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Foliar Application of Phosphorous, Zinc, and Boron Enhances Cotton Production

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Abstract: Cotton is single the most important natural fiber and source of oil and protein in the world. Its economic production is mainly governed by its management practices. To search for the best cotton nutrition option in the arid conditions of Karor Zone, Layyah-Pakistan, a field experiment was conducted by using micro and macronutrients on cotton crop through the soil and foliar application. This experiment was conducted at Adaptive Research Farm Karor during Kharif season 2017 and 2018 using cotton variety MNH-886. Among different treatments, application of recommended doses of NPK (222: 86: 94 kg ha^{-1}) with foliar application of phosphorus in form of DAP (1250 g ha^{-1} in three splits after 35, 50, and 65 days of sowing) produced significantly better results in all parameters except plant population and ginning outturn as compared to other treatments i.e. only recommended NPK dose, recommended NPK and zinc in the form of zinc sulfate at the rate of 500 g ha^{-1} and boron (11.3 %) in the form of Borax with 500 g ha^{-1}. Maximum seed cotton yield (1830 kg ha^{-1}), number of bolls $plant^{-1}$ (27.3), and boll weight (2.93 g) were obtained where phosphorus was sprayed with the recommended dose of NPK during both years. Results indicated that foliar application of phosphorus proved beneficial with the recommended dose of NPK application in cotton. In the future, different combinations of macro- and micro-nutrients should be explored to find alternates for higher cotton yield.

Keywords Macronutrients, NPK, Micronutrient, Cotton, nutrient management.

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1. Introduction

Cotton is termed "white gold" due to its importance as a commercial crop. It is the major source of raw material for the textile industry around the globe. Globally, Pakistan prevailed 4th position in cotton production (Shuli et al., 2018). Cotton contributes 0.8% to GDP and accounts for 4.5% of value addition in the agriculture of Pakistan (Government of Pakistan, 2019). In Pakistan, cotton is mainly cultivated in Punjab and Sindh provinces (Malik and Ahsan, 2016), but Punjab is the leading province in terms of sown area and production. Nearly 80% of cotton production comes from Punjab while Sindh province contributes ~18% (Ali et al., 2013).

Cotton crop production is dependent on genetic makeup, environment, and management practices such as irrigation, fertilizers, and plant protection. Among environmental factors, temperature is an important factor affecting the yield of different crops of the arid region like wheat, cotton, millet, and maize (Ahmad et al., 2015; Ahmed et al., 2018; Hussain et al., 2018 & 2020; Rehman et al., 2019a; Ullah et al., 2019). In Punjab, higher temperature is predicted (+2-3 °C) during mid-century under representative concentration pathways 8.5 (Hussain et al., 2020; Hussain et al.,

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2021). Among different inputs, fertilizers are important to make the soil more fertile for maximum production of cotton. Nitrogen, phosphorus, and potassium are major nutrients required to grow healthy crops especially cotton crop in the soils of Pakistan (Malghani et al., 2010; Awais et al., 2017; Awais et al., 2018). Soils of Pakistan are deficient in nitrogen (N), about 30% deficient in potassium, and 80 to 90% in phosphorus (Rehman et al, 2019b). Microelements in plants can be enriched by proper application of macronutrients NPK along with micronutrients fertilization. With major nutrients, minor nutrients are also important for crop growth and development (Awais et al., 2015.; Ndor et al., 2010). Deficiency of major and minor nutrients causes a reduction in final yield by affecting plant size, boll size and number of bolls, crop resistance to diseases and flowers and bolls shedding (Bronson et al. 2001; Waraich et al. 2012; Mubeen et al. 2016).

Plant growth and yield are directly proportionate to each other in presence of all nutrients otherwise negatively affected and resulted in low yield and poor lint quality (Jamro et al., 2016). It has been reported that foliar application of macro and micronutrients such as NPK, zinc, and boron reduces the flowers and boll shedding and enhances crop final yield. Macronutrients NPK are also required by the plant in sufficient quantity with proper time (Ekert, 2010, Malghani et al., 2010). Various studies (Rab and Haq 2012; Putra et al., 2012) concluded that six micronutrients (iron, boron, manganese, copper, molybdenum, and zinc) play an imperative role in the biophysical and biochemical development of the plant. Ahmed et al. (2018) examined zinc and concluded that Zn enhances the biological yield of cotton. Being an exhaustive crop and high productive cultivar, cotton requires plentiful potassium (K) for reproductive success and optimum growth in the cotton-wheat cropping system of Pakistan (Shazad et al., 2019). During stress conditions, zinc, boron, and potassium are required by the cotton plant heavily which moderate biochemical changes due to anti-oxidant enzymes (Corrales et al., 2008; Upadhyaya et al., 2013; Zahoor et al. 2017). Keeping in view the importance of micro and macronutrients, this study was conducted to explore the effect of soil and foliar applied NPK, P, boron and zinc on cotton growth and yield.

2. Materials and Methods

The experiment was conducted at Adaptive Research Farm Karor Lal Eson, Layyah, Pakistan (31.20° N and 71.09° E). The experiment was laid out in May, during kharif seasons of 2017 and 2018 using MNH-886 cotton cultivar. The crop was sown on sandy loam soil with pH 8.4-8.5, having organic matter 0.69% and available phosphorus 8 ppm. An experiment was arranged in a randomized complete block design (RCBD), conducted in triplicate with four treatments in 10×22 m^2 plot size. Four different fertilizers with various dose rates were analyzed i.e. recommended dose of NPK, phosphorus 1250 g ha^{-1}, zinc (as $ZnSO_4$) @ 500 g $ha^{-1,}$ and boron (11.3 %) in the form of Borax with 500 g ha^{-1}. All the doses were applied thrice i.e., after 35, 50, and 65 days of sowing. Land preparation, intercultural operations, and agronomic practices were kept uniform and homogeneity was maintained. Chemical control against sucking insects i.e. jassid, thrips, whitefly, and bollworm (pink bollworm) was done following local recommendations. For weed control insecticides were applied and required irrigation was also given to the research area.

Table 1. Soil chemical and physical properties

Parameter	Quantity
Sand	40.71%
Silt	37.29
Clay	21.99%
pH	8.1
Organic matter	0.85%
$CaCO_3$	5.5%
EC	1.5 dSm^{-1}
Available N	0.60 g kg^{-1}
Available P	10.5 mg kg^{-1}
Exchangeable K	125.0 mg kg^{-1}
AB-DTPA Extractable Zn	0.930 mg kg^{-1}
AB-DTPA Extractable Fe	2.950 mg kg^{-1}
AB-DTPA Extractable Mn	1.150 mg kg^{-1}

Table 2. Treatments of the experiment

Treatments	N (kg ha^{-1})	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})	Sprayed Nutrients
Treatment 1 (Recommended, Basal Application)	222	86	94	No Spray
Treatment 2	222	86	94	phosphorus 1250 g ha^{-1},
Treatment 3	222	86	94	Zinc (as $ZnSO_4$) @ 500 g ha^{-1}
Treatment 4	222	86	94	Boron as Borax (11.3 %) with g ha^{-1}

Table 3. Effect of foliar application of phosphorous, zinc, and boron on cotton growth and yield attributes during Kharif-2017

Treatments	Germination count (m^2)	Plant Height (cm)	No. of Boll /plant	Boll weight (g)	Seed cotton yield (kg/ha^1)	Biological Yield ($kg\ ha^{-1}$)	Ginning Out Turn (%)
NPK (Basal) ($kg\ ha^{-1}$)	5.6 ^{NS}	138 d	20.4 d	2.4 c	1322 d	8073 d	38.3 ^{NS}
NPK+ DAP (46%) @ 1250 g ha^{-1}	5.2 ^{NS}	160 a	26.4 a	2.98 a	1732 a	10385 a	38.5^{NS}
NPK+Zinc Sulphate 33% @ 500g ha^{-1}	5.8 ^{NS}	154 b	24.2 b	2.90 b	1579 b	9562 b	38.2 ^{NS}
Borax 11.3 % @ 500g ha^{-1}	5.6 ^{NS}	148 c	22.6 c	2.88 b	1468 c	8854 c	38^{NS}

Plant population (m^{-2}) was counted 3rd week after sowing. Average plant height (cm) was measured from randomly selected plants from each treatment during the last picking. Total numbers of bolls from the randomly selected plant were picked on each picking. Subsequently, all the bolls were added to which were picked from the selected plant and mean bolls per plant and boll weight were calculated and subsequently, seed cotton yield ($plant^{-1}$) and cotton yield ($kg\ ha^{-1}$) were obtained.

3. Results

3.1. Plant Population

Data given in Tables (Table 3 and 4), showed that the effect of plant population was non-significant and at par with each other. Average plant population of the cotton crop during both years (2017 and 2018) is depicted in Table 5. Pool data of germination count was also non-significant. Overall higher germination count was recorded during the year 2017 as compared to the year 2018.

3.2. Plant Height (cm)

The combined effect of genetic makeup, environment, and management practices determines the plant height. All treatments were statistically different during both experimental years (2017 & 2018; Table 3 & 4). The tallest plants were observed in the treatment T_2 (160 cm) followed by T_3 (154 cm) and T_4 (148 cm) during 2017. During 2018, plant height under T_2 was maximum with statistically different from all other treatments. After T_2, maximum height was observed T_3 (149 cm) followed by T_4 (143) during 2018. Minimum plant height was observed in T_1 during both years. Pooled data analysis of both years shows that where T_2 was statistically different from all treatments. Overall, foliar application of P in combination with NPK enhanced the plant height during both years as compared to other treatments.

3.3. No. of Bolls Plant^{-1}

Bolls $plant^{-1}$ is a significant component of final yield. Of cotton Data represented in the Tables 3 and 4 exhibited a significant difference among the treatments for the number of bolls $plant^{-1}$ during both experimental years (2017 and 2018). Maximum number of bolls were recorded in T_2 (26.4) as compared to T_3 (24.2), T_4 (22.6), and T_1 (20.4) during 2017. While during 2018, a similar response of the number of bolls was observed against all treatments. Mean bolls $plant^{-1}$ was higher during the experimental year 2018 as compared to 2017.

Pooled analysis of data showed that a maximum number of bolls were produced in T_2 (27.3) whereas fewer bolls were recorded in T_1 (21) where no foliar spray was applied. Number of bolls was significantly affected by foliar application of phosphorus @ 1250 g ha^{-1} followed by zinc (as $ZnSO_4$) @ 500 g ha^{-1}, and boron (11.3 %) in the form of Borax @ 500 g ha^{-1} after 35, 50, and 65 days of sowing.

3.4. Boll Weight (gm)

Boll weight of cotton plants keeps significant importance in seed cotton yield. Data of boll weight highlighted that the maximum weight of boll was obtained in T_2 (2.98 g) which was significantly higher than the boll weight of all other treatments during 2017 (Table 3). Boll weight of T_3 (2.90 g) and T_4 (2.88 g) were at par but different from T_1 (2.40 g) during the first year of study 2017. Results of the second year of study (2018) are given in Table 4. T_2 produced the heaviest boll of 2.93 g, as compared to T_3 (2.75 g), T_4 (2.71 g), and T_1 (2.39 g). T_3 and T_4 were statistically at par with each other but different from T_1.

Table 4. Effect of foliar application of phosphorous, zinc, and boron on cotton growth and yield attributes during Kharif-2018

Treatments	Germination count (m^2)	Plant Height (cm)	Bolls plant $^{-1}$	Boll weight (g)	Seed cotton yield (kg ha^1)	Biological Yield (kg ha^{-1})	Ginning Out Turn (%)
NPK kg/ha^{-1}(Basal)	4.4 ^{NS}	133 d	21 d	2.39 c	1518 d	8364 d	38.3^{NS}
NPK+ DAP (46%) @ 1250 g ha^{-1}	4.8 ^{NS}	155 a	28 a	2.93 a	1929 a	10847 a	38.6 ^{NS}
NPK+Zinc Sulphate 33% @ 500g ha^{-1}	4.4 ^{NS}	149. b	26 b	2.75 b	1775 b	9878 b	38.4 ^{NS}
Borax 11.3 % @ 500g ha^{-1}	4.4 ^{NS}	143c	24 c	2.71 b	1666 c	9487 c	38.3 ^{NS}

Average boll weight of both years showed the same trend as in 2017 and 2018. Overall, effects of P through foliar application @ 1250 g ha^{-1} were the most significant with basal dose of NPK as compared to zinc (as $ZnSO_4$) @ 500 g ha^{-1} with the same basal dose of NPK, and boron (11.3 %) in the form of Borax @ 500 g ha^{-1} with the same basal dose of NPK after 35, 50 and 65 days of sowing.

3.5. Seed Cotton Yield (kg ha^{-1})

Different nutrient treatments applied on cotton crop resulted in highly significant differences in cotton yield (kg ha^{-1}) during both experimental years (2017 & 2018) (Table 3 & 4). Minimum seed cotton yield was recorded (1322 kg ha^{-1}) in T_1 followed by T_4 where NPK (basal) with Borax 11.3% @ 500 g ha^{-1} was applied during 2017. Maximum seed cotton yield was attained in T_2 (1732.4 kg ha^{-1}) where NPK as basal dose and P @ 1250 g ha^{-1} was applied which is highly statistically significant from (1579 kg ha^{-1}) during 2017. Similar responses were obtained during the second experimental year (2018). Maximum seed cotton yield (1929 kg ha^{-1}) was obtained from treatment T_2 where Phosphorus was applied at the rate of 1250g ha^{-1} thrice after 35, 50, and 65 days of sowing followed by T_3 (1775 kg ha^{-1}), T_4 (1666 kg ha^{-1}) and T_1 (1518 kg ha^{-1}).

3.6. Biological Yield (kg ha^{-1}):

Biological yield has shown a similar response to different macro- and micro-nutrients applied through basal dose and foliar application. Maximum biological yield was observed in T_2 during 2017 (10385 kg ha^{-1}) and 2018 (10847 kg ha^{-1}) which were significantly different from all other treatments. Foliar application of phosphorus @ 1250 g ha^{-1} after 35, 50 and 65 days after sowing with the basal application of NPK has significantly affected the crop yield, biological yield, and other yield components. In the pooled analysis, it has been observed that T_2 (10566 kg ha^{-1}) is significantly different from all other treatments.

3.7. Ginning Out Turn (%):

During the experiment different treatments of macro and micro nutrients could not produce any significant difference. Maximum ginning out turn (38.6%) was obtained from foliar application of P with the basal dose of NPK (T_2) during 2018 while minimum ginning out turn (38.2%) was obtained from b zinc sulfate (33% @ 500 g ha^{-1}) foliar application with the basal dose of NPK.

4. Discussion

Among different management factors of cotton, nutrient management is important for cotton crop. Nutrients (macro and micro) are vital for enhancing crop growth and development. Cotton crop final yield is a product of different yield components including plant population density, number of bolls, and unit boll weight. These yield attributes are mainly dependent on soil fertilization and the environment (Rehman et al., 2019 a). Rate of nutrient application depends on method of their application e.g., basal or topdressing (Aslam et al., 2019). For example, for proper vegetative growth of cotton, basal dose of NPK is necessary, depending upon soil fertility level. However, foliar application of some nutrients during flowers and boll formation plays a vital role to mitigate stress conditions (Aslam et al., 2019) and boost final crop yield through enhancing flowers and bolls formation and decreasing their shedding (Ekert, 2010). In different studies, the beneficial impact of foliar applications has been reported. During vegetative growth, application of urea and DAP @ 2%, significantly reduced leaf reddening in Bt cotton. Application of recommended two to three sprays of $MgSO_4$ (1%) + $ZnSO_4$ (0.5%) at squaring, flowering, and boll development stage or two sprays of urea (2%) at flowering and 2% DAP at the boll development stage to obtain higher seed cotton yield. Foliar application of boron (0.15 kg ha^{-1}) at the early growth stages increased cotton yield and fiber length (Abid et al., 2007). However, a higher dose of foliar application was required at lateral stages (flowering) (Bogiani et al., 2014). Three rounds of foliar application of 0.2 % B (as borax or boric acid) at the seedling stage, early flowering, or boll formation stages increased cotton yield by 15.1%. The highest seed cotton yield of 8.12 t ha^{-1} was obtained from the combined application of the recommended NPK rate (120:60:60 kg ha^{-1}) + 1% Micnelf MS-16 at 30, 65, and 90 DAS (Namdev et al., 1992). Moreover, application of a recommended dose of phosphorus (60 kg ha^{-1}) produced significantly higher dry matter than control. Foliar application of P at the rate of 7.5 kg P_2O_5 ha^{-1} combined with 40 ppm Zn at 75 and 90 DAS, 7.5 kg P_2O_5 with 60 ppm of Ca at 80 and 95 DAS under clay loamy soil condition gave significantly higher cotton yield (cv. Giza 75). In a transplanted cotton cv. Giza 70, the number of bolls $plant^{-1}$, number of open bolls $plant^{-1}$, boll weight, and lint yield was the highest with foliar application of P at the budding stage and pre-flowering stage when 30 days old seedlings were transplanted (Zhao et al., 2019). Application of 2% DAP increased the number of bolls $plant^{-1}$ over control. Radharnani et al. (2003) reported that foliar application of P (0.2% or 0.5%) in three applications ten days after squaring gave higher seed cotton yields (1.21 - 1.26 t ha^{-1}) than 15 or 20 kg P ha^{-1} as single super phosphate applied to the soil (1.13 - 1.14 t ha^{-1}). Seed cotton yield and oil content and N, P, and K uptake of cotton were higher due to foliar application. Raju et al. (2008) reported that foliar application of DAP produced 10% more seed cotton yield, 16% higher B: C ratio with 7% higher boll numbers over soil application alone. Foliar application of DAP (2%) increased mean seed cotton yield between 219.5 and 500 kg ha^{-1} compared to control. The highest seed cotton yield of 1.79 t ha-1 was obtained by 15 kg $P_2\,O_5$ ha_{-1} at first irrigation through soil + 15 kg $P_2\,O_5$ ha_{-1} through 2% DAP spray. Phosphorus application improved seed and fiber strength (Rajendran et al., 2010).

4. Conclusion

Under the agroecological conditions of Karor Lal Eason, Punjab, Pakistan, the application of micro and macro nutrients significantly influenced the growth and yield parameters of the cotton crop. Seed cotton yield was maximum (1830.8 kg ha^{-1}) when Phosphorus was applied at the rate of 1250 g ha^{-1} thrice after 35, 50, and 65 days of sowing, during both years 2017 & 18 followed by other applications of zinc and boron (1677 & 1567 kg ha^{-1}) respectively. For better production foliar spray of Phosphorus @ 1250g ha^{-1} after 35, 50, and 65 days of sowing, is recommended.

Competing Interest Statement: All the authors declare that they have no competing interests

List of Abbreviations: NPK: Nitrogen Phosphorus and Potash; GDP: Gross Domestic Product

Author's Contribution: All authors have contributed equally for data collection, arrangement and manuscript preparation.

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