Influence of graded levels and split application of
nitrogen on growth and physiological attributes of
hybrid maize

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DOI: https://doi.org/10.22271/tpi.2020.v9.i12c.5432

Abstract
A field experiment to study the effect of graded levels and split application of nitrogen on growth and
physiological attributes of hybrid maize CO (MH) 6 was conducted at AC&RI, Madurai. The field
was laid on RBD design with three replications with treatments RDN (250 kg/ha), and STCR (167 kg/ha) on
3 splits and nitrogen levels 225, 200, 175 and 150 kg/ha under 3 splits and 4 splits. Results showed that
plant height was higher with T1 at 15, 30, 45DAS and with T2 at 60 and 75 DAS. At 45 DAS T1 showed
better results with all the physiological attributes. Similarly at 30 DAS dry matter production and SPAD
value was higher with T1. At 60 DAS T2 showed better leaf area index, SPAD value and dry mater
deposition, T3 also showed significant results at 75 DAS with leaf area index and SPAD value. At
harvest DMP was higher with T2. For CGR and RGR, at 30 to 40 DAS T1 showed higher results. Whereas
from 40 to 60 DAS and 60 to Harvest T2 recorded higher CGR and RGR.

Keywords: Nitrogen, optimization, split-application, STCR, CO (MH) 6, productivity

Introduction
Maize (Zea mays L.) is a plant belonging to the family Poaceae. Cultivated globally, it is
considered as the third most important cereal next to rice and wheat, in the world as well in
India. Maize satisfies the human nutrient requirement and also considered as an important raw
material for animal feed and manufacture of many industrial products such as corn starch,
maltodextrins, corn oil, corn syrup and products for fermentation and distillation industries.
Due to its immense potential and versatility it is also known as “miracle crop” and “queen of
cereals”.

Recent statistical survey showed that maize is cultivated over an area of about 177.73 million
hectares globally and with a production of about 961.85 million tonnes and with a productivity
of 5.41 metric tonnes per hectare (USDA, 2017) [20]. In India, maize constitutes nine per cent of
the total volume of cereals produced (India Maize Summit, 2016) [8] and occupies third place
among the cereals after rice and wheat. It is cultivated over an area of 8.81 million hectares
and with a production of 22.57 million tonnes with an average yield of 2.56 metric tonnes per
hectare (USDA, 2017) [20].

By 2020 AD, the requirement of maize for various sectors was estimated to be around 100
million tonnes, of which the demand in poultry sector alone will be around 31 million tones. It
is a very difficult task for our agriculturists to increase the maize production from the present
level of 22.57 million tonnes to 100 million tonnes by 2020 (Seshatah, 2006) [16].

Nitrogen, phosphorus and potassium are the essential nutrients for the production of maize.
They play a crucial role in deciding the growth and yield. On the other hand, intensive
cultivation results in considerable removal of already deficient nitrogen from the soil and their
replenishment through organic manure is very limited since the extent at which we produce, do
not match to efficiency of the chemical N-fertilizers. Thus newly evolved hybrids with good
yield potential show positive response to high levels of N fertilizers and their application
becomes necessary even though they are costly. It is inevitable that N-fertilizer usage cannot
be avoided but must be optimize the usage in order to obtain a sustainable growth for both in
production and farming.

Time and method of N application plays an important role in efficient utilization (Mohammad
et al., 1999) [10].
The time of application of nitrogen is critical and is regarded as the most important decision for high yielding hybrid maize production (Walsh, 2006) [22]. The rapid developmental phase of maize starts from V₃ until the highest N uptake takes place. Therefore, maize responds to the belated N application (Binder et al., 2000) [4]. Generally N application from V₃ to V₁₀ growth stages could be the appropriate time of N supply to meet its high demand (Hassan et al., 2010) [7]. Nitrogen application during late vegetative growth was considered to be an ideal application practice as a means to increase nitrogen use efficiency (Schmidt et al., 2002 and Muthukumar et al., 2005) [13, 14].

At present the recommended dose of nitrogen (RDN) is 250 kg/ha with three splits as 25% at basal, 50% at 25 DAS and 25% at 45 DAS. Hence, it was observed that there is scope for extended split application of nitrogen with graded level of nitrogen application. Generally, N uptake improved and grain yield increased with split N fertilization compared to one single application at planting under irrigation system. The split application at different plant growth stages leads to increase in yield attributes of maize (Sangoi et al., 2007) [14].

Thus the present attempt was made to study the influence of graded levels of N fertilizer and timing of split application of N fertilizer in increasing the productivity of hybrid maize for better uptake of nutrients and translocation of assimilates.

Materials and method

The experiment was conducted at the Department of Farm Management at AC & RI, Madurai (Tamil Nadu) during the Rabi season of 2016-2017 at location of 9°54’ N latitude, 78°54’ E longitude and 147 m altitude above mean sea level. The soil is sandy clay loam with low organic carbon (4.4 g/kg), low available nitrogen (242.3 kg/ha), medium in phosphorus (16 kg/ha) and high in potassium (450 kg/ha). The values of soil pH and EC were 8.1 and 0.17 dSm⁻¹ respectively.

The randomized block design with three replications was adapted for the study with treatments as applying six levels of nitrogen with three and four respective splits at different growth stages as T₁: RDN (250 kg/ha) in 3 splits at basal (25%), 25 DAS (50%) and 45 DAS (25%), T₂: STCR (167 kg N/ha) in 3 splits at basal (25%), 25 DAS (50%) and 45 DAS (25%), T₃: 225 kg N/ha in 3 splits at 7 DAS (25%), 25 DAS (50%) and 45 DAS (25%), T₄: 200 kg N/ha in 3 splits at 7 DAS (25%), 25 DAS (50%) and 45 DAS (25%), T₅: 175 kg N/ha in 3 splits at 7 DAS (25%), 25 DAS (50%) and 45 DAS (25%), T₆: 150 kg N/ha in 3 splits at 7 DAS (25%), 25 DAS (50%) and 45 DAS (25%), T₇: 225 kg N/ha in 4 equal splits at 7 DAS, 25 DAS, 45 DAS, 60 DAS, T₈: 200 kg N/ha in 4 equal splits at 7 DAS, 25 DAS, 45 DAS, 60 DAS, T₉: 175 kg N/ha in 4 equal splits at 7 DAS, 25 DAS, 45 DAS, 60 DAS, T₁₀: 150 kg N/ha in 4 equal splits at 7 DAS, 25 DAS, 45 DAS, 60 DAS. P and K was applied with the recommended dose of fertilizer (RDF) 75 kg/ha as basal along with doses of phosphorus and potassium. STCR recommendations for T₂ was obtained based on the fertilizer prescription equations (FPE) described for Palaviduthi series obtained from the STCR unit of the Department of Soil Science and Analytical Chemistry, Tamil Nadu Agricultural University, Coimbatore, India.

FN = 3.96 T - 0.62 SN - 0.69 ON
FPₒ₅ = 1.56 T - 1.93 SPₒ₅ - 0.60 OP
FKₒ = 1.66 T - 0.27 SKₒ - 0.49 OK

The variety maize hybrid Co MH 6 was used and their seeds were sown on the side of the ridges by adopting a spacing of 60 x 25 cm. Irrigation for the field was done on the need basis at an interval of 8 to 10 days. Pre-emergence herbicide atrazine was applied on 3 DAS @ 0.5 kg a.i./ha by using knapsack sprayer and followed by subsequent hand weeding when needed. In order to record biometric observations five random tagged plants were selected from each plot and their respective growth and physiological attributes were measured. Statistical analysis for all the data pertaining to crop was carried out using the procedure suggested by Gomez and Gomez (1984). Wherever the treatment differences were found significant critical difference was worked out at five per cent probability level and the values are furnished. The treatment differences that were not significant were denoted as “NS”.

Results and Discussion

Growth parameter

Plant height

The results obtained from the study (Fig.1) revealed that at 15, 30 and 45 DAS application of nitrogen at 250 kg/ha in three splits at basal (25%), 25 DAS (50%), 45 DAS (25%) (T₁). At 60 and 75 DAS the treatment wait 225 kg/ha in four equal splits at 7 DAS, 25 DAS, 45 DAS and 60 DAS (T₇) produced significantly higher plant height. The lowest value of plant height at 15, 30 and 45 DAS was associated the treatment T₁₀ (150 kg/ha of nitrogen at four equal splits at 7 DAS, 25 DAS, 45 DAS and 60 DAS). Whereas for 60 and 75 DAS the lowest plant height was with 150 kg/ha in three splits at 7 DAS (25%), 25 DAS (50%), 45 DAS (25%) (T₉). This increasing trend of plant height with increasing N application might be probably due to the role of N in increasing cell division and cell enlargement, which ultimately affect the vegetative growth particularly the height of the plant. Similar such results were reported earlier by Siva (2007) [17] and Srikanth et al. (2009) [18]. The observed plant height also indicates that application of nitrogen in four equal splits produce significantly higher plants. The increase in plant height with more number of splits might be due to application of N coinciding with the crop requirements at different growth stages of maize. Hence, split application of nitrogen could have promoted plant growth by increasing the number and length of the internodes which would result in progressive increase in plant height (Parbati et al., 2016) [13]. Amanullah et al. (2009a) [1] had earlier stated that split applications of N up to late silking would increased the plant height of maize.

Physiological attributes

Leaf area index

For leaf area index (Table 1), observations at 45 DAS showed that application of nitrogen at 250 kg/ha in three splits at basal (25%), 25 DAS (50%), 45 DAS (25%) (T₁) resulted in the highest leaf area index of 3.60. The lowest LAI was observed with application of 150 kg/ha in four equal splits at 7 DAS, 25 DAS, 45 DAS and 60 DAS (T₁₀). At 60 DAS, application of nitrogen at 225 kg/ha in four equal splits at 7 DAS, 25 DAS, 45 DAS and 60 DAS (T₇) recorded the highest leaf area index (5.39). The lowest leaf area index was associated with application of 150 kg/ha nitrogen in three splits at 7 DAS (25%), 25 DAS (50%) and 45 DAS (25%) (T₉). The observation pertaining to LAI at 75 DAS recorded a similar trend as that observed at 60 DAS.
The increased leaf area index with increased application of N in maize might due to the tendency of nitrogen to increase chlorophyll content of plant by affecting the cell and tissue growth, which in turn enhances the leaf area, leaf number and photosynthetic efficiency of the plant (Eltelib et al., 2006) [6]. Further, increasing the number of splits application of nitrogen promotes the plant growth; enhance leaf expansion and development by providing more nitrogen to the plant for uptake by reducing the losses in soil (Asim et al., 2012) [3]. These claims were also supported by Eltelib et al. (2006) [6] and Amanullah et al. (2007) [2].

Table 1: Effect of graded levels and split application of nitrogen on leaf area index (LAI) at various growth stages of hybrid maize

| Treatment                          | 45 DAS | 60 DAS | 75 DAS |
|-----------------------------------|--------|--------|--------|
| T1 - 250 kg N in 3 splits (RDN)   | 3.60   | 5.25   | 5.63   |
| T2 - 167 kg N in 3 splits (STCR)  | 2.70   | 4.37   | 4.67   |
| T3 - 225 kg N in 3 splits         | 3.45   | 4.92   | 5.36   |
| T4 - 200 kg N in 3 splits         | 3.25   | 4.67   | 4.98   |
| T5 - 175 kg N in 3 splits         | 2.95   | 4.45   | 4.75   |
| T6 - 150 kg N in 3 splits         | 2.65   | 4.20   | 4.48   |
| T7 - 150 kg N in 4 splits         | 3.32   | 5.39   | 5.74   |
| T8 - 200 kg N in 4 splits         | 3.02   | 5.05   | 5.40   |
| T9 - 175 kg N in 4 splits         | 2.79   | 4.72   | 5.13   |
| T10 - 150 kg N in 4 splits        | 2.42   | 4.22   | 4.51   |
| SEd                               | 0.05   | 0.09   | 0.10   |
| CD (P= 0.05)                      | 0.11   | 0.18   | 0.22   |

Fig 1: Effect of graded levels and split application of nitrogen on leaf area index (LAI) at various growth stages of hybrid maize

To further understand the impact of nitrogen application on plant height, Table 2 provides data on SPAD values of leaves and dry matter production for different treatment combinations.

Table 2: Effect of graded levels and split application of nitrogen on SPAD values and dry matter production (kg/ha) at various growth stages of hybrid maize

| Treatments                      | 30 DAS | 45 DAS | 60 DAS | 75 DAS | 30 DAS | 45 DAS | 60 DAS | Harvest |
|---------------------------------|--------|--------|--------|--------|--------|--------|--------|---------|
| T1 - 250 kg N in 3 splits (RDN) | 55.1   | 55.8   | 57.8   | 57.5   | 1350   | 5356   | 8220   | 17699   |
| T2 - 167 kg N in 3 splits (STCR)| 47.3   | 47.7   | 49.9   | 49.4   | 1083   | 4791   | 7625   | 15642   |
| T3 - 150 kg N in 3 splits       | 53.4   | 54.1   | 55.7   | 55.2   | 1291   | 5234   | 8043   | 16940   |
| T4 - 175 kg N in 3 splits       | 50.8   | 51.7   | 53.5   | 52.8   | 1225   | 5095   | 7794   | 16293   |

SPAD values of leaves
For SPAD values (Table 2), the application of nitrogen at 30 DAS at 250 kg/ha in three splits at basal (25%), 25 DAS (50%) and 45 DAS (25%) (T1) registered the highest SPAD value of 55.1 over the other treatments. The lowest value among the treatments was associated with application of nitrogen at 150 kg/ha in four equal splits at 7 DAS, 25 DAS, 45 DAS and 60 DAS (T10). The observations regarding SPAD values at 45 DAS recorded a similar trend in results as that observed at 30 DAS. At 60 DAS, the highest SPAD value of 58 was recorded with the application of 225 kg/ha nitrogen in four equal splits at 7 DAS, 25 DAS, 45 DAS and 60 DAS (T7). The lowest SPAD value among the treatment was registered with application nitrogen at 150 kg/ha in three splits at 7 DAS (25%), 25DAS (50%) and 45 DAS (25%) (T6). The observations at 75 DAS follow the similar trend in SPAD value as that observed at 60 DAS. This shows that the SPAD value of hybrid maize increased with increased dose of application of N as well as with extended split application up to 60 DAS. This is due to the fact that the time interval between application and crop uptake determines the length of exposure of fertilizer N to loss processes such as leaching and de-nitrification (El-Agodi et al., 2011) [9]. Thereby split application with proper timing of N reduces the chance of N losses and increased in N uptake to produce higher chlorophyll content (Vetsch and Randall, 2004) [21]. Due to this the extended split application maintains SPAD values at higher values as compared to SPAD values with higher dose of nitrogen.
Dry matter production
For dry matter production, the highest dry matter production (Table 2) of 1350 kg/ha at 30 DAS was associated with application of nitrogen at 250 kg/ha in three splits at basal (25%), 25 DAS (50%) and 45 DAS (25%) (T1). The lowest dry matter production of 1026 kg/ha was recorded with the application of nitrogen at 250 kg/ha in three splits at basal (25%), 25 DAS (50%) and 45 DAS (25%) (T2). Application of 150 kg/ha nitrogen in four equal splits at 7 DAS, 25 DAS, 45 DAS and 60 DAS (T10) recorded the lowest dry matter production recorded at 45 DAS has a comparable trend in soil N supply due to addition of nitrogenous fertilizer. These results were adheres to the results of Amanullah (2007) [2], (Pandy et al., 2000; Turgut, 2000) [12, 19].

Table 3: Effect of graded levels and split application of nitrogen on Crop Growth Rate (CGR) (g m⁻² day⁻¹) and Relative Growth Rate (RGR) (g g⁻¹ day⁻¹) at various growth stages of hybrid maize

| Treatments                  | 30-45 DAS | 45-60 DAS | 60 DAS - Harvest | 30-45 DAS | 45-60 DAS | 60 DAS - Harvest |
|-----------------------------|-----------|-----------|------------------|-----------|-----------|------------------|
| T₁ - 250 kg N in 3 splits   | 15.65     | 22.75     | 18.49            | 0.101     | 0.035     | 0.017            |
| T₂ - 167 kg N in 3 splits   | 13.16     | 19.89     | 15.03            | 0.095     | 0.028     | 0.014            |
| T₃ - 225 kg N in 3 splits   | 15.33     | 21.34     | 17.48            | 0.100     | 0.031     | 0.016            |
| T₄ - 200 kg N in 3 splits   | 14.52     | 20.87     | 16.12            | 0.099     | 0.029     | 0.014            |
| T₅ - 175 kg N in 3 splits   | 13.90     | 20.56     | 15.76            | 0.096     | 0.028     | 0.015            |
| T₆ - 150 kg N in 3 splits   | 12.85     | 19.25     | 13.70            | 0.094     | 0.025     | 0.013            |
| T₇ - 225 kg N in 4 splits   | 14.97     | 23.43     | 18.81            | 0.099     | 0.035     | 0.018            |
| T₈ - 200 kg N in 4 splits   | 14.39     | 22.17     | 17.93            | 0.097     | 0.032     | 0.016            |
| T₉ - 175 kg N in 4 splits   | 13.74     | 21.05     | 16.55            | 0.095     | 0.031     | 0.015            |
| T₁₀ - 150 kg N in 4 splits  | 12.63     | 19.73     | 14.42            | 0.092     | 0.027     | 0.013            |
| SEd                         | 0.32      | 0.43      | 0.30             | 0.0017    | 0.003     | 0.001            |
| CD (P = 0.05)               | 0.67      | 0.90      | 0.62             | 0.0035    | 0.006     | 0.002            |

Conclusion
Based on the results obtained from the present study that application of 225 kg N/ha of nitrogen in four equal splits at 7 DAS, 25 DAS, 45 DAS and 60 DAS (T₇) was found to be effective in terms of improving the growth and physiological attributes. Hence 225 kg N/ha in four equal splits is concluded as the optimum dose of nitrogen fertilizer for better growth and physiological attributes.

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