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Optimizing Fodder Crop Productivity in Maize (*Zea Mays* L.) Variety Kaptan Under Farmyard Manure and Boron Application Levels Strategies for Enhanced Yield and Quality.

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Article Info

Abstract

The experiment was conducted during Kharif, 2023 to study the growth and fodder yield performance of maize (*Zea mays* L.) variety Kaptan under farmyard manure and boron application levels. The experiment was laid at the Research Farm, The University of Agriculture Peshawar, Pakistan in a three replicated Randomized complete block design. The treatments included T_1 = Control (No Fertilizer), T_2 = FYM 1 ton + boron 1 kg, T_3 = FYM 3 ton + boron 2 kg, T_4 = FYM 5 ton + boron 3 kg, T_5 = FYM 7 ton + boron 4 kg and T_6 = FYM 9 ton + boron 5 kg. The results showed that the FYM 9 ton + boron 5 kg resulted maximum 81.35% plant population (m^2) , 187.94 cm plant height, 4.98 cm stem girth, 12.70 number of leaves $plant^{-1}$ and 26.95 tons ha^{-1} food yield. The maize crop under control (no fertilizer) with minimum 57.95% plant population (m^2), 106.95 cm plant height, 2.41 cm stem girth, 5.10 number of leaves $plant^{-1}$ and 5.1 tons ha^{-1} food yield. Upon reviewing the current research findings, it was determined that there is a simultaneous increase in the growth and yield of maize when applying higher levels of Farm Yard Manure (FYM) and boron; and the maize fertilized with FYM 9 ton + boron 5 kg resulted in highest fodder yield (26.95 tons ha^{-1}), followed by FYM 7 ton + boron 4 kg (25.36 tons ha^{-1}) and FYM 5 ton + boron 3 kg (19.47 tons ha^{-1}). Maize variety Kaptan may be preferred for better yield performance under climatic condition of Peshawar, Khyber Pakhtunkhwa, Pakistan.

Keywords:
Maize, Growth, Fodder Performance, Boron, Farmyard manure

Introduction

Maize (*Zea mays* L.) holds a prominent position as one of the world's top crops, ranking third in global cereal crop production, following wheat and rice (FAO, 2020). Fodder maize cultivation is widely practiced across various regions of Pakistan, including temperate, subtropical, and tropical areas, covering an extensive land area of approximately 10.85 million hectares. This large-scale cultivation aims to meet the demand for forage and silage required by farm animals, resulting in an impressive annual production of about 46.31 million metric tonnes (FAOSTAT, 2012). Due to its short growth duration, rapid growth rate, and extensive cultivation, maize possesses exceptional potential, surpassing other cereal crops in its capabilities. Given these remarkable attributes, it is often referred to as the "queen of cereals." (Begam et al., 2018). Maize is a versatile and traditional crop cultivated for multiple purposes, including food, feed, and fodder production (KC et al., 2015). Maize is regarded as a nutritious food and feed source due to its composition, which includes approximately 72% starch, 10% protein, 9.5% fiber, and 4% fat. It provides an energy density of about 365 Kcal per 100 grams, making it a valuable dietary resource (Scopel et al., 2020). From a practical standpoint, fodder maize is known for its ease of cultivation and ability to thrive in drought-prone conditions, ensuring consistenmat high yields with minimal input from the farmers. Additionally, forage maize extends the silage- making season as it is ensiled in September or October, well after the grass silage-making period is completed. The palatable silage produced by forage maize is favored by livestock, and it generates significantly less effluence compared to grass silage. This reduction in effluent production is particularly advantageous for farmers located near watercourses, as it mitigates the environmental risks associated with effluent pollution (Ginwal et al., 2019). Maize silage is recognized as an exceptional forage source, particularly for finishing cattle, due to its high starch content. An analysis of high-quality maize silage typically reveals around 28-32% dry matter, 11-11.5 MJ metabolizable energy per kilogram of dry matter, 28-32% starch, and 7-9% crude protein. These remarkable nutrient levels make it an optimal choice for enhancing the performance and productivity of cattle during the finishing phase (Tondey et al., 2021). Maize, hailed as the "queen of cereals," holds a prestigious position as the third most significant crop globally, following only rice and wheat in importance (Azees et al., 2017). Its extensive adaptability and capacity to yield a higher number of calories were pivotal factors in its selection as a key component of national food security crops (Abate et al., 2015). Maize, commonly referred to as corn, serves as a fundamental raw material for various industrial products, including oil, starch, alcoholic beverages, pharmaceuticals, food sweeteners, cosmetics, textiles, packaging, and paper industries. Its fiber content renders it beneficial for digestion and may contribute to preventing diabetes and hypertension. Maize boasts high nutritional value, comprising 72% starch, 10% protein, 8.5% fiber, 4.8% oil, 3.0% sugar, and 1.7% ash. The starch in maize can be hydrolyzed and subjected to enzymatic treatment to produce syrups like high fructose corn syrup, which acts as a sweetener. Additionally, maize can undergo fermentation and distillation to yield grain alcohol, a traditional source for Bourbon whiskey (Maruthadurai et al., 2020). In our country, Farmyard manure (FYM) plays a central role as the primary source of organic matter, providing crucial nutrients essential for plant growth, including primary, secondary, and micronutrients. Additionally, FYM serves as a consistent energy source for heterotrophic microorganisms, thereby fostering nutrient availability and improving crop quality. When using FYM as fertilizer, not all nutrients are immediately accessible for the initial crop. Approximately 30% of nitrogen, 60 to 70% of phosphorus, and 70% of potassium become readily available for the first crop. The remaining nutrients gradually release over time, ensuring sustained nourishment for subsequent crops, thereby maintaining soil fertility (Hussain et al., 2019). Furthermore, the application of FYM enhances the availability of plant nutrients in the soil. Acting as a nutrient reservoir, FYM contains all essential plant nutrients necessary for healthy growth and development. By incorporating FYM into the soil, it enriches the nutrient content, providing a continuous supply of vital elements for plant uptake and utilization (Aziz et al., 2019). In soil, Boron (B) primarily exists as boric acid or borate, percolating through the soil in the form of uncharged molecules rather than ions (Gilal et al., 2020). Boron is an essential nutrient crucial for optimal crop growth, development, yield, and quality. Insufficient boron supply hampers root elongation, resulting in deformed flowers and fruits due to impaired cell division in the meristematic region. Conversely, adequate boron supply promotes beneficial root development, vital for overall plant health and productivity (Brohi et al., 2022). Boron deficiency triggers enzymatic and nonenzymatic oxidation processes, increasing polyphenol oxidase and quinine concentrations, which can adversely affect plant growth and development by causing oxidative stress and disrupting physiological processes. Thus, maintaining sufficient boron levels is crucial for supporting healthy plant growth and overall crop productivity (Waris et al., 2023). Boron plays a pivotal role among nutrient elements due to its significant impact on plant Vigor, root growth, and crop yield quality. It is involved in cell division as a constituent of nucleoproteins, essential for cell reproduction processes. Additionally, boron participates in chemical reactions responsible for carbohydrate synthesis and degradation, seed and fruit formation, and crop maturation. It expedites fruit ripening and helps counteract the adverse effects of excessive nitrogen application, contributes to plant structural strength, prevents lodging, influences grain quality, and enhances plant resistance to diseases, making it indispensable for overall crop health and productivity (Rajnish et al., 2019).

MATERIAL AND METHOD

The field experiment was carried out at the Research Farm, The University of Agriculture Peshawar, Pakistan to determine the impact of soil-applied fertilizers on maize growth and yield. The experiment followed a completely randomized block design with a net plot size of 4m x 3m (12m^2). The land preparation methods recommended for maize plantations were implemented. The study focused on the local variety Kaptan and was replicated three times. The soil-applied fertilizers included Boron and Farmyard manure were applied as per treatments.

Culture Practices

A good seed bed was prepared by two dry ploughings and leveling the land. The recommended dose of Farmyard manure was applied as per treatments during the sowing time. Throughout this study, during the seeding, Boron fertilizer was applied to different stages of maize. The agronomical traits of the plants were observed by selecting five plants in each plot at five-day intervals during the initial 10 days following crop formation.

1. T_1 = Control (No Fertilizer)
2. T_2 = FYM 1 ton + boron 1 kg ha^{-1}
3. T_3 = FYM 3 ton + boron 2 kg ha^{-1}
4. T_4 = FYM 5 ton + boron 3 kg ha^{-1}
5. T_5 = FYM 7 ton + boron 4 kg ha^{-1}
6. T_6 = FYM 9 ton + boron 5 kg ha^{-1}

During the maturity stage, 15 plants were sampled from each experimental unit to measure their plant height (cm), stem girth (cm) and number of leaves plant-1. The seed heads were separated from each plant, threshed, and used to calculate the number of seeds head-1 and fodder yield (tons ha^{-1}) all of which were recorded.

Statistical analysis

The collected data was subjected to statistical analysis using computer software statistix-8.1 (Statistix, 2006). The LSD test was applied to compare treatments superiority, where necessary.

RESULTS

Plant population (m^{-2})

The result proved the significant difference ($p<0.05$) in maize at various levels of boron and farmyard manure. The highest seed germination rate (81.35%) was achieved when the maize was given 9 tons of FYM and 5 kg of boron, followed by 80.19%, 77.25%, and 70/.11% with 7 tons of FYM and 4 kg of boron, 5 tons of FYM and 3 kg of boron, and 3 tons of FYM and 2 kg of boron, respectively. The seed germination rate decreased to 66.25% when the maize was given 1 ton of FYM and 1 kg of boron. The lowest seed germination rate (57.95%) was observed in the control group (no fertilizer). This indicates that the combination of 9 tons of FYM and 5 kg of boron is the most effective in achieving maximum seed germination.

Table 1. Plant Population (m^2) of maize variety Kaptan as affected by different levels of FYM and boron

Treatments	Plant population (m^{-2})
T_1= Control (FYM and Boron not applied)	57.95 e
T_2= FYM 1 ton + boron 1 kg ha^{-1}	66.25 d
T_3 = FYM 3 ton + boron 2 kg ha^{-1}	70.11 c
T_4= FYM 5 ton + boron 3 kg ha^{-1}	77.25 b
T_5= FYM 7 ton + boron 4 kg ha^{-1}	80.19 a
T_6= FYM 9 ton + boron 5 kg ha^{-1}	81.35 a
S.E	0.7302
LSD (0.05)	1.6269
P value	0.0000

Plant height (cm)

The tallest plants (187.94 cm) were obtained when the maize was given 9 tons of FYM and 5 kg of boron, followed by 185.92 cm, 148.49 cm, and 136.99 cm with 7 tons of FYM and 4 kg of boron, 5 tons of FYM and 3 kg of boron, and 3 tons of FYM and 2 kg of boron, respectively. The plant height decreased to 127.65 cm when the maize was given 1 ton of FYM and 1 kg of boron. The control group, which did not receive any fertilizer, exhibited the shortest plant height, measuring 106.95 cm. This suggests that the combination of 9 tons of FYM and 5 kg of boron is the most effective in achieving the maximum plant height at maturity.

Table 2. Plant height (cm) of maize variety Kaptan as affected by different levels of FYM and boron

Treatments	Plant height (cm)
T_1= Control (FYM and Boron not applied)	106.95 e
T_2= FYM 1 ton + boron 1 kg ha^{-1}	127.65 d
T_3 = FYM 3 ton + boron 2 kg ha^{-1}	136.99 c
T_4= FYM 5 ton + boron 3 kg ha^{-1}	148.49 b
T_5= FYM 7 ton + boron 4 kg ha^{-1}	185.92 a
T_6= FYM 9 ton + boron 5 kg ha^{-1}	187.94 a
S.E	0.6233

LSD (0.05)	1.3887
P value	0.0000

Stem girth (cm)

The highest stem girth (4.98 cm) was achieved when the maize was treated with 9 tons of FYM and 5 kg of boron. Other treatments with 7 tons of FYM and 4 kg of boron, 5 tons of FYM and 3 kg of boron, and 3 tons of FYM and 2 kg of boron produced stem girths of 4.90 cm, 4.13 cm, and 3.74 cm, respectively. However, the stem girth decreased to 3.39 cm when the maize was treated with 1 ton of FYM and 1 kg of boron. The lowest stem girth (2.41 cm) was observed in the control group (without any fertilizer). These results suggest that the combination of 9 tons of FYM and 5 kg of boron is most effective in promoting maximum stem girth in maize.

Table 3. Stem girth (cm) of maize variety Kaptan as affected by different levels of FYM and boron

Treatments	**Stem girth (cm)**
T_1= Control (FYM and Boron not applied)	2.41 e
T_2= FYM 1 ton + boron 1 kg ha^{-1}	3.39 d
T_3 = FYM 3 ton + boron 2 kg ha^{-1}	3.74 c
T_4= FYM 5 ton + boron 3 kg ha^{-1}	4.13 b
T_5= FYM 7 ton + boron 4 kg ha^{-1}	4.90 a
T_6= FYM 9 ton + boron 5 kg ha^{-1}	4.98 a
S.E	0.0505
LSD (0.05)	0.1126
P value	0.0000

Number of leaves plant^{-1}

The maximum number of leaves plant^{-1} (12.70) was observed when the maize was given 9 tons of FYM and 5 kg of boron, followed by 11.92, 8.58, and 7.42 for 7 tons of FYM and 4 kg of boron, 5 tons of FYM and 3 kg of boron, and 3 tons of FYM and 2 kg of boron, respectively. The number of leaves plant^{-1} decreased to 6.42 with 1 ton of FYM and 1 kg of boron, but the minimum (5.10) was observed in the control (no fertilizer) treatment. This highlights that the treatment of 9 tons of FYM and 5 kg of boron is the most effective in yielding the maximum number of leaves plant^{-1} at maturity.

Table 4. Stem girth (cm) of maize variety Kaptan as affected by different levels of FYM and boron

Treatments	**Number of leaves plant^{-1}**
T_1= Control (FYM and Boron not applied)	5.10 e
T_2= FYM 1 ton + boron 1 kg ha^{-1}	6.42 d

T_3 = FYM 3 ton + boron 2 kg ha^{-1}	7.42 c
T_4= FYM 5 ton + boron 3 kg ha^{-1}	8.58 b
T_5= FYM 7 ton + boron 4 kg ha^{-1}	11.92 a
T_6= FYM 9 ton + boron 5 kg ha^{-1}	12.70 a
S.E	0.3510
LSD (0.05)	0.7821
P value	0.0000

Fodder yield (tons ha^{-1})

The highest fodder yield (26.95 tons ha^{-1}) was achieved when the maize was given 9 tons of FYM and 5 kg of boron, followed by 25.36 tons ha^{-1} , 19.47 tons ha^{-1} and 13.22 tons ha^{-1} for 7 tons of FYM and 4 kg of boron, 5 tons of FYM and 3 kg of boron, and 3 tons of FYM and 2 kg of boron, respectively. The maize fodder yield decreased to 9.25 tons ha^{-1} with 1 ton of FYM and 1 kg of boron, while the lowest (5.1 tons ha^{-1}) was observed in the control (no fertilizer) treatment. These results indicate that the treatment of 9 tons of FYM and 5 kg of boron is the most effective in achieving the maximum maize fodder yield at maturity.

Table 5. Fodder yield (tons ha^{-1}) of maize variety Kaptan as affected by different levels of FYM and boron

Treatments	**Fodder yield (tons ha^{-1})**
T_1= Control (FYM and Boron not applied)	5.1 e
T_2= FYM 1 ton + boron 1 kg ha^{-1}	9.25 d
T_3 = FYM 3 ton + boron 2 kg ha^{-1}	13.22 c
T_4= FYM 5 ton + boron 3 kg ha^{-1}	19.47 b
T_5= FYM 7 ton + boron 4 kg ha^{-1}	25.36 a
T_6= FYM 9 ton + boron 5 kg ha^{-1}	26.95 a
S.E	0.3942
LSD (0.05)	0.8784
P value	0.0000

DISCUSSION

The results showed that the FYM 9 ton + boron 5 kg resulted maximum 81.35% seed germination, 187.94 cm plant height, 4.98 cm stem girth, 12.70 number of leaves plant-1 and 26.95 tons ha^{-1} food yield. Similarly, FYM 7 ton + boron 4 kg resulted 80.19% plant population (m2), 185.92 cm plant height, 4.90 cm stem girth, 11.92 number of leaves $plant^{-1}$ and 25.36 tons ha-1 food yield. FYM 5 ton + boron 3 kg with 77.25% plant population (m^2), 148.49 cm plant height, 4.13 cm stem girth, 8.58 number of leaves plant-1 and 19.47 tons ha^{-1} food yield. Maize crop with FYM 3 ton + boron 2 kg with 70.11% plant population, 136.99 cm plant height, 3.74 cm stem girth, 7.42 number of leaves $plant^{-1}$ and 13.22 tons ha^{-1} food yield. The maize crop under control (no fertilizer) with minimum 57.95% plant population, 106.95 cm plant height, 2.41 cm stem girth, 5.10 number of leaves $plant^{-1}$ and 5.1 tons ha^{-1} food yield. After analyzing the current research findings, the study concluded that the growth and yield of maize exhibited a simultaneous increase with higher levels of both Farmyard Manure (FYM) and boron application. Maize treated with the combined elements exhibited significant enhancements in both growth and yield outcomes. The highest fodder yield of 26.95 tons per hectare was observed in the treatment receiving 9 tons of FYM combined with 5 kg of boron, followed by 7 tons of FYM with 4 kg of boron resulting in 25.36 tons per hectare, and 5 tons of FYM with 3 kg of boron yielding 19.47 tons per hectare. These findings resonate with Wahab et al. (2021) study, which highlighted the positive impact of FYM and boron combination on maize growth and yield in India. The use of organic fertilizers like FYM is known to enhance soil fertility and provide essential nutrients, thereby promoting increased growth and yield. Boron, being an essential micronutrient, plays a critical role in plant growth and development, particularly in cell wall and pollen tube formation. The present study's results are consistent with previous research on the synergistic effect of FYM and boron on maize growth and yield. For instance, Shori et al. (2019) demonstrated that the application of FYM and boron improved maize growth and yield in Jordan. The highest fodder yield recorded in the treatment receiving 9 tons of FYM combined with 5 kg of boron suggests the efficacy of this combination for optimal maize production. Similarly, Curie et al. (2021) investigated the impact of soil-applied nutrients, particularly boron, on maize growth and uptake in high-boron soil. Their study revealed a positive correlation between boron doses and uptake, with significant effects on maize shoot dry weight. Additionally, the application of farmyard manure improved maize growth parameters and soil nitrogen status, further supporting the beneficial impact of organic amendments. Both farmyard manure and boron are vital components of soil fertility management, contributing to maize growth and productivity. Farmyard manure provides organic matter and essential nutrients like nitrogen, phosphorus, and potassium, while boron serves as a micronutrient essential for proper plant growth and development. Application rates for farmyard manure and boron in maize cultivation depend on various factors such as manure quality, soil fertility, and crop requirements. However, a general recommendation is to apply 10 to 20 tons of well-decomposed FYM per hectare before planting. Nonetheless, based on the results, it is advisable to use FYM at a rate of 7 tons per hectare combined with 4 kg of boron per hectare to achieve higher maize development and fodder yield. Moreover, Cruz et al. (2022) also testified that the better growth and higher fodder yield of maize recommended dose of FYM 7 ton + boron 4 kg ha^{-1} was shown given greater fodder yield and highly recommended for local farmers.

Conclusions

It is concluded that the maize growth and fodder yield were influenced significantly ($p<0.05$) by boron and farmyard manure levels associated with control (no fertilizer). The fodder yield expanded linearly with increasing boron and farmyard manure levels. However, the plot fertilized with fertilizer of FYM 9 ton + boron 5 kg produced maximum (26.95 tons ha^{-1}) maize fodder yield followed using FYM 7 ton + boron 4 kg with (25.36 tons ha-1). Hence the difference between T5 and T6 are statistically almost same.

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