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Effect of graded levels of nitrogen application on yield and nutrient uptake of maize

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ABSTRACT

Among the world's cereal crops, maize ranks third after rice and wheat, and its dual value as human food and animal feed underlines its economic importance. Because maize is a heavy feeder, a balanced dose of 150:65:65 kg N, P₂O₅ and K₂O ha⁻¹ is generally recommended under irrigation, although the crop continues to respond favourably to nitrogen well beyond this level. Nitrogen, in particular, remains the nutrient of greatest concern in maize production systems, being the primary driver of vegetative growth and reproductive development. With this in view, a field trial was conducted at the Main Agricultural Research Station, University of Agricultural Sciences, Dharwad, during kharif 2020 to examine how graded nitrogen doses affect the yield and nutrient uptake of maize. The trial, laid out in a randomized complete block design, comprised nine treatments spanning 0 to 200 per cent of the recommended dose of nitrogen (RDN) in steps of 25 per cent. The 200 per cent RDN treatment produced the best yield-contributing traits, including cob length (17.6 cm), cob girth (4.70 cm), grains per row (35.5), grains per cob (566.2), test weight (32.8 g) and grain yield per cob (163.1 g), all significantly ahead of the remaining treatments. The same treatment also gave the highest grain yield (9627.6 kg ha⁻¹), straw yield (12243.8 kg ha⁻¹), harvest index (44.0 %) and NPK uptake, although it did not differ significantly from the 175 and 150 per cent RDN treatments.

Keywords: Nitrogen, Maize, Yield, Yield attributes, Nutrient uptake

Introduction

Globally, maize occupies third place among cereal crops in overall importance, trailing only rice and wheat, with roughly 85 per cent of its area sown during the *kharif* season. For nearly 900 million people in low-income households it serves as a preferred staple, contributing meaningfully to food security across developing economies. Nutritionally, maize grain comprises about 72 per cent starch, 10 per cent protein, 4.8 per cent oil, 8.5 per cent fibre, 3.0 per cent sugar and 1.7 per cent ash (Huma *et al.*, 2019) [1], and the crop is equally valued as fodder and grain under both irrigated and rainfed conditions (Kumar *et al.*, 2013) [2]. Its simultaneous role in human and livestock nutrition explains its widespread cultivation. Climate projections suggest that despite warmer temperatures and increasingly erratic rainfall, maize output will need to rise by at least 18 per cent by 2030 to satisfy demand driven by population growth and evolving diets (Anon, 2015) [3]. At present the crop is grown worldwide on 206.3 million hectares, yielding 780 million tonnes at an average productivity of 3150 kg ha⁻¹ (Anon, 2021) [4]. India accounts for 9.86 million hectares of this area and 31.51 million tonnes of production, while Karnataka, the country's leading producer, cultivates 1.68 million hectares at a productivity of 3092 kg ha⁻¹, somewhat below the national figure of 3195 kg ha⁻¹ (Anon, 2021) [4].

Being an exhaustive feeder, maize responds strongly to applied nutrients, which makes careful nutrient and water management central to its productivity. A balanced dose of 150:65:65 kg N, P₂O₅ and K₂O ha⁻¹ is the general recommendation for the irrigated crop. Among these nutrients, nitrogen holds particular significance as it is a structural component of every amino acid and of chlorophyll, the pigment that drives photosynthesis, and is consequently regarded as the nutrient with the single greatest bearing on grain yield. Nitrogen fertilizer underpins food production for more than half the world's population, even though its use efficiency typically remains only 30 to 50 per cent. Because it is the principal nutrient governing crop growth and development, nitrogen management continues to be a central concern in maize cultivation (Blumenthal *et al.*, 2008) [5]. A range of earlier studies has shown that nitrogen supply governs its own uptake as well as photosynthesis, leaf area development, the onset of senescence, kernel numbers and eventual yield potential (Hanjanatti *et al.*, 2021; Ciampitti *et al.*, 2011) [7, 6]. Elevated nitrogen doses have likewise been associated with greater plant height, thicker stems, larger leaf area and leaf area index, higher dry matter accumulation, improved net assimilation ratio and better productivity (Cheema *et al.*, 2010) [8]. Since nitrogen remains the most limiting of all nutrients, ensuring its adequate supply alongside other nutrients is essential for maintaining soil fertility and sustaining high crop productivity (Scharf *et al.*, 2002) [9]. Keeping these considerations

in view, the present study was undertaken to evaluate the effect of graded nitrogen levels on the yield and yield attributes of maize.

Material and methods

The field experiment was conducted at the Main Agricultural Research Station (MARS), University of Agricultural Sciences, Dharwad, located in the Northern Transition Zone of Karnataka (Zone-8) at 15° 30' 6" N latitude, 74° 59' 13.2" E longitude, at an elevation of 678 m above mean sea level. A randomized complete block design was used, comprising nine graded nitrogen levels — absolute control together with 25, 50, 75, 100, 125, 150, 175 and 200 per cent of the recommended dose of nitrogen — each replicated thrice. Urea, the nitrogen source, was applied in four split doses in line with standard package-of-practice recommendations for the respective treatments (Table 1). Pre-sowing analysis showed the experimental soil to be neutral to slightly alkaline (pH 7.71) with normal electrical conductivity (0.33 dS m⁻¹), low organic carbon (0.47%), low available nitrogen (259.3 kg N ha⁻¹), medium available phosphorus (33.4 kg P₂O₅ ha⁻¹) and high available potassium (377.5 kg K₂O ha⁻¹). Data generated during the study were compiled and statistically analysed following the procedure described by Gomez and Gomez (1984), and treatment means were compared using Duncan's Multiple Range Test (DMRT) based on the corresponding error mean sum of squares and degrees of freedom.

Results and discussion

Yield attributes, yield and harvest index of maize as influenced by graded levels of nitrogen

Graded nitrogen levels had a significant bearing on the yield attributes, the individual yield components (cob, grain and straw) and the harvest index of maize; the corresponding data are summarised in Tables 2 and 3.

Progressive increases in nitrogen supply exerted a favourable influence on the yield attributes of maize. The greatest cob length (17.6 cm), cob diameter (4.70 cm) and test weight (32.8 g) were obtained under 200 per cent RDN, a treatment that remained statistically on par with 175 per cent RDN (17.1 cm, 4.51 cm and 32.5 g, respectively) and 150 per cent RDN (16.4 cm, 4.38 cm and 32.1 g, respectively). Greater nitrogen availability and uptake at the higher doses appears to have promoted dry matter synthesis and its preferential movement towards reproductive structures, which likely explains this pattern. This is consistent with Majid *et al.* (2017) [10], who recorded significantly longer cobs with 345 kg N ha⁻¹ than with 115 kg N ha⁻¹, and with Matusso *et al.* (2016) [11], who also reported a positive association between cob length and other yield attributes as nitrogen dose increased.

Shelling percentage (82.2 %) peaked under 200 per cent RDN, remaining statistically comparable to all other treatments except the absolute control (72.2 %) and 25 per cent RDN (73.1 %). Likewise, grains per row (35.5), grains per cob (566) and grain weight per cob (163.1 g) reached their maximum under 200 per cent RDN, on par with 175 per cent RDN (35.0, 561 and 161.6 g), 150 per cent RDN (33.2, 515 and 148.3 g) and 125 per cent RDN (31.8, 496 and 142.8 g). This can largely be attributed to greater nitrogen uptake during the vegetative phase, which enhanced translocation of carbohydrate reserves from source to sink, thereby raising overall growth and dry matter production and, in turn, the number of rows per cob, grains per cob and test weight. Together, more rows per cob and more grains per

row produced a higher grain count per cob, which combined with heavier test weight to raise grain weight per cob. These findings agree with those of Ramachandiran *et al.* (2016) [12], Ngosong *et al.* (2019) [13] and Singh *et al.* (2021) [14] in maize, while Varshini *et al.* (2019) [15] similarly observed higher grain rows per cob, grains per row and grains per cob with 225 kg N ha⁻¹ applied in four equal splits.

Cob yield was likewise significantly greater under 200 per cent RDN (11150.7 kg ha⁻¹) than under the remaining treatments, though it stayed on par with 175 per cent RDN (10865.6 kg ha⁻¹), 150 per cent RDN (10576.6 kg ha⁻¹) and 125 per cent RDN (9929.8 kg ha⁻¹). Grain yield (9627.6 kg ha⁻¹) and straw yield (12243.8 kg ha⁻¹) followed the same pattern, peaking under 200 per cent RDN and remaining statistically similar to 175 per cent RDN (9308.9 and 12090.1 kg ha⁻¹) and 150 per cent RDN (8935.2 and 11859.2 kg ha⁻¹) (Fig. 1). Harvest index was also highest under 200 per cent RDN (45.0 %), on par with every treatment except the absolute control (37.3 %). These gains can be attributed to greater nitrogen uptake and more vigorous physiological activity under higher nitrogen doses, which supported stronger vegetative development and, consequently, greater production and translocation of photosynthates towards the reproductive parts. As before, higher rows per cob and grains per row raised grain numbers per cob, which together with heavier test weight enhanced grain weight per cob, ultimately lifting straw and grain yield. These outcomes are consistent with Kumar *et al.* (2021) [16], Hanjanatti *et al.* (2021) [7] and Mohapatro *et al.* (2022) [17], and align with Sharma *et al.* (2019) [18], who likewise reported higher cob yield with increasing nitrogen rates.

Effect of graded levels of nitrogen on nutrient uptake at harvest

Nitrogen uptake by grain (160 kg ha⁻¹), straw (56.7 kg ha⁻¹) and in total (216.7 kg ha⁻¹) at harvest was significantly greater under 200 per cent RDN than under the other treatments (Fig. 2), though comparable with 175 per cent RDN (154.2, 55.6 and 209.8 kg ha⁻¹) and 150 per cent RDN (145.2, 54.2 and 199.3 kg ha⁻¹). Higher nitrogen doses evidently sustained greater nitrogen availability throughout crop growth, which likely drove this increase in uptake (Dobermann *et al.*, 2002) [19]; this, in turn, boosted metabolic activity and the accumulation of dry matter and nutrients within it, ultimately raising both biomass and grain yield (Hussain *et al.*, 2005) [20]. Greater nitrogen content in the plant coupled with higher biomass thus translated into higher nitrogen uptake, a pattern also reported by Sunitha *et al.* (2012) [21] in sweet corn and by Rawal *et al.* (2014) [22] in maize.

Phosphorus and potassium uptake followed a similar trend, with the highest values for grain (30.5 and 73.3 kg ha⁻¹), straw (33.9 and 113.1 kg ha⁻¹) and total uptake (64.4 and 186.4 kg ha⁻¹) recorded under 200 per cent RDN, on par with 175 and 150 per cent RDN (Fig. 3 and 4). This can be explained by the positive interaction between nitrogen and the other two nutrients: as nitrogen application and uptake increased, so did biomass along with the phosphorus and potassium concentrations in grain and straw, ultimately raising total P and K uptake. Similar findings have been reported by Yinkun *et al.* (2014) [23] in rice, Mohanty *et al.* (2016) [24] in wheat, Suresh *et al.* (2017) [25] in maize and Ali *et al.* (2019) [26] in wheat.

Conclusion

The present study indicates that applying 200 per cent RDN gives significantly greater yield and yield attributes relative to the remaining treatments, although the 175 and 150 per cent RDN treatments produced statistically comparable yields.

Table 1. The basal, split application and total amount of N fertilizer applied as per the treatments

Treatments	Basal (10%)	20 DAS (20%)	35 DAS (30%)	50 DAS (30%)	65 DAS (10%)	Total (kg N ha ⁻¹)
T ₁ - Absolute control	0	0	0	0	0	0
T ₂ - 25% of RDN	3.75	7.5	11.25	11.25	3.75	37.5
T ₃ - 50% of RDN	7.5	15.0	22.5	22.5	7.5	75.0
T ₄ - 75% of RDN	11.25	22.5	33.75	33.75	11.25	112.5
T ₅ - 100% of RDN*	15.0	30.0	45.0	45.0	15.0	150.0
T ₆ - 125% of RDN	18.75	37.5	56.25	56.25	18.75	187.5
T ₇ - 150% of RDN	22.5	45.0	67.5	67.5	22.5	225.0
T ₈ - 175% of RDN	26.25	52.5	78.75	78.75	26.25	262.5
T ₉ - 200% of RDN	30.0	60.0	90.0	90.0	30.0	300.0

*(100 % RDN = 150 kg N)

Table 2. Yield attributes of maize as influenced by graded levels nitrogen

Treatments	Cob length (cm)	Cob diameter (cm)	No of rows per cob	No of grains per row	Test weight (g)	No of grains per cob	Grain yield per cob (g)
T ₁ -Absolute control	8.0 ^g	3.42 ^d	14.7 ^a	17.7 ^e	20.2 ^d	258.9 ^d	74.6 ^d
T ₂ - 25% of RDN	10.4 ^f	3.79 ^{cd}	14.7 ^a	22.0 ^d	21.0 ^d	323.2 ^{cd}	93.1 ^{cd}
T ₃ - 50% of RDN	12.0 ^{ef}	4.00 ^{bc}	15.5 ^a	24.7 ^d	22.1 ^{cd}	384.2 ^c	110.7 ^c
T ₄ - 75% of RDN	13.5 ^{de}	4.04 ^{bc}	15.5 ^a	30.8 ^c	23.2 ^{cd}	475.5 ^b	137.0 ^b
T ₅ - 100% of RDN	14.5 ^{cd}	4.16 ^{bc}	15.5 ^a	31.2 ^{bc}	24.8 ^{bc}	484.0 ^b	139.4 ^b
T ₆ - 125% of RDN	15.5 ^{bc}	4.25 ^{bc}	15.6 ^a	31.8 ^{abc}	27.7 ^b	495.8 ^{ab}	142.8 ^{ab}
T ₇ - 150% of RDN	16.4 ^{ab}	4.38 ^{ab}	15.5 ^a	33.2 ^{abc}	32.1 ^a	514.8 ^{ab}	148.3 ^{ab}
T ₈ -175% of RDN	17.1 ^{ab}	4.51 ^{ab}	16.0 ^a	35.0 ^{ab}	32.5 ^a	560.8 ^a	161.6 ^a
T ₉ - 200% of RDN	17.6 ^a	4.70 ^a	16.4 ^a	35.5 ^a	32.8 ^a	566.2 ^a	163.1 ^a
S.E.m.±	0.6	1.7	0.56	1.0	1.25	16.2	8.6

(N, P and K uptake values are expressed in kg ha^{-1})

Table 3. Yield (cob, grain and straw) and harvest index of maize as influenced by graded levels of nitrogen

Treatments	Cob yield (kg ha^{-1})	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index (%)	Shelling percent (%)
T ₁ -Absolute control	3265.5 ^f	2529.6 ^g	4232.0 ^e	37.4 ^a	70.6 ^d
T ₂ - 25% of RDN	5021.9 ^e	3930.6 ^f	6195.8 ^d	38.8 ^a	72.2 ^{cd}
T ₃ - 50% of RDN	6802.8 ^d	5380.4 ^e	7594.2 ^c	41.5 ^a	73.3 ^{bcd}
T ₄ - 75% of RDN	7842.0 ^{cd}	6322.6 ^{de}	8807.6 ^c	41.5 ^a	75.1 ^{a-d}
T ₅ - 100% of RDN	8972.9 ^{bc}	7243.3 ^{cd}	10517.1 ^b	40.8 ^a	75.9 ^{a-d}
T ₆ - 125% of RDN	9929.8 ^{ab}	8198.6 ^{bc}	11152.7 ^{ab}	42.3 ^a	78.9 ^{a-d}
T ₇ - 150% of RDN	10576.6 ^a	8935.2 ^{ab}	11859.2 ^a	43.0 ^a	81.8 ^{abc}
T ₈ -175% of RDN	10865.6 ^a	9308.9 ^{ab}	12090.1 ^a	43.6 ^a	83.2 ^{ab}
T ₉ - 200% of RDN	11150.7 ^a	9627.6 ^a	12243.8 ^a	44.0 ^a	84.2 ^a
S.Em.±	443.8	380.8	411.4	2.0	3.1

Table 4. Nutrient uptake by maize at harvest as influenced by graded levels of nitrogen

Treatments	N Grain	N Straw	N Total	P Grain	P Straw	P Total	K Grain	K Straw	K Total
T ₁ -Absolute control	33.0 ^f	14.6 ^f	47.5 ^g	7.1 ^f	8.7 ^f	15.8 ^g	17.3 ^g	37.3 ^e	54.6 ^g
T ₂ - 25% of RDN	52.7 ^e	23.3 ^e	76.1 ^f	11.1 ^e	13.2 ^e	24.2 ^f	27.0 ^f	55.2 ^d	82.2 ^f
T ₃ - 50% of RDN	73.5 ^d	31.6 ^d	105.2 ^e	15.8 ^d	16.4 ^d	32.2 ^e	38.4 ^e	68.3 ^c	106.7 ^e
T ₄ - 75% of RDN	90.0 ^d	38.2 ^c	128.2 ^d	18.5 ^d	20.0 ^c	38.5 ^d	45.6 ^{de}	79.4 ^c	125.0 ^d
T ₅ - 100% of RDN	108.4 ^c	46.0 ^b	154.4 ^c	22.2 ^c	24.2 ^b	46.4 ^c	53.0 ^{cd}	95.2 ^b	148.2 ^c
T ₆ - 125% of RDN	128.9 ^b	48.5 ^b	177.4 ^b	25.4 ^{bc}	26.8 ^b	52.2 ^b	60.4 ^{bc}	101.3 ^{ab}	161.7 ^b
T ₇ - 150% of RDN	145.2 ^{ab}	54.2 ^a	199.3 ^a	28.3 ^{ab}	31.6 ^a	59.9 ^a	66.0 ^{ab}	108.8 ^a	174.8 ^a
T ₈ -175% of RDN	154.2 ^a	55.6 ^a	209.8 ^a	29.5 ^a	33.1 ^a	62.5 ^a	70.1 ^a	110.9 ^a	181.1 ^a
T ₉ - 200% of RDN	160.0 ^a	56.7 ^a	216.7 ^a	30.5 ^a	33.9 ^a	64.4 ^a	73.3 ^a	113.1 ^a	186.4 ^a
S.E.m.±	5.7	1.8	5.8	1.2	1.0	1.4	2.8	3.7	4.3

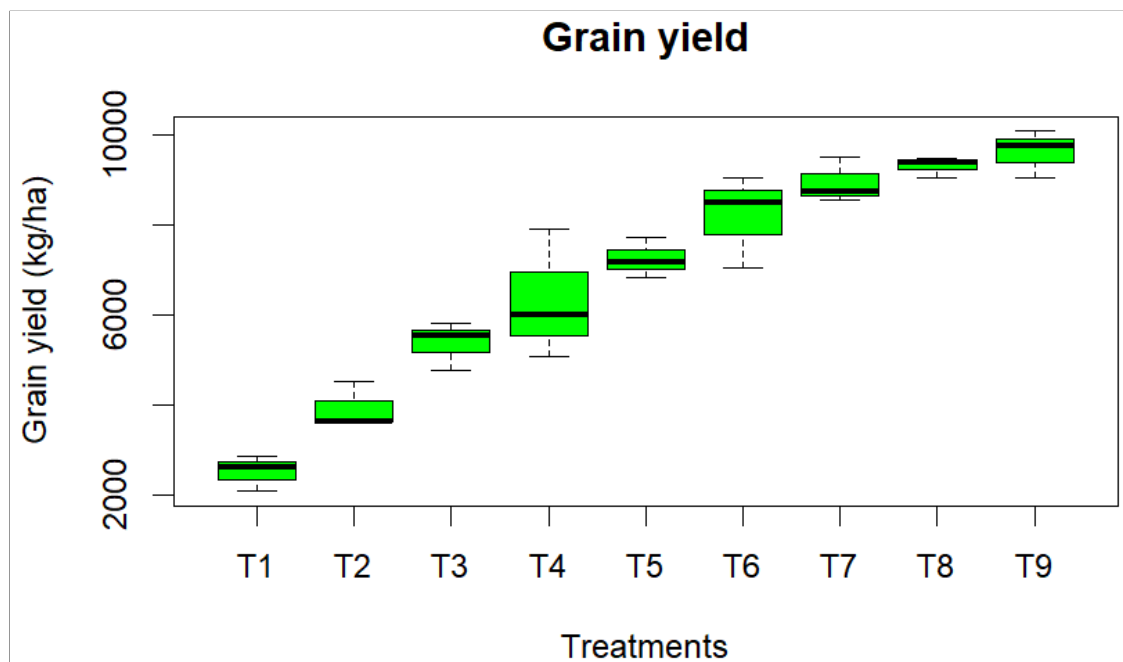


Figure 1. Grain yield of maize as influenced by graded levels of nitrogen

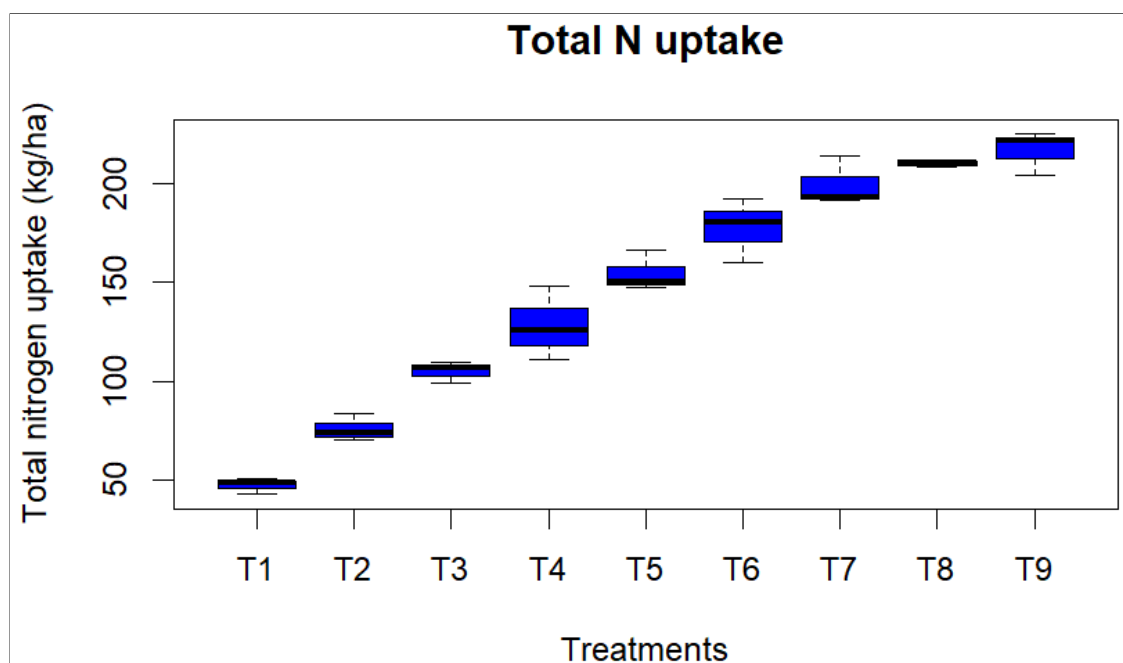


Figure 2. Total N uptake by maize at harvest as influenced by graded levels of nitrogen

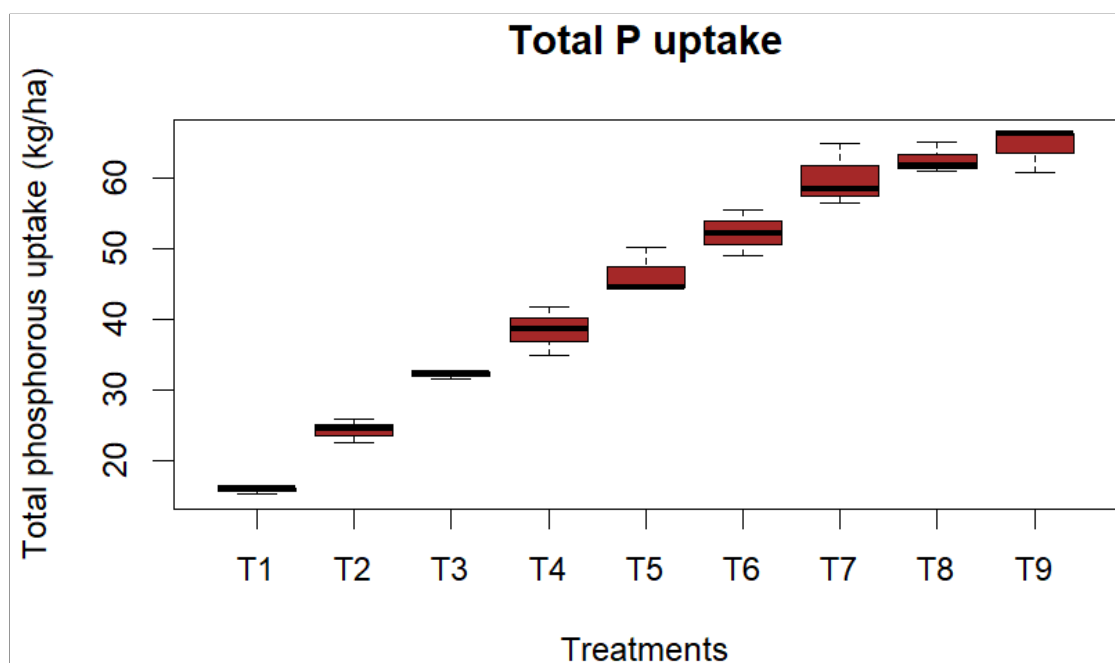


Figure 3. Total P uptake by maize at harvest as influenced by graded levels of nitrogen

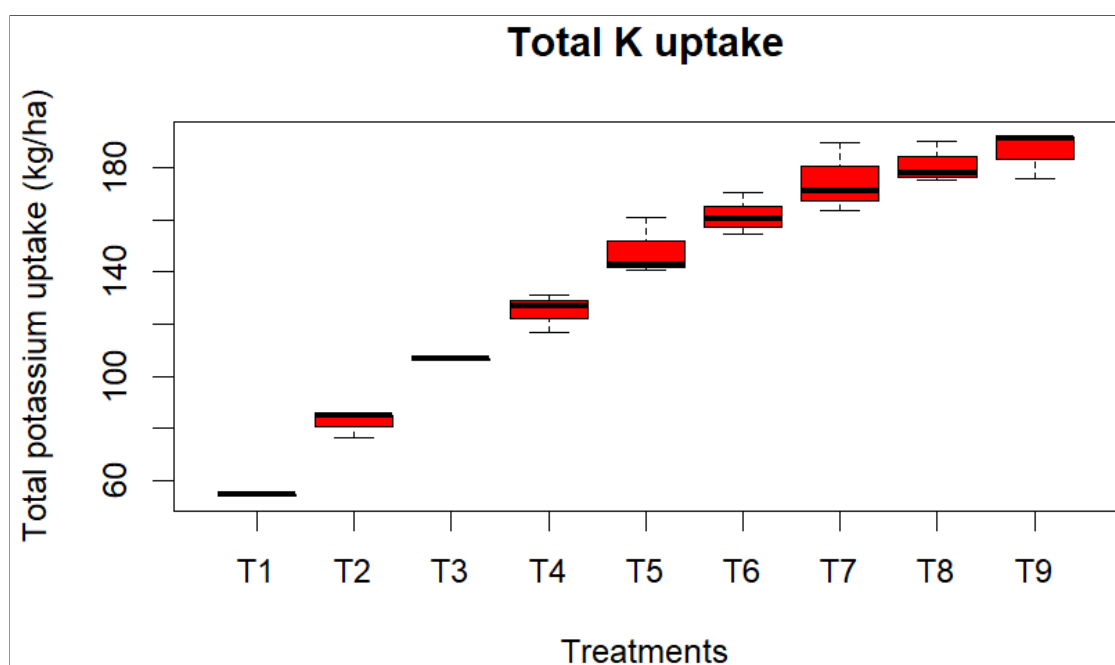


Figure 4. Total K uptake by maize at harvest as influenced by graded levels of nitrogen

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