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EFFECT OF FOLIAR SPRAY OF UREA AND ZINC ON FODDER MAIZE UNDER SALINE SOIL

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SUMMARY

A field experiment was conducted during spring 2023 and 2024 to evaluate the effect of foliar application of urea and $ZnSO_4$ on growth, biomass production, dry matter accumulation, green fodder yield and economics of fodder maize under saline soil conditions. Foliar application of urea and $ZnSO_4$ in combination enhanced crop growth and productivity, whereas $ZnSO_4$ application alone failed to produce a significant improvement. The combined application of Urea @ 2% + $ZnSO_4$ @ 1% recorded the highest biomass per plant (223 and 228 g), dry weight per plant (51.0 and 51.6 g) and green fodder yield (444 and 456 q/ha) during 2023 and 2024, respectively. This treatment also resulted in the highest net returns of 56,056 and 64,388 Rs/ha in 2023 and 2024, respectively. Overall, foliar application of Urea @ 2% + $ZnSO_4$ @ 1% was the most effective treatment, resulting in a increase of 7.8-9.4 % in green fodder yield along with enhanced biomass production, dry matter accumulation and profitability of fodder maize under saline soil conditions.

Key words: Foliar nutrition, green fodder yield, nitrogen fertilization, soil salinity, waterlogging and zinc nutrition

Soil salinity and water-logging are significant constraints to sustainable agricultural production in several parts of Haryana, particularly in the low-lying areas of Rohtak and Jhajjar districts (Grewal *et al.*, 2023). The problem is closely associated with a high groundwater table, inadequate natural drainage and accumulation of salts in the root zone. In these areas, prolonged irrigation and poor drainage conditions often result in water stagnation after the monsoon and *kharif* season. As a consequence, the soil remains saturated for an extended period, creating unfavourable conditions for the establishment and growth of subsequent winter crops (Singh *et al.*, 2026). Singh *et al.*, (2010) reported that approximately 500,000 ha of land in Haryana are affected by waterlogging and have become unproductive, with the extent of waterlogged areas continuing to increase. This increasing incidence of waterlogging and secondary salinization has emerged as a major challenge for maintaining the productivity and profitability of conventional rice-wheat cropping systems.

The rice-wheat system is one of the predominant cropping systems in Haryana and contributes substantially to food grain production. In waterlogged fields, particularly where the groundwater table remains close to the soil surface, timely field preparation and sowing of wheat become difficult. Excess soil moisture reduces soil aeration, restricts root respiration and creates an unsuitable seedbed, which may lead to poor germination and establishment of crop (Goel and Kumar, 1999). Furthermore, the accumulation of soluble salts under conditions of poor drainage can further impair seed germination, nutrient uptake and plant growth (Shrivastava and Kumar, 2015). Under such circumstances, there is a need to identify suitable alternative or contingency crops that can be established and harvested within the available cropping window and can provide economic returns under adverse soil conditions. Spring fodder maize (*Zea mays* L.) may offer a potential alternative for such situations (Singh *et al.*, 2026). Maize is a short-duration, fast-growing crop with considerable biomass-producing ability and is widely recognized as an important source of green fodder for livestock. Its relatively rapid growth, high biomass production and suitability for cultivation make it a promising crop for diversifying conventional cropping systems.

The introduction of spring fodder maize as a contingency crop can be particularly relevant in areas where wheat sowing is delayed or becomes impractical because of persistent waterlogging following rice harvest. Rather than leaving affected fields fallow, farmers may utilize the available land for producing green fodder, thereby generating additional farm output and supporting livestock production. Haryana has a large livestock population and a substantial demand for quality green fodder throughout the year. Seasonal shortages of green fodder can adversely affect livestock productivity and increase the cost of purchased feed. Therefore, the growing demand for green fodder for livestock can be addressed by effectively utilizing saline soils within existing cropping systems (Singh *et al.*, 2026).

However, the productivity of maize under saline and poorly drained conditions can be affected by several factors, including restricted root-zone aeration, osmotic stress and reduced availability or uptake of essential nutrients (Mahmood *et al.*, 2021). Foliar application of nutrients can provide a supplementary source of nutrients during critical growth stages and may help improve crop growth and productivity when nutrient uptake through the soil is restricted. Nitrogen is particularly important for maize because of its role in vegetative growth, chlorophyll formation and biomass accumulation, while zinc plays an important role in enzyme activity, plant growth regulation and various physiological processes. The combined application of urea and zinc sulphate through foliar spray may therefore be a promising approach for improving the performance of spring fodder maize under stressed soil conditions.

In view of these considerations, the present study was undertaken to evaluate spring fodder maize as a contingency crop option for areas affected by waterlogging and salinity in Haryana. The study particularly focuses on the potential of foliar nutrient management through urea and $ZnSO_4$ to enhance crop growth, biomass production, dry matter accumulation and green fodder yield under such conditions. This contingency cropping strategy could contribute to better utilization of affected agricultural land, increased green fodder availability and improved farm-level returns while providing an alternative to the conventional rice–wheat sequence under adverse soil conditions.

MATERIALS AND METHODS

An experiment was carried out at farmer's field in Dhighal Village, Jhajjar district, Haryana, India during the spring seasons of 2023 and 2024 to evaluate the effects of foliar application of Urea and Zinc. The experiment was laid out in randomized block design consisted nine treatments, *i.e.* T_1: Water spray, T_2: foliar application of Urea @ 1 %, T_3: foliar application of Urea @ 2%, T_4: foliar application of $ZnSO_4$@ 0.5%, T_5: foliar application of $ZnSO_4$@ 1 %, T_6:foliar application of Urea @ 1% + $ZnSO_4$@ 0.5%, T_7: foliar application of Urea @ 2% + $ZnSO_4$@ 0.5%, T_8: foliar application of Urea @1% + $ZnSO_4$@ 1% and T_9: foliar application of Urea @ 2% + $ZnSO_4$@ 1% with three replications. Zinc was applied in the form of zinc sulphate heptahydrated ($ZnSO_4 \cdot 7 H_2O$). All foliar sprays were applied at a spray volume of 500 L ha^{-1}. The mean monthly maximum temperatures were 35.8 and 41.2 °C, while the mean monthly minimum temperatures were 16.2 and 16.5°C during the crop periods of 2023 and 2024, respectively. The total rainfall received during the crop period was 194 mm in 2023 and 8.2 mm in 2024 (Fig. 1). The soil of the experiment was loamy textured with pH (7.6), medium in organic carbon, low in available phosphorus, medium in available potassium, deficient in zinc (Table 1). The spring fodder maize was sown according to the recommended package and practices of CCS Haryana Agricultural University on 15th March 2023 and 7th March 2024.The data obtained were subjected to statistical analysis by analysis of variance (ANOVA) for the randomized block design to test the significance of the overall difference among the treatments by the "F" test and conclusion was drawn at 5 % probability level.

TABLE 1
Initial soil properties before start of the experiment

Soil parameters	Value
Soil texture	Loam
EC (dS/m)	1.20
pH	7.6
OC (%)	0.39
Available P (kg/ha)	8.00
Available K (kg/ha)	282
Fe (ppm)	4.98
Mn (ppm)	7.80
Zn (ppm)	0.48
Cu (ppm)	2.20

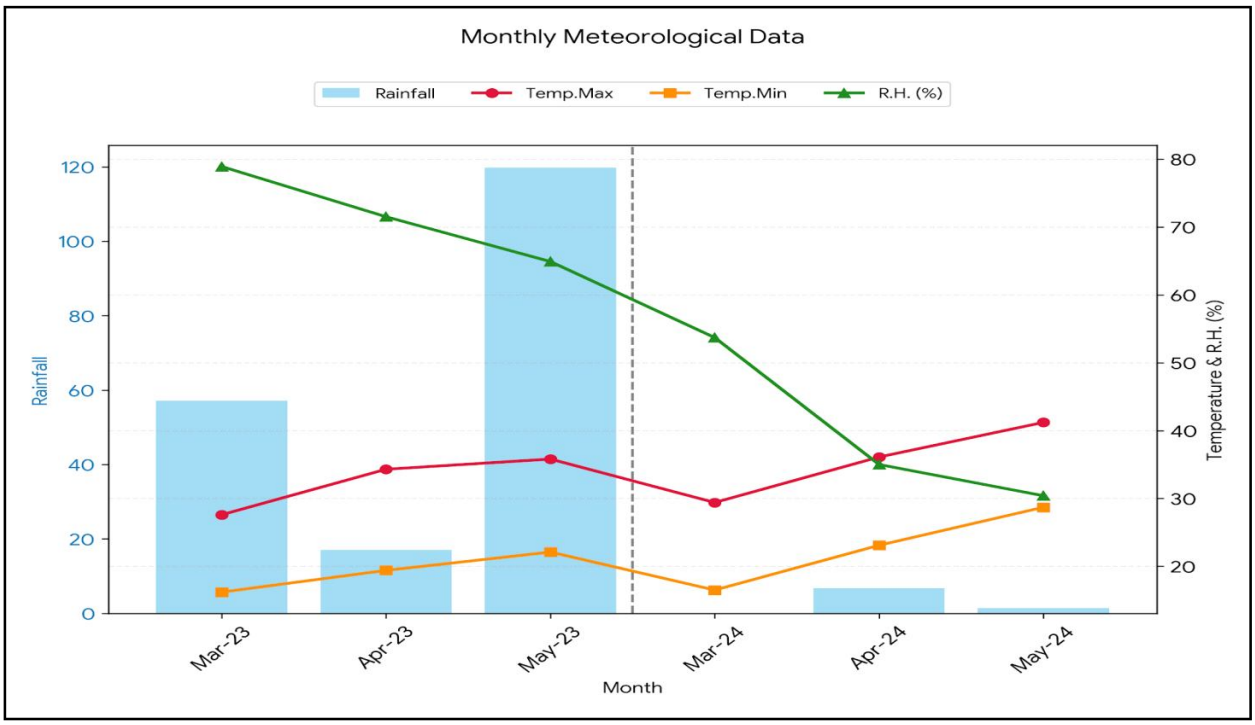

Fig. 1. Weather parameters recorded during the experimental period of 2023 and 2024.

RESULTS AND DISCUSSION

The results of the study under saline soil indicated that foliar application of urea and $ZnSO_4$ in combination, positively influenced plant growth, biomass production, dry matter accumulation and green fodder yield (GFY) during both 2023 and 2024 (Table 2 and Fig. 2), whereas, $ZnSO_4$ application alone failed to enhanced these parameters. The treatment Urea @ 2% + $ZnSO_4$ @ 1% recorded the highest plant height of 201 and 209 cm, biomass per plant of 223 and 228 g and dry weight per plant of 51.0 and 51.6 g during 2023 and 2024, respectively. However, the plant height did not increase significantly during 2023. It also recorded a GFY of 444 and 456 q/ha, respectively, which was at par with Urea @ 2% + $ZnSO_4$ @ 0.5% and Urea @ 1% + $ZnSO_4$ @ 1%. Among the individual nutrient treatments, Urea @ 2% performed better than Urea @ 1%for most of the growth and yield parameters. The water spray treatment consistently recorded the lowest values, with plant height of 183 and 186 cm and GFY of 412 and 417 q/ha in 2023 and 2024, respectively. Overall, the combined application of Urea @ 2% + $ZnSO_4$ @ 1% was the most effective treatment, enhancing plant growth, biomass accumulation and green fodder productivity in both years. Similar results were reported by Singh *et al.*, 2026 and Bhoumik *et al.*, 2026. Kashyp *et al.*, 2023 found that productivity and nutrition quality of fodder maize enhanced by the application of nano urea and zinc combination.

Soil salinity adversely affect the activity and diversity of soil microorganisms, which may negatively affect important soil processes such as residue decomposition, soil respiration and nitrogen (N) cycling (Schirawski and Perlin, 2018). Soil salinity can negatively affect nutrient availability and uptake, particularly nitrogen and zinc (Evelin *et al.*, 2019 and Iqbal *et al.*, 2018). Salinity also reduces root activity and nutrient uptake, resulting in lower nitrogen accumulation and plant growth. The foliar application is an effective way to delivering nutrients directly to the actively growing parts of the plant, which is limitation in saline ecosystem (Singh *et al.*, 2026). Tufail *et al.*, (2018) reported that Zn application improve plant tolerance to salinity. These findings suggest that combining nitrogen and zinc fertilization can improve nutrient use and plant performance under saline conditions.

The highest gross returns were obtained with the foliar application of Urea @ 2% + $ZnSO_4$ @ 1%, followed by Urea @ 2% + $ZnSO_4$ @ 0.5% and Urea @ 1% + $ZnSO_4$ @ 1% (Table 3). A similar trend was observed for net returns over variable costs (Table 3). The treatment Urea @ 2% + $ZnSO_4$ @ 1% recorded the highest net returns of Rs. 56,056/ha in 2023 and Rs. 64,388/ha in 2024. The lowest net returns were

TABLE 2
Effect of foliar application of urea and zinc on growth and green fodder yield of spring fodder maize

Treatments	Plant height (cm)		Biomass/plant at harvest (g)		Dry weight/plant at harvest (g)		Green fodder yield (q/ha)	
	2023	2024	2023	2024	2023	2024	2023	2024
Water spray	183	186	197	200	43.4	44.7	412	417
Urea @ 1%	189	190	207	209	45.9	46.3	425	435
Urea @ 2%	192	195	212	216	46.8	47.3	432	445
$ZnSO_4$ @ 0.5%	185	188	201	203	44.6	45.3	414	422
$ZnSO_4$ @ 1%	187	189	203	206	45.0	45.6	417	424
Urea @ 1%+$ZnSO_4$ @ 0.5%	193	197	215	220	47.9	48.6	434	448
Urea @ 2%+$ZnSO_4$ @ 0.5%	198	204	220	226	49.4	50.4	442	455
Urea @1%+$ZnSO_4$ @ 1%	196	200	218	223	48.8	49.2	440	453
Urea @ 2%+$ZnSO_4$ @ 1%	201	209	223	228	51.0	51.6	444	456
C.D. @ 5%	NS	10.3	17.0	13.5	3.5	3.4	23	26

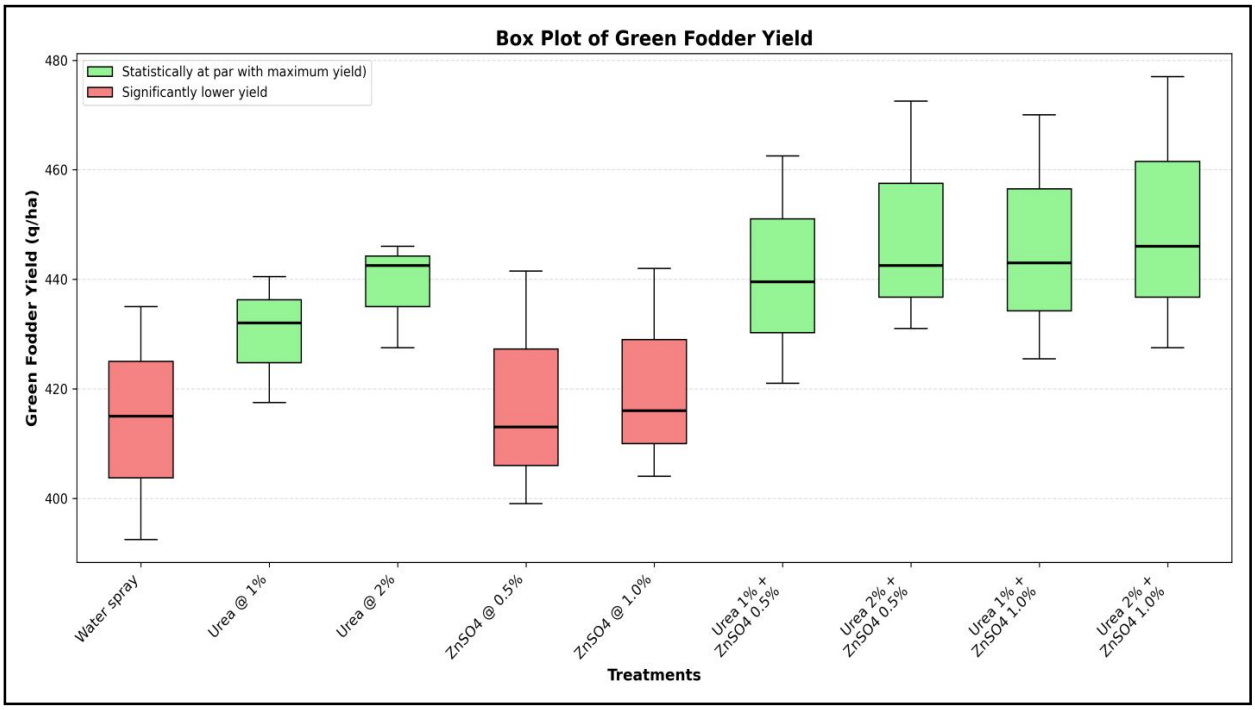

Fig. 2. Effect of foliar application of urea and zinc on green fodder yield of spring maize under saline conditions (pooled data).

recorded under water spray, with Rs. 50,272/ha in 2023 and Rs. 56,830/ha in 2024. Among the individual nutrient applications, Urea @ 2% resulted in higher net returns than Urea @ 1%, while $ZnSO_4$ @ 1% performed slightly better than $ZnSO_4$ @ 0.5%. The benefit-cost ratio[1] also followed a similar pattern. The highest B:C ratio was recorded with the foliar application of Urea @ 2% + $ZnSO_4$ @ 1% with3.09 in 2023 and 3.40 in 2024. The water spray treatment recorded comparatively lower B:C ratios of 2.90 in 2023 and 3.14 in 2024. Overall, the combined application of Urea @ 2% + $ZnSO_4$ @ 1% provided the highest gross and net returns in both years, indicating its economic advantage under the experimental conditions.

CONCLUSION

Foliar application of urea and $ZnSO_4$, improved growth, biomass production, dry matter accumulation and green fodder yield of spring fodder maize. The treatment Urea @ 2% + $ZnSO_4$ @ 1% recorded the best overall growth and yield performance in both years. Combined nutrient applications were generally more effective than individual applications. The highest gross and net returns were obtained with Urea @ 2% + $ZnSO_4$ @ 1%, while the B:C ratio was also favourable under combined applications. Overall, foliar application of Urea @ 2% + $ZnSO_4$ @ 1% proved most effective

TABLE 3
Effect of foliar application of urea and zinc on economics of spring fodder maize

Treatments	Gross returns (Rs/ha)		Net returns over variable cost (Rs./ha)		B:C	
	2023	2024	2023	2024	2023	2024
Water spray	76,776	83,333	50,272	56,830	2.90	3.14
Urea @ 1%	79,263	87,000	52,730	60,467	2.99	3.28
Urea @ 2%	80,630	89,000	54,068	62,438	3.04	3.35
$ZnSO_4$ @ 0.5%	77,211	84,333	50,583	57,705	2.90	3.17
$ZnSO_4$ @ 1%	77,833	84,800	51,079	58,047	2.91	3.17
Urea @ 1%+$ZnSO_4$ @ 0.5%	80,941	89,600	54,283	62,942	3.04	3.36
Urea @ 2%+$ZnSO_4$ @ 0.5%	82,495	91,000	55,808	64,313	3.09	3.41
Urea @1%+$ZnSO_4$ @ 1%	81,998	90,533	55,215	63,750	3.06	3.38
Urea @ 2%+$ZnSO_4$ @ 1%	82,868	91,200	56,056	64,388	3.09	3.40

Note : Calculated as benefit cost ratio relative to variable cost only.

for enhancing productivity and profitability of spring fodder maize.

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