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INFLUENCE OF SPLIT AND FOLIAR APPLICATION OF NITROGEN AND POTASSIUM ON GROWTH, YIELD AND UPTAKE OF RAINFED MAIZE IN ENTISOLS

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ABSTRACT

A field experiment was conducted during *Kharif* 2024 at the research farm of AICRP on maize, Zonal Agricultural Research Station, Sub-montane Zone, Kolhapur. The experiment aimed to evaluate the impact of split application of nitrogen and potassium combined with foliar application of KNO_3 on maize growth performance and yield in Entisols of Sub-montane Zone of Maharashtra. The findings indicated that application of nitrogen and potassium in three splits along with two foliar sprays of 2% KNO_3 at V6 and tasseling stage (T_8), recorded significantly higher plant height, cob girth, cob length, number of cobs per plot, grain weight per cob, and 100-seed weight over all the other treatments while, comparable with three splits of nitrogen and potassium along with one foliar spray of 2% KNO_3 at V6 stage (T_7). This enhanced growth performance consequently led to significantly highest grain yield (83.9 q ha^{-1}) and straw yield (101.2 q ha^{-1}) in treatment T_8 than all the other treatments however, it was statistically at par with T_7. Comparative to GRDP (T_2) with split application of nitrogen alone, treatment T_8 recorded 21.3% and 22.3% higher grain and straw yields, respectively, while treatment T_7 exhibited corresponding increases of 13.1% and 13.7%. With respect to total nutrient uptake, treatment T_8 recorded the significantly highest uptake of nitrogen (175.4 kg ha^{-1}), phosphorus (52.9 kg ha^{-1}) and potassium (187.0 kg ha^{-1}), surpassing all other treatments and remaining statistically at par with T7. These results substantiate the effectiveness of synchronized split applications of nitrogen and potassium in conjunction with foliar application of KNO_3 at critical growth stages in enhancing maize yield and nutrient assimilation under rainfed conditions

***Keyword*:** Growth, phenology, split application, uptake, yield

Introduction

Maize is a cereal crop, and nutrient depletion far exceeds replenishment in cereal-based cropping systems in India, leading to widespread soil multinutrient deficiencies. Managing nutrients in heavy feeders, such as maize, can be challenging due to their high nutrient removal from the soil. Maize absorbs nutrients throughout the season, with the vegetative stage absorbing the most nitrogen and potassium, followed by grain filling for phosphorus, sulphur, and zinc. Therefore, maintaining balanced crop nutrition throughout the season depends on maintaining a steady supply of nutrients. Splitting N, P and K fertilizer applications ensures a continuous supply of nutrients to the root zone, minimizing losses and enhancing soil CEC. Higher N, P and K concentrations in the soil solution and surrounding the root zone are probably the cause of the rise in soil CEC (Tiwari *et al.*, 2016). Higher potash levels and more split treatments were positively correlated with maize grain yields (Saleem *et al.*, 2011). During crucial stages of maize growth, such as the vegetative phase and tassel initiation, a consistent supply of nutrients is ensured through split fertilizer applications (Ojeniyi *et al.*, 2024). Entisols generally contain new and underdeveloped soils with negligeable horizon differentiation. Entisols are typically found in floodplains, river terraces, and erosion-prone areas, making them inherently low in fertility and organic matter content. Nitrogen and potassium deficiency is also prevalent in Entisols of the Sub-montane Zone of Maharashtra.

In the current scenario of climatic aberration, stress conditions become a common phenomenon or hindrance for obtaining optimum yields of crops. The Kolhapur region typically experiences one or two dry spells during 36th and 38th meteorological weeks (Chunale and Bansode, 2002). The foliar application of potassium nitrate during such stress condition could be an effective alternative to enhance the availability of nitrogen and potassium during the critical growth phase of the crop through its impact on transpiration, stomatal behaviors, root development, and water absorption (Nelson 1980, Hsiao and Lauchli, 1986). Plants treated with KNO_3 showed increased growth and a grain yield that was 32.2% higher than that of untreated plants when there was a water shortage (Avila *et al*., 2020). Using split potassium fertilizers in conjunction with foliar KNO_3 feeding might enhance the availability and transformation of potassium in these soils.

Material and Methods

Experimental Details

The experiment comprised of eight treatments *viz.* T_1; control , T_2; GRDF, T_3; 40 kg N + 20 kg K_2O at 25 DAS, T_4; 40 kg N + 20 kg K_2O at 25 DAS and foliar spray of 2% KNO_3 at V6 stage, T_5; 40 kg N + 20 kg K_2O at 25 DAS and two foliar sprays of 2% KNO_3 spray at V6 and tasseling stage, T_6; 40 kg N + 10 kg K_2O at 25 DAS and 40 kg N + 10 kg K_2O at 45 DAS, T_7; 40 kg N + 10 kg K_2O at 25 DAS and foliar spray of 2% KNO_3 at V6 stage and 40 kg N + 10 kg K_2O at 45 DAS and T_8; 40 kg N + 10 kg K_2O at 25 DAS and foliar spray of 2% KNO_3 at V6 stage and 40 kg N + 10 kg K_2O at 45 DAS and foliar spray of 2% KNO_3 at tasseling stage. In all split-application treatments, the remaining doses of nitrogen and potassium were calculated and applied as basal, while the entire phosphorus dose and 10/ t/ FYM/ ha^{-1} were uniformly applied as basal across all treatments except control. These treatments were replicated thrice and statistically tested using randomized block design.

Phenological Observations

The number of days to tasseling was recorded as the interval from sowing to the stage when 50% of the plants within a plot exhibited tassel emergence. Days to silking were determined as the duration from sowing until 50% of the plants showed visible silk extrusion. Physiological maturity was assessed as the number of days from sowing to the stage when kernels attained the black layer at the base, indicating physiological maturity of all plants in the respective plot.

Growth and Yield Attributes

Five plants were selected randomly at crop maturity from each plot to measure the plant height, cob length, cob girth, grain weight per ear, 100-seed weight and then averaged. The number of cobs per plot in maize was recorded at harvest by counting all fully developed, mature, and marketable cobs from plants within each net plot.

Grain and Stover Yield

Grain yield of maize was determined by adjusting the recorded yield to a standard moisture content of 14% using the following formula:

$$\text{Adjusted yield} = \frac{\text{Measured yield} \times (100 - \text{sample moisture content})}{(100 - \text{standard moisture content})}$$

The stover yield obtained after harvesting from the net plot area was sun dried, and dry weight was recorded for each plot in kilograms, which was later computed on a hectare basis.

Nutrient Analysis

The plant samples were analyzed by adopting standard analytical methods. Total nitrogen was determined by the Micro-Kjeldahl method (Parkinson and Allen, 1975). Total phosphorus was estimated by the vanadomolybdate yellow colour method in a nitric acid system following diacid digestion (Piper, 1966). Total potassium was measured using a Flame Photometer after diacid digestion (Chapman and Pratt, 1961).

Nutrient Uptake

The uptake of nitrogen, phosphorus, and potassium (kg ha^{-1}) was estimated by multiplying the nutrient concentration (%) in grain and straw with their respective dry matter yields. The total uptake was obtained by summing the nutrient uptake of grain and straw. The calculation was done using the following equations:

$$\text{Nutrient uptake (kg ha}^{-1}\text{)} = \frac{\text{Nutrient content (\%)} \times \text{Dry matter yield (kg ha}^{-1}\text{)}}{100}$$

Total uptake (kg ha^{-1}) = Grain uptake (kg ha^{-1}) + Straw uptake (kg ha^{-1})

Statistical Analysis

The statistical analyses were done as per Panse and Sukatme (1967).

Result and Discussion

Phenology

The phenological development of maize was markedly influenced by split applications of nitrogen and potassium in conjunction with foliar application of 2% KNO_3. Application of 40 kg N + 10 kg K_2O at 25 DAS followed

Table 1: Effect of different treatments on maize growth stages.

Tr. No	Days to tasseling	Days to Silking	Days to physiological maturity
T_1	65	71	99
T_2	56	62	92
T_3	56	62	92
T_4	54	61	91
T_5	53	60	90
T_6	54	61	91
T_7	52	59	90
T_8	52	58	89
SEm±	1.1	1.0	1.0
CD @ 5%	3.3	3.1	2.9

by foliar spray of 2% KNO_3 at V6 stage, and 40 kg N + 10 kg K_2O at 45 DAS with an additional foliar spray of 2% KNO_3 at tasseling stage (T_8) resulted in significant earliness, with tasseling, silking, and physiological maturity occurring at 52, 58, and 89 days, respectively. This was earlier than T_1, T_2, and T_3 and statistically comparable with other treatments. Notably, relative to T_2 (GRDF with N splits), T_8 advanced tasseling and silking by 4 days and physiological maturity by 3 days, with even greater earliness over the unfertilized control. These findings indicate that synchronized N and K splits coupled with foliar KNO_3 substantially accelerate maize phenology compared to split N application alone. This earliness may be attributed to enhanced plant height and accelerated tasseling and silking, resulting from improved uptake of nitrogen and potassium through three split applications and foliar application of 2% KNO_3. Similar findings were reported by Ali *et al*., (2016) and Amanullah *et al*., (2016), who observed a reduction in days to tasseling, silking, and physiological maturity under treatments involving potassium foliar sprays and split application of potassium.

Growth and Yield Attributes

The treatment T_8 comprising of three splits of N and K and two foliar applications *i.e.* application of 40 kg N

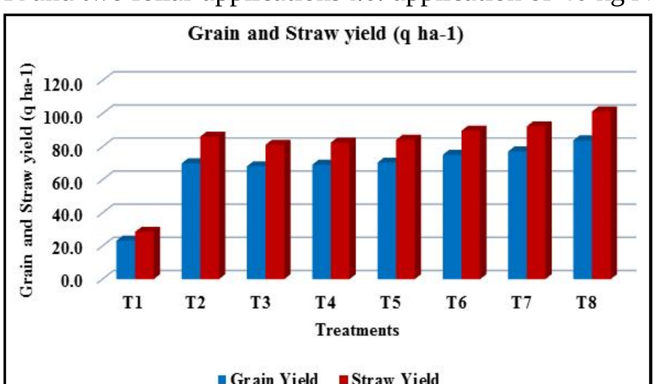

Fig. 1: Effect of different treatments on grain and straw yield.

Table 2: Effect of different treatments on yield attributes of maize.

Tr. No	PH	CG	CL	NCP	WGC	SW
T_1	179.6	15.0	15.5	42.7	119.5	26.9
T_2	250.4	16.4	19.9	65.3	171.6	30.3
T_3	231.5	16.4	19.8	67.0	167.8	30.2
T_4	249.8	16.4	19.8	67.3	170.4	30.2
T_5	250.6	16.4	19.9	68.7	173.1	30.3
T_6	251.8	16.5	19.9	69.0	176.4	30.4
T_7	264.3	16.5	20.6	71.7	183.5	30.5
T_8	270.0	16.7	21.2	73.7	188.2	31.3
SEm±	6.0	0.11	0.41	1.46	2.17	0.59
CD @ 5%	18.1	0.33	1.26	4.41	6.59	1.80

PH: Plant height; **CG:** Cob girth (cm); **CL:** Cob length (cm); **NCP:** No. of cobs $Plot^{-1}$; **WGC:** Wt. of grains cob^{-1} (g); **SW:** 100 seed wt. (g)

+ 10 kg K_2O at 25 DAS and foliar spray of 2% KNO_3 at V6 stage and 40 kg N + 10 kg K_2O at 45 DAS and foliar spray of 2% KNO_3 at tasseling stage recorded significantly superior plant height (270 cm), cob girth (16.7 cm), cob length (21.2 cm), number of cobs per plot (73.7), weight of grains per cob (188.2 g) and 100 seed weight (31.35 g) over all the other treatments of nutrient management. However, treatment T_7 having three splits of N and K and one foliar application 2% KNO_3 at V6 stage exhibited statistically similar results, while absolute control T_1 recorded the lowest growth and yield attributes. Enhanced growth attributes such as plant height, cob girth, cob length, and grain weight could be due to improved nutrient availability during critical growth stages. The split application of nitrogen likely enhanced nitrogen use efficiency by synchronizing nutrient supply with peak crop demand, while the split application of potassium ensured its continuous availability in the root zone, thereby minimizing leaching losses. In addition, foliar application of KNO_3 provided readily available nutrients, which supported critical physiological processes such as

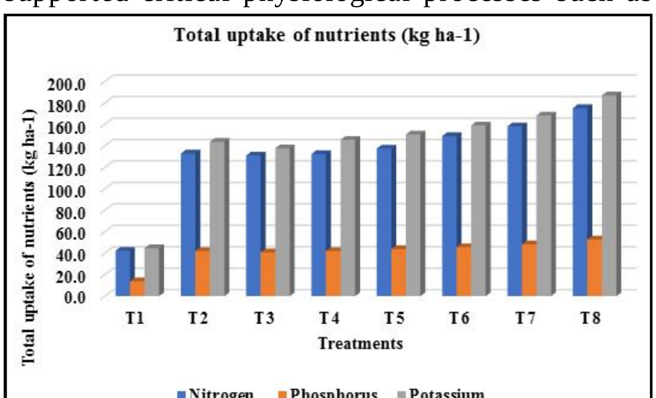

Fig. 2: Effect of different treatments on total uptake of nutrients.

Table 3: Effect of different treatments on grain yield and straw yield of maize.

Tr. No	Yield of Maize		Total uptake of Nutrients		
	GY	SY	N	P	K
T_1	23.3	28.5	42.4	13.9	45.0
T_2	70.0	86.2	133.0	42.1	144
T_3	68.2	81.2	131.2	40.9	138
T_4	69.1	82.5	132.6	42.1	146
T_5	70.4	84.2	137.7	43.9	151
T_6	75.1	89.6	149.3	45.7	159
T_7	77.2	92.3	158.3	48.4	169
T_8	83.9	101.2	175.4	52.9	187
SEm±	2.59	2.96	6.3	1.9	6.6
CD @ 5%	7.85	8.97	19.1	5.8	20.1

GY: Grain yield (q ha^{-1}); **SW:** Straw yield (q ha^{-1}); **N:** Nitrogen (kg ha^{-1}); **P:** Phosphorus (kg ha^{-1}); **K:** Potassium (kg ha^{-1})

photosynthesis, enzyme activation, and assimilate translocation during the reproductive growth stages. These results are consistent with the findings of Ajith *et al*., (2023), who reported significant improvements in cob number, grain weight per cob, and seed size under split application of nitrogen and potassium at different growth stages. Similarly, Channakeshava *et al*., (2022) observed notable increases in cob length, number of kernels per cob, and 100-seed weight when potassium was applied in three splits at basal, knee-height, and tasseling stages. Furthermore, the beneficial effects of foliar application of KNO_3 on both vegetative and reproductive traits have been well documented by Jothi *et al*., (2019), Singh *et al*., (2017), and Ávila *et al*., (2022).

Grain and Straw Yield

The significantly superior grain yield (83.9 q ha^{-1}) and straw yield (101.2 q ha^{-1}) were recorded in the treatment T_8 consisting three splits of N and K and two foliar applications over all the other treatments nevertheless it was statistically at par with treatment T_7 consisting three splits of N and K and one foliar application. The findings indicate that three split applications of nitrogen and potassium in combination were more effective in enhancing yield compared to two split applications of these nutrients. The observed increase in grain and straw yield of maize can be attributed to the improvement in key growth and yield-determining traits, including plant height, cob length, cob girth, number of cobs per plot, grain weight per cob, and 100-seed weight. The timely and adequate supply of nutrients during both vegetative and reproductive stages likely enhanced physiological functions, resulting in greater biomass accumulation and improved reproductive efficiency. In addition, foliar application of KNO_3 may have contributed to higher photosynthetic efficiency, osmotic regulation, and grain development by providing an immediate source of nutrients, particularly under conditions where root uptake was restricted. These findings are consistent with those of Ajith *et al.*, (2023), who reported significant increases in maize grain and stover yield under split application of nitrogen and potassium. Similarly, Channakeshava *et al.*, (2022) and Zhang *et al.*, (2022) demonstrated that timely split applications of these nutrients improved maize yield by synchronizing nutrient availability with crop physiological demand, thereby substantiating the advantages of synchronized nutrient management. Moreover, the positive effects of foliar potassium application on yield attributes have also been documented by Singh *et al*., (2017), Ávila *et al.*, (2022), and Abid Ali and Samraiz Ali (2016).

Total Uptake of Nutrients

The results exhibited that significantly highest total uptake of nitrogen (175.4 kg ha^{-1}), phosphorus (52.9 kg ha^{-1}), and potassium (187.0 kg ha^{-1}) was recorded with treatment T_8 which was statistically at par to treatment T_7 which recorded nitrogen, phosphorus and potassium uptake to the tune of 158.3, 48.4 and 169.0 kg ha^{-1} respectively. The lowest nitrogen (42.4 kg ha^{-1}), phosphorus (13.9 kg ha^{-1}) and potassium (45.0 kg ha^{-1}) uptake was recorded by unfertilized control (T_1).

Split applications increased total uptake of N, P, and K, as documented by Sitthaphanit *et al.*, (2010), Amanullah *et al.*, (2016), and Ghimire *et al.*, (2024), particularly under rainfed or stressed conditions. Improved nutrient use efficiency and synchronized nutrient supply were highlighted by Abbasi *et al.*, (2012), Fabunmi (2009), and Zhang *et al.*, (2022).

Conclusion

Split application of nitrogen and potassium at basal, 25, and 45 DAS, in combination with two foliar sprays of 2% KNO_3 at the V6 and tasseling stages, significantly improved maize growth, yield attributes, grain and straw yield, and total nutrient uptake in Entisols of the Sub-montane Zone. Nevertheless, a single foliar spray at the V6 stage, when applied alongside the same split N and K regime, produced statistically comparable outcomes, indicating that precise nutrient scheduling plays a pivotal role in optimizing maize productivity in sandy soils.

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