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# Grain yield and N-Uptake by *rabi* maize (*Zea mays* L.) at varying planting densities and nitrogen levels

**K Revathi, M Sree Rekha, MK Sheshama and Girraj Sharma**

**Abstract**
A field experiment was conducted during *rabi* season 2014-15 at Agricultural College Farm, Bapatla to study the "Growth and yield of *rabi* maize at varying planting densities and nitrogen levels". The experiment was laid out in a split plot design and replicated thrice. The results revealed that planting density of $M_1$ (1,00,000 plants $ha^{-1}$) and $S_8$ (300 kg N $ha^{-1}$+ 0.5% $ZnSO_4$ as foliar spray at tasseling) which was on a par with $M_1$ (1,00,000 plants $ha^{-1}$) and $S_4$ (300 kg N $ha^{-1}$) recorded highest yield attributes and yield. Foliar application of $ZnSO_4$ with nitrogen at tasseling influence the yield attributes, grain & straw yield significantly. The interaction between planting densities and nitrogen levels was found to be non significant.

**Keywords:** Maize, Planting densities, Nitrogen levels, Zinc foliar spray

## Introduction
Maize (*Zea mays* L.) has become the third most important cereal crop in the world, because of its high adaptability and productivity (Mosisa *et al.*, 2002) [8]. Maize is one of the major staple food in India. It has evolved from a purely subsistence to a successful commercial crop. It contains about 70 to 75 % starch, 8 to 12 % protein, 3 to 8 % oil and carbohydrates 1 to 3 %. Maize in India, is grown in 8.7 M.ha with an annual production of 22.5 M.t. In Andhra Pradesh, it is cultivated in 4.07 lakh ha area during *rabi* season (Directorate of Maize Research, 2012-2013). It is widely cultivated as a rainfed crop during *kharif* season but due to evolution of new genotypes it can be grown successfully as *rabi* season crop, harvesting bumper yields and also the yield of *rabi* crop is higher compared to *Kharif* crop. Widdicombe and Thelen (2002) [15] reported that maize grain yield increased, when row width was narrowed. Being an exhaustive crop maize needs a balanced application of macro and micro nutrients especially nitrogen. As it is important for good growth and it is a component of DNA, RNA and chlorophyll. Increasing level of nitrogen has increased yield components of maize during different research studies (Bangarwa *et el.*, 1989) [3] resulting in remarkable increase in grain yield. For each production system, there is a population that optimizes the use of available resources, allowing the expression of maximum attainable grain yield in that environment. The ideal plant number per unit area will depend on several factors, such as water availability, soil fertility, hybrid maturity group and row spacing.

## Material and methods
The experiment was conducted during *rabi* season 2014-15 at Agricultural College Farm, Bapatla, Andhra Pradesh. The experimental site is situated at $80^0$ 25' E longitude, $15^0$ 54' N latitude and at an altitude of 5.49 m and 7 km away from the Bay of Bengal. The experimental soil was sandy loam in texture, slightly alkaline in reaction (pH 6.6), medium in organic carbon (0.52%), low in available nitrogen (206 kg $ha^{-1}$), medium in available phosphorus (24.1 kg $ha^{-1}$), high in potassium (301.5 kg $ha^{-1}$) and low in zinc (0.3 ppm). Nitrogen was estimated by Modified Micro Kjeldahl's method (Piper, 1966) [11], phosphorus by Vanado Molybdate Phosphoric Acid method (Jackson, 1973) [5], potassium by Flame Photometer method (Jackson, 1973) [5] and zinc by DTPA extraction method (Lindsay and Norvell, 1978) [6]. The mean maximum and mean minimum temperatures were 30.0 $^0$C and 18.3 $^0$C. The experiment was laid out in a split plot design with three main treatments and eight sub treatments replicated thrice. The treatments consisted of three planting densities *viz*. $M_1$:50 cm x 20 cm,

(1,00,000 plants $ha^{-1}$), $M_2$ :60 cm x 20 cm (83,333 plants $ha^{-1}$) and $M_3$ :75 cm x 20 cm (66,666 plants $ha^{-1}$) allotted as main plots and eight nitrogen levels *viz.*, $S_1$ (120 kg N $ha^{-1}$ ), $S_2$ (180kg N $ha^{-1}$) $S_3$ (240 kg N $ha^{-1}$) $S_4$ (300kg N $ha^{-1}$), $S_5$ (120 kg N $ha^{-1}$ +0.5% $ZnSO_4$ as foliar spray at tasseling), $S_6$ (180 kg N $ha^{-1}$ +0.5% $ZnSO_4$ as foliar spray at tasseling), $S_7$ (240 kg N $ha^{-1}$ +0.5% $ZnSO_4$ as foliar spray at tasseling), $S_8$ (300 kg N $ha^{-1}$ +0.5% $ZnSo_4$ as foliar spray at tasseling) alloted as sub plots.

The maize hybrid, Laxmi-2277 was sown in 2nd week of November 2014. Thinning and gap filling was done at 15 DAS by keeping one seedling per $hill^{-1}$. Entire dose of phosphorus were applied as basal dose through single super phosphate and nitrogen was applied as per treatments in three equal splits through urea as basal, at 30 DAS and at 60 DAS. Potassium was applied twice as basal and at 60 DAS, through muriate of potash. Whereas 0.5% $ZnSO_4$ was applied as foliar spray at tasseling as per treatments.

## Results and discussion

### Test weight (g)

100-grain weight was not significantly influenced by planting densities but influenced by nitrogen levels. Interaction between them was found to be non significant (Table 1). Test weight was not statistically influenced by planting densities. However, numerically test weight recorded with 66,666 plants $ha^{-1}$ was high followed by 83,333 plants $ha^{-1}$ and 1,00,000 plants $ha^{-1}$. Low grain weight at high plant density might be due to availability of less photosynthates for grain development because of high inter specific competition resulting reduction in grain weight was reported by Zamir *et al*. (2011) [16]. And higher test weight was obtained with 300 kg N $ha^{-1}$+ 0.5% $ZnSO_4$ as foliar spray which was on a par with 240 kg N $ha^{-1}$+ 0.5% $ZnSO_4$ as foliar spray and significantly superior to other levels. Increase in test weight might due to better absorption of zinc through foliage and availability of nitrogen and their synergistic effect might have helped better grain filling and hence higher 100-grain weight. These lines are in conformity with Aruna *et al*. (2006) [1] and Paramasivan *et al*. (2011) [9].

### Kernel yield (kg $ha^{-1}$), Stover yield (kg $ha^{-1}$) and harvest index (%)

Kernel yield and stover yield was significantly influenced by planting densities and nitrogen levels not by their interaction. Harvest index was not significantly influenced by either planting densities or nitrogen levels or their interaction (Table 1).

Maximum grain and stover yield of 4767 kg $ha^{-1}$ and 6120 kg $ha^{-1}$, was recorded with $M_2$ and $M_1$, respectively. Significantly highest kernel and stover yields of maize recorded with $S_8$ which was on a par with only nitrogen $S_4$ and significantly superior to other levels. This indicates that decline in yield components was more compensated with increase in plant density per unit area and adequate availability of nutrients and moisture. Similar results was reported by Gollar and patil (2000) [4]. The increase in kernel yield at higher N levels together with Zn as foliar spray is due to better uptake of nutrients and zinc applied at tasseling. The results obtained are in consonance with the findings of Sekhar *et al*. (2012) [12]. Maximum stover yield of maize at higher plant densities might be due to variation in the crop stand per unit area. These results are in agreement with Zamir *et al*. (2011) [16]. As zinc place a role in metabolism of plant as an activator of enzymes which inturn directly or indirectly affect the synthesis of carbohydrates, soil application of NPK coupled with $ZnSO_4$ as foliar spraying at tasseling influenced the stover yield of maize. These findings are in agreement with Tyagi *et al*. (1998) [13]. Harvest index was not influenced by planting densities and nitrogen levels.

### Nitrogen uptake (kg $ha^{-1}$)

Nitrogen uptake at maturity was significantly influenced by planting densities and nitrogen levels and their interaction was found to be non significant (Table 2). At maturity, nitrogen uptake in kernel was significantly highest with $M_1$ (1,00,000 plants $ha^{-1}$) which was on par with $M_2$ (83,333 plants $ha^{-1}$) and significantly superior to $M_3$ (66,666 plants $ha^{-1}$). N uptake by stover at harvest was highest with $M_1$ (1,00,000 plants $ha^{-1}$) which was on par with $M_3$ (66,666 plants $ha^{-1}$) and significantly superior to $M_2$ (83,333 plants $ha^{-1}$).

At harvest, maximum N uptake in kernel and stover obtained when nitrogen @ 300 kg N $ha^{-1}$ along was supplemented with Zn @ 0.5% $ZnSO_4$ as foliar spray at tasseling which was on par with 300 kg N $ha^{-1}$ without zinc and significantly superior to the rest of the nitrogen levels with or without zinc foliar spray.

Nitrogen uptake by kernel and stover is the total nitrogen uptake. Total nitrogen uptake was maximum with 1,00,000 plants $ha^{-1}$ and at higher nitrogen level along with zinc application in $S_8$ (300 kg N $ha^{-1}$ + 0.5% $ZnSO_4$ as foliar spray at tasseling). The increase in planting density resulted in the highest uptake of nitrogen due to higher kernel and stover yield. Increase of nitrogen uptake along with zinc application at higher levels of nitrogen is due to more drymatter accumulation. These findings are in accordance with those of Potarzycki and Grzebisz (2009) [10] and Venkata Rao (2012) [14].

### Phosphorus uptake (kg $ha^{-1}$)

Phosphorus uptake by maize revealed that phosphorus uptake was significantly influenced by planting densities and nitrogen levels while, interaction between planting densities and nitrogen levels was non significant (Table 3). At harvest, (grain and stover), significantly the highest Phosphorus uptake was obtained with $M_1$ (1,00,000 plants $ha^{-1}$) which was on par with $M_2$ (83,333 plants $ha^{-1}$) and significantly superior to $M_3$ (66,666 plants $ha^{-1}$). However, phosphorus uptake both at tasseling and harvest was not discernible between $M_1$ (1,00,000 plants $ha^{-1}$) and $M_2$ (83,333 plants $ha^{-1}$). Significantly higher Phosphorus uptake was recorded with 300 kg N $ha^{-1}$ along with zinc @ 0.5% as foliar spray at tasseling, which was on par with 300 kg N $ha^{-1}$ without zinc and 240 kg N $ha^{-1}$ with zinc @ 0.5% as foliar spray and significantly superior to other lower doses. Higher total Phosphorus uptake was recorded with $M_1$ (1,00,000 plants $ha^{-1}$) and $S_8$ (300 N kg $ha^{-1}$ + 0.5% $ZnSO_4$ as foliar spray at tasseling). This may be due to maximum uptake at higher planting density with high nitrogen level. These results are in line with Mercy *et al*. (2012) [7].

### Potassium uptake (kg $ha^{-1}$)

The data on potassium uptake by maize recorded at tasseling and harvest were significantly influenced by planting densities and nitrogen levels but their interaction was found to be non significant (Table 4). Variations in planting densities resulted in significant effect on potassium uptake by maize. Significantly highest potassium uptake in kernel was obtained with $M_2$ (83,333 plants $ha^{-1}$) which was significantly superior to $M_1$ (1,00,000 plants $ha^{-1}$) and $M_3$ (66,666 plants $ha^{1}$).

However, stover uptake at harvest was highest with $M_1$ (1,00,000 plants $ha^{-1}$) which was on par with $M_2$ (83,333 plants $ha^{-1}$) and significantly superior to $M_3$ (66,666 plants $ha^{-1}$). Potassium uptake in kernel was maximum with nitrogen @ 300 kg N $ha^{-1}$ along with zinc @ 0.5% $ZnSO_4$ as foliar spray at tasseling which was significantly superior to other levels tested. Potassium uptake by stover was highest with 300 kg N $ha^{-1}$ along with zinc as foliar spray and was on par with 300 kg N $ha^{-1}$ without zinc and 240 kg N $ha^{-1}$ with zinc as foliar spray and significantly superior to other doses of nitrogen with and without zinc. At harvest, maximum total K uptake was recorded with $M_2$ (83,333 plants $ha^{-1}$) and $S_8$ (300 kg N $ha^{-1}$ + 0.5% $ZnSO_4$ as foliar spray at tasseling). As increased plant populations increased yield and demands on soil K increased with increase in uptake. Addition of N also greatly increased K uptake, which might be due to production of maximum stover yield at higher planting density. Similar results were reported by Venkata Rao (2012) [14].

**Zinc uptake (kg $ha^{-1}$)**

Planting densities and nitrogen levels significantly influenced the zinc uptake by maize by stover only. Zinc uptake by kernel was not influenced by planting densities and the interaction between planting densities and nitrogen levels was found to be non significant (Table 5). Zinc uptake by maize increased with each increase in planting density and nitrogen levels as well). At harvest, maximum uptake by stover was recorded with $M_1$ (1,00,000 plants $ha^{-1}$) which was on par with $M_2$ (83,333 plants $ha^{-1}$) and significantly superior to $M_3$ (66,666 plants $ha^{-1}$). In kernel, maximum Zn uptake was obtained numerically with $M_2$ (83,333 plants $ha^{-1}$) followed by $M_1$ (1,00,000 plants $ha^{-1}$) and $M_3$ (66,666 plants $ha^{-1}$). At harvest, maximum Zn uptake was obtained with application of 300 kg N $ha^{-1}$ along with 0.5% $ZnSO_4$ as foliar spray at tasseling and significantly superior to other levels tested both in kernel and stover.

Higher total Zn uptake was recorded with $M_1$ (1,00,000 plants $ha^{-1}$) and $S_8$ (300 kg $ha^{-1}$ + 0.5% $ZnSO_4$ as foliar spray at tasseling). This increase in zinc content might be due to its increased absorption from foliar spray and rapid translocation to kernel and stover besides reducing losses by fixation and production of maximum stover yield at higher planting density. Similar results were reported by Venkata Rao (2012) [14]. The uptake of nutrients might be because of better root establishment, resulting in higher absorption of nutrients to sustain increased growth as reported by Arya and Singh (2001) [2].

**Table 1:** Test weight and yield of maize at varying planting densities and nitrogen levels.

| Treatments | 100-grain weight (g) | Kernel yield (kg $ha^{-1}$) | Stover yield (kg $ha^{-1}$) | Harvest index (%) |
|---|---|---|---|---|
| **Main plots (Planting densities)** | | | | |
| $M_1$:50 cm x 20 cm (1,00,000 plants $ha^{-1}$) | 23.3 | 4586 | 6120 | 42.2 |
| $M_2$ :60 cm x 20 cm (83,333 plants $ha^{-1}$) | 24.0 | 4767 | 5095 | 48.1 |
| $M_3$ :75 cm x 20 cm (66,666 plants $ha^{-1}$) | 25.0 | 4081 | 4698 | 46.0 |
| S.Em ± | 0.43 | 131.7 | 137.3 | 1.33 |
| CD (P=0.05) | NS | 517.1 | 539 | NS |
| CV(%) | 8.3 | 14.4 | 12.6 | 14.3 |
| **Sub-plots (Nitrogen and zinc treatments)** | | | | |
| $S_1$:120 kg N $ha^{-1}$ | 22.1 | 3240 | 4033 | 43.5 |
| $S_2$:180 kg N $ha^{-1}$ | 22.7 | 3923 | 4841 | 44.5 |
| $S_3$:240 kg N $ha^{-1}$ | 23.9 | 4635 | 5646 | 45.0 |
| $S_4$:300 kg N $ha^{-1}$ | 24.9 | 5578 | 6291 | 46.4 |
| $S_5$: 120 kg N $ha^{-1}$+ 0.5% $ZnSO_4$ foliar spray at tasseling | 23.6 | 3427 | 4301 | 44.5 |
| $S_6$: 180 kg N $ha^{-1}$+ 0.5% $ZnSO_4$ foliar spray at tasseling | 24.1 | 4203 | 5144 | 45.1 |
| $S_7$: 240 kg N $ha^{-1}$+ 0.5% $ZnSO_4$ foliar spray at tasseling | 25.3 | 5002 | 5697 | 47.1 |
| $S_8$:300 kg N $ha^{-1}$+ 0.5% $ZnSO_4$ foliar spray at tasseling | 26.5 | 5816 | 6478 | 47.6 |
| S.Em ± | 0.86 | 146.4 | 209.9 | 1.84 |
| CD (P=0.05) | 2.4 | 417 | 599.3 | NS |
| CV(%) | 10.8 | 16.0 | 11.8 | 12.2 |
| **Interaction** | | | | |
| **Planting densities at same level of nitrogen** | | | | |
| S.Em ± | 1.47 | 409.0 | 366.8 | 3.27 |
| CD (P=0.05) | NS | NS | NS | NS |
| **Nitrogen levels at same or different planting densities** | | | | |
| S.Em ± | 1.51 | 414.0 | 363.7 | 3.19 |
| CD (P=0.05) | NS | NS | NS | NS |

**Table 2:** Nitrogen content (%) and uptake (kg $ha^{-1}$) by maize at varying planting densities and nitrogen levels.

| Treatments | Kernel | | Stover | | Total uptake (kg $ha^{-1}$) |
|---|---|---|---|---|---|
| | N % | N uptake (kg $ha^{-1}$) | N % | N uptake (kg $ha^{-1}$) | |
| **Main plots (Planting densities)** | | | | | |
| $M_1$:50 cm x 20 cm (1,00,000 plants $ha^{-1}$) | 1.54 | 76.4 | 0.65 | 73.9 | 150.3 |
| $M_2$ :60 cm x 20 cm (83,333 plants $ha^{-1}$) | 1.39 | 73.8 | 0.59 | 60.6 | 134.4 |
| $M_3$ :75 cm x 20 cm (66,666 plants $ha^{-1}$) | 1.67 | 69.9 | 0.73 | 68.0 | 134.9 |
| S.Em ± | - | 1.23 | - | 1.76 | - |
| CD (P=0.05) | - | 4.8 | - | 6.9 | - |
| CV(%) | - | 8.2 | - | 12.9 | - |
| **Sub-plots (Nitrogen and zinc treatments)** | | | | | |
| $S_1$:120 kg N $ha^{-1}$ | 1.25 | 62.4 | 0.50 | 34.9 | 97.3 |

| | | | | | |
|---|---|---|---|---|---|
| $S_2$:180 kg N $ha^{-1}$ | 1.39 | 70.3 | 0.57 | 52.0 | 122.3 |
| $S_3$:240 kg N $ha^{-1}$ | 1.51 | 75.4 | 0.69 | 70.2 | 145.6 |
| $S_4$:300 kg N $ha^{-1}$ | 1.67 | 81.0 | 0.75 | 91.7 | 172.7 |
| $S_5$: 120 kg N $ha^{-1}$+ 0.5% $ZnSO_4$ foliar spray at tasseling | 1.37 | 62.3 | 0.57 | 42.0 | 104.3 |
| $S_6$: 180 kg N $ha^{-1}$+ 0.5% $ZnSO_4$ foliar spray at tasseling | 1.53 | 69.0 | 0.68 | 60.9 | 129.9 |
| $S_7$: 240 kg N $ha^{-1}$+ 0.5% $ZnSO_4$ foliar spray at tasseling | 1.62 | 80.6 | 0.68 | 76.4 | 157.0 |
| $S_8$:300 kg N $ha^{-1}$+ 0.5% $ZnSO_4$ foliar spray at tasseling | 1.86 | 85.9 | 0.82 | 94.2 | 180.1 |
| S.Em ± | - | 1.74 | - | 3.37 | - |
| CD (P=0.05) | - | 4.5 | - | 9.6 | - |
| CV(%) | - | 7.1 | - | 15.2 | - |
| **Interaction** | | | | | |
| **Planting densities at same level of nitrogen** | | | | | |
| S.Em ± | - | 3.08 | - | 5.84 | - |
| CD (P=0.05) | - | NS | - | NS | - |
| **Nitrogen levels at same or different planting densities** | | | | | |
| S.Em ± | - | 3.02 | - | 5.74 | - |
| CD (P=0.05) | - | NS | - | NS | - |

**Table 3:** Phosphorus content (%) and uptake (kg $ha^{-1}$) by maize at varyingplanting densities and nitrogen levels.

| Treatments | Kernel | | Stover | | Total uptake (kg $ha^{-1}$) |
|---|---|---|---|---|---|
| | P % | P uptake (kg $ha^{-1}$) | P% | P uptake (kg $ha^{-1}$) | |
| **Main plots (Planting densities)** | | | | | |
| $M_1$:50 cm x 20 cm (1,00,000 plants $ha^{-1}$) | 0.49 | 21.4 | 0.17 | 18.3 | 39.7 |
| $M_2$ :60 cm x 20 cm (83,333 plants $ha^{-1}$) | 0.44 | 20.8 | 0.19 | 17.9 | 38.7 |
| $M_3$ :75 cm x 20 cm (66,666 plants $ha^{-1}$) | 0.49 | 19.1 | 0.21 | 16.7 | 35.8 |
| S.Em ± | - | 0.38 | - | 0.31 | - |
| CD (P=0.05) | - | 1.48 | - | 1.2 | - |
| CV(%) | - | 9.0 | | 8.6 | - |
| **Sub-plots (Nitrogen and zinc treatments)** | | | | | |
| $S_1$:120 kg N $ha^{-1}$ | 0.54 | 17.2 | 0.24 | 15.9 | 33.1 |
| $S_2$:180 kg N $ha^{-1}$ | 0.47 | 17.4 | 0.19 | 16.7 | 34.1 |
| $S_3$:240 kg N $ha^{-1}$ | 0.42 | 19.0 | 0.17 | 17.4 | 36.6 |
| $S_4$:300 kg N $ha^{-1}$ | 0.42 | 23.0 | 0.16 | 18.3 | 41.3 |
| $S_5$: 120 kg N $ha^{-1}$+ 0.5% $ZnSO_4$ foliar spray at tasseling | 0.53 | 17.9 | 0.24 | 17.2 | 35.1 |
| $S_6$: 180 kg N $ha^{-1}$+ 0.5% $ZnSO_4$ foliar spray at tasseling | 0.48 | 20.1 | 0.20 | 17.4 | 37.7 |
| $S_7$: 240 kg N $ha^{-1}$+ 0.5% $ZnSO_4$ foliar spray at tasseling | 0.48 | 23.9 | 0.16 | 18.3 | 42.2 |
| $S_8$:300 kg N $ha^{-1}$+ 0.5% $ZnSO_4$ foliar spray at tasseling | 0.45 | 24.8 | 0.15 | 19.0 | 43.8 |
| S.Em ± | - | 0.92 | - | 0.57 | - |
| CD (P=0.05) | - | 2.6 | - | 1.6 | - |
| CV(%) | - | 13.5 | - | 9.7 | - |
| **Interaction** | | | | | |
| **Planting densities at same level of nitrogen** | | | | | |
| S.Em ± | - | 1.54 | - | 0.99 | - |
| CD (P=0.05) | - | NS | - | NS | - |
| **Nitrogen levels at same or different planting densities** | | | | | |
| S.Em ± | - | 1.60 | - | 0.97 | - |
| CD (P=0.05) | - | NS | - | NS | - |

**Table 4:** Potassium content (%) and uptake (kg $ha^{-1}$) by maize at varying planting densities and nitrogen levels.

| Treatments | Kernel | | Stover | | Total uptake (kg $ha^{-1}$) |
|---|---|---|---|---|---|
| | K % | K uptake (kg $ha^{-1}$) | K % | K uptake (kg $ha^{-1}$) | |
| **Main plots (Planting densities)** | | | | | |
| $M_1$:50 cm x 20 cm (1,00,000 plants $ha^{-1}$) | 0.61 | 27.6 | 0.71 | 80.3 | 107.9 |
| $M_2$ :60 cm x 20 cm (83,333 plants $ha^{-1}$) | 0.64 | 31.0 | 0.79 | 77.9 | 108.9 |
| $M_3$ :75 cm x 20 cm (66,666 plants $ha^{-1}$) | 0.68 | 26.9 | 0.81 | 70.2 | 97.1 |
| S.Em ± | - | 0.80 | - | 1.97 | - |
| CD (P=0.05) | - | 3.1 | - | 7.7 | - |
| CV(%) | - | 13.8 | - | 12.6 | - |
| **Sub-plots (Nitrogen and zinc treatments)** | | | | | |
| $S_1$:120 kg N $ha^{-1}$ | 0.68 | 15.0 | 0.76 | 56.5 | 71.5 |
| $S_2$:180 kg N $ha^{-1}$ | 0.77 | 24.0 | 0.70 | 65.8 | 89.8 |
| $S_3$:240 kg N $ha^{-1}$ | 0.81 | 31.3 | 0.73 | 75.6 | 106.9 |
| $S_4$:300 kg N $ha^{-1}$ | 0.76 | 36.1 | 0.77 | 92.4 | 128.5 |
| $S_5$: 120 kg N $ha^{-1}$+ 0.5% $ZnSO_4$ foliar spray at tasseling | 0.70 | 17.7 | 0.83 | 61.1 | 78.8 |
| $S_6$: 180 kg N $ha^{-1}$+ 0.5% $ZnSO_4$ foliar spray at tasseling | 0.78 | 27.0 | 0.86 | 77.7 | 104.7 |
| $S_7$: 240 kg N $ha^{-1}$+ 0.5% $ZnSO_4$ foliar spray at tasseling | 0.82 | 35.2 | 0.79 | 87.4 | 122.6 |
| $S_8$:300 kg N $ha^{-1}$+ 0.5% $ZnSO_4$ foliar spray at tasseling | 0.89 | 42.0 | 0.72 | 92.5 | 134.5 |
| S.Em ± | - | 1.54 | - | 4.05 | - |

| | | | | | |
|---|---|---|---|---|---|
| CD (P=0.05) | - | 4.4 | - | 11.55 | - |
| CV(%) | - | 16.2 | - | 15.96 | - |
| **Interaction** | | | | | |
| **Planting densities at same level of nitrogen** | | | | | |
| S.Em ± | - | 2.63 | - | 6.85 | - |
| CD (P=0.05) | - | NS | - | NS | - |
| **Nitrogen levels at same or different planting densities** | | | | | |
| S.Em ± | - | 2.67 | - | 7.01 | - |
| CD (P=0.05) | - | NS | - | NS | - |

**Table 5:** Zinc content (µg $g^{-1}$) and uptake (g $ha^{-1}$) by maize at varying planting densities and nitrogen levels.

| Treatments | Kernel | | Stover | | Total uptake (g $ha^{-1}$) |
|---|---|---|---|---|---|
| | Zn µg $g^{-1}$ | Zn uptake (g $ha^{-1}$) | Zn µg $g^{-1}$ | Zn uptake (g $ha^{-1}$) | |
| **Main plots (Planting densities)** | | | | | |
| $M_1$:50 cm x 20 cm (1,00,000 plants $ha^{-1}$) | 5.09 | 236.9 | 6.74 | 733.0 | 969.9 |
| $M_2$ :60 cm x 20 cm (83,333 plants $ha^{-1}$) | 5.00 | 245.4 | 6.78 | 666.5 | 911.9 |
| $M_3$ :75 cm x 20 cm (66,666 plants $ha^{-1}$) | 5.34 | 210.9 | 6.92 | 600.4 | 811.3 |
| S.Em ± | - | 7.88 | - | 17.63 | - |
| CD (P=0.05) | - | NS | - | 69.2 | - |
| CV(%) | - | 16.7 | - | 12.9 | - |
| **Sub-plots (Nitrogen and zinc treatments)** | | | | | |
| $S_1$:120 kg N $ha^{-1}$ | 4.00 | 123.4 | 7.18 | 513.9 | 637.3 |
| $S_2$:180 kg N $ha^{-1}$ | 4.19 | 158.2 | 6.57 | 598.5 | 756.7 |
| $S_3$:240 kg N $ha^{-1}$ | 5.04 | 232.6 | 6.45 | 668.9 | 901.5 |
| $S_4$:300 kg N $ha^{-1}$ | 4.97 | 274.5 | 6.30 | 756.3 | 1030.8 |
| $S_6$: 180 kg N $ha^{-1}$+ 0.5% $ZnSO_4$ foliar spray at tasseling | 5.31 | 223.6 | 7.25 | 648.7 | 872.3 |
| $S_7$: 240 kg N $ha^{-1}$+ 0.5% $ZnSO_4$ foliar spray at tasseling | 6.34 | 314.9 | 6.61 | 739.6 | 1054.5 |
| $S_8$:300 kg N $ha^{-1}$+ 0.5% $ZnSO_4$ foliar spray at tasseling | 7.32 | 385.7 | 6.62 | 845.2 | 1230.9 |
| S.Em ± | - | 13.65 | - | 29.52 | - |
| CD (P=0.05) | - | 38.9 | - | 84.2 | - |
| CV(%) | - | 17.7 | - | 13.2 | - |
| **Interaction** | | | | | |
| **Planting densities at same level of nitrogen** | | | | | |
| S.Em ± | - | 23.47 | - | 50.97 | - |
| CD (P=0.05) | - | NS | - | NS | - |
| **Nitrogen levels at same or different planting densities** | | | | | |
| S.Em ± | - | 23.64 | - | 51.12 | - |
| CD (P=0.05) | - | NS | - | NS | - |

## Conclusions

From the present study, it was clearly indicated that among the plant spacings adopted, 50 cm x 20 cm (1,00,000 plants $ha^{-1}$) resulted higher yield, with $S_8$ (300 kg N $ha^{-1}$ +0.5% $ZnSO_4$ as foliar spray at tasseling) and highest nutrient uptake (N, P,K and Zn) was recorded with higher plant density of $M_1$ (1,00,000 plants $ha^{-1}$) with $S_8$ (300 kg N $ha^{-1}$ + 0.5% $ZnSO_4$ as foliar spray at tasseling) compared to $M_1$ (1,00,000 plants $ha^{-1}$) with $S_4$ (300 kg N $ha^{-1}$)

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