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BROADCAST AND FOLIAR APPLICATION OF MICRO AND MACRONUTRIENTS ON MAIZE (ZEA MAIZE L.) IN DISTRICT CHARSADDA

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Abstract
Maize plays a crucial role in food security and livelihoods within Charsadda District. This study examined the effects of broadcast and foliar micro and macronutrient applications on maize production, utilizing Jalal (Pirsabak) and CS 220 (Petal) maize hybrids. Results indicated that foliar application of NPK with micronutrients significantly improved maize growth, yield, and quality.1 Jalal (Pirsabak) consistently outperformed CS 220 (Petal). Notably, the combined application of foliar NPK + micronutrients on Jalal (Pirsabak) yielded the highest results, demonstrating a synergistic effect. This research highlights the importance of tailored nutrient management strategies for optimizing maize cultivation in Charsadda District, suggesting that targeted foliar applications, particularly with superior varieties, can significantly enhance crop production.
Keywords: *Agricultural productivity, Crop nutrition, Maize yield, Nutrient management, Plant growth*

INTRODUCTION

Maize (*Zea mays* L.) is from Gramineae family is popular for cereal crop throughout the world (1). It's out is more than other crops (2). It is also important for getting nutritional for human race and also for poultry and livestock. Micro nutrients is one of the most important nutrients which play a vital role in the growth of crop plants and it's essential for and crop and it's require in very small amount. Iron (Fe), Manganese (Mn), Copper (Cu) and Zinc (Zn) are very important micronutrients for plant development and many growth parameters. These micronutrients take place an integral role in many plant functions, like enzymatic activities, gene expression, synthesis of protein and nucleic acid formation. The production of chlorophyll and secondary metabolites and the synthesis of carbohydrates are also attached with the availability of micronutrients (3).

The lacks or unavailability of micronutrients in soil is not only effects crop production but it has also an adverse effect on human health. For example, Fe (Iron) is very important for human health and the deficiency of Fe (Iron) may cause Anemia in humans. The intensive farming system may cause the unavailability of micronutrients in the soil; however, this progress has brought forth a few issues, but rapid depletion of micronutrients from agricultural lands may cause the deficiency to plant and it's very essential to maintain the requirements of plant with a proper way to get available these nutrients to the plant in soil (4).
Among the primary micronutrients, Fe (iron), Manganese (Mn) and Zin (Zn) play a very important roles in maize crop production, but due to many reasons these elements are unavailable to the plant. In which one of the main things is proper management and proper method of application of micronutrients. Manganese and zinc, behaving as cations in the soil, stand apart from anions in their characteristics. Iron, a micronutrient, provides the electric charge necessary for numerous enzymatic transformations in maize plants. Additionally, it serves as a structural component of porphyrin, facilitating oxidation-reduction reactions crucial for

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respiration and photosynthesis, both vital for plant growth (5). Zinc, on the other hand, plays a significant role in various enzymatic activities, including dehydrogenase and proteinase. In the case of manganese, it activates decarboxylase and oxidase enzymes, further contributing to the intricate web of plant metabolic processes (6).

Soil environmental conditions influence the availability of macro and micronutrients applied to the soil, resulting in varied losses. When a same amount of fertilizer is given to the soil, only 10% of it is used. Foliar fertilizers are up to 20 times more effective in sandy loam than soil fertilizers. Foliar feeding is a fertilization method in which you apply a diluted liquid fertilizer straight to the plant's leaves. The nutrients in the fertilizers spray are absorbed immediately by the plant through its leaves. Foliar application is a technique for supplying macro and micronutrients that prevents nutrient wastage or loss, improves nutrient use efficiency, and lowers production costs (7). Foliar spraying was shown to be 6 to 20 periods extra effective than soil application, depending on soil conditions. Foliar application may be beneficial to crop growth. (8). Acute nutrient deficits, on the other hand, can frequently be detected and treated more quickly with foliar fertilization than with slower-uptake soil supplements (9).

Broadcast application, where fertilizer is spread across the soil surface, is commonly used for high-volume applications and when residual nutrients are intended for future crops. However, research indicates that this method can disrupt natural water and nutrient transport processes within the soil, with these disruptions varying depending on soil type (10). Plant growth and development are mostly influenced by nutrient availability; consequently, understanding the subtleties of nutrient uptake, transportation, assimilation, and organic relations is critical for improving agricultural plant yield (11). Crop plants frequently encounter nutrient imbalances, and these imbalances have detrimental effects on various metabolic processes. Nevertheless, plants have evolved mechanisms to adapt to nutrient deficiencies. Plant growth and development hinge on the recognition of 17 essential elements within the intricate composition of the soil. The substantial quantities of macronutrients such as nitrogen (N), phosphorus (P), potassium (K), calcium, sulfur (S), and magnesium play a crucial role. Additionally, micronutrients like iron (Fe), zinc (Zn), copper, boron, manganese, molybdenum, chloride, and others, though required in smaller amounts, remain indispensable for the growth and enhancement of crop plants. One of the essential aspects in producing enough food resources to support the world's increasing human population has been the usage of N and P fertilizers, which is measured near stand single of the significant mechanisms of the Green Revolt throughout the 1960s (12).

MATERIALS AND METHODS

A field experiment was conducted at the Agricultural Research Farm (ARF), Bacha Khan University Charsadda. The experiment followed a Randomized Complete Block Design (RCBD) with three replications. Plots consisted of 4 rows, 3m long, with 45 cm row spacing and 22.5 cm plant spacing. A 1m distance was maintained between plots and replications. Maize hybrid varieties CS 220 (Petal) and Jalal (Pirsabak) were treated against four levels of fertilizer application consisted of NPK (conventional), NPK (Foliar), NPK (broadcast) + micronutrients (Mg, Ca, B, Zn, S, Cu, Mn and Fe) and NPK (Foliar) + (Mg, Ca, B, Zn, S, Cu, Mn and Fe). For accurate application of Nitrogen (N), Phosphorus (P) and Potassium (K) fertilizers prior soil analysis was performed (Table 1). Data was recorded on various yield parameters of the both maize crops including protein content in grain and straw for comparison.

Table I. Soil analysis of the experimental field

pH	EC	OM	N	P	K	$CaCO_3$	Clay	Silt	Sand	Texture
8.14	.32	1.03	.051	8.2	138	2.50	13	54	33	Silt Loam

RESULTS

PLANT HEIGHT (CM)

Plant height, a significant indicator of final maize yield and nutrient efficiency, displayed notable variations across different varieties. Specifically, Jalal (Pirsabak) exhibited the tallest plant height at 173.0 cm (Fig. 1a), highlighting varietal differences. The interaction between maize varieties and nutrient treatments

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also significantly impacted plant height. Among the nutrient applications, the foliar application of NPK with micronutrients resulted in the greatest plant height, reaching 179.0 cm, followed by conventional NPK with micronutrients and foliar NPK alone. Conversely, conventional NPK application yielded the shortest plant height at 160.6 cm.

EAR WIDTH (CM)

Ear width is a critical factor influencing maize yield, as it determines the potential for maximum yield when combined with proper nutrient management and suitable maize varieties. Results (Fig. 1b) showed significant variation in ear width among maize hybrid varieties and nutrient applications. Jalal (Pirsabak) produced the maximum ear width (1.7 cm), followed by CS 220 (Petal) (1.6 cm). The variation in ear width may be attributed to genetic differences among varieties. NPK Foliar + Micro nutrients yielded the maximum ear width (1.7 cm), while NPK conventional resulted in the minimum (1.6 cm). The interaction between Jalal (Pirsabak) and NPK Foliar + Micro nutrients produced the maximum ear width (1.8 cm).

EAR LENGTH (CM)

Analysis of ear length data (Fig. 1c) revealed significant variation due to nutrient applications, maize varieties, and their interaction. Jalal (Pirsabak) had the maximum ear length (18.4 cm), while CS 220 (Petal) had the minimum (17.5 cm). Genetic differences among varieties likely contributed to the variation in ear length. NPK Foliar + Micro nutrients resulted in the maximum ear length (19.3 cm), while NPK conventional had the minimum (14.8 cm). The interaction between Jalal (Pirsabak) and NPK Foliar + Micro nutrients yielded the maximum ear length (20.2 cm).

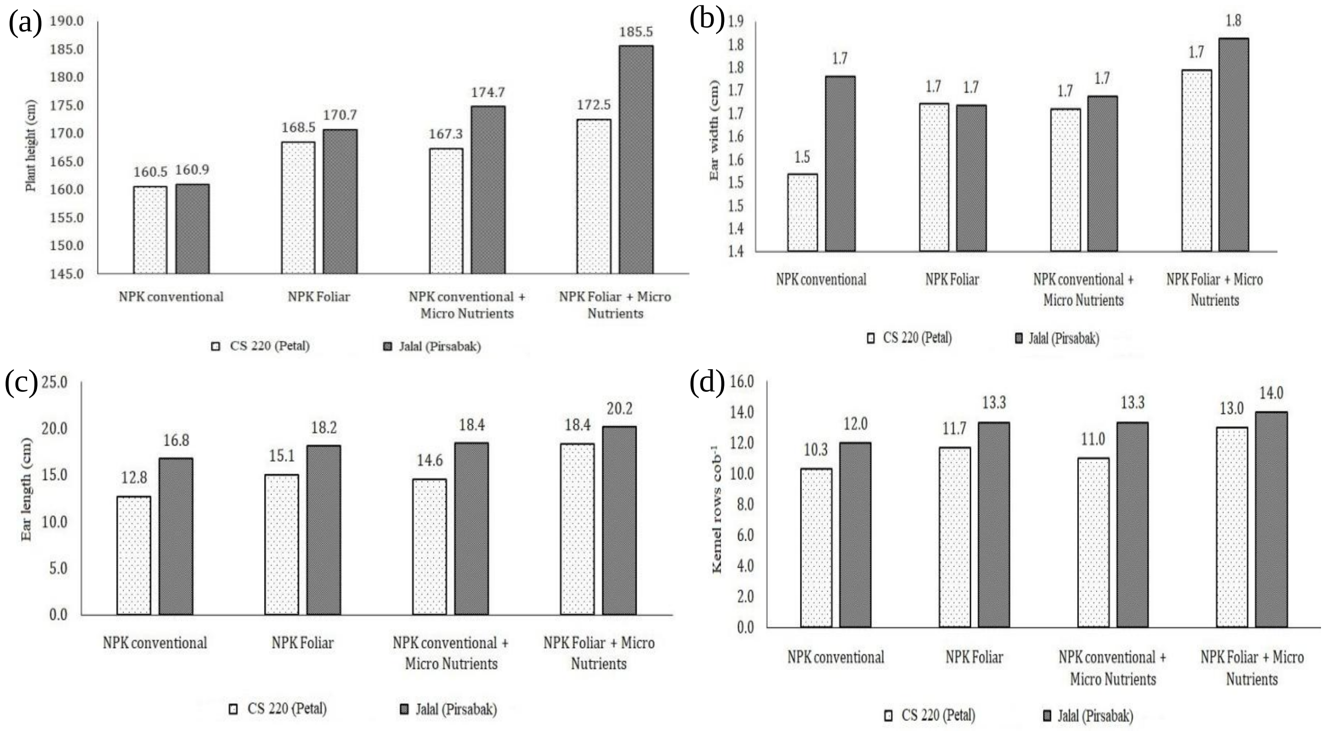

Fig. 1a. Plant height (cm) as affected by maize hybrid and different nutrients. **Fig. 1b**. Ear width (cm) as affected by maize hybrid and different nutrients. **Fig. 1c**. Ear length (cm) as affected by maize hybrid and different nutrients. **Fig. 1d**. Kernel rows cob^{-1} as affected by maize hybrid and different nutrients

KERNEL ROWS COB^{-1}

The number of kernel rows per cob, a crucial factor influencing maize yield, was significantly impacted by both nutrient treatments and variety selection, as depicted in Fig. 1d. Among the tested varieties, Jalal (Pirsabak) exhibited the highest average kernel rows per cob at 13.2, surpassing CS 220 (Petal). Regarding nutrient treatments, the foliar application of NPK supplemented with micronutrients resulted in the greatest number of kernel rows per cob, averaging 13.5, while conventional NPK application yielded the lowest at 11.2. Notably, the most significant outcome was the combined effect of Jalal (Pirsabak) and the foliar NPK + micronutrient treatment, which produced an optimal 14.0 kernel rows per cob, demonstrating a strong synergistic interaction.

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WEIGHT OF 100 KERNEL (G)

The 100-grain weight, a critical determinant of maize yield and quality, was significantly affected by variety, nutrient treatment, and their interaction (Fig. 2a). Jalal (Pirsabak) exhibited the highest 100-grain weight (32.8g), surpassing CS 220 (Petal) (30.2g). Foliar application of NPK with micronutrients yielded the greatest 100-grain weight (37.9g), while conventional NPK application resulted in the lowest (25.9g). Notably, the combined application of foliar NPK + micronutrients on Jalal (Pirsabak) produced the optimal 100-grain weight (39.4g), demonstrating a strong synergistic effect.

BIOLOGICAL YIELD (KG HA^{-1})

Fig. 2b presents data on biological yield. Analysis revealed significant effects of nutrient applications, maize hybrids, and their interaction on biological yield. Jalal (Pirsabak) outperformed CS 220 (Petal), producing a maximum biological yield of 16087.4 kg/ha. Genetic differences among varieties contributed to variations in grain yield. The combination of NPK Foliar + Micro nutrients yielded the highest biological yield (16673.9 kg/ha), while NPK conventional resulted in the lowest (14324.2 kg/ha). The interaction between Jalal (Pirsabak) and NPK Foliar + Micro nutrients produced the maximum yield (17203.6 kg/ha).

GRAIN YIELD (KG HA^{-1})

Grain yield, a paramount factor in maize production with significant implications for food security and nutrition, was demonstrably influenced by nutrient applications, maize variety, and their combined effect. Jalal (Pirsabak) exhibited a superior grain yield of 5176.7 kg/ha (Fig. 2c), surpassing CS 220 (Petal), thus highlighting the impact of genetic variations. Furthermore, the application of NPK Foliar + Micro nutrients resulted in the highest grain yield, reaching 5702 kg/ha, while conventional NPK application yielded the lowest at 4373.4 kg/ha. Notably, the interaction between Jalal (Pirsabak) and NPK Foliar + Micro nutrients produced the highest yield of 6027.8 kg/ha, indicating a strong synergistic effect.

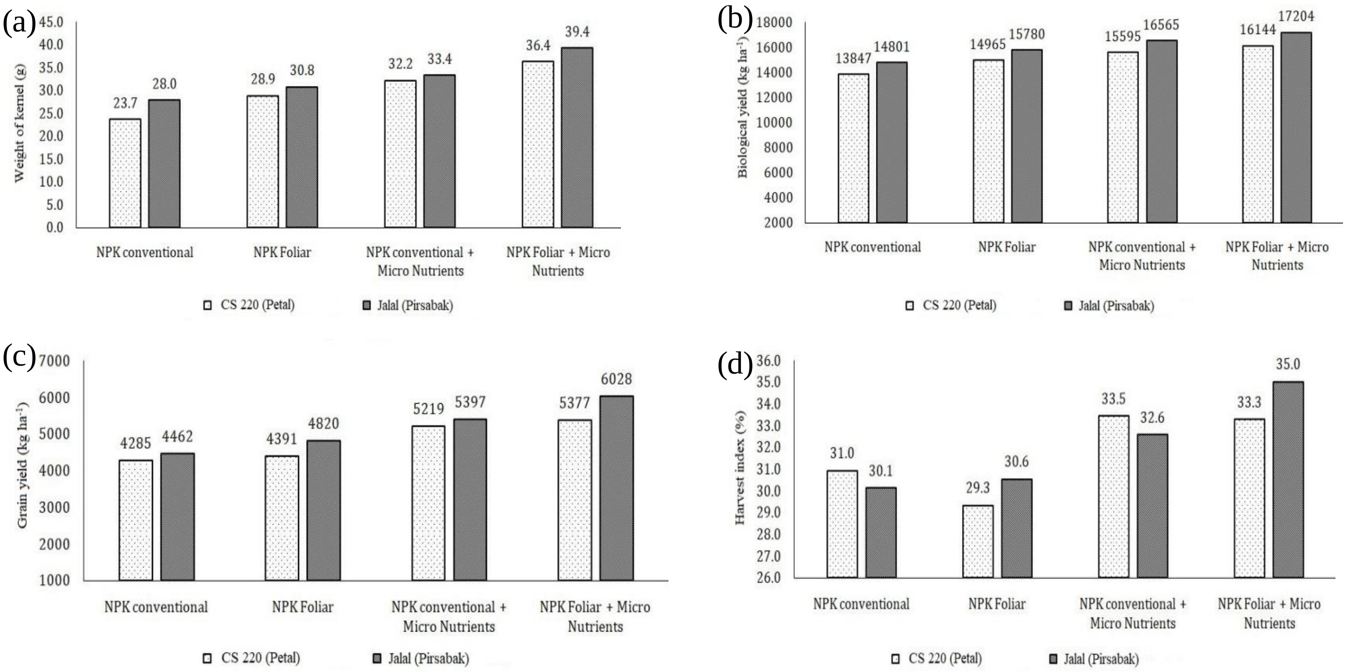

Fig. 2a. Weight of kernel as affected by maize hybrid and different nutrients. **Fig. 2b.** Biological yield (kg ha^{-1}) as affected by maize hybrid and different nutrients. **Fig. 2c.** Grain yield (kg ha^{-1}) as affected by maize hybrid and different nutrients. **Fig. 2d.** Harvest index (%) as affected by maize hybrid and different nutrients

HARVEST INDEX (%)

Analysis revealed significant effects of maize hybrids, nutrients, and their interaction on harvest index (Fig. 2d). Jalal (Pirsabak) had a maximum harvest index (32.1%), outperforming CS 220 (Petal) (31.8%). NPK Foliar + Micro Nutrients resulted in the highest harvest index (34.2%), while NPK Conventional had the

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lowest (30.6%). The interaction between Jalal (Pirsabak) and NPK Foliar + Micro Nutrients showed optimal results.

PROTEIN CONTENT IN GRAIN (%)

Maize is a valuable source of plant-based protein, offering various health benefits. Fig. 3a presents data on protein content in maize grains. Analysis revealed significant effects of nutrients, maize hybrids, and their interaction on protein content. Jalal (Pirsabak) had the highest protein content (10.1%), outperforming CS 220 (Petal) (8.2%). NPK Foliar + Micro nutrients resulted in the highest protein content (10.6%), followed by NPK Conventional + Micro nutrients and NPK Foliar. The interaction between Jalal (Pirsabak) and NPK Foliar + Micro nutrients showed optimal results.

PROTEIN IN STRAW (%)

Fig. 3b illustrates the protein content of maize straw, revealing significant impacts from both maize varieties and nutrient applications, as well as their combined effect. Jalal (Pirsabak) exhibited the highest straw protein content at 5.9%, significantly exceeding the 4.7% observed in CS 220 (Petal). The foliar application of NPK with micronutrients yielded the highest protein content, reaching 6.5%, followed by conventional NPK with micronutrients and then foliar NPK alone. Notably, the most substantial protein content, 7.4%, was achieved through the combined application of foliar NPK + micronutrients on Jalal (Pirsabak), demonstrating a clear synergistic effect.

DISCUSSION

This study reveals significant variation in plant height among maize varieties, with Maize Variety Jalal (Pirsabak) exhibiting the maximum height. This supports previous research showing plant height as a crucial indicator of final yield in maize (13). The interaction between maize hybrids and nutrients was significant, with NPK Foliar + Micro nutrients yielding the maximum plant height. This aligns with recent research demonstrating the benefits of foliar nutrient application (14). In contrast, NPK conventional application resulted in the minimum plant height, underscoring the limitations of traditional nutrient management strategies (15).

Ear width is a critical factor influencing maize yield, as it determines the potential for maximum yield when combined with proper nutrient management and suitable maize varieties (16). This study found significant variation in ear width among maize hybrid varieties and nutrient applications. The maximum ear width was observed in Jalal (Pirsabak), which may be attributed to genetic differences among varieties (17). NPK Foliar + Micro nutrients yielded the maximum ear width, while NPK conventional resulted in the minimum. This finding supports recent research highlighting the benefits of foliar nutrient application for improving maize yield. The interaction between Jalal (Pirsabak) and NPK Foliar + Micro nutrients produced the maximum ear width (1.8 cm), emphasizing the importance of optimizing nutrient management for specific maize varieties.

The analysis of ear length data revealed significant variation due to nutrient applications, maize varieties, and their interaction. Jalal (Pirsabak) exhibited the maximum ear length, likely attributed to genetic differences among varieties (17). NPK Foliar + Micro nutrients resulted in the maximum ear length, while NPK conventional had the minimum. This finding supports recent research highlighting the benefits of foliar nutrient application for improving maize yield. The interaction between Jalal (Pirsabak) and NPK Foliar + Micro nutrients yielded the maximum ear length, emphasizing the importance of optimizing nutrient management for specific maize varieties.

Kernel rows per cob are a critical determinant of final maize yield. This study found significant effects of nutrients and maize varieties on kernel rows per cob. Jalal (Pirsabak) exhibited the maximum kernel rows per cob, followed by CS 220 (Petal). The optimal results were obtained with NPK Foliar + Micro nutrients, highlighting the benefits of foliar nutrient application for improving maize yield. The interaction between Jalal (Pirsabak) and NPK Foliar + Micro nutrients showed the highest kernel rows per cob, emphasizing the importance of optimizing nutrient management for specific maize varieties (18).

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The 100-grain weight is a crucial factor influencing maize yield and quality. This study found significant effects of hybrid varieties, nutrients, and their interaction on 100-grain weight. Jalal (Pirsabak) exhibited the maximum 100-grain weight (32.8g), outperforming CS 220 (Petal). NPK Foliar + Micro nutrients resulted in the highest 100-grain weight (37.9g), highlighting the benefits of foliar nutrient application for improving maize yield and quality (19). The interaction between Jalal (Pirsabak) and NPK Foliar + Micro nutrients showed optimal results, emphasizing the importance of optimizing nutrient management for specific maize varieties.

The analysis of biological yield revealed significant effects of nutrient applications, maize hybrids, and their interaction. Jalal (Pirsabak) outperformed CS 220 (Petal), producing a maximum biological yield. Genetic differences among varieties contributed to variations in grain yield (20). The combination of NPK Foliar + Micro nutrients yielded the highest biological yield, highlighting the benefits of foliar nutrient application for improving maize yield (20**).** The interaction between Jalal (Pirsabak) and NPK Foliar + Micro nutrients produced the maximum yield, emphasizing the importance of optimizing nutrient management for specific maize varieties.

Grain yield is a critical factor in maize production, directly impacting food security and nutrition. This study found significant effects of nutrient applications, maize hybrids, and their interaction on grain yield. Jalal (Pirsabak) outperformed CS 220 (Petal), producing a maximum grain yield. Genetic differences among varieties contributed to variations in grain yield **(21).** The combination of NPK Foliar + Micro nutrients yielded the highest grain yield, highlighting the benefits of foliar nutrient application for improving maize yield (22). The optimal yield was obtained from the interaction between Jalal (Pirsabak) and NPK Foliar + Micro nutrients (6027.8 kg/ha), emphasizing the importance of tailored nutrient management strategies for specific maize varieties.

The analysis of harvest index revealed significant effects of maize hybrids, nutrients, and their interaction. Jalal (Pirsabak) exhibited a maximum harvest index, outperforming CS 220 (Petal). NPK Foliar + Micro Nutrients resulted in the highest harvest index, highlighting the benefits of foliar nutrient application for improving maize yield and efficiency (23). The interaction between Jalal (Pirsabak) and NPK Foliar + Micro Nutrients showed optimal results, emphasizing the importance of tailored nutrient management strategies for specific maize varieties (24**)**

Maize is a vital source of plant-based protein, offering numerous health benefits. This study found significant effects of nutrients, maize hybrids, and their interaction on protein content in maize grains. Jalal (Pirsabak) exhibited the highest protein content, outperforming CS 220 (Petal). NPK Foliar + Micro nutrients resulted in the highest protein content, highlighting the benefits of foliar nutrient application for enhancing maize nutritional quality**.** The optimal results obtained from the interaction between Jalal (Pirsabak) and NPK Foliar + Micro nutrients emphasize the importance of tailored nutrient management strategies for specific maize varieties (25).

The analysis of protein content in maize straw revealed significant effects of maize hybrids, nutrients, and their interaction. Jalal (Pirsabak) exhibited the highest protein content in straw, outperforming CS 220 (Petal). NPK Foliar + Micro nutrients resulted in the highest protein content (6.5%), highlighting the benefits of foliar nutrient application for enhancing maize straw nutritional quality (26). The optimal results obtained from the interaction between Jalal (Pirsabak) and NPK Foliar + Micro nutrients emphasize the importance of tailored nutrient management strategies for specific maize varieties (27).

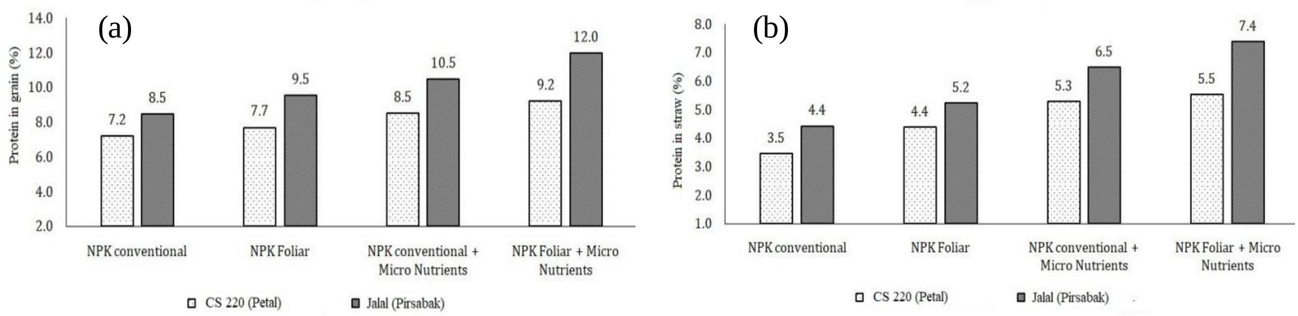

Fig. 3a. Protein in grain (%) as affected by maize hybrid and different nutrients. **Fig. 3b.** Protein in straw (%) as affected by maize hybrid and different nutrients

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CONCLUSIONS

This research conclusively demonstrates that maximizing maize yields and performance hinges on a strategic combination of variety selection and nutrient management, particularly through foliar applications. The significant boost in maize performance observed with foliar NPK and micronutrient application is likely due to the efficient nutrient uptake bypassing soil limitations. Notably, Jalal (Pirsabak) exhibited superior performance over CS 220 (Petal), highlighting its advantageous genetic traits. The most impactful finding was the synergistic interaction between Jalal (Pirsabak) and the foliar nutrient treatment, emphasizing the necessity of tailored, variety-specific nutrient management. Therefore, farmers are strongly recommended to prioritize Jalal (Pirsabak) cultivation in suitable areas, adopt foliar nutrient application as a standard practice, and develop variety-specific nutrient management plans. Further research should focus on determining optimal nutrient ratios, evaluating long-term soil health impacts, and assessing grain nutritional quality. An integrated approach combining foliar fertilization with other best management practices is crucial. Farmer training and extension services are essential for disseminating these findings, ultimately enabling farmers to enhance yields, improve nutritional quality, and contribute to sustainable agricultural practices.

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Ethical statement:

No ethical issues were raised during the course of study.

Author's contribution:

Concept: ZH, RA. Plan: ZH, RA, AHU. Data analysis: RK, WAS. Writing, review and editing: AHU, RA, RK, MA. And M.F Writing, review and editing. All authors have reviewed and consented to the final version of the manuscript for publication.

Conflict of interest:

The authors declare no conflict of interest.

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