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Response of enhanced dose and differential time of nitrogen application on growth, yield and economics of irrigated hybrid maize (*Zea mays* L.)

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Abstract
A field experimental study was conducted during *rabi* season (2016-17) at Research farm of Tamil Nadu Agricultural University, Coimbatore to study the effect of enhanced dose and differential time of nitrogen application on the performance of irrigated hybrid maize (*Zea mays* L.). The experiment was laid out in a Factorial Randomized Block Design with three replications. The treatments comprised of two factors, in factor A, nitrogen at two levels *viz.*, N_1 - Recommended dose (250 kg/ha), N_2 - Enhanced (125% of RD) dose (313 kg/ha) and factor B consists of differential time of nitrogen application *viz.*, T_1 - application of nitrogen in three uneven splits (25% as basal, 50% on 30 DAS and 25% on 45 DAS), T_2 - application of nitrogen in four even splits (25% each at basal, 15 DAS, 30 DAS and 45 DAS), T_3 - application of nitrogen in four uneven splits (20% as basal, 30% on 30 DAS, 30% on 45 DAS and 20% on 60 DAS), T_4 - application of nitrogen in five even splits (20% each at basal, 15 DAS, 30 DAS, 45 DAS and 60 DAS) and T_5 - application of nitrogen in five uneven splits (10% as basal, 20% on 15 DAS, 30% on 30 DAS, 30% on 45 DAS and 10% on 60 DAS). The growth characters *viz.,* plant height, dry matter production, leaf area index and CGR were significantly influenced by application of nitrogen at enhanced dose (125% RD) when compared to the recommended dose (100% RD). Enhanced N dose (125% RD) also showed a significant increase in yield attributes *viz.,* cob length, cob weight, number of grains per cob hundred grain weight, shelling percentage, grain yield and stover yield of maize over the recommended dose. Among the differential time of nitrogen application, nitrogen in five even splits was comparable with application of N in five uneven splits in producing higher grain and stover yield of hybrid maize.

Keywords: Enhanced dose, recommended dose, differential time, split

Introduction
Maize (*Zea mays* L.) known as "Queen of Cereals" is having the highest genetic yield potential among the cereals. It is a versatile crop that can be grown over a wide range of agro climatic zones due to its C_4 nature. Maize is a staple food for human being and quality feed for animals, besides serves as a basic raw material to thousands of industrial products. It registered the highest growth rate among all food grains and in India, maize constitutes around 9% of the total cereals production and ranks third most important food grain after rice (42%) and wheat (38%). India is currently among top five exporters of maize in the world. However, maize is an exhaustive crop which requires macro as well as micro nutrients for attaining maximum growth and yield. Among different essential nutrients, nitrogen is highly limiting in Indian soils that exerts a profound effect on plant growth. Nitrogen is the most critical element and it plays a key role in many physiological as well as metabolic functions (Balasubramaniyan and Palaniappan, 2001) [4]. It is an essential constituent of protein and nucleic acids. Moreover, it influences cell size, leaf area, and photosynthetic activity(Lawrence *et al.*, 2008) [11].Maize requires only a fraction of nitrogen during the seedling stage, but its need is rapid once it reaches the knee high stage and by about two weeks, reaches tasseling under favorable conditions. Plant needs for nitrogen will not end at the tasseling stage and about one-third of nitrogen requirement still have to be met during the reproductive period. Uptake of nitrogen initiates during the middle of vegetative growth period with maximum rate of nitrogen uptake occurring near silking stage (Hanway, 1962) [9]. Crop phenology is one of the most important aspects of crop yield determination (Carcova and Oteguai, 2001) [5]. Therefore, it is essential for predicting growth and physiological responses under varying field conditions. Gungula *et al.* (2007) [7] noted that there will be more synchrony in flowering with application of higher N. Synchronized application of nitrogen helps the plant to utilize nutrients at the time of its need. The beneficial effects of nitrogen on maize crop production are well documented. The potentiality of maize crop for its growth and development can be fully exploited by adopting suitable agronomic practices and efficient nutrient anagement is one such important strategy to enhance its productivity.

Materials and Methods

The effects of enhance dose and time of nitrogen application on the response of irrigated hybrid maize (*Zea mays* L.) was investigated at the agronomic research farm of TNAU during *rab*i season. The study area is geographically situated in Western Agro- Climatic Zone of Tamil Nadu with the coordinates of 11° N latitude, 77° E longitude and an altitude of 426.7 m above mean sea level. The soil type of experimental site is clay loam in texture, slightly alkaline pH (8.34) with low soluble salts (EC 1.34) and with low in available nitrogen (198 kg/ha), medium in available phosphorus (19.5 kg/ha) and high in available potassium (648 kg/ha). During the cropping period (Sept 2016 – Jan 2017), a total rainfall of 139.7 mm and a mean solar radiation 352.2cal/cm^2/day were received. The mean maximum and minimum temperatures were31.8ºC and 21.5ºC, respectively. TNAU maize hybrid CO 6 was used for the experimental study. The recommended cultural practices were carried out. The experimental trial was laid out in Factorial Randomized Block Design with three replications. The treatments comprised of two factors, in factor A, nitrogen at two levels *viz.*, N_1 - Recommended dose (250 kg/ha), N_2 - Enhanced (125% of RD) dose (313 kg/ha) and factor B consists of different time of nitrogen application *viz.*, T_1 - application of nitrogen in three uneven splits (25% as basal, 50% on 30 DAS and 25% on 45 DAS), T_2 - application of nitrogen in four even splits (25% each at basal, 15 DAS, 30 DAS and 45 DAS), T_3 - application of nitrogen in four uneven splits (20% as basal, 30% on 30 DAS, 30% on 45 DAS and 20% on 60 DAS), T_4 - application of nitrogen in five even splits (20% each at basal, 15 DAS, 30 DAS, 45 DAS and 60 DAS) and T_5 - application of nitrogen in five uneven splits (10% as basal, 20% on 15 DAS, 30% on 30 DAS, 30% on 45 DAS and 10% on 60 DAS).

The observations on growth parameters like plant height, dry matter accumulation, leaf area index, CGR, grain yield and stover yield were recorded as per the standard procedures. Soil and plant analysis were done and nutrient uptake was worked out. Soil available N, P and K status after harvest of the crop were calculated. It was done mainly to evaluate the effect of the treaments over the crop growth, nutrient uptake and soil nutrient status at periodic intervals and ultimately its influence over yield and yield attributes.

Result and Discussion

The effect of N dose and time of application had a significant influence over the growth parameters. Plant height is a direct index to assess the growth and vigour of the plant. In general, maximum plant height was recorded with application of enhanced N dose (125% N) when compared to the recommended N dose (100% N) (Table.1.). When the N dose was enhanced from 100% RDN to 125% RDN, plant height increased by 4.2% at harvest stage. The increase in plant height with respect to increased N application indicate maximum vegetative growth of the plants under higher N availability. These results are in conformity with the results obtained by Akbar *et al.* (1999) [1] who found that plant height in maize increased with increase in N rate. Application of N in four even splits (25% each at basal, 15, 30 and 45 DAS) produced taller plants as compared to other split applications. The possible reasons might be due to steady supply of the nutrient to plants particularly during the vegetative phase and more accumulation in plant. This might have resulted in more synthesis of nucleic acids, amino acids, amide substances in meristematic tissues that ultimately enhanced multiplication of cell division and thereby increased the plant height. Similar findings were reported by Palled and Shenoy (2006) [14].

Table 1: Effect of enhanced dose and time of nitrogen application on plant height (cm) at different growth stages of hybrid maize

Treatments	15 DAS			30 DAS		45 DAS			60 DAS			Harvest		
	N_1	N_2	Mean	N_1	Mean	N_1	N_2	Mean	N_1	N_2	Mean	N_1	N_2	Mean
T_1	29.5	29.8	29.7	81.5	83.4	171.3	181.0	176.2	223.0	235.3	229.2	230.3	240.0	235.2
T_2	29.4	29.7	29.6	90.9	93.0	182.3	190.0	186.2	247.3	256.0	251.7	255.0	262.0	258.5
T_3	28.8	28.9	28.9	79.1	80.8	159.7	170.6	165.2	233.6	245.3	239.5	237.0	249.3	243.2
T_4	28.7	29.2	29.0	88.9	91.3	176.0	188.0	182.0	241.0	253.3	247.2	251.0	262.6	256.8
T_5	28.5	28.7	28.6	88.1	90.0	175.3	186.0	180.7	237.0	248.6	242.8	245.0	256.0	250.5
Mean	29.0	29.3		85.7		172.9	183.1		236.4	247.7		243.7	254.0	
	N	T	N x T	N	N x T	N	T	N x T	N	T	N x T	N	T	N x T
SEd	0.26	0.42	0.59	1.5	3.4	3.6	5.7	8	3.7	5.9	8.3	3.3	5.2	7.3
CD(0.05)	NS	NS	NS	3.2	NS	7.5	11.9	NS	7.8	12.4	NS	6.9	10.9	NS

Table 2: Effect of enhanced dose and time of nitrogen application on dry matter production (kg/ha) at different growth stages of hybrid maize

Treatments	15 DAS			30 DAS			45 DAS			60 DAS			Harvest		
	N_1	N_2	Mean	N_1	N_2	Mean	N_1	N_2	Mean	N_1	N_2	Mean	N_1	N_2	Mean
T_1	73	77	75	1693	1794	1744	3943	4463	4203	11133	12600	11867	13433	15434	14433
T_2	72	77	74	1943	2103	2023	4537	5318	4928	13267	15733	14500	15217	18299	16758
T_3	71	75	73	1662	1756	1709	3831	4384	4108	10800	12533	11667	13134	15367	14250
T_4	71	75	73	1927	2069	1998	4376	5101	4739	12600	15000	13800	15933	19100	17516
T_5	70	74	72	1883	2037	1960	4251	4993	4622	12067	14533	13300	15233	18399	16816
Mean	71	75		1822	1952		4188	4852		11973	14080		14680	17546	
	N	T	N x T	N	T	N x T	N	T	N x T	N	T	N x T	N	T	N x T
S Ed	1	2	3	33	52	73	81	129	182	233	368	521	288	455	644
CD (0.05)	3	NS	NS	69	109	NS	171	270	NS	489	774	NS	605	957	NS

The results of the experiment indicated that the maize DMP at various growth stages increased significantly with enhanced N dose (Table.2.).The increase in dry matter at enhanced dose (*i.e.*, 125% RDN) when compared to the recommended N dose (100% RDN)might be due to the increased plant height, leaf area, LAI and LAD, in turn resulting in more photo synthates accumulation. Greef *et al.* (1999) [6] reported a positive correlation between N rate and dry matter yield in maize. Similarly, dry matter at various growth stages had increased significantly with increase in number of N splits. Higher DMP was noticed in more number of splits *i.e.,* application of N in four even splits. And it was comparable with N application in five (even and uneven) splits. Application of N at later vegetative stage of the crop extended the regular availability of nutrient in soil (Amanullah *et al.,* 2009) [2] and could produce relatively more assimilates. This might be the possible cause of greater DMP of maize with increased number of N split applications. Similar findings were reported by several researchers (Rajcan and Tollenaar, 1999; Mariga *et al.,* 2000; Scharf *et al.,* 2002) [16, 12] .

Table 3: Effect of enhanced dose and time of nitrogen application on leaf area index at different growth stages of hybrid maize

Treatments	15 DAS			30 DAS			45 DAS			60 DAS			Harvest		
	N_1	N_2	Mean	N_1	N_2	Mean	N_1	N_2	Mean	N_1	N_2	Mean	N_1	N_2	Mean
T_1	0.26	0.27	0.26	1.93	1.96	1.95	3.20	3.60	3.40	4.33	4.80	4.56	2.70	3.26	2.98
T_2	0.25	0.27	0.26	2.16	2.36	2.26	3.66	4.40	4.03	4.80	5.53	5.16	3.00	3.63	3.31
T_3	0.25	0.27	0.26	1.90	1.96	1.93	3.13	3.53	3.33	4.40	5.20	4.80	3.10	3.73	3.41
T_4	0.25	0.27	0.26	2.16	2.33	2.25	3.56	4.13	3.85	4.63	5.26	4.95	3.53	3.80	3.66
T_5	0.24	0.26	0.25	2.13	2.23	2.18	3.53	4.03	3.80	4.60	5.20	4.90	3.23	3.76	3.50
Mean	0.25	0.27		2.06	2.17		3.42	3.94		4.55	5.20		3.11	3.64	
	N	T	NXT	N	T	N x T	N	T	N x T	N	T	N x T	N	T	N x T
SEd	0.004	0.007	0.01	0.033	0.053	0.076	0.066	0.105	0.149	0.088	0.139	0.197	0.061	0.096	0.137
CD(0.05)	0.009	NS	NS	0.071	0.112	NS	0.141	0.223	NS	0.185	0.294	NS	0.128	0.204	NS

The data on table.3.indicates that Leaf area index showed a steady increase up to 60 DAS and thereafter a declining trend was noticed towards harvest stage. The increase in LAI was possibly due to higher N level which increased the LAI because of increased chlorophyll content of plants influencing the cell and tissue growth with increased photosynthetic efficiency. The results are in concordance with the findings of Oscar and Tollenaar (2006) [16].Application of N in four even splits at basal, 15, 30 and 45 DAS enhanced the LAI at 30, 45 and 60 DAS, while N application in five even splits produced higher LAI at harvest. Application of N in maximum number of splits (four or five) and up to later stage of crop growth because of optimum and timely availability of N had increased the photosynthetic activity and LAI of maize. The results are in accordance with the findings of Pandey *et al.* (2015) [15]. However there was no significant interaction effect observed between the nitrogen doses and time of application on influencing the leaf area index of maize.

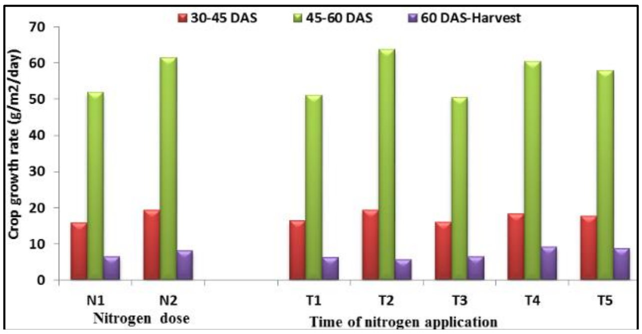

Fig 1: Effect of enhanced dose and time of nitrogen application on crop growth rate (g/m^2/day) at periodic growth intervals to till harvest stage of hybrid maize

The graphical data represented figure .1. Revealed that nitrogen dose and time of application had significantly influenced the CGR of hybrid maize. Among them, application of enhanced N dose (125% RD) registered higher CGR compared to recommended N dose (N_1) at the respective growth stage periods. Increase in CGR with increased N application might be due to larger LAI, as CGR is a product of LAI and NAR as reported by Hammad *et al.* (2011) [8]. With regard to time of N application, application of N in four even splits (T_2) recorded the highest CGR values of 13.0, 19.36 and 63.82 g/m^2/day in 15-30 DAS, 30-45 DAS and 45-60 DAS, respectively. However, the treatment was statistically comparable with treatments T_4 and T_5 in 15-30 DAS while with the treatment T_4 alone in 30-45 DAS and 45-60 DAS. At 60 DAS - harvest period, application of N in five even splits (T_4) registered significantly highest CGR value of 9.29 g/m^2/day. The lowest CGR of 13.00, 19.36 and 63.82 g/m^2/day was recorded with application of N in four uneven splits (T_3) at 15-30 DAS, 30-45 DAS and 45-60 DAS, respectively, while it was treatment T_2 (5.65 g/m^2/day) at 60 DAS-harvest period. It was observed no significant difference between the N doses and time of application in their interaction effect on CGR of maize. Grain yield is the main economic output of a crop. It is the cumulative behavior of all the yield attributes. The effectiveness of enhanced N dose and its scheduling is ultimately determined by the grain yield obtained. Application of nitrogen as enhanced dose (125% RDN) had produced higher grain yield (6557 kg/ha) significantly over the recommended N dose (100% RD) with an additional increment in grain yield of 7.5 per cent (Table .4.). The resulted increase in grain yield is the reflection of increased performance of the growth and yield attributes due to the application of enhanced N over the other. The results are in agreement with the findings of Lawrence *et al.* (2008) [11], who reported that grain yield increased with increasing N rates. Application of N in five even splits at basal, 15, 30, 45 and 60 DAS produced significantly higher grain yield (6764 kg/ha) than other split applications. Such a remarkable difference in grain yield is the consequent achievement of improved growth and yield attributes, resulted due to steady and continuous N supply at the periods of actual need of the crop and reduced losses due to leaching and DE nitrification. This is in consonance with the remarks of Amanullah and shah (2010) [3]. Stover yield also showed the similar trend as that of grain yield. It was significantly higher with enhanced N dose (125% RD) than with the recommended dose (100% RDN) which could be attributed to the favourable influence of increased N on vegetative growth rather than grain yield. Application of N in five even splits produced higher stover yield of 13403 kg/ha, but comparable with N application in five uneven splits (13290 kg/ha).This revealed that application of N in more number of splits delayed the phenological development, increased CGR, LAI and plant height, which ultimately resulted in higher stover yield when compared to lesser splits. The results are in agreement with the findings of Roshan Chaudhary *et al.* (2013) [17].

Table 4: Effect of enhanced dose and time of nitrogen application on grain yield (kg/ha) and stover yield (kg/ha) on hybrid maize

Treatments	Grain yield (kg/ha)			Stover yield (kg/ha)		
	N1	N2	Mean	N1	N2	Mean
T1	5776	5984	5880	12063	12566	12315
T2	6001	6509	6255	12535	13603	13069
T3	5898	6366	6132	11386	12435	11911
T4	6513	7014	6764	12911	13896	13403
T5	6315	6914	6615	12795	13786	13290
Mean	6101	6557		12338	13257	
	N	T	N x T	N	T	N x T
SEd	137	217	307	284	449	635
CD (P =0.05)	288	455	NS	597	943	NS

Economic efficiency and viability of crop production are dependent on higher crop productivity with lesser cost of cultivation which could result in better economic parameters like higher net return and B: C ratio. In general during the course of experimentation, cost of cultivation was higher with application of enhanced N (125% RDN) as compared to the recommended dose (100%) due to increased cost of N fertilizer. In addition, N application in five splits required comparatively higher cost because of extra labour involved in top dressing of fertilizer over other split applications. Maximum gross return, net return and B:C ratio were achieved with the application of enhanced N dose (125% RDN) with five even splits at basal, 15, 30, 45 and 60 DAS and it was followed by enhanced N application with five uneven splits (Fig. 2). This was attributed to the production of higher grain and stover yields among other treatment combinations. Though, the cost of cultivation was also high with enhanced N dose and increased splits, increased gross return was so much that it could not only compensated the cost but also increased net return to the maximum. B: C ratio followed the same trend as that of gross return and net return among the treatments. The results are in conformity with the findings of Sankaran *et al.* (2005) [18] and Kumar *et al.* (2014) [10].

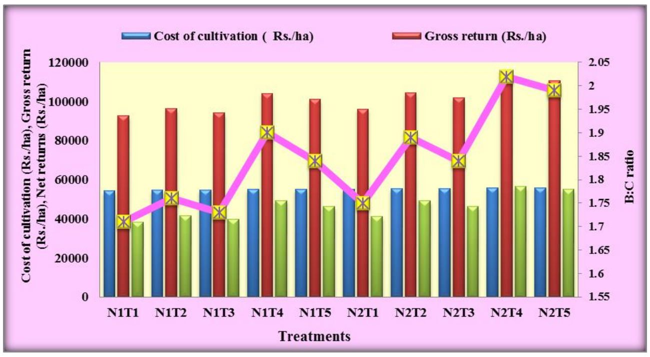

Fig 2: Effect of nitrogen dose and time of application on economics of hybrid maize

Conclusion

Application of enhanced dose of nitrogen @ 125% RDN (313 kg N/ha) has significantly improved the growth and yield attributes of hybrid maize CO -6 under irrigated conditions. It could be concluded that the application of enhanced nitrogen dose @ 125% RD (313 kg/ha) in five even splits (20% each on basal, 15, 30, 45 and 60 DAS) was found to maximize the productivity and profitability of TNAU maize hybrid CO 6 under irrigated conditions.

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