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REVIEW

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Introduction to bioactive zinc coated urea and its effectiveness on yield of rice, wheat and maize

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ABSTRACT

Growing soil health (SH) issues pose challenges to worldwide agricultural yield (AY) and food security (FS). On the other hand, the agricultural industry must produce more yield to fulfill the world's hunger while facing environmental and resource constraints. Bioactive zinc-coated urea (BAZU) has been introduced to overcome AY and FS challenges. BAZU makes sure the optimum availability of Nitrogen and Zinc according to plant requirements. In past years, various research trials were conducted on RWM to check the impacts of Engro Zabardast Urea which (EZU) is BAZU, on AY. Trails were conducted in various regions of Pakistan in which EZU was tested against various common fertilizer types. EZU resulted in significantly enhanced AY in most regions and more than equal AY in a few regions against ordinary Zinc and Urea fertilizers. This review summarizes the research conclusions, driving efficiency of EZU in field trials and assessments of integrative application of EZU for more AY to fulfill FS issues.

KEYWORDS

Soil health; Bioactive zinc coated urea; Agricultural yield; Food security; Nutrients

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Introduction

Rice, wheat and maize (RWM) are the backbone of global food security as are major source of calories and nutrition for billions of people [1]. Production rate of these crops directly and indirectly depend on soil health which includes nutrients availability from zinc plays vital role in impacting plant growth and yield [2,3]. Moreover, various fertigation methods fail to overcome nutrient deficiencies like varying climatic conditions impact nitrogen (N) availability due to its volatile nature. Unavailability of certain nutrient leads to reduced yield and food security issues mostly in those regions where agricultural sector is challenged by unstable climate, nutrient loss and resources limitations [4]. Bioactive zinc coated urea (BAZU) is an innovative fertilizer chemistry aims for optimum nutrients availability and uptake by plants [5]. This formulation enhances the yield of RWM by maximizing N and Zinc (Zn) availability that can help to resolve food insecurity and soil health challenges [6].

As RWM is commonly cultivated crop globally so it's vital source of diet. Including Asia in some countries rice accounts for more than 20% daily calorie intake. Moreover, it's important source of vitamins and minerals i.e., manganese and B-complex vitamins [7]. Wheat is a vital crop contributing to overcome food security challenges because of its high caloric and protein content as well as a rich source of dietary fiber, vitamins and minerals such as iron, magnesium and selenium. Maize is also a versatile crop contains essential micronutrients such as vitamins A, C and B and contributes [8,9]. N is necessary for growth and productivity of plant [3]. BAZU is an innovative form of urea coated with bioactive Zn that enhances the effectiveness of both N and Zn [10,11].

Engro Zabardast Urea (EZU) is a urea coated fertilizer with bioactive zinc which claims increased crop yields in RWM production. EZU is a controlled N release method that improves N use efficiency by reducing losses and also maintain Zn availability at optimum level of plant requirement. EZU is committed to minimizing environmental impacts such as groundwater contamination and greenhouse gas emissions [12,13]. EZU gradually releases N and Zn into the soil and provides a continuous source of these nutrients for plant uptake. EZU coating releases Zn ions which are required for enzyme activation, metabolism and hormone regulation in plants [12]. The objectives of this article are to summarize the effects of EZU on rice, wheat, and maize yields and to provide a comprehensive overview of its impact on crop productivity. The study analyzed academic papers to provide a comprehensive overview of key factors influencing EZU performance.

Impacts of EZU on Rice Yield

Two field trials were conducted by Hasnain to analyze the impacts of EZU with Zn and N on rice grain content, yield, and growth [14]. Research trials were conducted at the Ayub Agricultural Research Institute, Faisalabad (FSD) and at a farmer's field in Chiniot District (CHN) in Pakistan. The soil samples were salt-free, low in organic matter, and moderate in phosphorus (P) and potassium (K). The available Zn was 0.95

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mg kg^{-1} in CHN and 0.71 mg kg^{-1} in FSD. The experiment involved three treatments and three replications at two locations. Treatments included T0 (control without Zn), T1 (zinc sulfate plus urea, P and K) and T2 (EZU plus recommended P and K). The experiments were conducted using randomized complete block design (RCBD) and irrigated with tubewell water and canal water with conductivities of 1.34 dSm^{-1} and 0.97 dSm^{-1} respectively (Figure 1 a and b).

Table 1. LSD of research trial on rice in FSD and CHN region to study impacts of EZU particularly on yield [14].

Reg	T	PL (cm)	NGPL^{-1}	1000 GWt (g)	HI (%)
FSD	T1	25.9 ± 0.24 ^{b}	68 ± 1.45 ^{b}	25.5 ± 0.40 ^{c}	0.58 ^{b}
	T2	25.7 ± 0.40 ^{a}	72 ± 1.16 ^{ab}	26.0 ± 0.32 ^{b}	0.59 ^{a}
	T3	26.6 ± 0.35 ^{a}	75 ± 1.86 ^{a}	27.5 ± 0.17 ^{a}	0.59 ^{a}
CHN	T1	23.1 ± 0.39 ^{b}	70 ± 0.88 ^{b}	24.7 ± 0.76 ^{b}	0.56 ^{b}
	T2	25.9 ± 0.45 ^{a}	76 ± 0.58 ^{a}	25.3 ± 0.44 ^{ab}	0.57 ^{b}
	T3	26.2 ± 0.32 ^{a}	76 ± 1.20 ^{a}	27.6 ± 0.68 ^{a}	0.62 ^{a}

Reg: Region; FSD: Faisalabad; CHN: Chinote; T: Treatment; EZU: Zabardast Urea; PL: Panicle length; NGPL: No. of grains panicle^{-1}; GWt: Grain weight; HI: Harvesting index.

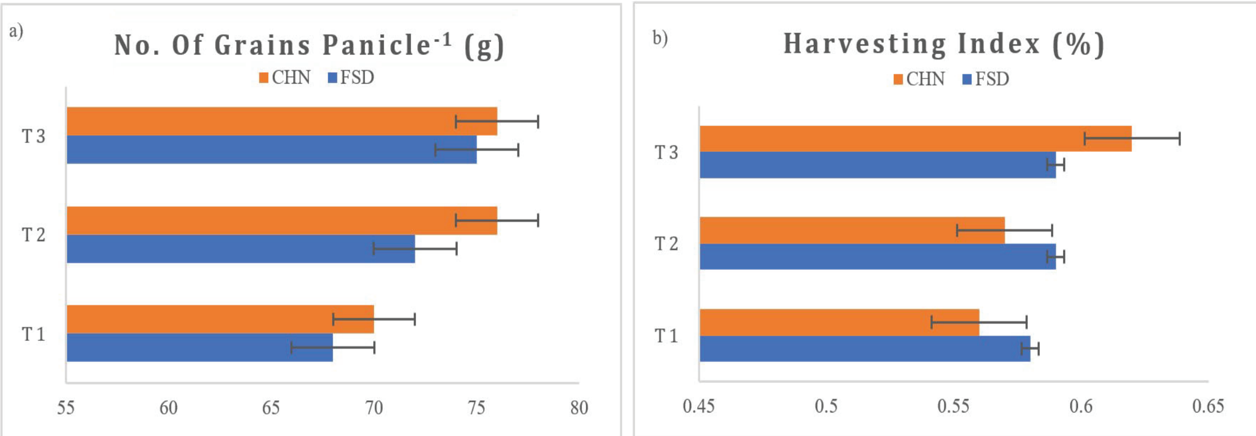

Figure 1. a) No of grains per panicle (g) of rice recorded in T1, T2 and T3 of FSD and CHN region. b) Harvesting index (%) of rice observed in T1, T2 and T3 of FSD and CHN region [14].

Table 1 showed trials conducted in FSD and CHN have shown that the use of EZU and zinc sulfate significantly improved key yield parameters of rice. In FSD, both EZU and zinc sulfate were found to increase panicle length, with maximum increase of 2.7% for EZU. Additionally, both fertilizers significantly increased grain count, but no specific percentage increase was provided. In the CHN trial, panicle length increased significantly in EZU by 13.4%, and thousand kernel weight increased by 11.7% under CHN and 7.8% under FSD. The application of EZU was statistically similar to zinc sulfate, showing its effectiveness in enhancing these parameters. Furthermore, EZU trials showed the highest harvest index at CHN, followed by EZU at FSD, showing improved nutrient utilization efficiency and yield stability. EZU treatment also resulted in the highest grain yield and straw yield under FSD, with an 8.8% increase over zinc sulfate. Furthermore, both zinc application methods increased zinc concentration in grains, with EZU increasing by 18% at FSD. These results highlight the effectiveness of EZU in improving rice yield parameters, showing its potential to contribute to increased productivity and food security.

Another practical study used super basmati rice seeds from Rice Research Institute Kala Shah Kaku and FSD 2008 wheat seeds from Wheat Research Institute, Ayub Agricultural Research Institute, FSD by Shah [12]. The experiments were conducted following a rice-wheat-rice-wheat rotation in RCBD, with four replicates of treatment plots at each site over two years. After the seedlings are transplanted, the fields are flooded, drained and refilled. Treatments include T1 (urea), T2 (urea + zinc sulfate), T3 (EZU + urea) and T4 (EZU + urea).
Fertilizers were applied according to recommendations (Table 2) and EZU tests were conducted at two different levels. Zinc sulfate is imported from Kirns Chemical Ltd. of China, while EZU is sourced locally from Engro Fertilizers Pvt. Ltd. Pakistan. For rice cultivation, the recommended fertilizer rates and treatments are as follows: T1 involves the application of urea (46% N) at a rate of 185 kgha^{-1}. T2 consisted of 185 kgha^{-1} urea (46% N) and 15 kgha^{-1} zinc sulphate (Zinc sulphate, 33% Zn). T3 consists of 100 kgha^{-1} of EZU (42% N) plus 62 kgha^{-1} of urea (46% N) and 1 kgha^{-1} of 1% EZU. T4 contains 125 kgha^{-1} of EZU (42% N) plus 62 kgha^{-1} of urea (46% N) and 1.25 kgha^{-1} of 1% EZU. P and K fertilizers were applied at 86 kgha^{-1} and 74 kgha^{-1} respectively, using diammonium phosphate (DAP; 46% P; 18% N) and potassium chloride (MOP; 60% K2O). Full doses of phosphorus and potassium are administered as a basal dose. Nitrogen in the form of urea (46% N) was applied in two equal parts during the tillering and panicle germination stages. For T3 and T4, EZU (42% N + 1% Zn) was applied in a single application and the remaining N was applied as urea (46% N) in a second application. The full dose of zinc sulfate in T2 is administered with the first urea split (Figure 2a and b).

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Table 1. LSD of research trial on rice in FSD and CHN region to study impacts of EZU particularly on yield [14].

Reg	T	PL (cm)	NGPL	1000 GWt (g)	HI (%)
MUX	T1	22.0 ± 0.15 ^{b}	69 ± 1.53 ^{bc}	21.87 ± 0.26 ^{c}	41.5 ^{bc}
	T2	22.4 ± 0.23 ^{b}	76 ± 2.65 ^{ab}	22.65 ± 0.32 ^{b}	42.4 ^{ab}
	T3	22.0 ± 0.30 ^{b}	76 ± 2.08 ^{ab}	22.58 ± 0.17 ^{b}	42.4 ^{ab}
	T4	23.0 ± 0.21 ^{a}	83 ± 1.86 ^{a}	23.65 ± 0.19 ^{a}	43.3 ^{a}
FSD	T1	25.9 ± 0.23 ^{b}	67 ± 2.08 ^{bc}	25.50 ± 0.40 ^{c}	39.6 ^{ab}
	T2	25.7 ± 0.40 ^{b}	73 ± 3.21 ^{ab}	26.23 ± 0.18 ^{b}	40.3 ^{ab}
	T3	25.5 ± 0.23 ^{b}	74 ± 2.65 ^{ab}	26.07 ± 0.18 ^{b}	40.9 ^{a}
	T4	26.6 ± 0.34 ^{a}	80 ± 2.08 ^{a}	27.33 ± 0.15 ^{a}	41.1 ^{a}
SHL	T1	27.1 ± 0.55 ^{c}	99 ± 2.08 ^{bc}	24.49 ± 0.17 ^{c}	39.8 ^{b}
	T2	28.0 ± 0.49 ^{b}	107 ± 2.52 ^{ab}	25.50 ± 0.20 ^{b}	41.0 ^{b}
	T3	29.4 ± 0.23 ^{ab}	106 ± 1.73 ^{ab}	25.62 ± 0.27 ^{b}	40.9 ^{ab}
	T4	29.3 ± 0.29 ^{ab}	113 ± 2.33 ^{a}	26.34 ± 0.23 ^{a}	41.5 ^{a}
LHR	T1	29.1 ± 0.55 ^{b}	107 ± 2.08 ^{b}	23.43 ± 0.25 ^{c}	39.9 ^{bc}
	T2	29.4 ± 0.43 ^{ab}	118 ± 3.60 ^{ab}	24.37 ± 0.20 ^{b}	40.7 ^{ab}
	T3	29.8 ± 1.01 ^{ab}	118 ± 3.15 ^{ab}	24.36 ± 0.18 ^{b}	40.7 ^{ab}
	T4	30.6 ± 1.15 ^{a}	122 ± 2.64 ^{a}	25.36 ± 0.17 ^{a}	41.5 ^{a}

Reg: Region; MUX: Multan; FSD: Faisalabad; SHL: Sahiwal; T: Treatment; PL: Panicle length; NGPL: No. of grains panicle^{-1}; GWt: Grain weight; HI: Harvesting Index; ±: Standard error.

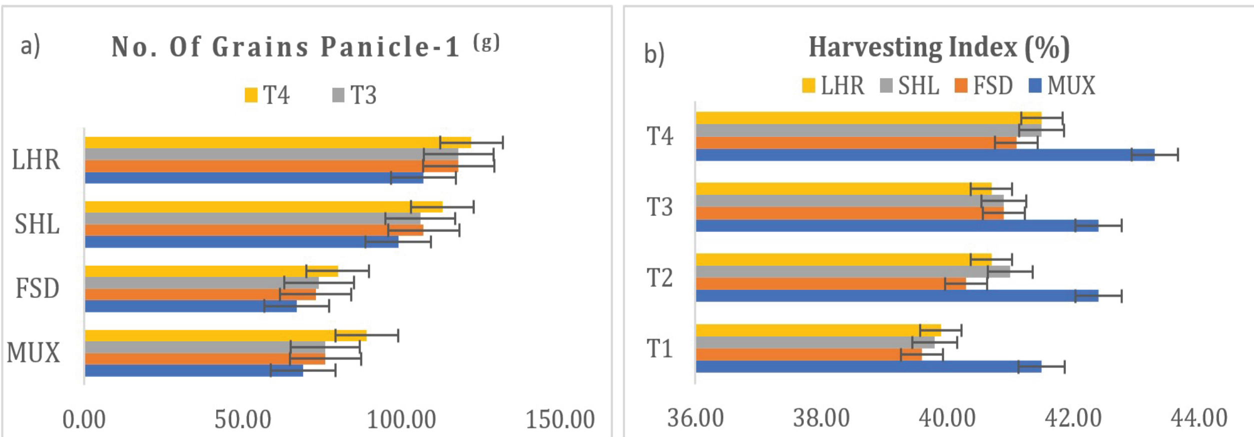

Figure 2. a) No of grains per panicle (g) of rice recorded in T1, T2, T3 and T4 of MUX, FSD, SHL and LHR region. b) Harvesting index (%) of rice recorded in T1, T2, T3 and T4 of MUX, FSD, SHL and LHR region [12].

EZU demonstrated significant improvements in key yield parameters of rice in different regions. EZU resulted in a significant increase in panicle length (PL) in LHR and Sialkot (SHL), with PL being 5% and 8% higher, respectively, compared to the control (T1). However, PL remained similar between FSD and Multan (MUX) treatments. Furthermore, EZU significantly increased the number of grains per panicle at all locations, with the highest increase of 21% in MUX compared to T1, followed by 19% in FSD, 14% in SHL, and 14% in LHR. In addition, the 1000-pellet weight increased significantly under EZU treatment, with FSD increasing by 7% and MUX, SHL and LHR increasing by 8% compared to T1. Furthermore, EZU had a 4% higher harvest index at each experimental site compared to T1, while similar HI values were observed between T2 and T3 compared to T1 at each site. These results indicate that EZU has the potential to significantly improve rice yield parameters, including panicle length, grain number, grain weight, and harvest index, helping to improve productivity and food security.

Impacts of EZU on Wheat Yield

Research trail was continued by Shah in which wheat seeds were sown (after harvesting rice) at a rate of 125 kgha^{-1} and the fields were irrigated to maintain soil field water capacity [12]. Treatments include T1 (urea 46% N @ 185 kgha^{-1}), T2 (urea 46% N @ 185 kgha^{-1}, zinc sulfate 33% Zn @ 15 kgha^{-1}), T3 (EZU 42 % N @ 100 kgha^{-1} + Urea 46% N @ 62 kgha^{-1} + 1% Zn @ 1 kgha^{-1}) and T4 (EZU 42% N @ 125 kgha^{-1} + Urea 46% N @ 62 kgha^{-1} + 1% EZU @ 1.25 kgha^{-1}). Fertilizer application rates followed the recommendations of the Bureau of Agricultural Information, Government of Punjab, Pakistan, except for EZU, which was tested at two different levels. Recommended rates of P and K (86:74 kgha^{-1}) were used as DAP and MOP respectively. During tillering and panicle germination stages, N in urea (46% N) was applied in two batches, whereas for T3 and T4, EZU was applied in a single batch and the remaining N was applied as urea in the second batch (Figure 3 a and b). Zinc sulfate in T2 is administered with the first urea split (Table 3).

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Table 3. . LSD of research trial on wheat in MUX, FSD, SHL and LHR region to study impacts of EZU particularly on yield [12].

Reg	T	SL (cm)	NGS	1000 GWt (g)	HI (%)
MUX	T1	10.2 ± 0.17 ^{bc}	43.0 ± 1.00 ^{c}	29.10 ± 0.25 ^{c}	43.8 ^{c}
	T2	10.6 ± 0.16 ^{b}	47.6 ± 1.20 ^{b}	30.77 ± 0.24 ^{b}	44.7 ^{b}
	T3	11.0 ± 0.46 ^{ab}	47.3 ± 0.88 ^{b}	30.63 ± 0.14 ^{b}	44.7 ^{b}
	T4	11.8 ± 0.26 ^{a}	51.0 ± 1.00 ^{a}	31.47 ± 0.21 ^{a}	45.3 ^{a}
FSD	T1	9.8 ± 0.17 ^{b}	39.0 ± 0.57 ^{ab}	37.10 ± 0.44 ^{c}	43.3 ^{b}
	T2	10.0 ± 0.23 ^{ab}	41.0 ± 1.00 ^{b}	38.50 ± 0.44 ^{b}	43.5 ^{b}
	T3	9.9 ± 0.14 ^{ab}	41.5 ± 1.44 ^{b}	38.30 ± 0.23 ^{b}	43.8 ^{b}
	T4	10.2 ± 0.23 ^{a}	43.0 ± 1.15 ^{a}	39.80 ± 0.19 ^{a}	45.1 ^{a}
SHL	T1	10.7 ± 0.17 ^{b}	48.0 ± 1.53 ^{c}	27.23 ± 0.20 ^{c}	43.9 ^{c}
	T2	11.0 ± 0.14 ^{ab}	51.0 ± 1.55 ^{b}	28.43 ± 0.15 ^{b}	44.8 ^{b}
	T3	11.3 ± 0.17 ^{ab}	50.6 ± 2.33 ^{b}	28.40 ± 0.27 ^{b}	44.9 ^{b}
	T4	12.1 ± 0.13 ^{a}	54.0 ± 1.15 ^{a}	29.67 ± 0.27 ^{a}	45.7 ^{a}
LHR	T1	9.3 ± 0.11 ^{ab}	51.0 ± 1.53 ^{b}	33.40 ± 0.20 ^{c}	41.7 ^{c}
	T2	9.6 ± 0.09 ^{a}	52.0 ± 1.73 ^{b}	34.60 ± 0.17 ^{b}	42.5 ^{b}
	T3	9.6 ± 0.21 ^{a}	52.0 ± 1.45 ^{b}	34.50 ± 0.21 ^{b}	42.6 ^{b}
	T4	9.8 ± 0.17 ^{a}	57.0 ± 1.53 ^{a}	35.90 ± 0.29 ^{a}	43.3 ^{a}

Reg: Region; MUX: Multan; FSD: Faisalabad; SHL: Sahiwal; T: Treatment; SL: Spike length; NGS: No. of grains spike^{-1}; GWt: Grain weight; HI: Harvesting Index; ±: Standard error.

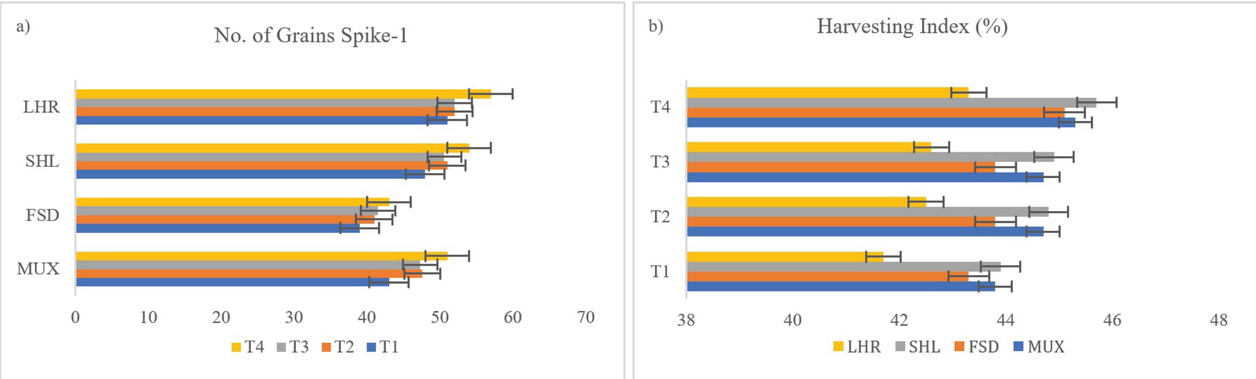

Figure 3. a) No of grains per spikes (g) of wheat recorded in T1, T2, T3 and T4 of MUX, FSD, SHL and LHR region. b) Harvesting index (%) of wheat recorded in T1, T2, T3 and T4 of MUX, FSD, SHL and LHR region.

Table 3 shows the results of wheat productivity and efficiency showed significant improvements in various indicators when treated with EZU (T4) compared to the control group (T1). Spike length (SL) was significantly higher under T4, with an increase of 16% under MUX and 13% under SHL, whereas no significant changes were observed under FSD and LHR. The number of grains per panicle also increased significantly under T4 treatment, with increases of 19%, 10%, 13% and 12% under MUX, FSD, SHL and LHR treatments, respectively, while there was no significant difference between T2 and T3 treatments compared to T1. Compared with T1, the number of tillers recorded under T4 increased by 14%, 13%, 11%, and 14% in MUX, FSD, SHL, and LHR, respectively. Furthermore, under T4, the thousand grain weight of MUX, FSD, SHL and LHR increased by 8%, 7%, 9% and 7% respectively, T2 and T3 treatments also improved compared to T1 but remained similar to T1.

Grain yield increased significantly under T4, with yields under MUX, FSD, SHL and LHR being 5.36 t ha^{-1}, 4.57 t ha^{-1}, 4.90 t ha^{-1} and 4.07 t ha^{-1} respectively, while 4.80 t ha^{-1} is 4.80 t ha^{-1}. Yields from treatments T2 and T3 were similar to T1 at all sites. Among them, MUX has the highest grain yield, followed by SHL, FSD and LHR. Harvest index also followed a similar trend, with T4 plants showing 3%, 4%, 4% and 4% growth respectively for MUX, FSD, SHL and LHR compared to T1, while T2 and T3 also showed higher growth than T1. Overall, T4 consistently resulted in significant improvements in wheat yield and efficiency across study sites.

Impacts of EZU on Maize Yield

Research was conducted by Ali at the Sahiwal Maize and Millet Research Institute in the spring of 2021 and 2022 [15]. Initial soil analysis at two depths (0-15 cm and 15-30 cm) revealed a loam texture with specific physicochemical properties, including SAR, pH, EC and available nutrients.

The experimental setup consisted of 4.2m × 5m plots sown on both sides of a 1.05 m wide seedbed. Five treatments were applied: control without added fertilizer (T1), pure fertilizer using DAP, MOP and urea (T2), Zarkhez Plus combined with EZU replacing 1/3 of urea (T3), Zarkhez Plus with EZU replacing 2/3 Urea (T4), and another Zarkhez Plus where EZU replaces 1/3 of the urea (T5) (Figure 4). All treatments except

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the control were balanced at 92 kg/acre N, 46 kg/acre P, and 37 kg/acre K_2O. Fertilizers were manually added to the soil before sowing, while urea and EZU were applied in three phases at 20, 30 and 45 days after sowing (Table 4).

Table 4. LSD of research trial on maize to study impacts of EZU particularly on yield.

T	PH (cm)	GL (kg/Acre)
T1	201.9 ± 2.74 ^{c}	714.00 ± 12.37 ^{d}
T2	217.4 ± 0.69 ^{b}	3791.49 ± 65.67 ^{c}
T3	218.2 ± 0.46 ^{ab}	4724.20 ± 81.83 ^{b}
T4	221.4 ± 0.53 ^{a}	4907.28 ± 85.00 ^{a}
T5	220.5 ± 0.36 ^{ab}	4916.24 ± 85.15 ^{a}

T: treatment; PH: Plant height; GL: Grain yield; ±: Standard error.

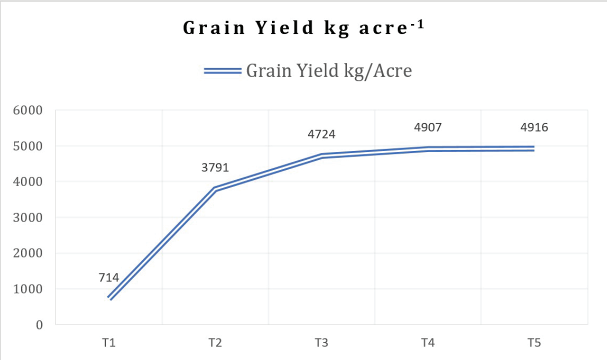

Figure 4. Grain Yield (kg acre^{-1}) of maize observed from T1, T2, T3, T4 and T5 [15].

As table 4 shows the different fertilizer treatments have significant effects on plant height and yield. At 90 days, T4 treatment produced the tallest plants at 221.4 cm, followed by T5 at 220.5 cm and T3 at 218.2 cm. Treatment T2 produced plants with a height of 217.4 cm, while the control treatment (T1) produced the shortest plants at 201.9 cm. From the perspective of grain yield, the T5 treatment yielded the highest yield at 4816 kg/acre, followed by the T4 treatment at 4907 kg/acre, and the T3 treatment at 4724 kg/acre. Treatment T2 had a yield of 3791 kg/acre, while the control treatment (T1) had the lowest yield of 714 kg/acre. The results clearly showed that application of EZU fertilizer treatments significantly increased grain yield of maize.

Conclusions

As discussed, field experiments conducted by Shah, Hasnain and Ali stated that the use of EZU (Engro Zabardast Urea) showed promising results in improving yield parameters of RWM in different regions of Pakistan [12,14,15]. EZU and zinc sulfate significantly improved rice yield including panicle length, grain number, thousand-grain weight and harvest index, showing increased productivity and nutrient use efficiency, especially in FSD district. The use of EZU in wheat cultivation showed significant improvements in various aspects such as panicle length, grain number, tiller number, grain yield and harvest index at various study sites. In maize cultivation, EZU fertilizer significantly increased plant height and grain yield compared with other treatments.

The integration of BAZU like EZU can ensure global food security by improving soil health and increasing agricultural yields. Future research should focus on optimizing application methods, long-term soil health monitoring, crop rotation strategies, precision agriculture technologies, climate resilience, economic feasibility, farmer adoption, policy support, extension services and collaborative research measures. Governments and agricultural extension services can promote the adoption of BAZU through policy support, subsidies and education programs to ensure sustainable agricultural yield and food security under faced challenges.

Disclosure Statement

No potential conflict of interest was reported by the authors.

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