agricultural poor in the hot and dry areas of the world, which include Pakistan (Vadez *et al.,* 2012).

As a C4 plant, because of the upright leaf type (Carberry *et al.,* 1985) and excessive radiation use efficiency (RUE) (Squire *et al.,* 1986) to 4 g MJ-1 (Ram *et al.,* 1999). Despite its excessive efficiency, the production of pearl millet in Pakistan is very low in comparison to other countries (Ayub *et al.,* 2007; ICRISAT, 2016). The fundamental motives for the low yields in Pakistan are the shortage of most beneficial production options (poor crops, poor planting time), incorrect management methods and insufficient use of micronutrients (mainly zinc and boron) and different grain competition and incapability to fulfill crop demand (Ayub *et al.,* 2007; Sanon *et al.,* 2014). Therefore, it is important to attend our research on a way to great recognize the productiveness ability through figuring out appropriate development measures to grow the yield of millet through suitable farming techniques. Keeping moisture is the maximum important. The results of this study show that zero-tillage improves crop growth and yield (Table 1,2). Nema *et al.* (2008) and Sinha *et al.* (2011) mentioned the useful results of numerous tillage strategies on water retention and Kharif grain yield, by minimizing the threat of crop failure under rain-fed conditions (Aina *et al.,* 1991). The outcomes of our study confirmed that the maximum relative water content, MSI, chlorophyll content, plant height, number of tillers, stem thickness, ear length, number of spikelets, number of grains per ear, organic yield, grain yield, and harvest index were recorded under no-tillage (Table 1,2). It is well known that NT control practices were documented as a part of environmentally wise agricultural practices that can grow crop yields and soil nutrient content (Huang *et al.,* 2018; Devita *et al.,* 2007). In addition, the usage of no-till techniques to return residues to the soil has an effective impact on soil nutrient accumulation and crop yields. Using this method, straw residues are allotted on the top of the soil for the duration of the sowing process; only the soil within the row is disturbed. When evaluating NT with conventional farming techniques, NT confirmed sustained crop yields and improved soil fertility (Wang *et al.,* 2017; Yang *et al.,* 2016; Omara *et al.,* 2019). It is predicted that about 155 million hectares of land globally are controlled through the Northern Territory agricultural system. When thinking about the yield overall performance response to NT practice, it is really well worth noting that there's additionally a certain consistency with the literature results (Pittelkow *et al.,* 2015).

Micronutrient deficiency can significantly have an effect on plant yield and quality, in addition to the health of farm animals and humans (Welch, 2003). The application of micronutrients through leaves is 10 to 20 times extra efficient than soil application (Zaman and Schumann, 2006). The outcomes of this examine confirmed that the micronutrients boron and zinc progressed the growth and yield attributes of pearl millet (Table 1,2). Reason of this improvement may be that boron (B) is a micronutrient important to the growth and health of all crops. It is a necessary part of plant cell walls and reproductive structures. It is a mobile nutrient in the soil, which means it is easy to move in the soil. Since a small quantity is needed, it is essential to provide B as evenly as possible across the field (Jaison *et al.,* 2018). Boron is one of the important micronutrients of plants. It is unique among essential elements because a narrow concentration range may mean the difference between plant deficiency and phytotoxicity. Although parts per million may be required, components per million may be harmful to plants (Muntean, 2009). Therefore, it is important to apply B in peanuts to promote growth and development and increase crop yields on an equal time. Application of B also promoted the absorption of N by peanuts, increasing plant height, plant dry weight, and the total number of pods (Jing *et al.,* 1994). Abbas *et al.* (2009) determined that different Zn ranges drastically affect ear length, ear number, thousand-grain weight, and straw yield. Abbas *et al.* (2009) pointed out that foliar micronutrients (boron and zinc) give the largest average of the yield parameters of all studies. (Ali *et al.,* 2009) talked about that the number of ears heads m^{-2}, 1000 grain weight, biological yield, and grain yield were increased with the foliar application of zinc and boron (Bergman, 1992).

CONCLUSION

It is concluded from the results combine application of Zn and B under no tillage improves pearl millet growth and yield under arid climate of Layyah. Combine application of Zn and B with 2 kg ha^{-1} and 15 kg ha^{-1} rate respectively enhanced the pearl millet growth attributes photosynthetic traits and yield behavior under no tillage system.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

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