



Quality and Productivity Improvement of Fodder Maize (*Zea mays* L.) Through the Foliar Application of Urea with Zinc

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10.18805/ag.D-5997

ABSTRACT

Background: Since fodder maize is a demanding crop that requires a lot of minerals to meet its nutritional demands, the misuse of chemical fertilizers has decreased soil fertility. Nevertheless, using large amounts of fundamental nutrients should not adversely affect the soil's health. In light of these considerations, the current study was directed to identify the most effective management strategy to increase fodder maize quality and yield in Punjab conditions.

Methods: The experimental site was Eastern India which falls under the zone of Northern Plain of agro-climatic zones of Punjab. The experiment consisted of three replications and was set up using a randomized block design (RBD). Two different treatment levels of urea (1% and 2%) and two different treatment levels of zinc (0.25% and 0.50%), together with recommended dose of fertilizer (RDF) and an absolute control, were applied to the fodder maize crop. These treatments were employed and organized into nine distinct treatment combinations.

Result: The results were found that total ash (9.6%), ether extract (2.75%), hemicellulose (24.87%), carbohydrate (58.98%), crude protein yield (12.68%) and dry fodder yield (118.59 q ha⁻¹) were seen to be significantly higher at 65 days after sowing when the crop was treated with RDF + 2% urea + 0.50% zinc as compared to absolute control and other quality parameters also showed significant results. The foliar application of urea and zinc along with RDF to fodder maize significantly reduced the fibre fraction and increased the nutritional values (DCP, DMI, DMD, TDN and NEL).

Key words: Fodder maize, Fodder quality, Fodder productivity, Urea, Zinc.

INTRODUCTION

India's agricultural production methods are built on mixed farming, where crops and animals are the two main enterprises. In order to maximize family income, farmers combine these two businesses to diversify their resource utilization. The primary source of work and livelihood for 70% of the people in rural regions, livestock production is the backbone of Indian agriculture, with the national GDP contributing 7%. The production of fodder must blossom, as must its productivity, to fulfill the demands of the perpetually increasing livestock population. However, the area devoted to the production of fodder has decreased because of the expansion of the cultivation of cereals and cash crops. As a result of a decreasing proportion of land accessible for the production of fodder, there is a huge strain from livestock on the total amount of feed and fodder available.

Currently, the nation has a net deficit of concentrate feeds of 64%, dry leftover of agricultural products 21.9% and 61.1% green fodder (Chaudhary *et al.*, 2012). Maize is the 3rd predominant crop grown for human consumption, behind rice and wheat. In addition to being utilized as a food grain crop, it is also grown for vegetables and grazing. Maize, which has a high concentration of water-soluble carbohydrates and a low protein content, is regarded as the ideal crop to create silage due to its poor buffering capacity and ease of ensiling. Considering that maize is a grain, nutrition management is crucial, particularly in India's northwest and in the Indian great plains, where an intense

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How to cite this article: Bhaumik, S. and Rajeev. (2024). Quality and Productivity Improvement of Fodder Maize (*Zea mays* L.) Through the Foliar Application of Urea with Zinc. Agricultural Science Digest. 1-7. doi: 10.18805/ag.D-5997.

Submitted: 16-05-2024 **Accepted:** 23-10-2024 **Online:** 13-12-2024

cereal-cereal cropping system is predominant. Wider adoption of high-quality and high-protein maize will occur if hybrids are created that maintain improved nutritional quality while performing agronomically similarly to regular hybrids (Subba *et al.*, 2022)

Since fodder maize is toxic-free, it may be given to animals without risk at any stage of crop development (Kumar *et al.*, 2016). Reducing the accompanying loss in production has required the creation of quality protein maize (QPM) hybrids that are resistant to terminal stress conditions (Teja *et al.*, 2024). Crop plants need nitrogen as one of the essential nutrients for growth and development. When used correctly, nitrogen is crucial for developing protoplast and protein, which promote cell division and launch cognitive processes. The addition of nitrogen not only increases maize's fodder output but also

enhances other aspects of its quality, particularly its protein content (Haque *et al.* 2001). According to reports, adding nitrogen to maize increases the nutritional value of the feed by raising the amount of crude protein and lowering the amount of fiber. The development of management strategies for greater fodder output per unit area of this crop might benefit from research on nitrogen management. On the other hand, agricultural plants require zinc to grow and develop properly. It is an essential source of crop nutrition since in plants need it to carry out different enzymatic reactions, oxidation reactions and metabolic processes. In addition, numerous enzymes are required for the metabolism of nitrogen, the transmission the energy and creation of proteins depends on zinc (Hafeez *et al.*, 2013).

Therefore, the current study was conducted to examine the combined effect of various levels of urea and zinc and to determine their dose suitable for increasing the yield and quality of maize. A research study in the field was accomplished at Agricultural Research Farm, Department of Agronomy, School of Agriculture, Lovely Professional University, Phagwara, Punjab during the Rabi season in 2022-23 to study the effect of urea and zinc as a foliar application on quality parameters of fodder maize (*Zea mays* L.). The main aim of this experimental trial was to study the effect of urea and zinc as foliar applications on the quality of fodder maize crops.

MATERIALS AND METHODS

The experimental work was directed at Agricultural Research Farm, Department of Agronomy, School of Agriculture, Lovely Professional University, Phagwara, Punjab during Rabi season in 2022-23, which lies in the zone of Northern Plain between 75.69° E and 31.24°N. The field's climate comes under the Agro-ecological sub-region (Northern Plain, hot sub-humid eco region, Punjab) and agro-climatic zone (Trans Gangetic Plain region). The area comes under the semi-arid zone with an annual rainfall of 600 mm. The soil of the empirical field had pH 8.4, electrical conductivity 0.410 mmhos cm⁻¹, 0.45% organic carbon and 0.776% organic matter. Available nitrogen, phosphorus and potassium were 322.56, 25.10 and 70.56 kg ha⁻¹. The empirical design was conducted in randomized block design (RBD) with three replications and nine treatments (T₁: Absolute control; T₂: RDF + 0.25% Zinc; T₃: RDF + 0.50% Zinc; T₄: RDF + 1% Urea; T₅: RDF + 1% Urea + 0.25% Zinc; T₆: RDF + 1% Urea + 0.50% Zinc; T₇: RDF + 2% Urea; T₈: RDF + 2% Urea + 0.25% Zinc; T₉: RDF + 2% Urea + 0.50% Zinc). The recommended dose of fertilizers (RDF) were applied @ 60 kg nitrogen ha⁻¹, 40 kg Phosphorus ha⁻¹ and 20 kg Potassium ha⁻¹ through Urea, Di-ammonium phosphate (DAP) and Muriate of potash (MOP). Zinc was supplied through the zinc oxide suspension concentrate (39.5% Zn). The half dose of nitrogen and full dose of phosphorus and potassium were applied as basal dose and the other half of nitrogen was applied as two split doses at 25 days after sowing (DAS)

and 45 DAS in granular form. Percentage of zinc and urea were applied as two foliar sprays at 30 DAS and 50 DAS. In this case, nitrogen was supplied by urea as per the recommendation of fodder maize and also the percentage of urea was applied by mixing with water. That means nitrogen in the form of urea was applied in both solid and liquid form. We used the hybrid fodder maize seed which belongs to the variety of Laxmi® 207 with a seed rate of 40 kg/ha.

The samples of green fodder were collected at 45 DAS and 65 DAS. After collection, the fresh weight was taken and kept in a hot air oven at 65±5°C for drying. After that, the fully dried samples were collected, weighed them and calculated the dry fodder yield. The dried samples of plants were grounded through the mixture grinder machine for quality analysis. The dusted materials were chemically analyzed for total ash (AOAC 2005, method 942.05), ether extract (AOAC 2005, method 920.39), crude fibre and Kjeldahl nitrogen (AOAC 2005, method 984.13). The crude protein of the plant was calculated from the nitrogen concentration by multiplying 6.25. The procedure of Van Soest *et al.* (1991) was followed for the determination of neutral detergent fibre (NDF). AOAC 2005, method 973.18 was followed for the determination of acid detergent fibre (ADF). Total carbohydrate was estimated as the sum of total ash, ether extract and crude fibre subtracted from 100. Hemicellulose was calculated by the subtraction of ADF% from NDF%. Acid detergent lignin (ADL) was estimated by the following Klason method. Cellulose was calculated by the subtraction of ADL% from ADF% in the plant. Other quality parameters viz. dry matter intake (DMI), digestible crude protein (DCP), net energy for lactation (NEL), total digestible nutrients (TDN) and dry matter digestibility (DMD) were calculated by the following equations:

DMI (%) = 120/NDF% (Horrocks and Vallentine 1999).

DCP (%) = (0.929 × CP%) - 3.52 (Demarquilly and Weiss 1970).

NEL (Mcal/kg) = [1.044 - (0.0119 × ADF%)] × 2.205 (Horrocks and Vallentine 1999).

TDN (%) = (-1.291 × ADF%) + 101.35 (Horrocks and Vallentine, 1999).

DMD (%) = 88.9 - (0.779 × ADF%) (Horrocks and Vallentine 1999).

4.184 is used as a conversion factor of Mcal/kg to MJ/kg in the case of NEL.

The analysis of variance (ANOVA) technique was used for analyzing the experimental data for randomized block design (RBD). Least significant differences (LSD) and Duncan test were used for various parameters to see the significant differences among treatment mean at 0.05 probability level by using SPSS software.

RESULTS AND DISCUSSION

Crude protein, ether extract and total ash yield

Different treatments significantly affected CP, EE and TA yield (Table 1). The foliar spray of 2 % urea and 0.50 % zinc along with RDF showed significantly higher CP, EE and TA yield than the absolute control and other treatments during

both observable days (45 DAS and 65 DAS). The result showed that the application of the proper amount of fertilizer along with 2% urea and 0.5% zinc as foliar application TA content increases as the crop slowly matures due to less dilution of minerals and a large number of minerals were accumulated which increased the digestibility of dry matter (Kar *et al.*, 2016). An adequate supply of macronutrients, as well as micronutrients during the crop-growing period, increased the CP, TA and EE yield. Crude fat/ ether extract was additionally influenced by the crop's harvesting phase since it decreases with maturity (Ayub *et al.*, 2001). The result showed that the application of the proper amount of fertilizer along with 2% urea and 0.5% zinc as foliar application CP content increases due to more uptake, retained and utilized nitrogen and zinc. Nitrogen metabolism is also influenced by the zinc activity for this reason nitrogen uptake and contents of protein also increased (Cakmak, 2002; Alloway, 2004). Many researchers showed that protein content also increased by the application of nitrogen and zinc (Asif *et al.*, 2013).

Nutritional values/energy

After determining and calculating all quality parameters, we have shown that digestible crude protein (DCP), dry matter intake (DMI), dry matter digestibility (DMD), total digestible nutrients (TDN) and net energy for lactation (NEL) contents were significantly influenced by the nutrients (Table 2). The higher value of DCP, DMI, DMD, TDN and NEL was shown by the application of T9 treatment as compared to the value of absolute control and other treatment conditions. NDF is inversely correlated with DMI and TDN. Hence, the reduction of NDF led to the improvement of DMI and TDN. On the other hand, ADF is inversely correlated with DMD and NEL. Hence, the reduction of ADF led to the improvement of DMD and NEL. Salama and Zeid (2016) similarly observed that these fodder quality indicators had better values as a result of reduced fiber percentages.

Fibre fractions

The nutrient management strategies significantly caused the variations in the case of the fractions of fibre contents. The higher values of ADF, NDF, ADL, Cellulose and CF were observed by the determination in the case of absolute control condition as compared to other treatment conditions (Table 3). But, Hemicellulose content was higher in case of T7, T8, T9 as compared to the absolute control condition due to the application of zinc (Fig 1). Since fractions of fibre (ADF, NDF, ADL, Cellulose and CF) contents are inversely proportional to CP, EE and TA yield, for lowering fibre fractions it may be one reason (Tondey *et al.*, 2021). The amount of fibre components is substantially decreased by the greater intake of important nutrients, especially nitrogen (Yadav *et al.*, 2007). Plant's structural components, the ADF and NDF, which are made of cellulose, hemicellulose and lignin, play a crucial role in forage digestibility. Less ADF and NDF values indicated that fodder is good in quality. The data of present study reported that reduction of the value of ADF, NDF, ADL and CF contents of fodder maize was statistically significant. Islam *et al.* (2008) reported that ADF content was increased by the increase of nitrogen content.

Carbohydrates fractions

In pre sent study, it was noticed that the total carbohydrate content is significantly influenced by the application of nitrogen and zinc on forage maize. Carbohydrates are a structural component of plants and is composed of structural carbohydrates and non-structural carbohydrates. The main energy source for your livestock is carbohydrates. The data of the present study reported that higher carbohydrates were shown in T7 at 45 DAS (Fig 2). However, the higher value of total carbohydrates was shown in T7, T8 and T9 at 65 DAS (Fig 2). In comparison of sugarcane (78.55%) and sorghum (73.18%), fodder maize crop has the greatest percentage of carbohydrates (83.30%) when the required quantity of nitrogen is applied, according to a study by Kar *et al.* (2016). Because maize crops contain

Table 1: Effect of urea and zinc on crude protein, ether extract and total ash yield of fodder maize at 45 and 65 DAS.

Treatments	Crude protein (%)		Ether extract (%)		Total ash yield (%)	
	45 DAS	65 DAS	45 DAS	65 DAS	45 DAS	65 DAS
T ₁ : Absolute Control	6.84e±1.00	7.19e±1.00	1.50f±1.00	1.59f±1.00	7.27h±1.00	7.17h±1.00
T ₂ : RDF + 0.25% Zinc	9.04d±0.42	10.03d±0.91	1.63e±1.00	2.31b±0.89	7.53g±1.00	7.37g±0.06
T ₃ : RDF + 0.50% Zinc	9.31d±0.42	10.05d±0.91	1.76d±0.11	1.81e±0.53	7.80f±1.00	7.53g±0.06
T ₄ : RDF + 1% Urea	9.69c±0.07	10.88c±0.28	1.80d±0.11	1.78e±0.53	8.03e±1.00	7.83f±1.00
T ₅ : RDF + 1% Urea + 0.25% Zinc	9.67c±0.07	11.04c±0.28	1.95cd±0.07	1.91d±1.00	8.37d±1.00	8.10e±1.00
T ₆ : RDF + 1% Urea + 0.50% Zinc	9.89c±0.07	11.15c±0.28	2.00c±0.07	2.06c±0.45	8.77c±0.42	8.57d±1.00
T ₇ : RDF + 2% Urea	10.67b±0.19	11.79b±0.93	1.94d±0.63	2.03c±0.45	8.83c±0.42	8.77c±1.00
T ₈ : RDF + 2% Urea + 0.25% Zinc	10.81ab±0.10	11.77b±0.93	2.34b±1.00	2.32b±0.89	9.17b±1.00	9.40b±1.00
T ₉ : RDF + 2% Urea + 0.50% Zinc	10.99a±0.10	12.68a±1.00	2.68a±1.00	2.75a±1.00	9.53a±1.00	9.60a±1.00
SEm (±)	0.07	0.17	0.02	0.03	0.06	0.06
CD at 5%	0.21	0.51	0.06	0.10	0.18	0.18

Table 2: Effect of urea and zinc on nutritional values / Energy of fodder maize at 45 and 65 DAS.

Treatments	Digestible crude protein (%)		Dry matter intake (%)		Dry matter digestibility (%)		Total digestible nutrients (%)		Net energy for lactation (%)	
	45 DAS	65 DAS	45 DAS	65 DAS	45 DAS	65 DAS	45 DAS	65 DAS	45 DAS	65 DAS
T ₁ : Absolute Control	2.84e±1.00	3.16e±1.00	1.79f±1.00	1.79h±1.00	55.51h±1.00	53.87h±1.00	46.01h±1.00	43.29h±1.00	1.18h±1.00	1.12h±1.00
T ₂ : RDF + 0.25% Zinc	5.21d±0.42	5.79d±0.92	1.80e±1.00	1.80g±1.00	56.08g±0.07	55.40g±1.00	46.95g±0.07	45.83g±1.00	1.19g±0.07	1.17g±1.00
T ₃ : RDF + 0.50% Zinc	5.13d±0.42	5.82d±0.92	1.82d±1.00	1.82f±1.00	55.87g±0.07	55.77f±1.00	46.61g±0.07	46.44f±1.00	1.19g±0.07	1.19f±1.00
T ₄ : RDF + 1% Urea	5.84c±0.07	6.59c±0.28	1.83c±0.21	1.83e±0.57	56.31f±1.00	56.29e±1.00	47.34f±1.00	47.30e±1.00	1.20f±1.00	1.20e±1.00
T ₅ : RDF + 1% Urea + 0.25% Zinc	5.47c±0.07	6.73c±0.28	1.85bc±0.06	1.84cd±0.06	56.94e±1.00	56.59d±1.00	48.38e±1.00	47.81d±1.00	1.23e±1.00	1.21d±1.00
T ₆ : RDF + 1% Urea + 0.50% Zinc	5.67c±0.07	6.84c±0.28	1.84bc±0.06	1.84bc±0.09	57.25d±1.00	56.90c±0.08	48.89d±1.00	48.33c±0.08	1.24d±1.00	1.22c±0.08
T ₇ : RDF + 2% Urea	6.39b±0.19	7.44b±0.93	1.84bc±0.06	1.83de±0.06	57.66c±1.00	57.14c±0.08	49.58c±1.00	48.72c±0.08	1.25c±1.00	1.23c±0.08
T ₈ : RDF + 2% Urea + 0.25% Zinc	6.52ab±0.10	7.42b±0.93	1.85ab±0.06	1.84b±0.06	57.89b±1.00	57.58b±1.00	49.97b±1.00	49.45b±1.00	1.26b±1.00	1.25b±1.00
T ₉ : RDF + 2% Urea + 0.50% Zinc	6.69a±0.10	8.26a±1.00	1.86a±0.06	1.86a±1.00	58.34a±1.00	57.89a±1.00	50.69a±1.00	49.97a±1.00	1.27a±1.00	1.26a±1.00
SEm (±)	0.06	0.16	0.003	0.002	0.07	0.07	0.12	0.12	0.002	0.002
CD at 5%	0.19	0.47	0.009	0.006	0.22	0.23	0.37	0.38	0.01	0.007

Table 3: Effect of urea and zinc on fibre fractions of fodder maize at 45 and 65 DAS.

Treatments	ADF (%)		NDF (%)		ADL (%)		Cellulose (%)		Crude fibre (%)	
	45 DAS	65 DAS	45 DAS	65 DAS	45 DAS	65 DAS	45 DAS	65 DAS	45 DAS	65 DAS
T ₁ : Absolute Control	42.87a±1.00	44.97a±1.00	67.07a±1.00	66.90a±1.00	5.80a±0.06	5.90a±0.11	37.07a±0.79	39.07a±1.00	32.97a±1.00	33.07a±1.00
T ₂ : RDF + 0.25% Zinc	42.13b±0.07	43.00b±1.00	66.57b±1.00	66.50b±1.00	5.60a±0.6	5.77a±0.11	36.53b±1.00	37.23b±0.10	31.80b±0.09	32.47b±0.15
T ₃ : RDF + 0.50% Zinc	42.40b±0.07	42.53c±1.00	65.83c±1.00	66.00c±1.00	5.30b±0.35	5.53b±0.08	37.10a±0.79	37.00b±0.10	31.67b±0.09	32.07bc±0.15
T ₄ : RDF + 1% Urea	41.83c±1.00	41.87d±1.00	65.27d±0.22	65.60d±0.57	5.30b±0.35	5.50b±0.08	36.53b±1.00	36.37c±1.00	31.77b±0.09	31.70cd±0.19
T ₅ : RDF + 1% Urea + 0.25% Zinc	41.03d±1.00	41.47e±1.00	65.03de±0.22	65.30ef±0.06	5.20bc±0.35	5.53b±0.08	35.83c±0.07	35.93d±1.00	31.53b±0.09	31.37d±0.23
T ₆ : RDF + 1% Urea + 0.50% Zinc	40.63e±1.00	41.07f±0.08	65.13de±0.22	65.10fg±0.10	5.03cd±0.13	5.50b±0.08	35.60c±0.07	35.57e±0.24	29.93c±0.17	30.60e±1.00
T ₇ : RDF + 2% Urea	40.10f±1.00	40.77f±0.08	65.23de±0.22	65.53de±0.57	5.07cd±0.13	5.37bc±0.08	35.03d±0.19	35.40e±0.24	29.73c±0.17	30.00f±1.00
T ₈ : RDF + 2% Urea + 0.25% Zinc	39.80g±1.00	40.20g±1.00	64.86ef±0.06	65.03g±0.57	4.93de±0.22	5.20cd±0.05	34.87d±0.19	35.00f±0.10	29.33d±1.00	29.40g±1.00
T ₉ : RDF + 2% Urea + 0.50% Zinc	39.23h±1.00	39.80h±1.00	64.53f±0.06	64.67h±1.00	4.73e±0.06	5.03d±0.05	34.50e±1.00	34.77f±0.10	29.00e±1.00	28.67h±1.00
SEm (±)	0.09	0.09	0.11	0.07	0.07	0.05	0.08	0.08	0.08	0.19
CD at 5%	0.29	0.29	0.34	0.22	0.21	0.16	0.24	0.26	0.24	0.58

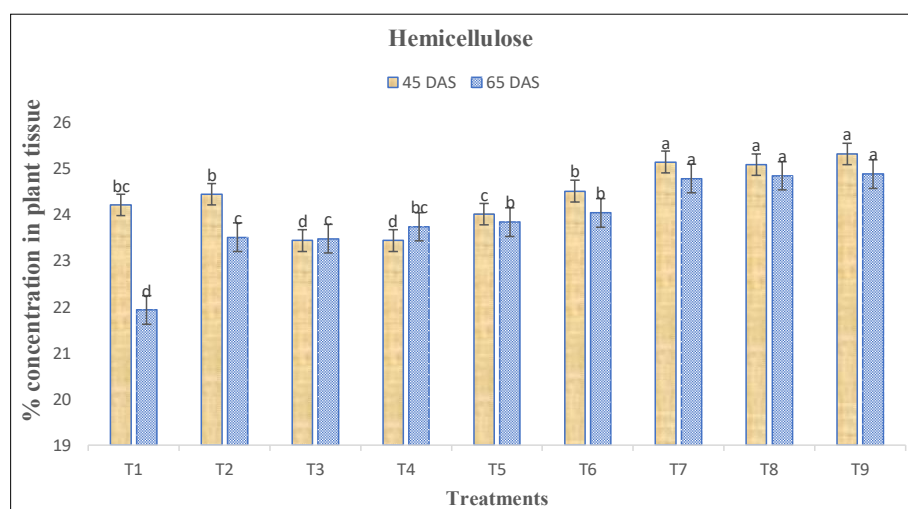


Fig 1: Effect of urea and zinc on hemicellulose of fodder maize at 45 and 65 DAS.

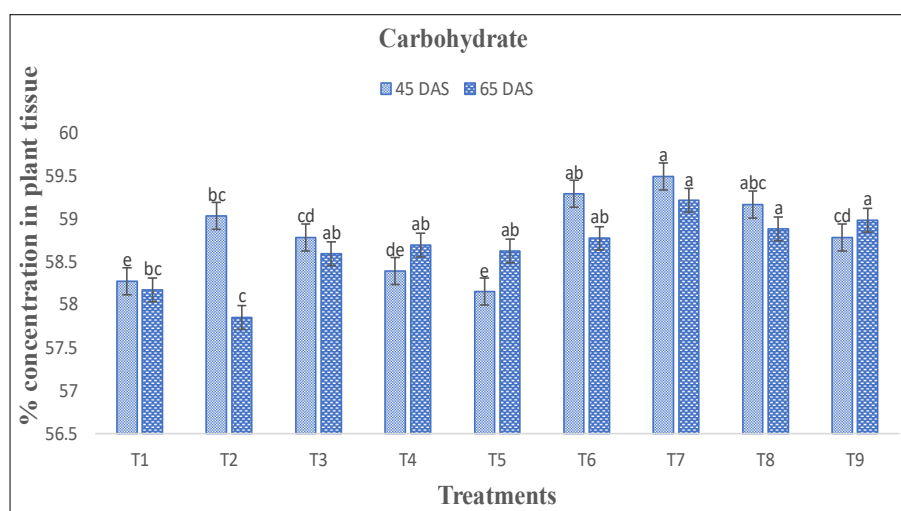


Fig 2: Effect of urea and zinc on carbohydrate of fodder maize at 45 and 65 DAS.

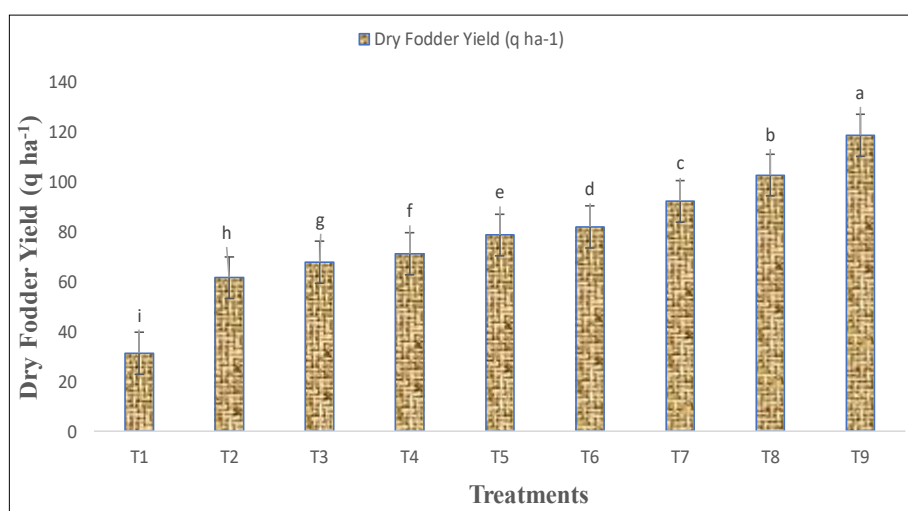


Fig 3: Effects of urea and zinc application on dry fodder yield of fodder maize crop.

the most carbohydrates, they have a high energy value as a reliable fodder crop.

Dry fodder yield (DFY)

The experiment evaluated different treatments for enhancing dry fodder yield in a crop (Fig 3). The absolute control treatment (T_1) yielded 31.24 q ha⁻¹. Application of RDF along with various concentrations of zinc (T_2 : 0.25% ; T_3 : 0.50%) led to enhanced the yields of 61.55 q ha⁻¹ and 67.74 q ha⁻¹, respectively. In the addition of 1% urea along with RDF and various concentrations of zinc (T_4 : no application of zinc, T_5 : 0.25%, T_6 : 0.50%) led to increased the yields of 71.07 q ha⁻¹, 78.64 q ha⁻¹ and 81.87 q ha⁻¹, respectively. Similarly, the addition of 2% urea along with RDF and various concentrations of zinc (T_7 : no application of zinc, T_8 : 0.25%, T_9 : 0.50%) led to increased the yields of 92.14 q ha⁻¹, 102.67 q ha⁻¹ and 118.59 q ha⁻¹, respectively. The application of urea and zinc on foliar application showed positive effects on green fodder yield, likely due to enhanced nutrient availability and utilization. Notably, the yield improvements varied based on the concentration of urea and zinc. These finding align with previous research highlighting the benefits of nitrogen and zinc application on fodder maize (Jamil *et al.*, 2015; Kumar *et al.*, 2015; Kumar and Bohra, 2014).

CONCLUSION

From the present study, it is concluded that application of RDF + 2% Urea + 0.50% Zinc improves the fodder quality with crude protein, ether extract, total ash, nutritional values / Energy, carbohydrates fractions, dry fodder yield and by decreasing fibre fractions. Exploring the synergistic effects of combining urea and zinc foliar application. Assessing the impact of urea and zinc foliar application on nutrient use efficiency, particularly nitrogen and zinc uptake and utilization by maize plants. Overall further research and practical application of urea and zinc foliar application in maize production have the potential to enhance crop productivity and quality, improve nutrient management practices and contribute to sustainability of agricultural systems. The results are based on only single season, which must be experimented and repetition through more experiments to obtain valid conclusions and suggest the farmers as the best treatment.

ACKNOWLEDGEMENT

We are highly thankful to Department of Agriculture, Lovely professional University for their cooperation during fieldwork and providing the financial support for the research work.

Conflict of interest

All authors declare that they have no conflicts of interest.

REFERENCES

Alloway, B. (2004). Zinc in Soils and Crop Nutrition. Areas of the World with Zinc Deficiency Problems. (Available online at <http://www.zinc-crops.org/Crops/Alloway-all.php>).

- AOAC. (2005). Official Methods of Analysis, 18th edn, p. 684. Association of Official Analytical Chemists. Arlington, Virginia, USA.
- Asif, M., Saleem, M.F., Anjum, S.A., Wahid, M.A. and Bilal, M.A. (2013). Effect of nitrogen and zinc sulphate on growth and yield of maize (*Zea mays* L.). Journal of Agricultural Research. 43(1): 104-109. doi: 10.18805/ag.R-2098.
- Ayub, M., Ma Choudhry, Tanveer, A. and Ahmad, B. (2001). Effect of different levels of nitrogen and seeding density on growth, yield and quality of maize fodder. Andhra Agricultural Journal (India).
- Cakmak, I. (2002). Plant nutrition research: Priorities to meet human needs for food in sustainable ways. Plant Soil. 247: 3-24.
- Chaudhary, D.P., Kumar, A., Sapna, S., Mandhania, Srivastava, P. and Kumar, R.S. (2012). Maize As Fodder? An alternative approach, Directorate of Maize Research, Pusa Campus, New Delhi - 110 012, Technical Bulletin 2012/04 pp. 32.
- Demarquilly, C. and Weiss, P. (1970). Tableau de la valeur alimentaire des fourrages. Et. 42: Versailles INRA-SEI.
- Hafeez, B.M.K.Y., Khanif, Y.M. and Saleem, M. (2013). Role of zinc in plant nutrition-A review. American Journal of Experimental Agriculture. 3(2): 374-391.
- Haque, M.M., Hamid, A. and Bhuiyan, N.I. (2001). Nutrient uptake and productivity as affected by nitrogen and potassium application levels in maize/sweet potato intercropping system. Korean Journal of Crop Science. 46: 1-5.
- Horrocks, R.D. and Vallentine, J.F. (1999): Harvested Forages, 1st edn, Academic Press, London, UK. p. 426.
- Islam, M.R., Rahman, S.M.E., Islam, K.M.S. and Chowdhury, R. (2008). Effect of the application of dried slurry on yield and chemical composition of maize fodder (*Zea mays* L.). Bangladesh Journal of Animal Science. 37: 52-57.
- Jamil, M., Sajad, A., Ahmad, M., Akhtar, M.F., Abbasi, G.H. and Arshad, M. (2015). Growth, yield and quality of maize (*Zea mays* L.) fodder as affected by the nitrogen-zinc interaction in arid climate. Pakistan Journal of Agriculture Science. 52(3): 637-643.
- Kar, S., Singh, M., Kumar, R. and Kumar, P. (2016). Fodder yield and quality of sugarcane, sorghum and maize as affected by nitrogen sources. Indian Journal of Animal Nutrition. 33 (2): 160-163. doi: 10.5958/2231-6744. 2016.00027.X
- Kumar, R. and Bohra, J.S. (2014). Effect of NPKS and Zn application on growth, yield, economics and quality of baby corn. Archives of Agronomy and Soil Science. 60(9): 1193-1206. <https://doi.org/10.1080/03650340.2013.873122>.
- Kumar, R., Bohra, J.S., Kumawat, N. and Singh, A.K. (2015). Fodder yield, nutrient uptake and quality of baby corn (*Zea mays* L.) as influenced by NPKS and Zn fertilization. Research on Crops. 16 (2): 243-249. DOI: 10.5958/2348-7542. 2015. 00036.4.
- Kumar, R., Rathore, D.K., Meena, B.S., Ashutosh, Singh, M., Kumar, U. and Meena, V.K. (2016). Enhancing productivity and quality of fodder maize through soil and foliar zinc nutrition. Indian Journal of Agricultural Research. 50(3): 259-263. doi: 10.18805/ijare.v50i3.10747.
- Salama, H.A.S. and Zeid, M.M.K. (2016). Hay quality evaluation of summer grass and legume forage monocultures and mixtures grown under irrigated conditions. Australian Journal Crop Science. 11(11): 1543-1550.

- Subba, V., Nath, A., Kundagrami, S. and Ghosh, A. (2022). Study of combining ability and heterosis in quality protein maize using line $\times$ tester mating design. *Agricultural Science Digest*. 42(2): 159-164. doi: 10.18805/ag.D-5460.
- Teja, K.V., Raju, K.K., Reddy, K.R., Sil, P., Rao, M.S. and Gupta, V.K. (2024). Genetic evaluation of heterosis and combining ability of quality protein maize (*Zea mays* L.) hybrids under terminal heat stress conditions. *Agricultural Science Digest*. 44(5): 806-815. doi: 10.18805/ag.D-6027.
- Tondey, M., Kalia, A., Singh, A., Dheri, G.S., Taggar, M.S., Nepovimova, E., Krejcar, O. and Kuca, K. (2021). Seed priming and coating by nano-scale zinc oxide particles improved vegetative growth, yield and quality of fodder maize (*Zea mays*). *Agronomy*. 11: 729. <https://doi.org/10.3390/agronomy11040729>.
- Van Soest, P.J., Robertson, J.B. and Lewis, B.A. (1991). Methods for dietary fibre, neutral detergent fibre and non-starch polysaccharides in relation to animal nutrition. *Journal of Dairy Science*. 74(10): 3583-3597.
- Yadav P C, Sadhu A C and Swamkar P K. (2007). Yield and quality of multi-cut forage sorghum (*Sorghum sudanense*) as influenced by integrated nitrogen management. *Indian Journal of Agronomy*. 52(4): 330-334.