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Effect of macro and micro nutrients on the growth and grain yield of maize (*Zea mays* L.)

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Abstract

The study revealed that treatment T_7 = NPK + Zinc (130 + 65 + 35 + 2 kg ha^{-1}) recorded maximum plant population (7.6 m^{-2}), plant height (193.3 cm), stem girth (6.4 cm), cobs $plant^{-1}$ (2.2), cob length (21.3 cm), cob weight (163.0 g), seed weight cob^{-1} (70.6 g), seed index (212.3 g), biological yield (13333 kg ha^{-1}) and grain yield (3433.33 kg ha^{-1}) followed by plant population (6.6 m^{-2}), plant height (179.3 cm), stem girth (6.0 cm) cobs $plant^{-1}$ (1.9), cob length (17.3 cm), cob weight (149.6 g), seed weight cob^{-1} (65.0 g) seed index (193.3 g) biological yield (12833 kg ha^{-1}) and grain yield (3000.0 kg ha^{-1}) observed in treatment T_8 = NPK + Boron (140 + 70 + 40 + 2 kg ha^{-1}). Application of treatment T_2 = NPK + Boron (100 + 50 + 25 + 2 kg ha^{-1}), treatment T_3 = NPK + Zinc (100 + 50 + 25 + 2 kg ha^{-1}), treatment T_4 = NPK + Boron (120 + 60 + 30 + 2 kg ha^{-1}), treatment T_5 = NPK + Zinc (120 + 60 + 30 + 2 kg ha^{-1}), treatment T_6 = NPK + Boron (130 + 65 + 35 + 2 kg ha^{-1}) and treatment T_9 = NPK + Zinc (140 + 70 +40 + 2 kg ha^{-1}) were ranked in each related ranking 3rd, 4th, 5th, 6th, 7th and 8th almost all traits studied. Whereas, the minimum plant population (3.7 m^{-2}), plant height (143.7 cm), stem girth (3.3 cm), cobs $plant^{-1}$ (1.0), cob length (10.0 cm), cob weight (110.0 g), seed weight cob^{-1} (42.6 g), seed index (175.6 g), biological yield (11683 kg ha^{-1}) and grain yield (2236.7 kg ha^{-1}) was observed under treatment T_1 = Control (un-treated) where no any fertilizer was applied. The results were statistically significant at ($P<0.05$) as affected by different applications of macro and micro nutrients on the growth and yield of maize. It is concluded that the crop was fertilized with NPK + Zinc (130 + 65 + 35 + 2 kg ha^{-1}) macro and micro nutreitns gave best results for getting higher yield of maize crop as compared to other applications of the macro and micro nutrients.

Keywords: nutrients, growth, grain, maize

1. Introduction

Maize (*Zea mays* L.) has high genetic yield potential than other cereal crops. Hence it is called as 'miracle crop' and also as 'queen of cereals'. As heavy feeder of nutrients, maize productivity is largely dependent on nutrient management. The fertility of soil is deteriorating gradually due continuous cropping, soil erosions, loss of nutrients, accumulation of salts and other toxic elements, water logging and unbalanced nutrient compensation [1]. The soils are severely deficient of macro and micro nutrients, because farmers are practicing continuous cropping and insufficient use of manures to the soil. Both macro and micro nutrients are essential for plant growth and if a plant does not get enough nutrients, the deficiency symptoms appear on the plant [2]. Macronutrients are those elements needed in large amounts by the crop and large quantities have to be applied if the soil is deficient in one or more of them. Nitrogen (N), phosphorus (P) and potassium (K) are the "primary macronutrient" and these form the basis of NPK fertilizer compounds. The "secondary macronutrients" are calcium (Ca), magnesium (Mg) and sulphur (S). Fertilizers containing these elements are available in the market but not many maize farmers use these fertilizers.

Meanwhile, micronutrients are those elements required in very small quantities. Despite being needed in small quantities, micronutrients are essential for the overall performance and health of the maize crop. They include iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), molybdenum (Mo) and boron (B) [3] and [4]. Micronutrient deficiencies are usually appear on the new leaves of maize for example: zinc hunger symptoms may appear with in the first two weeks after crop emergence as a broad band of yellowing tissue on one or both sides of the leaf mid rib (leaf center). Symptoms may be reversed using zinc sulphate fertilizer. Another acutely deficient micronutrient in arable soils is boron. Boron deficiency may easily be mistaken for iron deficiency where there is a general stunted growth and leaves fail to uncurl properly.

However, without boron, leaves may fail to emerge altogether. Boron availability is reduced under low rain fall/drought conditions or in soils low in organic matter. Farmers maintaining high levels of organic matter in their fields normally do not face boron deficiencies [4]. The maize crop needs adequate supply of nitrogen and phosphorus through mineral fertilizer use. Excessive application of nitrogen and phosphorus fertilizers may induce copper deficiencies. It important to note that the extent and severity of nutrient hunger symptoms can be addressed by a variety or fertilizers, which may be applied basally or as foliar applications [4].

N, P and K are essentially required elements for crop production. Plants are surrounded by the N in our atmosphere. Despite nitrogen being one of the most abundant elements on earth, nitrogen deficiency is probably the most common nutritional problem affecting plants worldwide. Nitrogen is considered as an essential element of bio-molecules such as amino acids, proteins, nucleic acids, phytohormoes and number of enzymes and coenzymes. N strongly stimulates growth, expansion of the crop canopy and interception of solar radiation [5]. P is another essential nutrient both as a part of several key plant structure compounds and as a catalysis in the conversion of numerous key biochemical reactions on plants. P is noted especially for its role in capturing and converting the sun's energy into useful plant compounds: thus P is essential for the general health and vigor of plants.

Some specific growth factors that have been associated with P are: stimulated root development, increased stem strength, improved flower formation and seed production, more uniform and earlier crop maturity, increased nitrogen N-fixing capacity of crops, improvements in crop quality and increased resistance to plant diseases [6]. Similarly, K is also essential nutrient required for plant growth and reproduction. It is classified as a macro nutrient, as are N and P.

Potash is defined as K_2O and is used to express the content of various fertilizer materials containing potassium, such as muriate of potash (KCl), sulphate of potash (K_2SO_4), double sulphate of potash and magnesium (K_2SO_4, $MgSO_4$) and nitrate of potash (KNO_3). K plays a vital role in photosynthesis, translocation of photosynthates, protein synthesis, control of ionic balance, regulation of plant stomata and water use, activation of plant enzymes and many other processes [7]. Application of both macro and micro nutrients have been reported to crop productivity [8].

Amongst the cereals, maize is a rich source of essential nutrients needed by both human beings and animals. In plant nutritional condition, as stated for maize and wheat [9, 10]. However, micronutrients can be applied directly into the soil as well. Soil applied Zn is effective in enhancing the grain yield whereas Zn concentration in grain improves based on particular studies, [11] is of the view that soil applications of zinc enhances the yield of crops whereas [12] have also concluded that increased Zn uptake and accumulation in crop grain has been found with soil application Zn. Similarly boron is nonmetal micronutrient element tourmaline, a complex borosilicate is the main boron containing mineral found in most soils. Release of boron from this mineral is quite slow [13]. Boron availability decreased with increasing soil pH, thus it is often inadequately available in calcareous soils.

Boron uptake by plants correlates extractable soil boron [14]. Boron deficiency in plants results in terminal bud growth stoppage young leaves die, impaired flowering and boll development, thickened, wilted or curled leaves, thickened, cracked or water-soaked condition of petioles and stems, discoloration cracking or rotting of fruit, tubers or roots. Boron is also associated with sugar translocation and its requirements vary greatly from crop to crop [15].

Therefore study will be conducted to evaluate effect of both macro and micro nutrient on growth and yield of maize crop at agro ecological condition of Tandojam.

2. Materials and methods

The experiment was carried out at Student's Experimental Farm, Department of Agronomy, sindh Agriculture University Tandojam to evaluate the effect of macro and micronutrients on the growth and grain yield of maize. The experiment was laid out in a three replicated randomized complete block design (RCBD) having net plot size of 4 m x 3 m (12 m^2). Land was prepared by two dry ploughing and leveling to prepare a good seed bed. Variety Hycorn 11 plus was sown at the seed rate of 30 kg ha^{-1} by drilling method on 12th March 2016 the distance between row to row was kept 60 cm and 15 cm between plant to plant.

Four irrigations were given from sowing to harvesting. For fertilizers: Urea was applied for nitrogen half dose at 1st irrigation and half at 2nd irrigation, for phosphorus and potash single super phosphate and sulphate of potash was applied respectively. Whereas, Borax was applied for boron and $ZnSO_4$ was applied for zinc according to the treatments: The details of treatments given under:

2.1 Treatments = 9

T_1 = Control (un-treated)
T_2 = NPK + Boron (100 + 50 + 25 + 2 kg ha^{-1})
T_3 = NPK + Zinc (100 + 50 + 25 + 2 kg ha^{-1})
T_4 = NPK + Boron (120 + 60 + 30 + 2 kg ha^{-1})
T_5 = NPK + Zinc (120 + 60 + 30 + 2 kg ha^{-1})
T_6 = NPK + Boron (130 + 65 + 35 + 2 kg ha^{-1})
T_7 = NPK + Zinc (130 + 65 + 35 + 2 kg ha^{-1})
T_8 = NPK + Boron (140 + 70 + 40 + 2 kg ha^{-1})
T_9 = NPK + Zinc (140 + 70 +40 + 2 kg ha^{-1})

2.2 Observations recorded

1. Plant population (m^2)
2. Plant height (cm)
3. Stem girth (cm)
4. Cobs $plant^{-1}$
5. Cob length (cm)
6. Cob weight (g)
7. Seed weight cob^{-1}(g)
8. Seed index (1000 grain weight, g)
9. Biological yield (kg ha^{-1})
10. Grain yield (kg ha^{-1})

2.3 Statistical analysis

The data was subjected to statistical analysis using Statistix 8.1 computer software (Statistix, 2006). The difference among the treatments mean was compared by the least significant difference (LSD) test where necessary.

2.4 Layout plan of the experiment

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2.5 Experimental design = Randomized complete block design (RCBD)

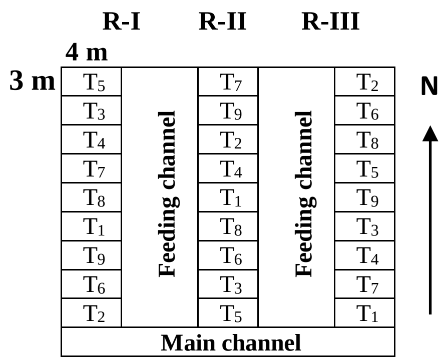
2.6 Replications = Three

2.7 Net plot size = 4 m x 3 m (12 m^2)

2.8 Variety = Hycorn 11 plus

2.9 Treatments = 9

T_1 = Control (un-treated)
T_2 = NPK + Boron (100 + 50 + 25 + 2 kg ha^{-1})
T_3 = NPK + Zinc (100 + 50 + 25 + 2 kg ha^{-1})
T_4 = NPK + Boron (120 + 60 + 30 + 2 kg ha^{-1})
T_5 = NPK + Zinc (120 + 60 + 30 + 2 kg ha^{-1})
T_6 = NPK + Boron (130 + 65 + 35 + 2 kg ha^{-1})
T_7 = NPK + Zinc (130 + 65 + 35 + 2 kg ha^{-1})
T_8 = NPK + Boron (140 + 70 + 40 + 2 kg ha^{-1})
T_9 = NPK + Zinc (140 + 70 +40 + 2 kg ha^{-1})



3. Results & Discussion

The experiment was conducted at Student's Experimental Farm, Department of Agronomy, Sindh Agriculture University, Tandojam. Randomized complete block design (RCBD) experimental design was used with three replications and nine treatments *i.e* T_1 = Control (un-treated), T_2 = NPK + Boron (100 + 50 + 25 + 2 kg ha^{-1}), T_3 = NPK + Zinc (100 + 50 + 25 + 2 kg ha^{-1}), T_4 = NPK + Boron (120 + 60 + 30 + 2 kg ha^{-1}), T_5 = NPK + Zinc (120 + 60 + 30 + 2 kg ha^{-1}), T_6 = NPK + Boron (130 + 65 + 35 + 2 kg ha^{-1}), T_7 = NPK + Zinc (130 + 65 + 35 + 2 kg ha^{-1}), T_8 = NPK + Boron (140 + 70 + 40 + 2 kg ha^{-1}), T_9 = NPK + Zinc (140 + 70 +40 + 2 kg ha^{-1}). The data were collected on traits of economic importance such as: plant population (m^{-2}), plant height (cm), stem girth (cm), cobs $plant^{-1}$, cob length (cm), cob weight (g), seed weight cob^{-1} (g), seed index (1000 grain weight, g), biological yield (kg ha^{-1}) and grain yield (kg ha^{-1}). The data on the above traits are presented in Tables 1-10.

3.1 Plant population (m^{-2})

The data regarding plant population (m^{-2}) of maize as affected by different levels of macro and micro nutrients is presented in Table-1. The results revealed that maximum plant population (7.6 m^{-2}) was observed in treatment T_7 = NPK + Zinc (130 + 65 + 35 + 2 kg ha^{-1}) followed by (6.6 m^{-2}) under treatment T_8 = NPK + Boron (140 + 70 + 40 + 2 kg ha^{-1}). However, treatment T_9 = NPK + Zinc (140 + 70 +40 + 2 kg ha^{-1}) (6.5 m^{-2}) ranked as 3rd, treatment T_6 = NPK + Boron (130 + 65 + 35 + 2 kg ha^{-1}) (6.0 m^{-2}), treatment T_5 = NPK + Zinc (120 + 60 + 30 + 2 kg ha^{-1}) (6.0 m^{-2}) and treatment T_4 = NPK + Boron (120 + 60 + 30 + 2 kg ha^{-1}) (6.0 m^{-2}) equally ranked as 4th, treatment T_3 = NPK + Zinc (100 + 50 + 25 + 2 kg ha^{-1}) (5.7 m^{-2}) ranked as 5th and treatment T_2 = NPK + Boron (100 + 50 + 25 + 2 kg ha^{-1}) ranked as 6th with (5.3 m^{-2}) respectively. Whereas, the minimum plant population (3.7 m^{-2}) was observed under treatment T_1 = Control (un-treated).

3.2 Plant height (cm)

The data regarding plant height (cm) of maize as affected by different levels of macro and micro nutrients is presented in Table-2. The results revealed that maximum plant height (193.3 cm) was observed in treatment T_7 = NPK + Zinc (130 + 65 + 35 + 2 kg ha^{-1}) followed by (179.3 cm) under treatment T_8 = NPK + Boron (140 + 70 + 40 + 2 kg ha^{-1}). However, treatment T_9 = NPK + Zinc (140 + 70 + 40 + 2 kg ha^{-1}), treatment T_6 = NPK + Boron (130 + 65 + 35 + 2 kg ha^{-1}), treatment T_5 = NPK + Zinc (120 + 60 + 30 + 2 kg ha^{-1}), treatment T_4 = NPK + Boron (120 + 60 + 30 + 2 kg ha^{-1}), treatment T_3 = NPK + Zinc (100 + 50 + 25 + 2 kg ha^{-1}) and treatment T_2 = NPK + Boron (100 + 50 + 25 + 2 kg ha^{-1}) were ranked as 3rd, 4th, 5th, 6th, 7th and 8th with (172.7 cm), (169.0 cm), (165.3 cm), (163.6 cm), (160.3 cm) and (159.6 cm) respectively. Whereas, the minimum plant height (143.7 cm) was observed under treatment T_1 = Control (un-treated).

3.3 Stem girth (cm)

The data regarding stem girth (cm) of maize as affected by different levels of macro and micro nutrients is presented in Table-3. The results revealed that maximum stem girth (6.4 cm) was observed in treatment T_7 = NPK + Zinc (130 + 65 + 35 + 2 kg ha^{-1}) followed by (6.0 cm) under treatment T_8 = NPK + Boron (140 + 70 + 40 + 2 kg ha^{-1}). However, treatment T_9 = NPK + Zinc (140 + 70 +40 + 2 kg ha^{-1}), treatment T_6 = NPK + Boron (130 + 65 + 35 + 2 kg ha^{-1}), treatment T_5 = NPK + Zinc (120 + 60 + 30 + 2 kg ha^{-1}), treatment T_4 = NPK + Boron (120 + 60 + 30 + 2 kg ha^{-1}), treatment T_3 = NPK + Zinc (100 + 50 + 25 + 2 kg ha^{-1}) and treatment T_2 = NPK + Boron (100 + 50 + 25 + 2 kg ha^{-1}) were ranked as 3rd, 4th, 5th, 6th, 7th and 8th with (5.4 cm), (5.3 cm), (5.1 cm), (4.8 cm), (4.7 cm) and (4.5 cm) respectively. Whereas, the minimum stem girth (3.3 cm) was observed under treatment T_1 = Control (un-treated).

3.4 Cobs $plant^{-1}$

The data regarding cobs $plant^{-1}$ of maize as affected by different levels of macro and micro nutrients is presented in Table-4. The results revealed that maximum cobs $plant^{-1}$ (2.2) was observed in treatment T_7 = NPK + Zinc (130 + 65 + 35 + 2 kg ha^{-1}) followed by (1.9) under treatment T_8 = NPK + Boron (140 + 70 + 40 + 2 kg ha^{-1}). However, treatment T_9 = NPK + Zinc (140 + 70 + 40 + 2 kg ha^{-1}) (1.5) ranked as 3rd, treatment T_6 = NPK + Boron (130 + 65 + 35 + 2 kg ha^{-1}), treatment T_5 = NPK + Zinc (120 + 60 + 30 + 2 kg ha^{-1}), treatment T_4 = NPK + Boron (120 + 60 + 30 + 2 kg ha^{-1}), treatment T_3 = NPK + Zinc (100 + 50 + 25 + 2 kg ha^{-1}) and treatment T_2 = NPK + Boron (100 + 50 + 25 + 2 kg ha^{-1}) were ranked as 4th with (1.4) cobs $plant^{-1}$ each respectively. Whereas, the minimum cobs $plant^{-1}$ (1.0) was observed under treatment T_1 = Control (un-treated).

3.5 Cob length (cm)

The data regarding cob length (cm) of maize as affected by different levels of macro and micro nutrients is presented in Table-5. The results revealed that maximum cob length (21.3 cm) was observed in treatment T_7 = NPK + Zinc (130 + 65 + 35 + 2 kg ha^{-1}) followed by (17.3 cm) under treatment T_8 = NPK + Boron (140 + 70 + 40 + 2 kg ha^{-1}). However, treatment T_9 = NPK + Zinc (140 + 70 + 40 + 2 kg ha^{-1}) (14.6 cm) and treatment T_6 = NPK + Boron (130 + 65 + 35 + 2 kg ha^{-1}) equally (14.6 cm) ranked as 3rd, treatment T_5 = NPK + Zinc (120 + 60 + 30 + 2 kg ha^{-1}) (14.3 cm) and treatment T_4 = NPK + Boron (120 + 60 + 30 + 2 kg ha^{-1}) (14.3 cm) equally ranked as 4th, treatment T_3 = NPK + Zinc (100 + 50 + 25 + 2 kg ha^{-1}) (13.6) ranked as 5th and treatment T_2 = NPK + Boron (100 + 50 + 25 + 2 kg ha^{-1}) ranked as 6th with (12.6 cm) respectively. Whereas, the minimum cob length (10.0 cm) was observed under treatment T_1 = Control (un-treated).

3.6 Cob weight (g)

The data regarding cob weight (g) of maize as affected by different levels of macro and micro nutrients is presented in Table-6. The results revealed that maximum cob weight

(163.0 g) was observed in treatment T_7 = NPK + Zinc (130 + 65 + 35 + 2 kg ha^{-1}) followed by (149.9 g) under treatment T_8 = NPK + Boron (140 + 70 + 40 + 2 kg ha^{-1}). However, treatment T_6 = NPK + Boron (130 + 65 + 35 + 2 kg ha^{-1}) (135.3 g) and treatment T_5 = NPK + Zinc (120 + 60 + 30 + 2 kg ha^{-1}) (135.3 g) equally ranked as 3rd, treatment T_4 = NPK + Boron (120 + 60 + 30 + 2 kg ha^{-1}) (133.6 g) ranked as 4th, treatment T_3 = NPK + Zinc (100 + 50 + 25 + 2 kg ha^{-1}) (133.0 g) and treatment T_2 = NPK + Boron (100 + 50 + 25 + 2 kg ha^{-1}) (133.0) equally ranked as 5th and treatment T_9 = NPK + Zinc (140 + 70 + 40 + 2 kg ha^{-1}) was ranked as 6th with (132.6 g) respectively. Whereas, the minimum cob weight (110.0 g) was observed under treatment T_1 = Control (un-treated).

3.7 Seed weight cob^{-1} (g)
The data regarding seed weight cob^{-1} (g) of maize as affected by different levels of macro and micro nutrients is presented in Table-7. The results revealed that maximum seed weight cob^{-1} (70.6 g) was observed in treatment T_7 = NPK + Zinc (130 + 65 + 35 + 2 kg ha^{-1}) followed by (65.0 g) under treatment T_6 = NPK + Boron (130 + 65 + 35 + 2 kg ha^{-1}). However, treatment T_8 = NPK + Boron (140 + 70 + 40 + 2 kg ha^{-1}), treatment T_9 = NPK + Zinc (140 + 70 + 40 + 2 kg ha^{-1}), treatment T_5 = NPK + Zinc (120 + 60 + 30 + 2 kg ha^{-1}), treatment T_4 = NPK + Boron (120 + 60 + 30 + 2 kg ha^{-1}), treatment T_3 = NPK + Zinc (100 + 50 + 25 + 2 kg ha^{-1}) and treatment T_2 = NPK + Boron (100 + 50 + 25 + 2 kg ha^{-1}) were ranked as 3rd, 4th, 5th, 6th, 7th and 8th with (57.0 g), (55.6 g), (54.6 g), (54.3 g), (53.3 g) and (51.0 g) respectively. Whereas, the minimum seed weight cob^{-1} (42.6 g) was observed under treatment T_1 = Control (un-treated).

3.8 Seed index (g)
The data regarding seed index (g) of maize as affected by different levels of macro and micro nutrients is presented in Table-8. The results revealed that maximum seed index (212.3 g) was observed in treatment T_7 = NPK + Zinc (130 + 65 + 35 + 2 kg ha^{-1}) followed by (193.3 g) under treatment T_8 = NPK + Boron (140 + 70 + 40 + 2 kg ha^{-1}). However, treatment T_9 = NPK + Zinc (140 + 70 + 40 + 2 kg ha^{-1}) (186.0 g) and treatment T_6 = NPK + Boron (130 + 65 + 35 + 2 kg ha^{-1}) (186.0 g) equally ranked as 3rd, treatment T_4 = NPK + Boron (120 + 60 + 30 + 2 kg ha^{1}) (184.3 g) ranked as 4th, treatment T_5 = NPK + Zinc (120 + 60 + 30 + 2 kg ha^{-1}) (184.0 g) ranked as 5th, treatment T_3 = NPK + Zinc (100 + 50 + 25 + 2 kg ha^{-1}) (182.6 g) ranked as 6th and treatment T_2 = NPK + Boron (100 + 50 + 25 + 2 kg ha^{-1}) ranked as 7th with (181.0 g) respectively. Whereas, the minimum seed index (175.6 g) was observed under treatment T_1 = Control (un-treated).

3.9 Biological yield (kg ha^{-1})
The data regarding biological yield (kg ha^{-1}) of maize as affected by different levels of macro and micro nutrients is presented in Table-9. The results revealed that maximum biological yield (13333 kg ha^{-1}) was observed in treatment T_7 = NPK + Zinc (130 + 65 + 35 + 2 kg ha^{-1}) followed by (12833 kg ha^{-1}) under treatment T_8 = NPK + Boron (140 + 70 + 40 + 2 kg ha^{-1}). However, treatment T_9 = NPK + Zinc (140 + 70 + 40 + 2 kg ha^{-1}), treatment T_6 = NPK + Boron (130 + 65 + 35 + 2 kg ha^{-1}), treatment T_5 = NPK + Zinc (120 + 60 + 30 + 2 kg ha^{-1}), treatment T_4 = NPK + Boron (120 + 60 + 30 + 2 kg ha^{-1}), treatment T_3 = NPK + Zinc (100 + 50 + 25 + 2 kg ha^{-1}) and treatment T_2 = NPK + Boron (100 + 50 + 25 + 2 kg ha^{-1}) were ranked as 3rd, 4th, 5th, 6th, 7th and 8th with (12453 kg ha^{-1}), (12 kg ha^{-1}413 kg ha^{-1}), (12267 kg ha^{-1}), (12133 kg ha^{-1}), (12080 kg ha^{-1}) and (11877 kg ha^{-1}) respectively. Whereas, the minimum biological yield (11683 kg ha^{-1}) was observed under treatment T_1 = Control (un-treated).

3.10 Grain yield (kg ha^{-1})
The data regarding grain yield (kg ha^{-1}) of maize as affected by different levels of macro and micro nutrients is presented in Table-10. The results revealed that maximum grain yield (3433.33 kg ha^{-1}) was observed in treatment T_7 = NPK + Zinc (130 + 65 + 35 + 2 kg ha^{-1}) followed by (3000.0 kg ha^{-1}) under treatment T_8 = NPK + Boron (140 + 70 + 40 + 2 kg ha^{-1}). However, treatment T_9 = NPK + Zinc (140 + 70 + 40 + 2 kg ha^{-1}), (treatment T_6 = NPK + Boron (130 + 65 + 35 + 2 kg ha^{-1}), treatment T_5 = NPK + Zinc (120 + 60 + 30 + 2 kg ha^{-1}), treatment T_4 = NPK + Boron (120 + 60 + 30 + 2 kg ha^{-1}), treatment T_3 = NPK + Zinc (100 + 50 + 25 + 2 kg ha^{-1}) and treatment T_2 = NPK + Boron (100 + 50 + 25 + 2 kg ha^{-1}) were ranked as 3rd, 4th, 5th, 6th, 7th and 8th with (2630.0 kg ha^{-1}), (2616.7 kg ha^{-1}), (2603.3 kg ha^{-1}), (2543.3 kg ha^{-1}), (2530.0 kg ha^{-1}) and (2425.0 kg ha^{-1}) respectively. Whereas, the minimum grain yield (2236.7 kg ha^{-1}) was observed under treatment T_1 = Control (un-treated).

Macronutrients are those elements needed in large amounts by the crop and large quantities have to be applied if the soil is deficient in one or more of them. Nitrogen (N), phosphorus (P) and potassium (K) are the “primary macronutrients” and these form the basis of NPK fertilizer compounds. The “secondary macronutrients” are calcium (Ca), magnesium (Mg) and sulphur (S) [3] and [4]. N, P and K are essentially required elements for crop production. Plants are surrounded by the N in our atmosphere.

Despite nitrogen being one of the most abundant elements on earth, nitrogen deficiency is probably the most common nutritional problem affecting plants worldwide. Nitrogen is considered as an essential element of bio-molecules such as amino acids, proteins, nucleic acids, phytohormoes and number of enzymes and coenzymes. N strongly stimulates growth, expansion of the crop canopy and interception of solar radiation [5]. Phosphorus is another essential nutrient both as a part of several key plant structure compounds and as a catalysis in the conversion of numerous key biochemical reactions on plants.

P is noted especially for its role in capturing and converting the sun’s energy into useful plant compounds: thus P is essential for the general health and vigor of plants. Some specific growth factors that have been associated with P are: stimulated root development, increased stem strength, improved flower formation and seed production, more uniform and earlier crop maturity, increased nitrogen N-fixing capacity of crops, improvements in crop quality and increased resistance to plant diseases [6].

Similarly, K is also essential nutrient required for plant growth and reproduction. It is classified as a macro nutrient, as are N and P. Potash is defined as K_2O and is used to express the content of various fertilizer materials containing potassium, such as muriate of potash (KCl), sulphate of potash (K_2SO_4), double sulphate of potash and magnesium (K_2SO_4, $MgSO_4$) and nitrate of potash (KNO_3). K plays a vital role in photosynthesis, translocation of photosynthates, protein synthesis, control of ionic balance, regulation of plant stomata and water use, activation of plant enzymes and many other processes [7]. Although the present results show that all the traits of maize like plant population (m^{-2}), plant height (cm), stem girth (cm), cobs $plant^{-1}$, cob length (cm), cob weight (g), seed weight cob^{-1} (g), seed index (1000 grain weight, g), biological yield (kg ha^{-1}) and grain yield (kg ha^{-1}) were statistically significant ($P<0.05$) under the different levels of macro and micro nutrients. Similarly, applications of both macro and micro nutrients have been reported to crop productivity [8].

Amongst the cereals, maize is a rich source of essential nutrients needed by both human beings and animals. In plant nutritional condition, as stated for maize and wheat [9, 10]. However, micronutrients can be applied directly into the soil as well. Soil applied Zn is effective in enhancing the grain yield whereas Zn concentration in grain improves based on particular studies [11] reported that soil applications of zinc enhances the yield of crops. [12] Concluded that increased Zn uptake and accumulation in crop grain has been found with soil Zn. Similarly, boron is nonmetal micronutrient element tourmaline, a complex borosilicate is the main boron containing mineral found in most soils. Release of boron from this mineral is quite slow [13].

Boron availability is reduced under low rain fall/drought conditions or in soils low in organic matter. Farmers maintaining high levels of organic matter in their fields normally do not face boron deficiencies [4].

4. Tables

Table 1: Plant population (m^{-2}) of maize as affected by application of macro and micro nutrients

Treatments	R-I	R-II	R-II	Mean
Control (un-treated)	4	3	4	3. 7 c
NPK + Boron (100 + 50 + 25 + 2 kg ha^{-1})	5	5	6	5.3 b
NPK + Zinc (100 + 50 + 25 + 2 kg ha^{-1})	6	5	6	5.7 b
NPK + Boron (120 + 60 + 30 + 2 kg ha^{-1})	6	6	6	6.0 b
NPK + Zinc (120 + 60 + 30 + 2 kg ha^{-1})	7	6	5	6.0 b
NPK + Boron (130 + 65 + 35 + 2 kg ha^{-1})	6	6	6	6.0 b
NPK + Zinc (130 + 65 + 35 + 2 kg ha^{-1})	8	7	8	7.6 a
NPK + Boron (140 + 70 + 40 + 2 kg ha^{-1})	7	6	7	6.6 ab
NPK + Zinc (140 + 70 +40 + 2 kg ha^{-1})	6	7	7	6.5 ab

SE = 0.4479; **LSD 5%** = 1.5946

Table 2: Plant height (cm) of maize as affected by application of macro and micro nutrients

Treatments	R-I	R-II	R-III	Mean
Control (un-treated)	140	143	148	143.7 f
NPK + Boron (100 + 50 + 25 + 2 kg ha^{-1})	157	159	163	159.6 e
NPK + Zinc (100 + 50 + 25 + 2 kg ha^{-1})	158	160	163	160.3 e
NPK + Boron (120 + 60 + 30 + 2 kg ha^{-1})	160	163	168	163.6 de
NPK + Zinc (120 + 60 + 30 + 2 kg ha^{-1})	161	160	175	165.3 de
NPK + Boron (130 + 65 + 35 + 2 kg ha^{-1})	166	168	173	169.0 cd
NPK + Zinc (130 + 65 + 35 + 2 kg ha^{-1})	189	193	198	193.3 a
NPK + Boron (140 + 70 + 40 + 2 kg ha^{-1})	176	180	182	179.3 b
NPK + Zinc (140 + 70 +40 + 2 kg ha^{-1})	170	174	174	172.7 c

SE = 1.7769; **LSD 5%** = 6.3260

Table 3: Stem girth (cm) of maize as affected by application of macro and micro nutrients

Treatments	R-I	R-II	R-III	Mean
Control (un-treated)	3.0	3.3	3.5	3.3 e
NPK + Boron (100 + 50 + 25 + 2 kg ha^{-1})	4.5	4.6	4.4	4.5 d
NPK + Zinc (100 + 50 + 25 + 2 kg ha^{-1})	4.8	4.7	4.8	4.7 cd
NPK + Boron (120 + 60 + 30 + 2 kg ha^{-1})	5.0	4.8	4.8	4.8 cd
NPK + Zinc (120 + 60 + 30 + 2 kg ha^{-1})	5.3	5.0	5.1	5.1 bc
NPK + Boron (130 + 65 + 35 + 2 kg ha^{-1})	5.5	5.3	5.2	5.3 b
NPK + Zinc (130 + 65 + 35 + 2 kg ha^{-1})	6.2	6.3	6.6	6.4 a
NPK + Boron (140 + 70 + 40 + 2 kg ha^{-1})	5.9	6.0	6.1	6.0 a
NPK + Zinc (140 + 70 +40 + 2 kg ha^{-1})	5.0	5.1	5.0	5.4 bc

SE = 0.1253; **LSD 5%** = 0.4462

Table 4: Cobs $plant^{-1}$ of maize as affected by application of macro and micro nutrients

Treatments	R-I	R-II	R-III	Mean
Control (un-treated)	1.0	1.0	1.0	1.0 c
NPK + Boron (100 + 50 + 25 + 2 kg ha^{-1})	1.5	1.4	1.3	1.4 b
NPK + Zinc (100 + 50 + 25 + 2 kg ha^{-1})	1.4	1.6	1.2	1.4 b
NPK + Boron (120 + 60 + 30 + 2 kg ha^{-1})	1.5	1.3	1.4	1.4 b

NPK + Zinc (120 + 60 + 30 + 2 kg ha^{-1})	1.6	1.4	1.4	1.4 b
NPK + Boron (130 + 65 + 35 + 2 kg ha^{-1})	1.4	1.5	1.5	1.4 b
NPK + Zinc (130 + 65 + 35 + 2 kg ha^{-1})	2.2	2.1	2.3	2.2 a
NPK + Boron (140 + 70 + 40 + 2 kg ha^{-1})	2.0	1.9	2.0	1.9 a
NPK + Zinc (140 + 70 +40 + 2 kg ha^{-1})	1.8	1.4	1.4	1.5 b

SE = 0.0984; **LSD 5%** = 0.3505

Table 5: Cob length (cm) of maize as affected by application of macro and micro nutrients

Treatments	R-I	R-II	R-III	Mean
Control (un-treated)	10	9	11	10.0 e
NPK + Boron (100 + 50 + 25 + 2 kg ha^{-1})	13	12	13	12.6 d
NPK + Zinc (100 + 50 + 25 + 2 kg ha^{-1})	13	14	14	13.6 cd
NPK + Boron (120 + 60 + 30 + 2 kg ha^{-1})	15	14	14	14.3 cd
NPK + Zinc (120 + 60 + 30 + 2 kg ha^{-1})	14	15	14	14.3 cd
NPK + Boron (130 + 65 + 35 + 2 kg ha^{-1})	14	15	15	14.6 c
NPK + Zinc (130 + 65 + 35 + 2 kg ha^{-1})	21	22	21	21.3 a
NPK + Boron (140 + 70 + 40 + 2 kg ha^{-1})	17	18	17	17.3 b
NPK + Zinc (140 + 70 +40 + 2 kg ha^{-1})	15	14	15	14.6 c

SE = 0.5443; **LSD 5%** = 1.9379

Table 6: Cob weight (g) of maize as affected by application of macro and micro nutrients

Treatments	R-I	R-II	R-III	Mean
Control (un-treated)	108	110	112	110.0 d
NPK + Boron (100 + 50 + 25 + 2 kg ha^{-1})	132	133	134	133.0 c
NPK + Zinc (100 + 50 + 25 + 2 kg ha^{-1})	128	134	137	133.0 c
NPK + Boron (120 + 60 + 30 + 2 kg ha^{-1})	130	135	136	133.6 c
NPK + Zinc (120 + 60 + 30 + 2 kg ha^{-1})	131	136	139	135.3 c
NPK + Boron (130 + 65 + 35 + 2 kg ha^{-1})	134	132	140	135.3 c
NPK + Zinc (130 + 65 + 35 + 2 kg ha^{-1})	163	161	165	163.0 a
NPK + Boron (140 + 70 + 40 + 2 kg ha^{-1})	150	148	151	149.6 b
NPK + Zinc (140 + 70 +40 + 2 kg ha^{-1})	132	130	136	132.6 c

SE = 1.6574; **LSD 5%** = 5.9005

Table 7: Seed weight cob^{-1}(g) of maize as affected by application of macro and micro nutrients

Treatments	R-I	R-II	R-III	Mean
Control (un-treated)	42	41	45	42.6 e
NPK + Boron (100 + 50 + 25 + 2 kg ha^{-1})	51	50	52	51.0 d
NPK + Zinc (100 + 50 + 25 + 2 kg ha^{-1})	53	53	54	53.3 cd
NPK + Boron (120 + 60 + 30 + 2 kg ha^{-1})	54	54	55	54.3 cd
NPK + Zinc (120 + 60 + 30 + 2 kg ha^{-1})	56	52	56	54.6 cd
NPK + Boron (130 + 65 + 35 + 2 kg ha^{-1})	64	64	67	65.0 bc
NPK + Zinc (130 + 65 + 35 + 2 kg ha^{-1})	69	68	75	70.6 a
NPK + Boron (140 + 70 + 40 + 2 kg ha^{-1})	56	55	60	57.0 b
NPK + Zinc (140 + 70 +40 + 2 kg ha^{-1})	57	53	57	55.6 c

SE = 1.0744; **LSD 5%** = 3.8250

Table 8: Seed index (1000 grain weight, g) of maize as affected by application of macro and micro nutrients

Treatments	R-I	R-II	R-III	Mean
Control (un-treated)	172	170	185	175.6 c
NPK + Boron (100 + 50 + 25 + 2 kg ha^{-1})	184	173	186	181.0 c
NPK + Zinc (100 + 50 + 25 + 2 kg ha^{-1})	184	181	183	182.6 bc
NPK + Boron (120 + 60 + 30 + 2 kg ha^{-1})	184	183	186	184.3 bc
NPK + Zinc (120 + 60 + 30 + 2 kg ha^{-1})	185	182	185	184.0 bc
NPK + Boron (130 + 65 + 35 + 2 kg ha^{-1})	190	184	184	186.0 bc
NPK + Zinc (130 + 65 + 35 + 2 kg ha^{-1})	212	210	215	212.3 a
NPK + Boron (140 + 70 + 40 + 2 kg ha^{-1})	200	188	192	193.3 b
NPK + Zinc (140 + 70 +40 + 2 kg ha^{-1})	185	185	188	186.0 bc

SE = 3.0026; **LSD 5%** = 10.689

Table 9: Biological yield (kg ha^{-1}) of maize as affected by application of macro and micro nutrients

Treatments	R-I	R-II	R-III	Mean
Control (un-treated)	11200	11350	12500	11683 d
NPK + Boron (100 + 50 + 25 + 2 kg ha^{-1})	11300	12100	12230	11877 cd

NPK + Zinc (100 + 50 + 25 + 2 kg ha^{-1})	11900	12000	12340	12080 cd
NPK + Boron (120 + 60 + 30 + 2 kg ha^{-1})	11900	12100	12400	12133 bcd
NPK + Zinc (120 + 60 + 30 + 2 kg ha^{-1})	12000	12300	12500	12267 bcd
NPK + Boron (130 + 65 + 35 + 2 kg ha^{-1})	12300	12400	12540	12413 bc
NPK + Zinc (130 + 65 + 35 + 2 kg ha^{-1})	13400	13100	13500	13333 a
NPK + Boron (140 + 70 + 40 + 2 kg ha^{-1})	12800	12700	13000	12833 ab
NPK + Zinc (140 + 70 +40 + 2 kg ha^{-1})	12450	12350	12560	12453 bc

SE = 199.04; **LSD 5%** = 708.59

Table 10: Grain yield (kg ha^{-1}) of maize as affected by application of macro and micro nutrients

Treatments	R-I	R-II	R-III	Mean
Control (un-treated)	2010	2100	2600	2236.7 c
NPK + Boron (100 + 50 + 25 + 2 kg ha^{-1})	2015	2580	2680	2425.0 c
NPK + Zinc (100 + 50 + 25 + 2 kg ha^{-1})	2450	2570	2570	2530.0 bc
NPK + Boron (120 + 60 + 30 + 2 kg ha^{-1})	2600	2430	2600	2543.3 bc
NPK + Zinc (120 + 60 + 30 + 2 kg ha^{-1})	2500	2600	2710	2603.3 bc
NPK + Boron (130 + 65 + 35 + 2 kg ha^{-1})	2550	2600	2700	2616.7 bc
NPK + Zinc (130 + 65 + 35 + 2 kg ha^{-1})	3500	3100	3700	3433.33a
NPK + Boron (140 + 70 + 40 + 2 kg ha^{-1})	3000	2850	3150	3000.0 ab
NPK + Zinc (140 + 70 +40 + 2 kg ha^{-1})	2680	2530	2680	2630.0 bc

SE = 151.02; **LSD 5%** = 537.66

5. Conclusion

It is concluded that the crop was fertilized with the NPK + Zinc (130 + 65 + 35 + 2 kg ha^{-1}) macro and micro nutreitns gave best results for obtaining higher yield (3433.33 kg ha^{-1}) of maize crop as compared to other applications of the macro and micro nutrients.

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7. References

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