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

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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 T_1 at 15, 30, 45DAS and with T_7 at 60 and 75 DAS. At 45 DAS T_1 showed better results with all the physiological attributes. Similarly at 30 DAS dry mater production and SPAD value was higher with T_1. At 60 DAS T_7 showed better leaf area index, SPAD value and dry mater production. T_7 also showed significant results at 75 DAS with leaf area index and SPAD value. At harvest DMP was higher with T_7. For CGR and RGR, at 30 to 40 DAS T_1 showed higher results. Whereas from 40 to 60 DAS and 60 to Harvest T_7 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 (Seshaiah, 2000) [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 V_6 during the highest N uptake takes place. Therefore, maize responds to the belated N application (Binder *et al*., 2000) [4]. Generally the N application from V_8 to V_{10} growth stages could be the appropriate time of N supply to meets 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) [15, 11].

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 with an average rainfall of 856 mm. 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 $T_{1:}$ RDN (250 kg/ha) in 3 splits at basal (25%), 25 DAS (50%) and 45 DAS (25%), T_2: STCR (167 kg N/ha) in 3 splits at basal (25%), 25 DAS (50%) and 45 DAS (25%), T_3: 225 kg N/ha in 3 splits at 7 DAS (25%), 25 DAS (50%) and 45 DAS (25%), T_4: 200 kg N/ha in 3 splits at 7 DAS (25%), 25 DAS (50%) and DAS (25%), T_5: 175 kg N/ha in 3 splits at 7 DAS (25%), 25 DAS (50%) and 45 DAS (25%), T_6: 150 kg N/ha in 3 splits at 7 DAS (25%), 25 DAS (50%) and 45 DAS (25%), T_7: 225 kg N/ha in 4 equal splits at 7 DAS, 25 DAS, 45 DAS, 60 DAS, T_8: 200 kg N/ha in 4 equal splits at 7 DAS, 25 DAS, 45 DAS, 60 DAS, T_9: 175 kg N/ha in 4 equal splits at 7 DAS, 25 DAS, 45 DAS, 60 DAST_{10}: 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 T_2 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.

$$FN = 3.96\,T - 0.62\,SN - 0.69\,ON$$

$$FP_2O_5 = 1.56\,T - 1.93\,SP_2O_5 - 0.60\,OP$$

$$FK_2O = 1.66\,T - 0.27\,SK_2O - 0.49\,OK$$

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%) (T_1). 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 (T_7) produced significantly higher plant height. The lowest value of plant height at 15, 30 and 45 DAS was associated the treatment T_{10} (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%) (T_6).

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%) (T_1) 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 (T_{10}). At 60 DAS, application of nitrogen at 225 kg/ha in four equal splits at 7 DAS, 25 DAS, 45 DAS and 60 DAS (T_7) 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%) (T_6). 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
T_1 - 250 kg N in 3 splits (RDN)	3.60	5.25	5.63
T_2 - 167 kg N in 3 splits (STCR)	2.70	4.37	4.67
T_3 - 225 kg N in 3 splits	3.45	4.92	5.36
T_4 - 200 kg N in 3 splits	3.25	4.67	4.98
T_5 - 175 kg N in 3 splits	2.95	4.45	4.75
T_6 - 150 kg N in 3 splits	2.65	4.20	4.48
T_7 - 225 kg N in 4 splits	3.32	5.39	5.74
T_8 - 200 kg N in 4 splits	3.02	5.05	5.40
T_9 - 175 kg N in 4 splits	2.79	4.72	5.13
T_{10} - 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

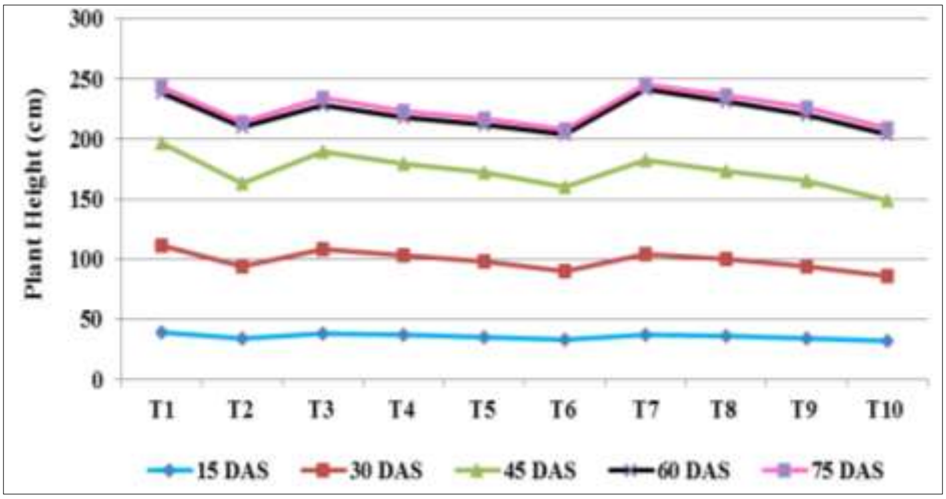

Fig 1: Effect of graded levels and split application of nitrogen on plant height (cm) at various growth stages of hybrid maize

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%) (T_1) 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 (T_{10}). 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 (T_7). 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%) (T_6). 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-Agrodi *et al.*, 2011) [5]. 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.

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

	SPAD values				Dry matter production (kg/ha)			
Treatments	30 DAS	45 DAS	60 DAS	75 DAS	30 DAS	45 DAS	60 DAS	Harvest
T_1 - 250 kg N in 3 splits (RDN)	55.1	55.8	57.8	57.5	1350	5356	8220	17699
T_2 - 167 kg N in 3 splits (STCR)	47.3	47.7	49.9	49.4	1083	4791	7625	15642
T_3 - 225 kg N in 3 splits	53.4	54.1	55.7	55.2	1291	5234	8043	16940
T_4 - 200 kg N in 3 splits	50.8	51.7	53.5	52.8	1225	5095	7794	16293

T_5 - 175 kg N in 3 splits	49.1	49.3	51.4	50.0	1154	4952	7638	15681
T_6 - 150 kg N in 3 splits	45.9	46.4	48.4	47.9	1038	4716	7479	15035
T_7 - 225 kg N in 4 splits	51.6	52.3	58.0	58.0	1230	5115	8237	18077
T_8 - 200 kg N in 4 splits	49.5	50.0	56.0	55.5	1165	4973	8065	17085
T_9 - 175 kg N in 4 splits	47.5	48.2	53.7	53.2	1097	4834	7886	16326
T_{10} - 150 kg N in 4 splits	45.1	44.5	48.6	48.1	1026	4595	7482	15064
SEd	0.7	0.8	0.9	0.8	27	56	73	291
CD (P= 0.05)	1.5	1.6	1.8	1.7	56	117	153	611

Dry matter production

For dry mater production, the highest dry mater 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%) (T_1). The lowest dry mater production of 1026 kg/ha was recorded with application of 150 kg N/ha in four equal splits at 7 DAS, 25 DAS, 45 DAS and 60 DAS (T_{10}). The trend of results on dry mater production recorded at 45 DAS has a comparable trend with the DMP observed at 30 DAS. At 60 DAS, application of N at 225 kg/ha in four equal splits at 7 DAS, 25 DAS, 45 DAS and at 60 DAS (T_7). Nitrogen applied at 150 kg/ha in three splits at 7 DAS (25%), 25 DAS (50%) and 45 DAS (25%) (T_6) recorded the lowest values of DMP. At harvest showed that application of 225 kg N/ha in four equal splits at 7 DAS, 25 DAS, 45 DAS and 60 DAS (T_7) results in significantly higher dry matter production. The lowest dry matter production was recorded with the application of 150 kg/ha of nitrogen in three splits at 7 DAS (25%), 25 DAS (50%) and 45 DAS (25%) (T_6).

The dry matter production (DMP) of a crop reflects its efficiency in utilizing the available resources. Therefore providing enough nitrogen at critical stages of crop growth by split application produced significantly higher DMP. Form the results it is also evident that the higher dose of application results in more dry matter production up to 60 DAS, wherein application of 250 kg N in three splits recorded the highest dry matter production. In general greater dry matter accumulation in maize is associated with greater leaf longevity which in turn could have been enhanced by increase 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].

Crop growth rate and Relative growth rate

At 30 to 45 DAS, highest crop growth rate (Table 3) (15.65 g m^{-2} day^{-1}) and relative growth rate (0.101 g g^{-1} day^{-1}) was observed with application of 250 kg N/ha applied in three splits at basal (25%), 25 DAS (50%) and 45 DAS (25%) (T_1). Application of 150 kg/ha of nitrogen in four equal splits at 7 DAS, 25 DAS, 45 DAS and 60 DAS (T_{10}) recorded the lowest crop growth rate and relative growth rate.

Observations at 45 to 60 DAS revealed that the highest crop growth rate (23.43 g m^{-2} day^{-1}) and relative growth rate (0.035 g g^{-1} day^{-1}) was registered with 225 kg/ha of nitrogen applied in four equal splits at 7 DAS, 25 DAS, 45 DAS and 60 DAS (T_7). The lowest crop growth rate and relative growth rate was associated with application of 150 kg/ha nitrogen in three splits at 7 DAS (25%), 25 DAS (50%) and 45 DAS (25%) (T_6). The crop growth rate and relative growth rate between 60 DAS to harvest showed a similar trend of results as that of CGR observed at 45 to 60 DAS. The CGR and RGR being derived from DMP over time helped these parameters to increase with the corresponding increase in DMP with increasing doses of N application as well as with delayed split application of N up to 60 DAS. The data of both CGR and RGR decreased from 60 DAS to harvest. This might be decrease leaf number and leaf area. The result of the present findings corroborates with the results of Jovanovic *et al.* (2004) [9].

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	CGR(g m^{-2} day^{-1})			RGR(g g^{-1} day^{-1})		
	30-45 DAS	45-60 DAS	60 DAS- Harvest	30-45 DAS	45-60 DAS	60 DAS- Harvest
T_1 - 250 kg N in 3 splits (RDN)	15.65	22.75	18.49	0.101	0.033	0.017
T_2 - 167 kg N in 3 splits (STCR)	13.16	19.89	15.03	0.095	0.028	0.014
T_3 - 225 kg N in 3 splits	15.33	21.34	17.48	0.100	0.031	0.016
T_4 - 200 kg N in 3 splits	14.52	20.87	16.12	0.099	0.029	0.014
T_5 - 175 kg N in 3 splits	13.90	20.56	15.76	0.096	0.028	0.015
T_6 - 150 kg N in 3 splits	12.85	19.25	13.70	0.094	0.025	0.013
T_7 - 225 kg N in 4 splits	14.97	23.43	18.81	0.099	0.035	0.018
T_8 - 200 kg N in 4 splits	14.39	22.17	17.93	0.097	0.032	0.016
T_9 - 175 kg N in 4 splits	13.74	21.05	16.55	0.095	0.031	0.015
T_{10} - 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 (T_7) 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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