*J. Farm. Sci., 33(2): (192-196) 2020*

**RESEARCH PAPER**

# Optimization of nitrogen to maize hybrids in northern transition zone of Karnataka, India

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*(Received: December, 2019 ; Accepted: April, 2020)*

**Abstract:** A field experiment was conducted during rainy seasons of 2015 and 2016 in northern transition zone (NTZ) of Karnataka, India under rainfed condition to optimize nitrogen (N) fertilizer to selected maize hybrids. The treatments were laid out in a split plot design wherein three rates of N ($N_1$= 50, $N_2$=100 and $N_3$= 150 kg N ha$^{-1}$) applied to four maize hybrids ($H_1$= Nithyashree, $H_2$= NK-6240, $H_3$=GH-0727 and $H_4$= 900-M-Gold) with N as main plots and hybrids as sub-plots.The pooled analysis of results indicated that the most of the crop growth and yield attributes *viz*., plant height, LAI, total above ground biomass, number of rows per cob and grains per cob were highest with the application of 150 kg N ha$^{-1}$, but were found on par with those at 100 kg N ha$^{-1}$. The highest yield however was recorded at 150 kg N ha$^{-1}$ (87.4 q ha$^{-1}$) but was closely followed by that at 100 kg N ha$^{-1}$ (87.1 q ha$^{-1}$). Among the four hybrids tested NK-6240 and 900-M-Gold hybrids in that order were found to be the highest yielders in NTZ under rainfed conditions with 91.7 and 89.0 q ha$^{-1}$ of grain yield, respectively. The interaction among three N levels and four hybrids showed that hybrid NK-6240 at 150 kg N ha$^{-1}$ gave the highest yield (92.1 q ha$^{-1}$), but was found on par with that at 100 kg N ha$^{-1}$ (91.9 q ha$^{-1}$). This study showed that 100 kg N ha$^{-1}$ is the economically optimum level and among the hybrids NK-6240 and 900-M-Gold in that order are the best performers for NTZ on black soils.

**Key words**: Grain yield, Maize, Nitrogen, NK-6240, 900-M-Gold

## Introduction

Maize is the third most important cereal crop after rice and wheat in India, and it accounts for nine per cent of the total food grain production. In Karnataka state it is grown on 1.34 m ha area with a production and productivity of 4.4 m t and 2921 kg ha$^{-1}$, respectively. However, the productivity of maize in India is by far lower as compared to global average of 5500 kg ha$^{-1}$ due to changing genotypes grown across climatic conditions and management practices followed. The productivity of any crop,including maize, depends on its genetic potential, environment and management; hence for a given agro-climatic condition yield mainly depends on balanced nutrition (Chetan *et al.*, 2017). Maize is a thermo-insensitive, long day kharif cereal crop and is adapted well to the diverse climatic conditions; hence is grown across the world under different environments. The currently popular maize hybrids are high yielding and needs proper nutrition, especially nitrogen (N). Climatic variability, on the other, has a direct influence on the quantity and quality of maize production and water shortage combined with thermal stress adversely affect maize productivity. To deal with the impact of climate change, the potential adaptation strategies include identifying stress resistant genotypes, changing sowing windows, crop diversification, varying fertilizer input and adopting integrated farming systems, among others (Pathak *et al*., 2011).

Nitrogen is a component of protoplasm, proteins, nucleic acids, chlorophyll and plays a vital role both in vegetative and reproductive phase of crop growth, and is often the most limiting factor in crop production. Hence, application of N fertilizer results in higher biomass and protein yields when concentration of N in plant tissue is increased. Maize has been recognised as a heavy feeder and uses more N than any other nutrient element. Higher N rates are reported to increase plant height, leaf area index, stem thickness, seed to straw ratio etc (Bakht *et al.*, 2006). Adequate N supply is essential to exploit natural resources such as radiation and water to realize the yield potential of maize genotypes. Typically, 22-27 kg N is required to produce one ton of grain, of which around 12-16 kg is moved to grains and the remaining is left in crop residue (Bhuvaneshwari *et al.*, 2019). Recently released maize genotypes have production potential of 10-12 t ha$^{-1}$ (Chetan *et al*., 2017), but recommended dose of N for maize in Karnataka is fixed at 100 kg ha$^{-1}$ for rainy season (June-Sept). Therefore, the experiment was conducted to test and optimize N rate to selected maize hybrids under the prevailing rainfed environmental condition on deep black soils of northern transitional zone (NTZ) of Karnataka, India.

## Material and methods

A field experiment was conducted during rainy seasons of 2015 and 2016 at the University of Agricultural Sciences, Dharwad, Karnataka state, India under rainfed condition to optimize N fertilizer to selected maize hybrids. The treatments were laid out in a split plot design wherein three rates of N ($N_1$= 50 kg N ha$^{-1}$, $N_2$=100 kg N ha$^{-1}$ and $N_3$= 150 kg N ha$^{-1}$) applied to four currently cultivated maize hybrids ($H_1$= Nithyashree, $H_2$= NK-6240, $H_3$=GH-0727 and $H_4$= 900-M-Gold) with N as main plots and hybrids as sub-plots. The soil of the experimental plot was clay in texture with the average bulk density of 1.33 g cm$^{-3}$, neutral pH (7.6) and low in organic carbon (0.34 %). When it came to major nutrient elements the soil was low in available N (175.6 and 168 kg ha$^{-1}$), medium in

available phosphorus (11.9 and 11.3 kg ha$^{-1}$), and high in available potassium (388.60 and 425 kg ha$^{-1}$) during 2015 and 2016, respectively. The fertilizer was applied following the timing and method recommended by the University of Agricultural Sciences, Dharwad, Karnataka state, India. The N fertilizer was applied in the form of urea as per the pre-determined treatment rates, in which 50 per cent was applied at the time of planting and other 50 per cent at grand growth stage (60 days after sowing). All of P and K were applied in the form of di-ammonium phosphate (DAP) and murate of potash (MOP) at the time of sowing.

Growth parameters *viz*., leaf area index (LAI), plant height at different phenological stages were measured from three randomly selected plants using standard methodologies. The yield attributes *viz*., ear length, ear girth, number of rows per cob, grains per row, grain number per cob were worked out from 10 randomly selected plants. The grain yield per hectare, total above-ground biomass per hectare were estimated by converting 10 plant values per ha. Data collected during two seasons were subjected to ANOVA by using SAS package (Ver. 9.3 USA). Means were separated by the least significant difference (LSD) test at the probability rate of ≥ 0.05. The significant treatment and interactions for most of the variables evaluated and the treatment effects are discussed.

## Results and discussion

### Plant height

The pooled analysis of plant height of maize hybrids recorded at different growth stages as influenced by N rates is presented stage wise here (Tables 1 and 2). At two leaf stage no effect of N rates was recorded, however, it showed significant difference at six leaf stage and onwards, albeit inconsistently. At six leaf stage the highest plant of 55.20 cm was recorded with application of 150 kg ha$^{-1}$ followed by application of 100 kg ha$^{-1}$ (52.70 cm). Gokmen (2001) in a study on maize crop reported that plant height, test weight and grain yield increased significantly with 100 kg N ha$^{-1}$. At six leaf stage significant difference in plant height among maize hybrids was observed. Pooled analysis showed that the highest plant height of 54.60 cm was recorded with NK-6240, but it was found on par with Nithyashree and GH-0727. The lowest plant height of 51.9 cm was recorded with 900-M-Gold, which was again on par with latter two hybrids. At tasseling stage the highest plant height of 186.4 cm was recorded at 100 kg ha$^{-1}$, but was found at par with 150 kg N ha$^{-1}$ (Table 1), whereas the lowest plant height of 178.3 cm was recorded at 50 kg N ha$^{-1}$. However, the tested four hybrids did not show any significant difference among themselves with regard to plant height at tasseling stage.

Table 1. Plant height and leaf area index of maize hybrids as influenced by N rates at different stages of crop (Mean of two years)

| Treatment | Plant height (cm) | | | | | Leaf area index | | |
|---|---|---|---|---|---|---|---|---|
| | Two leaf | Six leaf | Tasseling | Dough | Maturity | Tasseling stage | Dough stage | Maturity |
| | | | | | N levels | | | |
| 50 kg N ha$^{-1}$ | 18.5$^{a}$ | 51.3$^{b}$ | 178.3$^{b}$ | 184.1$^{b}$ | 184.1$^{c}$ | 4.33$^{b}$ | 4.08$^{c}$ | 3.72$^{b}$ |
| 100 kg N ha$^{-1}$ | 19.0$^{a}$ | 52.7$^{b}$ | 186.4$^{a}$ | 189.9$^{a}$ | 191.6$^{b}$ | 4.66$^{a}$ | 4.36$^{a}$ | 3.98$^{a}$ |
| 150 kg N ha$^{-1}$ | 18.5$^{a}$ | 55.2$^{a}$ | 185.2$^{a}$ | 189.8$^{a}$ | 192.1$^{a}$ | 4.23$^{c}$ | 4.24$^{b}$ | 3.96$^{a}$ |
| S.Em.± | 0.42 | 0.89 | 1.52 | 0.20 | 0.18 | 0.02 | 0.04 | 0.04 |
| | | | | | Hybrids | | | |
| Nithyashree | 19.0$^{ab}$ | 53.0$^{ab}$ | 182.9$^{a}$ | 191.1$^{b}$ | 191.1$^{b}$ | 4.41$^{c}$ | 4.15$^{c}$ | 3.73$^{b}$ |
| NK-6240 | 19.3$^{a}$ | 54.6$^{a}$ | 183.1$^{a}$ | 188.8$^{c}$ | 190.1$^{c}$ | 4.52$^{b}$ | 4.59$^{a}$ | 4.22$^{a}$ |
| GH-0727 | 17.9$^{b}$ | 52.7$^{ab}$ | 181.8$^{a}$ | 179.8$^{d}$ | 179.8$^{d}$ | 4.05$^{d}$ | 3.81$^{d}$ | 3.45$^{c}$ |
| 900-M-Gold | 18.3$^{ab}$ | 51.9$^{b}$ | 185.3$^{a}$ | 192.0$^{a}$ | 196.0$^{a}$ | 4.65$^{a}$ | 4.36$^{b}$ | 4.16$^{a}$ |
| S.Em.± | 0.49 | 1.03 | 1.76 | 0.24 | 0.21 | 0.02 | 0.04 | 0.05 |

Table 2. Interaction effects between N levels and maize hybrids on plant height and leaf area index at different stages of crop

(Mean of two years)

| Treatment | Plant height (cm) | | | | | Leaf area index | | |
|---|---|---|---|---|---|---|---|---|
| | Two leaf | Six leaf | Tasseling | Dough | Maturity | Tasseling stage | Dough stage | Maturity |
| $N_1H_1$ | 17.7$^{a}$ | 49.0$^{c}$ | 180.0$^{a}$ | 190.0$^{c}$ | 190.0$^{f}$ | 4.44$^{e}$ | 4.12$^{c}$ | 3.84$^{c}$ |
| $N_1H_2$ | 19.5$^{a}$ | 53.7$^{ab}$ | 177.7$^{a}$ | 183.3$^{d}$ | 183.3$^{g}$ | 4.42$^{e}$ | 4.21$^{c}$ | 3.78$^{c}$ |
| $N_1H_3$ | 18.3$^{a}$ | 49.7$^{bc}$ | 176.0$^{a}$ | 173.0$^{e}$ | 173.0$^{h}$ | 3.83$^{h}$ | 3.68$^{d}$ | 3.45$^{de}$ |
| $N_1H_4$ | 18.3$^{a}$ | 52.7$^{b}$ | 179.3$^{a}$ | 190.0$^{c}$ | 190.0$^{f}$ | 4.63$^{c}$ | 4.32$^{b}$ | 3.82$^{c}$ |
| $N_2H_1$ | 19.8$^{a}$ | 52.7$^{ab}$ | 183.0$^{a}$ | 192.0$^{b}$ | 192.0$^{e}$ | 4.50$^{d}$ | 4.15$^{c}$ | 3.68$^{cd}$ |
| $N_2H_2$ | 20.2$^{a}$ | 55.0$^{a}$ | 188.7$^{a}$ | 191.3$^{b}$ | 193.0$^{d}$ | 4.82$^{b}$ | 4.75$^{a}$ | 4.37$^{ab}$ |
| $N_2H_3$ | 17.5$^{a}$ | 52.0$^{ab}$ | 185.7$^{a}$ | 183.3$^{d}$ | 183.3$^{g}$ | 4.44$^{e}$ | 4.14$^{c}$ | 3.55$^{d}$ |
| $N_2H_4$ | 18.3$^{a}$ | 51.0$^{b}$ | 188.3$^{a}$ | 193.0$^{a}$ | 198.0$^{b}$ | 4.89$^{a}$ | 4.41$^{b}$ | 4.33$^{e}$ |
| $N_3H_1$ | 19.5$^{a}$ | 57.3$^{a}$ | 185.7$^{a}$ | 191.3$^{b}$ | 191.3$^{e}$ | 4.29$^{f}$ | 4.18$^{c}$ | 3.66$^{c}$ |
| $N_3H_2$ | 18.2$^{a}$ | 55.0$^{ab}$ | 183.0$^{a}$ | 191.7$^{b}$ | 194.0$^{c}$ | 4.33$^{f}$ | 4.82$^{a}$ | 4.51$^{a}$ |
| $N_3H_3$ | 17.8$^{a}$ | 56.3$^{ab}$ | 183.7$^{a}$ | 183.0$^{d}$ | 183.0$^{g}$ | 3.87$^{g}$ | 3.62$^{e}$ | 3.35$^{e}$ |
| $N_3H_4$ | 18.3$^{a}$ | 52.0$^{bc}$ | 188.3$^{a}$ | 193.0$^{a}$ | 200.0$^{a}$ | 4.44$^{e}$ | 4.37$^{b}$ | 4.32$^{b}$ |
| S.Em.± | 0.85 | 1.78 | 3.04 | 0.42 | 0.36 | 0.03 | 0.07 | 0.09 |

$N_1$, $N_2$ and $N_3$ = 50, 100, 150 Kg N ha$^{-1}$, and $H_1$, $H_2$, $H_3$ and $H_4$ = Nithyashree, NK-6240, GH-0727 and 900-M-Gold, respectively

At dough stage the highest plant height of 189.9 cm was recorded with 100 kg N $ha^{-1}$, but was found at par with that at 150 kg N $ha^{-1}$. Among the hybrids, at dough stage, 900-M-Gold recorded the highest plant height of 192.0 cm followed by Nithyashree (191.1 cm). At maturity the highest plant height was observed with 150 kg N $ha^{-1}$ (192.1 cm) and the lowest at 50 kg N $ha^{-1}$ (184.1 cm), whereas among the hybrids 900-M-Gold recorded the highest plant height of 196.0 cm followed by Nithyashree (191.1 cm), whereas GH-0727 recorded the lowest plant height of 179.8 cm (Table 1). The interaction effect between N rates and maize hybrids showed significant effect on plant height from dough tasseling (Table 2). At dough and physiological maturity stage, respectively, the tallest plants of 193 and 200 cm were recorded with $N_3H_4$, wherein the plants at dough stage were found at par with $N_2H_4$, but at maturity $N_3H_4$ was the best treatment combination.

**Leaf Area Index**

The pooled analysis of LAI as influenced by maize hybrids across N rates recorded at different growth stages is presented in Tables 1 and 2. At tasseling stage the highest LAI of 4.66 was recorded with 100 kg N $ha^{-1}$ followed by 50 kg N $ha^{-1}$ (4.33), whereas at dough and maturity stage the highest LAI of 4.36 and 3.98, respectively, was recorded with 100 kg N $ha^{-1}$ (Table 3). However, at maturity stage LAI at 150 kg N $ha^{-1}$ (3.96) was found at par with that at 100 kg N $ha^{-1}$. Among the hybrids at tasseling stage the highest LAI of 4.65 was observed with 900-M-Gold and the lowest of 4.05 with GH-0727. At dough and maturity stages, the highest LAI were recorded with NK-6240 (4.59 and 4.22, respectively), but its LAI at maturity was found on par with 900-M-Gold (4.16). At both these stages GH-0727 recorded the lowest LAI of 3.81 and 3.45, respectively.

The interaction between N rates and hybrids showed that at tasseling stage $N_2H_4$ recorded the highest LAI of 4.89 followed by $N_2H_2$ (4.82) and $N_2H_4$ (4.63), whereas the lowest LAI of 3.83 was recorded with $N_2H_3$. At dough and maturity stages, $N_3H_2$ recorded the highest LAI of 4.82 and 4.52, respectively, but were found at par with LAI of $N_3H_4$, $N_2H_4$ and $N_1H_4$ at dough stage and with $N_3H_4$ at maturity stage.

**Total above ground biomass**

The analysis of total above ground biomass (TAGB) (q $ha^{-1}$) recorded at maturity stage in 2015, 2015 and pooled data of both the year as influenced by maize hybrids across N rates is presented in Tables 3 and 4. During 2015 the highest TAGB of 172.9 q $ha^{-1}$ was recorded with 150 kg N $ha^{-1}$ but found at par with 100 kg N ha-1 (168.1 q $ha^{-1}$), whereas in 2016 it was with 100 kg N $ha^{-1}$ (177.0 q $ha^{-1}$), but again found at par with 150 kg N $ha^{-1}$ (173.8 q $ha^{-1}$). The pooled analysis, however, recorded the highest TAGB with 150 kg N $ha^{-1}$ (173.3 q $ha^{-1}$) which was closely followed by 100 kg N $ha^{-1}$ (172.6 q $ha^{-1}$). This shows that the highest biomass could be realized with the application of 150 kg N $ha^{-1}$, but economically optimum would be 100 kg N $ha^{-1}$ under rainfed situations of NTZ. Among the hybrids tested, the highest TAGB was recorded with NK-6240 during 2015 (180.0 q $ha^{-1}$), 2016 (181.7 q $ha^{-1}$) and also for pooled analysis of both the years (180.9 q $ha^{-1}$), which was closely followed by 900-M-Gold (174.0, 179.0 and 176.5 q $ha^{-1}$, respectively). However, the lowest ATGB was recorded with GH-0727. The interaction effects for pooled analysis showed that $N_1H_2$ recorded the highest TAGB (184.0 q $ha^{-1}$) followed by $N_2H_1$ (182.3 q $ha^{-1}$) and $N_3H_4$ (182.0 q $ha^{-1}$). The lowest TAGB, however, was recorded with $N_2H_3$ (149.4 q $ha^{-1}$).

**Yield parameters**

The analysis of number of rows per cob, grains per row and grains per cob as influenced by maize hybrids across N rates recorded at maturity stage in 2015 and 2016, and its pooled data is presented in Tables 3 and 4. The N rates showed no significant effect on rows per cob whereas among the hybrids 900-M-Gold recorded the highest number of rows per cob *i.e*., 15.6, 14.0 and 14.8, respectively, during 2015, 2016 and pooled analysis of both the years while other three hybrids were found on par with regard to rows per cob. Interaction effect showed that $N_3H_4$ recorded the highest number of rows per cob (16.0) during 2015, but was found at par with $N_1H_4$ (15.9). During 2016 it was $N_2H_4$ (15.1) which recorded the highest rows per cob. Pooled analysis of both the years showed that both $N_3H_4$ and $N_1H_4$ had the same the highest values (15.1) that is Nithyashree with 50 kg N $ha^{-1}$ and 900-M-Gold with 150 kg N $ha^{-1}$ gave the highest number of rows per cob.

Analysis of data on number of grains per row showed that N rates had significant effect. During 2015 at 150 kg N $ha^{-1}$ the highest number of grains per row was recorded (22.5) while in 2016 it was again 150 kg N $ha^{-1}$ (23.3), but was found at par with other N rates (Table 3). However, pooled analysis showed that 150 kg N $ha^{-1}$ recorded the highest number of grains per row (23.3). Interactions showed that during 2015 it was $N_3H_1$ (23.7) closely followed by $N_3H_2$ (23.0) while in 2016 it was 900-M-Gold hybrid at all levels of N recorded the highest number of grains per row (24.3). Pooled analysis showed that it was $N_3H_1$ (24.0) followed by $N_3H_2$ (23.7) recorded the highest number of grains per row and both were found at par with each other.

When it came to number of grains per cob it was 150 kg N $ha^{-1}$ which gave significantly the highest number during both the years (325.6 and 322.4, respectively) as well with pooled analysis (323.9) and with reduction in N rates the numbers decreased significantly suggesting the role of optimum N to realize the highest number of grains on the cob which directly affects yield per ha. The pooled analysis of grains per cob revealed that it was $N_3H_1$ (339.2) closely followed by $N_3H_4$ (336.1) and both were found at par with each other.

**Grain yield and Harvest Index**

Application of 150 kg N $ha^{-1}$ recorded the highest grain yield of 87.2, 87.6 and 87.4 q $ha^{-1}$ during 2015, 2016 and with pooled analysis, respectively (Table 5). Reduction in N rates below 150 kg N $ha^{-1}$ significantly reduced the yield, which suggested that these four hybrids tested in this study, released by private companies and currently popular with the farmers, do respond to high level of N under rainfed situations of NTZ

Table 3. Total above ground biomass, rows cob$^{-1}$, grains row$^{-1}$ and grains cob$^{-1}$ in different maize hybrids across N levels at physiological maturity stage

| Treatment | Total above ground biomass (q ha$^{-1}$) | | | Rows cob$^{-1}$ | | | Grains row$^{-1}$ | | | Grains cob$^{-1}$ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2015 | 2016 | Pooled | 2015 | 2016 | Pooled | 2015 | 2016 | Pooled | 2015 | 2016 | Pooled |
| | | | | | | N levels | | | | | | |
| 50 kg N ha$^{-1}$ | 167.6$^{c}$ | 165.8$^{c}$ | 166.7$^{c}$ | 15.0$^{a}$ | 14.1$^{a}$ | 14.5$^{a}$ | 20.2$^{b}$ | 22.1$^{a}$ | 21.0$^{c}$ | 298.9$^{c}$ | 309.3$^{c}$ | 304.1$^{c}$ |
| 100 kg N ha$^{-1}$ | 168.1$^{b}$ | 177.0$^{a}$ | 172.6$^{b}$ | 14.8$^{a}$ | 14.1$^{a}$ | 14.4$^{a}$ | 20.6$^{b}$ | 23.1$^{a}$ | 21.8$^{b}$ | 303.8$^{b}$ | 323.8$^{a}$ | 313.8$^{b}$ |
| 150 kg N ha$^{-1}$ | 172.9$^{a}$ | 173.8$^{b}$ | 173.3$^{a}$ | 14.7$^{a}$ | 13.9$^{a}$ | 14.3$^{a}$ | 22.5$^{a}$ | 23.3$^{a}$ | 22.8$^{a}$ | 325.6$^{a}$ | 322.3$^{a}$ | 323.9$^{a}$ |
| S.Em.± | 0.03 | 0.013 | 0.02 | 0.18 | 0.22 | 0.23 | 0.32 | 0.49 | 0.39 | 0.37 | 3.13 | 2.41 |
| | | | | | | Hybrids | | | | | | |
| Nithyashree | 168.8$^{c}$ | 176.8$^{c}$ | 172.8$^{c}$ | 14.8$^{b}$ | 14.3$^{a}$ | 14.6$^{ab}$ | 20.9$^{b}$ | 23.4$^{a}$ | 22.2$^{b}$ | 308.8$^{c}$ | 333.0$^{a}$ | 320.9$^{ab}$ |
| NK-6240 | 180.0$^{a}$ | 181.7$^{a}$ | 180.9$^{a}$ | 14.5$^{b}$ | 13.7$^{a}$ | 14.1$^{b}$ | 22.4$^{a}$ | 24.0$^{a}$ | 23.2$^{a}$ | 325.0$^{a}$ | 326.3$^{a}$ | 325.7$^{a}$ |
| GH-0727 | 155.4$^{d}$ | 151.1$^{d}$ | 153.3$^{d}$ | 14.4$^{b}$ | 14.0$^{a}$ | 14.2$^{b}$ | 20.4$^{b}$ | 20.9$^{b}$ | 20.7$^{c}$ | 292.1$^{d}$ | 290.7$^{b}$ | 291.4$^{c}$ |
| 900-M-Gold | 174.0$^{b}$ | 179.0$^{b}$ | 176.5$^{b}$ | 15.6$^{a}$ | 14.0$^{a}$ | 14.8$^{a}$ | 20.2$^{b}$ | 23.0$^{a}$ | 21.5$^{bc}$ | 311.8$^{b}$ | 323.7$^{a}$ | 317.7$^{b}$ |
| S.Em.± | 0.023 | 0.03 | 0.024 | 0.24 | 0.29 | 0.27 | 0.39 | 0.49 | 0.44 | 0.54 | 3.9 | 2.1 |

Table 4. Interaction effects between N levels and maize hybrids on total above ground biomass, rows cob$^{-1}$, grains row$^{-1}$ and grains cob$^{-1}$ at physiological maturity stage

| Treatment | Total above ground biomass (q ha$^{-1}$) | | | Rows cob$^{-1}$ | | | Grains row$^{-1}$ | | | Grains cob$^{-1}$ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2015 | 2016 | Pooled | 2015 | 2016 | Pooled | 2015 | 2016 | Pooled | 2015 | 2016 | Pooled |
| $N_1H_1$ | 158.3$^{i}$ | 155.0$^{g}$ | 156.7$^{i}$ | 14.9$^{ab}$ | 14.4$^{ab}$ | 14.7$^{ab}$ | 18.7$^{c}$ | 22.7$^{a}$ | 20.7$^{bc}$ | 279.0$^{i}$ | 323.0$^{b}$ | 301.0$^{d}$ |
| $N_1H_2$ | 185.0$^{a}$ | 183.0$^{b}$ | 184.0$^{a}$ | 14.8$^{b}$ | 14.1$^{ab}$ | 14.4$^{ab}$ | 22.7$^{ab}$ | 23.3$^{ab}$ | 23.0$^{ab}$ | 335.0$^{b}$ | 323.0$^{b}$ | 329.0$^{b}$ |
| $N_1H_3$ | 161.8$^{h}$ | 153.0$^{h}$ | 157.4$^{h}$ | 14.4$^{b}$ | 13.5$^{b}$ | 13.9$^{b}$ | 20.7$^{b}$ | 20.7$^{b}$ | 20.7$^{bc}$ | 298.3$^{f}$ | 276.0$^{c}$ | 287.2$^{e}$ |
| $N_1H_4$ | 165.4$^{g}$ | 172.0$^{f}$ | 168.7$^{g}$ | 15.9$^{a}$ | 14.4$^{ab}$ | 15.1$^{a}$ | 18.0$^{c}$ | 21.7$^{b}$ | 19.8$^{c}$ | 283.3$^{h}$ | 315.0$^{b}$ | 299.2$^{d}$ |
| $N_2H_1$ | 170.0$^{f}$ | 194.5$^{a}$ | 182.3$^{b}$ | 15.3$^{a}$ | 14.4$^{ab}$ | 14.9$^{ab}$ | 20.3$^{bc}$ | 23.3$^{ab}$ | 21.8$^{b}$ | 313.0$^{d}$ | 332.0$^{a}$ | 322.5$^{b}$ |
| $N_2H_2$ | 177.5$^{d}$ | 182.1$^{c}$ | 179.8$^{d}$ | 14.4$^{b}$ | 13.3$^{b}$ | 13.9$^{b}$ | 21.7$^{b}$ | 24.3$^{a}$ | 23.0$^{ab}$ | 315.0$^{d}$ | 323.0$^{b}$ | 319.0$^{c}$ |
| $N_2H_3$ | 149.5$^{k}$ | 149.3$^{j}$ | 149.4$^{k}$ | 14.4$^{b}$ | 15.1$^{a}$ | 14.7$^{ab}$ | 20.0$^{bc}$ | 20.3$^{b}$ | 20.2$^{bc}$ | 284.0$^{h}$ | 307.0$^{b}$ | 295.5$^{d}$ |
| $N_2H_4$ | 175.6$^{e}$ | 182.0$^{c}$ | 178.8$^{f}$ | 14.9$^{ab}$ | 13.6$^{ab}$ | 14.3$^{ab}$ | 20.3$^{bc}$ | 24.3$^{a}$ | 22.3$^{ab}$ | 303.0$^{e}$ | 333.0$^{a}$ | 318.0$^{c}$ |
| $N_3H_1$ | 178.0$^{c}$ | 181.0$^{d}$ | 179.5$^{e}$ | 14.3$^{b}$ | 14.1$^{ab}$ | 14.2$^{ab}$ | 23.7$^{a}$ | 24.3$^{a}$ | 24.0$^{a}$ | 334.3$^{b}$ | 344.0$^{a}$ | 339.2$^{a}$ |
| $N_3H_2$ | 177.5$^{d}$ | 180.0$^{e}$ | 178.8$^{f}$ | 14.4$^{b}$ | 13.6$^{ab}$ | 14.0$^{b}$ | 23.0$^{a}$ | 24.3$^{a}$ | 23.7$^{a}$ | 325.0$^{c}$ | 333.0$^{a}$ | 329.0$^{b}$ |
| $N_3H_3$ | 155.0$^{j}$ | 151.0$^{i}$ | 153.0$^{j}$ | 14.3$^{b}$ | 13.6$^{ab}$ | 13.9$^{b}$ | 20.7$^{b}$ | 21.7$^{b}$ | 21.2$^{bc}$ | 294.0$^{g}$ | 289.0$^{c}$ | 291.5$^{e}$ |
| $N_3H_4$ | 181.0$^{b}$ | 183.0$^{b}$ | 182.0$^{c}$ | 16.0$^{a}$ | 14.1$^{ab}$ | 15.1$^{a}$ | 21.7$^{b}$ | 23.0$^{ab}$ | 22.3$^{ab}$ | 349.0$^{a}$ | 323.0$^{b}$ | 336.0$^{a}$ |
| S.Em.± | 0.04 | 0.05 | 0.04 | 0.42 | 0.51 | 0.47 | 0.68 | 0.85 | 0.76 | 0.94 | 6.75 | 3.64 |

$N_1$, $N_2$ and $N_3$ = 50, 100, 150 Kg N ha$^{-1}$, and $H_1$, $H_2$, $H_3$ and $H_4$ = Nithyashree, NK-6240, GH-0727 and 900-M-Gold, respectively

Table 5. Grain yield and harvest index of different maize hybrids across N levels at physiological maturity stage

| Treatment | Grain yield (q ha$^{-1}$) | | | Harvest Index (%) | | |
|---|---|---|---|---|---|---|
| | 2015 | 2016 | Pooled | 2015 | 2016 | Pooled |
| | | | N levels | | | |
| 50 kg N ha$^{-1}$ | 82.1$^{c}$ | 82.0$^{b}$ | 82.0$^{c}$ | 49.3$^{b}$ | 49.3$^{b}$ | 49.3$^{b}$ |
| 100 kg N ha$^{-1}$ | 86.6$^{b}$ | 87.6$^{a}$ | 87.1$^{b}$ | 49.5$^{b}$ | 49.6$^{b}$ | 50.5$^{a}$ |
| 150 kg N ha$^{-1}$ | 87.2$^{a}$ | 87.6$^{a}$ | 87.4$^{a}$ | 50.4$^{a}$ | 50.3$^{a}$ | 50.4$^{a}$ |
| S.Em.± | 0.13 | 0.08 | 0.08 | 0.10 | 0.10 | 0.1 |
| | | | Hybrids | | | |
| Nithyashree | 85.5$^{c}$ | 85.4$^{c}$ | 85.5$^{c}$ | 48.1$^{d}$ | 48.1$^{d}$ | 48.1$^{b}$ |
| NK-6240 | 91.3$^{a}$ | 92.2$^{a}$ | 91.7$^{a}$ | 50.8$^{a}$ | 50.8$^{a}$ | 50.8$^{a}$ |
| GH-0727 | 75.4$^{d}$ | 76.2$^{d}$ | 75.8$^{d}$ | 50.3$^{b}$ | 50.3$^{b}$ | 50.3$^{b}$ |
| 900-M-Gold | 88.9$^{b}$ | 89.0$^{b}$ | 89.0$^{b}$ | 50.6$^{c}$ | 50.7$^{c}$ | 50.6$^{a}$ |
| S.Em.± | 0.12 | 0.06 | 0.09 | 0.30 | 0.10 | 0.12 |

Table 6. Interaction effects between N levels and maize hybrids on grain yield and harvest index at physiological maturity stage

| Treatment | Grain yield (q ha$^{-1}$) | | | Harvest Index (%) | | |
|---|---|---|---|---|---|---|
| | 2015 | 2016 | Pooled | 2015 | 2016 | Pooled |
| $N_1H_1$ | 76.2$^{e}$ | 75.0$^{f}$ | 75.6$^{f}$ | 48.0$^{d}$ | 48.0$^{e}$ | 48.0$^{g}$ |
| $N_1H_2$ | 92.0$^{a}$ | 90.5$^{c}$ | 91.3$^{b}$ | 49.3$^{c}$ | 49.3$^{d}$ | 49.3$^{e}$ |
| $N_1H_3$ | 76.0$^{e}$ | 76.5$^{e}$ | 76.3$^{e}$ | 50.0$^{c}$ | 49.0$^{c}$ | 49.5$^{f}$ |
| $N_1H_4$ | 84.0$^{d}$ | 85.8$^{d}$ | 84.9$^{d}$ | 51.0$^{c}$ | 50.0$^{c}$ | 50.5$^{d}$ |
| $N_2H_1$ | 90.0$^{c}$ | 90.4$^{c}$ | 90.2$^{d}$ | 50.3$^{e}$ | 49.3$^{f}$ | 49.7$^{e}$ |
| $N_2H_2$ | 90.8$^{b}$ | 93.0$^{a}$ | 91.9$^{a}$ | 51.0$^{b}$ | 52.0$^{b}$ | 51.5$^{b}$ |
| $N_2H_3$ | 75.0$^{f}$ | 76.2$^{e}$ | 75.6$^{f}$ | 51.0$^{b}$ | 50.5$^{b}$ | 50.5$^{d}$ |
| $N_2H_4$ | 90.5$^{c}$ | 90.7$^{b}$ | 90.6$^{c}$ | 50.0$^{c}$ | 50.0$^{c}$ | 50.0$^{c}$ |
| $N_3H_1$ | 90.3$^{c}$ | 90.8$^{b}$ | 90.5$^{c}$ | 51.0$^{c}$ | 50.0$^{c}$ | 50.5$^{d}$ |
| $N_3H_2$ | 91.0$^{b}$ | 93.1$^{a}$ | 92.1$^{a}$ | 51.4$^{a}$ | 52.0$^{a}$ | 51.7$^{b}$ |
| $N_3H_3$ | 75.2$^{f}$ | 76.0$^{e}$ | 75.6$^{f}$ | 49.9$^{c}$ | 50.0$^{c}$ | 49.3$^{e}$ |
| $N_3H_4$ | 92.2$^{a}$ | 90.5$^{c}$ | 91.4$^{b}$ | 50.8$^{cd}$ | 49.3$^{d}$ | 50.2$^{a}$ |
| S.Em.± | 0.21 | 0.10 | 0.16 | 0.27 | 0.17 | 0.21 |

$N_1$, $N_2$ and $N_3$ = 50, 100, 150 Kg N ha$^{-1}$, and $H_1$, $H_2$, $H_3$ and $H_4$ = Nithyashree, NK-6240, GH-0727 and 900-M-Gold, respectively

on deep black soils where south-west monsoon (June-September) is quite assured and uniform in its distribution supported by favourable temperature range. However, among the four hybrids tested it was NK-6240 which gave the highest grain yield of 91.3, 92.2 and 91.7 q ha$^{-1}$ during 2015, 2016 and with pooled analysis, respectively (Table 5). Second best hybrid was 900-M-Gold which gave 88.9, 89.0 and 89.0 q ha$^{-1}$ during 2015, 2016 and with pooled analysis, respectively. Hybrid GH-0727 recorded the lowest grain yield. Interaction between N

rates and hybrids with pooled analysis of both the years showed that $N_3H_2$ *i.e.*, NK-6240 hybrid with 150 kg N $ha^{-1}$ gave the highest yield of 91.1 q $ha^{-1}$ and was closely followed by $N_2H_2$ (91.9 q $ha^{-1}$) *i.e.*, NK-6240 hybrid with 100 kg N $ha^{-1}$, but were on par with each other (Table 6). This suggested that while NK-6240 can respond up to 150 kg N $ha^{-1}$ under rainfed conditions of NTZ, but economically optimum levels is 100 kg N $ha^{-1}$. A study by Dhaiko Abel (2013) at Dharwad also revealed that among many maize hybrids tested NK-6240 and 900-M-Gold performed better and both these hybrids responded well to higher levels of N as much as 150 per cent of the recommended dose of N. Another study by Belay and Patil (2018) where the authors tested the same four hybrids across different sowing dates found that NK-6240 and 900-M-Gold are the highest yielders in NTZ under rainfed conditions.

Pooled analysis of data on harvest index showed that application of 100 kg N $ha^{-1}$ was the best as it recorded 50.5 per cent of harvest index and further increase in N level to 150 kg N $ha^{-1}$ did not increase the harvest index as it recorded harvest index of 50.4 per cent (Table 5). That means anything beyond 100 kg N $ha^{-1}$ did not help increase harvest index. Among the hybrids NK-6240 recorded the highest harvest index of 50.8 per cent and was closely followed by that of 900-M-Gold (50.6 %), and both were found on par with each other. Among the interactions $N_3H_2$ *i.e.*, NK-6240 with 150 kg N $ha^{-1}$ recorded the highest harvest index of 51.7 per cent and was closely followed by the same hybrid with only 100 kg N $ha^{-1}$ (51.5 %) and both were found at par with each other (Table 6).

## Conclusion

This field study conducted under rainfed environments on the black soils of NTZ of Karnataka, India to optimize nitrogen (N) fertilizer to selected maize hybrids showed that the highest yield was recorded with the application of 150 kg N $ha^{-1}$ (87.4 q $ha^{-1}$), but was very closely followed by that at 100 kg N $ha^{-1}$ (87.1 q $ha^{-1}$). Among the four hybrids tested NK-6240 gave the highest yield of 91.7 q $ha^{-1}$ followed by 900-M-Gold with 89.0 q $ha^{-1}$. The interaction between N levels and hybrids showed that hybrid NK-6240 at 150 kg N $ha^{-1}$ gave the highest yield (92.1 q $ha^{-1}$), but was found on par with that at 100 kg N $ha^{-1}$ (91.9 q $ha^{-1}$). This study showed that 100 kg N $ha^{-1}$ is economically the optimum level on black soils of NTZ under rainfed conditions, and among the hybrids NK-6240 was the best performer which was closely followed by 900-M-Gold.

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