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Growth and yield of *rabi* maize (*Zea mays* L.) influenced by different foliar treatments of urea and nano urea

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Abstract
A field experiment entitled "Growth and yield of *rabi* maize (*Zea mays* L.) influenced by different foliar treatments of urea and nano urea" was carried out under clayey soil having pH 7.9 and EC 0.36 dS/m during *rabi* season of 2022-23 at Instructional Farm, Department of Agronomy, College of Agriculture, Junagadh Agricultural University, Junagadh (Gujarat). The experiment was laid out in randomized block design with three replications. The experiment comprising of 10 treatments *viz*., T_1 -Control (No fertilizer), T_2 -100% RDN + Water spray at 25, 35 and 45 DAS, T_3 -75% RDN + Foliar spray of 2% urea at 25 and 45 DAS, T_4 -75% RDN + Foliar spray of 2 ml/L nano urea at 25 and 45 DAS, T_5 -75% RDN + Foliar spray of 4 ml/L nano urea at 25 and 45 DAS, T_6 -75% RDN + Foliar spray of 6 ml/L nano urea at 25 and 45 DAS, T_7 -75% RDN + Foliar spray of 2% urea at 25, 35 and 45 DAS, T_8 -75% RDN + Foliar spray of 2 ml/L nano urea at 25, 35 and 45 DAS, T_9 -75% RDN + Foliar spray of 4 ml/L nano urea at 25, 35 and 45 DAS and T_{10} -75% RDN + Foliar spray of 6 ml/L nano urea at 25, 35 and 45 DAS. The *rabi* maize (GAYMH-3) was sown on 23th November 2022 at a spacing of 60 x 20 cm using seed rate of 25 kg/ha with standard package of practices. The result of field experiment revealed that the application of 75% RDN + Foliar spray of 4 ml/L nano urea at 25, 35 and 45 DAS recorded significantly higher values of growth parameters *viz.*, plant height, number of leaves per plant, SPAD value and dry matter production per plant at harvest; yield attributes and yield *viz.*, number of grains per cob, cob length, 100 grains weight, grain yield (6424 kg/ha) and dry fodder yield (8942 kg/ha), over control. Economic analysis showed that the maximum net return (98373 ₹/ha) and BCR (3.16) were obtained with the application of 75% RDN + Foliar spray of 4 ml/L nano urea at 25, 35 and 45 DAS over control.

Keywords: Foliar spray, *rabi* maize, nano urea, growth, SPAD value, yield and economics

Introduction
Maize (*Zea mays* L.) is one of the most versatile emerging crops, having wider adaptability under varied agro-climatic conditions. It belongs to the *Poaceae* family. Globally, maize is known as the "queen of cereals" because of its high genetic potential among cereals. In India, maize is the third most important food crop after rice and wheat. Maize cultivation is done in two production environments, namely traditional (Bihar, Madhya Pradesh, Rajasthan and Uttar Pradesh) and non-traditional maize areas (Karnataka and Andhra Pradesh). In Gujarat, total maize area, production and productivity were 3.9 lakh ha, 8.16 lakh tones and 2089 kg/ha, respectively. While, the total area under *rabi* maize was nearly 0.9 lakh ha with a production of 2.29 lakh tones and productivity of 2529 kg/ha (Anon., 2022) [1].
Maize crop requires a regulated and assured supply of nutrients particularly nitrogen, throughout its growing period right from the seedling stage to grain filling stage. The demand of plants for nitrogen is more than any other nutrient and it is noticed that deficiency at any stage of growth, especially at tasseling and silking stage, may lead to virtual crop failure. Nitrogen deficiency is characterized by stunted plant growth with yellowing of green foliage, particularly the lower leaves. Nitrogenous fertilizers, mainly urea account for more than 80% of the synthetic chemical fertilizers used in India (Chandana *et al*., 2021b) [3]. As of now, just 30-45% of nitrogen from urea is utilized by plants at farm level, while the rest waste due to quick chemical transformation because of leaching, which contaminates soil and water bodies and volatilization that causes

emissions of ammonia gas in the atmosphere leading to air pollution and global warming along with low nutritional efficiency for the crop. Imbalanced fertilization is one of the most critical factors to be considered for N management. This is a very serious issue causing nitrate pollution in groundwater and eutrophication in aquatic system (Manikanandan and Subramaniam, 2016) [7]. Over the long run, the application of nitrogen-based fertilizers with less efficiency might deteriorate the quality of maize and pollute the environment (Samui *et al*., 2022) [13]. These losses of nitrogen fertilizer cannot be completely avoided, but losses can be minimized through using advanced techniques such as foliar application, split application and usage of slow-release fertilizers. Soil-applied nitrogenous fertilizers were influenced by various environmental factors and thereby limits its efficiency in nutrient use. Consequently, resulted in the appearance of acute deficiency symptoms adversely affecting crop growth and development. In this case, supplementation of nitrogen, through foliar spray could be the most efficient and appropriate strategy. Foliar application is the application of fertilizer directly on the leaves of a plant. Plants are able to absorb nutrients through foliage. Field crops normally absorb the majority of nutrients from the soil through root absorption, but above ground plant structures, especially leaves, are capable of absorbing limited amounts of some nutrients. Foliar fertilization of crops offer specific advantages over soil applied fertilizers, because the nutrients are applied and taken up directly by their target organs, providing a specific and rapid response (Jadhav *et al.*, 2022) [5].

Split applications of nitrogenous fertilizer can play an important role in a nutrient management strategy that is productive, profitable and environmentally responsible. Dividing total nitrogen application into two or more splits can help enhance nutrient efficiency, promote optimum yields and mitigate the loss of nutrients. Smart materials that can systematically release nutrients to specific targeted sites in plants could be beneficial in controlling their deficiencies in agriculture while keeping intact the natural soil structure. Nanotechnology is a powerful tool in agriculture, that utilizes nanomaterials of less than 100 nm in size and has emerged as an innovative science to develop concentrated sources of plant nutrients with a higher absorption rate, utilization efficacy and minimum losses (Upadhyay *et al*., 2023) [18]. Nanotechnology-based fertilizers are made by encapsulating or developing plant nutrients in its nanoforms and ultimately delivering in the form of nano-sized emulsions. Nano fertilizers are very effective for controlled nutrient supply to plants at different growth stages. Nanoscale nutrients can effectively enter into plant leaves, trigger nutrient pathways and achieve higher nutrient use efficiency.

IFFCO has successfully innovated and developed nano urea liquid (nano nitrogen) at its Nano Biotechnology Research Centre (NBRC) in Kalol, Gujarat. It contains 4% N and has a shelf life of about 2 years. When nano urea is sprayed on leaves, it easily gets absorbed and also enters through stomata due to its nano size (<100 nm). It is distributed to other plant parts through phloem translocation and metabolically assimilated as per the plant's need. Nano urea contains nanoscale nitrogen particles (18-30 nm), which have more surface area (10,000 times over 1 mm urea prill) and number of particles (55,000 nano nitrogen particles over 1 mm urea prill). Nano nitrogen particles with pore size (20 nm) can easily penetrate through cell wall and reach up to plasma membrane. Large size particles (20 - 50 nm) can penetrate through stomatal pores. These are also transported via phloem cells through plasmodesmata (40 nm diameter) to other plant parts (Kumar *et al*., 2021) [6].

Materials and Methods

The present study entitled "Growth and yield of *rabi* Maize (*Zea mays* L.) influenced by different foliar treatments of urea and nano urea" was conducted at the D-7 plot of Instructional Farm, Department of Agronomy, College of Agriculture, Junagadh Agricultural University, Junagadh during *rabi* season of the year 2022-23. The experiment was laid out in a Randomized Block Design (RBD) with ten treatments in three replications. The details of treatments are given below:

Table 1: Treatment details

Tr. No.		Treatments detail
T_1	:	Control (No fertilizer)
T_2	:	100% RDN + Water spray at 25, 35 and 45 DAS
T_3	:	75% RDN + Foliar spray of 2% urea at 25 and 45 DAS
T_4	:	75% RDN + Foliar spray of 2 ml/L nano urea at 25 and 45 DAS
T_5	:	75% RDN + Foliar spray of 4 ml/L nano urea at 25 and 45 DAS
T_6	:	75% RDN + Foliar spray of 6 ml/L nano urea at 25 and 45 DAS
T_7	:	75% RDN + Foliar spray of 2% urea at 25, 35 and 45 DAS
T_8	:	75% RDN + Foliar spray of 2 ml/L nano urea at 25, 35 and 45 DAS
T_9	:	75% RDN + Foliar spray of 4 ml/L nano urea at 25, 35 and 45 DAS
T_{10}	:	75% RDN + Foliar spray of 6 ml/L nano urea at 25, 35 and 45 DAS

Note: RDF (150-60-00 N-P_2O_5-K_2O kg/ha), Soil applied nitrogen was applied in four equal split *i.e.*, basal, 4 leaf stage, 8 leaf stage and at tasseling stage through Urea and DAP fertilizers, respectively. The full dose of phosphorus was applied uniformly in all the treatments except T_1 as basal through DAP fertilizer.

Results and Discussion

Impact of foliar spray of urea and nano urea on growth parameters of *rabi* maize

A. Plant height (cm): The mean plant height as influenced by different treatments of foliar application is furnished in Table 2. Significantly higher plant height (54.40 cm) of maize at 30 DAS was recorded with the application of 100% RDN + Water spray at 25, 35 and 45 DAS (T_2) and it remained statistically at par with T_9, T_{10}, T_7, T_5, T_6 and T_3. Significantly higher plant height at 60 DAS (152.07 cm) was recorded under the T_9 (75% RDN + Foliar spray of 4 ml/L nano urea at 25, 35 and 45 DAS) and remained at par with T_{10}, T_2 and T_7. Treatment T_9 recorded a significantly higher plant height of 195.07 cm at harvest and it remained statistically at par with T_{10} and T_2.

Number of leaves/plants

A glance of data (Table 3.) revealed that the number of leaves per plant at 30 DAS was not significantly influenced by different treatments. Number of leaves per plant (13.00) at 60 DAS recorded significantly higher under the treatment of 75% RDN + Foliar spray of 4 ml/L nano urea at 25, 35 and 45 DAS (T_9) and which was remained at par with T_{10}, T_2 and T_7. At harvest time number of leaves obtained higher (14.93) under T_9 and which remained statistically at par with T_{10}, T_2 and T_7.

Table 2: Impact of different treatments on plant height of *rabi* maize

Treatments		Plant height (cm)		
		At 30 DAS	At 60 DAS	At harvest
T_1	Control (No fertilizer)	40.40	119.53	143.13
T_2	100% RDN + Water spray at 25, 35 and 45 DAS	54.40	148.00	181.53
T_3	75% RDN + Foliar spray of 2% urea at 25 and 45 DAS	48.00	129.73	156.73
T_4	75% RDN + Foliar spray of 2 ml/L nano urea at 25 and 45 DAS	43.13	125.93	149.27
T_5	75% RDN + Foliar spray of 4 ml/L nano urea at 25 and 45 DAS	48.67	130.40	160.20
T_6	75% RDN + Foliar spray of 6 ml/L nano urea at 25 and 45 DAS	48.07	129.80	157.87
T_7	75% RDN + Foliar spray of 2% urea at 25, 35 and 45 DAS	50.53	141.33	166.00
T_8	75% RDN + Foliar spray of 2 ml/L nano urea at 25, 35 and 45 DAS	43.87	127.93	155.67
T_9	75% RDN + Foliar spray of 4 ml/L nano urea at 25, 35 and 45 DAS	51.00	152.07	195.07
T_{10}	75% RDN + Foliar spray of 6 ml/L nano urea at 25, 35 and 45 DAS	50.67	149.60	184.80
	S. Em. ±	2.50	6.76	9.67
	C.D at 5%	7.44	20.10	28.72
	C. V. %	9.06	8.65	10.15

Table 3: Impact of different treatments on number of leaves of *rabi* maize

Treatments		Number of leaves per plant		
		At 30 DAS	At 60 DAS	At harvest
T_1	Control (No fertilizer)	6.13	9.73	10.33
T_2	100% RDN + Water spray at 25, 35 and 45 DAS	8.07	12.20	13.80
T_3	75% RDN + Foliar spray of 2% urea at 25 and 45 DAS	7.67	10.73	12.07
T_4	75% RDN + Foliar spray of 2 ml/L nano urea at 25 and 45 DAS	6.87	10.47	11.93
T_5	75% RDN + Foliar spray of 4 ml/L nano urea at 25 and 45 DAS	8.00	11.00	12.73
T_6	75% RDN + Foliar spray of 6 ml/L nano urea at 25 and 45 DAS	7.93	10.87	12.33
T_7	75% RDN + Foliar spray of 2% urea at 25, 35 and 45 DAS	7.67	11.53	12.87
T_8	75% RDN + Foliar spray of 2 ml/L nano urea at 25, 35 and 45 DAS	7.33	10.53	12.00
T_9	75% RDN + Foliar spray of 4 ml/L nano urea at 25, 35 and 45 DAS	8.07	13.00	14.93
T_{10}	75% RDN + Foliar spray of 6 ml/L nano urea at 25, 35 and 45 DAS	8.00	12.53	14.27
	S. Em. ±	0.44	0.59	0.69
	C.D at 5%	NS	1.76	2.06
	C. V.%	10.14	9.09	9.42

SPAD meter value

The data of effect on SPAD meter value are presented in (Table 4.) SPAD meter readings were taken from the upper, middle and lower leaves of the plant before each foliar spray and 6 days after each foliar spray.

SPAD meter value (28.45) in maize before 1st spray influenced by different treatments and found significant with T_2 (100% RDN + Water spray at 25, 35 and 45 DAS). While, all of the SPAD value observation taken after 1st spray, before 2nd spray, after 2nd spray, before 3rd spray and after 3rd spray received higher with T_9 (75% RDN + Foliar spray of 4 ml/L nano urea at 25, 35 and 45 DAS) (32.29, 35.84, 40.34, 45.70 and 51.19, respectively). The lowest SPAD value of all above parameters were observed in T_1 (Control).

The measurement of chlorophyll content with the SPAD meter is indicative of the greenness of the plant. Photosynthetic cells contain chlorophyll and other light-sensitive pigments that capture solar energy. In the presence of carbon dioxide, such cells are able to convert this solar energy into energy-rich organic molecules, such as glucose. Foliar application of nano nitrogen increases leaf N and chlorophyll content. Nano N particles were able to permeate maize plant biological membranes and boost chlorophyll pigments, notably chlorophyll-a, that boost the photosynthetic rate in maize and ultimately the growth of maize. The results are closely related to those of Sharma *et al.* (2022) [15] and Rundan *et al.* (2023) [11].

Table 4: Impact of different treatments on SPAD value of *rabi* maize

Treatments		SPAD value					
		Before 1st spray	After 1st spray	Before 2nd spray	After 2nd spray	Before 3rd spray	After 3rd spray
T_1	Control (No fertilizer)	20.51	23.83	26.36	28.66	32.85	36.64
T_2	100% RDN + Water spray at 25, 35 and 45 DAS	28.45	30.55	32.70	35.84	40.22	45.58
T_3	75% RDN + Foliar spray of 2% urea at 25 and 45 DAS	23.98	28.34	30.19	33.39	38.04	43.08
T_4	75% RDN + Foliar spray of 2 ml/L nano urea at 25 and 45 DAS	24.16	27.64	28.80	31.05	35.24	39.07
T_5	75% RDN + Foliar spray of 4 ml/L nano urea at 25 and 45 DAS	25.05	30.79	31.84	35.44	40.74	48.05
T_6	75% RDN + Foliar spray of 6 ml/L nano urea at 25 and 45 DAS	24.87	28.34	30.29	33.14	37.54	42.54
T_7	75% RDN + Foliar spray of 2% urea at 25, 35 and 45 DAS	25.47	31.75	33.38	35.28	40.18	47.71
T_8	75% RDN + Foliar spray of 2 ml/L nano urea at 25, 35 and 45 DAS	24.67	27.72	29.60	33.33	37.35	41.63
T_9	75% RDN + Foliar spray of 4 ml/L nano urea at 25, 35 and 45 DAS	26.27	32.29	35.84	40.34	45.70	51.19
T_{10}	75% RDN + Foliar spray of 6 ml/L nano urea at 25, 35 and 45 DAS	26.31	31.03	33.38	38.58	43.75	49.15
	S.Em. ±	1.04	1.46	1.35	1.64	1.85	2.68
	C.D at 5%	3.09	4.35	4.01	4.88	5.51	7.98
	C.V. %	7.22	8.67	7.48	8.25	8.20	10.46

Dry matter production per plant at harvest (g)

Mean data presented in Table 5. indicated that significantly the highest dry matter production (257.00 g) was obtained under treatment 75% RDN + Foliar spray of 4 ml/L nano urea at 25, 35 and 45 DAS (T_9) and which remained statistically at par with 75% RDN + Foliar spray of 6 ml/L nano urea at 25, 35 and 45 DAS (T_{10}) and 100% RDN + Water spray at 25, 35 and 45 DAS (T_2). On the contrary, the treatment T_1 (Control) recorded significantly the lowest dry matter production (153.67 g). Growth parameters highly respond to foliar sprays especially urea and nano urea. Nitrogen is one of the major elements, that influences the metabolic activities of plants. The increase in plant height and number of leaves may be due to timely and readily supplied of N through soil and foliar applied nano urea at critical growth stages of plant. Especially, foliar application of nano N increase nitrogen uptake through leaves which might have led to increased mobilization of synthesized carbohydrates into amino acids and proteins which stimulated rapid cell division and elongation. Thus, plants with sufficient nitrogen will experience high rates of photosynthesis and that leads to rapid food manufacture and speedy translocation to various plant parts thereby accumulating of food and nutrients in the plant which helps to increase the dry matter of the plant. Similar findings were observed in rice by Chanadana *et al*. (2021a), in maize by Rajesh *et al*. (2021) [10], in pearl millet by Sharma *et al*. (2022) [15], in wheat by Singh *et al*. (2022) [16] and in little millet by Chavan *et al*. (2023) [4] and in maize by Meena *et al*. (2023) [8].

Table 5: Impact of different treatments on dry matter production of *rabi* maize

Treatments		Dry matter production at harvest (g)
T_1	Control (No fertilizer)	153.67
T_2	100% RDN + Water spray at 25, 35 and 45 DAS	231.60
T_3	75% RDN + Foliar spray of 2% urea at 25 and 45 DAS	190.80
T_4	75% RDN + Foliar spray of 2 ml/L nano urea at 25 and 45 DAS	168.27
T_5	75% RDN + Foliar spray of 4 ml/L nano urea at 25 and 45 DAS	214.07
T_6	75% RDN + Foliar spray of 6 ml/L nano urea at 25 and 45 DAS	201.40
T_7	75% RDN + Foliar spray of 2% urea at 25, 35 and 45 DAS	216.27
T_8	75% RDN + Foliar spray of 2 ml/L nano urea at 25, 35 and 45 DAS	183.87
T_9	75% RDN + Foliar spray of 4 ml/L nano urea at 25, 35 and 45 DAS	257.00
T_{10}	75% RDN + Foliar spray of 6 ml/L nano urea at 25, 35 and 45 DAS	232.67
	S. Em. ±	13.67
	C.D at 5%	40.61
	C. V. %	11.55

Impact of different treatments on yield attributes of *rabi* maize

Number of cobs per plant

Data on the number of cobs per plant of maize crop are presented in Table 6. An assessment of data revealed that the number of cobs per plant at harvest did not influence by the different treatments on maize.

Number of grains per cob

Among different treatments, treatment T_9 (75% RDN + Foliar spray of 4 ml/L nano urea at 25, 35 and 45 DAS) recorded a significantly higher number of grains per cob (382.33). While, it was statistically at par with T_{10} (75% RDN + Foliar spray of 6 ml/L nano urea at 25, 35 and 45 DAS) and T_2 (100% RDN + Water spray at 25, 35 and 45 DAS). A lower number of grains per cob of maize (274.53) was reported in treatment T_1 (Control).

Cob length (cm)

Cob length of maize was significantly influenced by different treatments. Significantly higher cob length (22.53 cm) was observed under treatment T_9 (75% RDN + Foliar spray of 4 ml/L nano urea at 25, 35 and 45 DAS), which was found statistically at par with T_{10} (75% RDN + Foliar spray of 6 ml/L nano urea at 25, 35 and 45 DAS) and T_2 (100% RDN + Water spray at 25, 35 and 45 DAS). While, the treatment T_1 (Control) recorded significantly the lowest cob length (17.73 cm).

100 grains weight (g)

The data on 100 grains weight are presented in Table 6. The data showed that among different treatments, treatment T_9 (75% RDN + Foliar spray of 4 ml/L nano urea at 25, 35 and 45 DAS) recorded a significantly higher 100 grains weight (34.82 g). While, it was statistically at par with T_{10} and T_2. A lower 100 grains weight of maize (25.27 g) was reported in treatment T_1 (Control). Yield is a result of yield attributes that are influenced by a variety of factors including genetics, climate, soil fertility, irrigation and most importantly nutrients management. The main concepts for achieving balanced nutrition management are the 5Rs: right time, right technique, right quantity, right place and right source. Soil applied N through split application and foliar application of nano urea is most effective in ensuring adequate supply of plant nutrients quickly and directly to the plant that enhances efficient use of nutrients, translocates them up to the sink site and ultimately increases the length and girth of the maize cob. Thus, greater availability of photosynthates, metabolites and nutrient availability throughout growth period of crop to develop reproductive structures seems to have resulted in increased number of grains per cob and 100 grains weight. The result of the present investigation is in close accordance with the findings of Samui *et al.* (2022) [13], Meena *et al*. (2023) [8] and Sannathimappa *et al.* (2023) [14].

Table 6: Impact of different treatments on number of cobs, grains per cob, cob length and 100 grains weight of *rabi* maize

Treatments		No. of cobs/plant	No. of grains/cob	Cob length (cm)	100 grains weight (g)
T_1	Control (No fertilizer)	1.27	274.53	17.73	25.27
T_2	100% RDN + Water spray at 25, 35 and 45 DAS	1.60	355.53	21.27	32.79
T_3	75% RDN + Foliar spray of 2% urea at 25 and 45 DAS	1.40	316.60	18.80	28.35
T_4	75% RDN + Foliar spray of 2 ml/L nano urea at 25 and 45 DAS	1.33	291.67	18.13	27.24
T_5	75% RDN + Foliar spray of 4 ml/L nano urea at 25 and 45 DAS	1.47	322.87	19.40	29.41
T_6	75% RDN + Foliar spray of 6 ml/L nano urea at 25 and 45 DAS	1.47	319.80	19.20	28.78
T_7	75% RDN + Foliar spray of 2% urea at 25, 35 and 45 DAS	1.53	326.87	19.53	29.46
T_8	75% RDN + Foliar spray of 2 ml/L nano urea at 25, 35 and 45 DAS	1.33	310.93	18.40	28.00
T_9	75% RDN + Foliar spray of 4 ml/L nano urea at 25, 35 and 45 DAS	1.73	382.33	22.53	34.82
T_{10}	75% RDN + Foliar spray of 6 ml/L nano urea at 25, 35 and 45 DAS	1.67	367.27	21.60	33.65
	S. Em. ±	0.10	18.35	1.00	1.80
	C.D at 5%	NS	54.52	2.96	5.34
	C. V. %	11.54	9.72	8.79	10.45

Impact of different treatments on yield of *rabi* maize

Grain yield (kg/ha)

A perusal of data (Table 7.) revealed that different treatments significantly influenced the grain yield of maize. The application of T_9 (75% RDN + Foliar spray of 4 ml/L nano urea at 25, 35 and 45 DAS) had an apparently higher grain yield (6424 kg/ha). However, it remained statistically at par with treatments T_{10} (75% RDN + Foliar spray of 6 ml/L nano urea at 25, 35 and 45 DAS) and T_2 (100% RDN + Water spray at 25, 35 and 45 DAS). In the meantime, a lower grain yield of 4164 kg/ha was observed with treatment T_1 (Control). Treatments T_9, T_{10} and T_2 produced 54.27, 48.39 and 41.04% higher grain yields respectively as compared to T_1 (Control).

Dry Fodder yield (kg/ha)

The data presented in Table 7. showed that different treatments of urea and nano urea significantly influenced the dry fodder yield of maize. Among all treatments tested, treatment T_9 (75% RDN + Foliar spray of 4 ml/L nano urea at 25, 35 and 45 DAS) had apparently higher dry fodder yield (8942 kg/ha). However, it remained statistically at par with treatments T_{10} and T_2. The magnitude of the increase in dry fodder yield under treatments T_9, T_{10} and T_2 was to the extent of 58.46, 52.61 and 42.33% over treatments T_1, respectively. In contrast to it, a lower dry fodder yield of 5643 kg/ha of maize was recorded under T_1 (Control).

Use of both soil and foliar application of fertilizers simultaneously is probably the most effective method to maintain healthy sustainable soil system while increasing productivity. Increase in grain yield and dry fodder yield may be attributed to the reason that the foliar application of nitrogen, which normally reduces the loss through leaching and other process associated with soil application and its application prompt correction for nutrient deficiencies. The superiority of foliar nutrition might be due to coincidence of foliar application with peak nutrition requirement of the crop as a supplementation to soil application. These finding are corroborating with the results of Rajesh *et al.* (2021) [10], Sahu *et al.* (2022) [12], Samui *et al.* (2022) [13], Sharma *et al.* (2022) [15], Chavan *et al.* (2023) [4], Meena *et al.* (2023) [8] and Sannathimappa *et al.* (2023) [14].

Impact of different treatments on economics of *rabi* maize

Net Return: Scrutiny of data (Table 7.) revealed that the maximum net return of 98373 ₹/ha was realized with T_9 (75% RDN + Foliar spray of 4 ml/L nano urea at 25, 35 and 45 DAS) followed by the treatments T_{10} (75% RDN + Foliar spray of 6 ml/L nano urea at 25, 35 and 45 DAS) and T_2 (100% RDN + Water spray at 25, 35 and 45 DAS). The minimum net return of 56428 ₹/ha were achieved under T_1 (Control).

BCR

An appraisal of the data (Table 7.) showed that the maximum BCR of 3.16 was achieved with T_9 (75% RDN + Foliar spray of 4 ml/L nano urea at 25, 35 and 45 DAS), followed by T_2 (100% RDN + Water spray at 25, 35 and 45 DAS) and T_{10} (75% RDN + Foliar spray of 6 ml/L nano urea at 25, 35 and 45 DAS). The minimum BCR of 2.42 was accrued under T_4 (75% RDN + Foliar spray of 2 ml/L nano urea at 25 and 45 DAS).

The higher net returns under these treatments are obviously due to higher grain and dry fodder yield recorded with these treatments along with comparatively less cost than additional income. These results are in close agreement with Rajesh *et al.* (2021) [10], Patel *et al.* (2023) [9] and Singh *et al.* (2023) [17].

Table 7: Impact of different treatments on yield and economics of *rabi* maize

Treatments		Seed yield (kg/ha)	Fodder yield (kg/ha)	Net income (₹/ha)	BCR
T_1	Control (No fertilizer)	4164	5643	56428	2.54
T_2	100% RDN + Water spray at 25, 35 and 45 DAS	5873	8032	87613	3.00
T_3	75% RDN + Foliar spray of 2% urea at 25 and 45 DAS	5109	7066	71454	2.67
T_4	75% RDN + Foliar spray of 2 ml/L nano urea at 25 and 45 DAS	4713	6682	62090	2.42
T_5	75% RDN + Foliar spray of 4 ml/L nano urea at 25 and 45 DAS	5230	7397	72876	2.64
T_6	75% RDN + Foliar spray of 6 ml/L nano urea at 25 and 45 DAS	5201	7225	71329	2.58
T_7	75% RDN + Foliar spray of 2% urea at 25, 35 and 45 DAS	5328	7630	76169	2.76
T_8	75% RDN + Foliar spray of 2 ml/L nano urea at 25, 35 and 45 DAS	4999	6953	67599	2.52
T_9	75% RDN + Foliar spray of 4 ml/L nano urea at 25, 35 and 45 DAS	6424	8942	98373	3.16
T_{10}	75% RDN + Foliar spray of 6 ml/L nano urea at 25, 35 and 45 DAS	6179	8612	91780	2.97
S. Em. ±		339	428		
C.D at 5%		1007	1271		
C. V. %		11.03	9.99		

Conclusion

Based on one year's field experimentation, it seems quite logical to concluded that higher growth, SPAD value, production and monetary returns from *rabi* maize can be achieved by the application of 75% RDN (112.5-60-00 N-P_2O_5-K_2O kg/ha) with four equal split dose application at basal, 4 leaf stage, 8 leaf stage and at tasseling stage + Foliar spray of 4 ml/L nano urea at 25, 35 and 45 DAS under South Saurashtra Agro-climatic Zone of Gujarat.

Author's contribution

Kinjal Dodiya formulated the theory and conducted the calculations. Kinjal Dodiya validated the analytical techniques. Under the guidance of Prof. A. C. Detroja. The results were collectively deliberated by all authors, and each played a role in shaping the final manuscript.

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