

Original Research Article

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Effect of Spatial Pattern and Nitrogen Scheduling on Yield Attributes, Yield and Harvest Index in Maize (*Zea mays* L.)

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ABSTRACT

Keywords

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Field experiments were conducted at Department of Agronomy of Tamil Nadu Agricultural University, Coimbatore. The main objective of the study is to evaluate various planting pattern and nitrogen scheduling approaches on yield attributes, yield and harvest index of maize. The experiments were laid out in split plot design and replicated thrice. Main plots treatments comprised of spatial pattern viz., 60 x 25, 30 x 30, 35 x 35, 40 x 40, 45 x 45 and 50 x 50 cm. Three nitrogen scheduling approaches were assigned to sub plots. Fixed growth stage based N scheduling approaches were compared with Leaf colour chart based (LCC) N management. The results of the study revealed that planting at 35 x 35 cm resulted more number of grain rows cob⁻¹ (15.1 and 15.4). Whereas other yield attributes like of grains row⁻¹ (34.04 and 34.53), of grains cob⁻¹ (522 and 531) and test weight (42.27 and 44.97) were maximum under 50 x 50 cm pattern. LCC based N scheduling significantly increased the yield attributes. Outcome of this study indicated that spatial pattern of 35 x 35 cm with LCC based N management recorded maximum grain yield (11292 and 11558 kg ha⁻¹), than other treatments.

Introduction

Maize is a miracle crop called as queen of cereals and is grown in more than 166 countries occupying 168 million hectares with production of 854 million tonnes and productivity of 5120 kg ha⁻¹. In general, maize was cultivated in larger distance between rows than within the same row. Maddonni *et al.*, (2001) have detected that maize leaf orientation in horizontal plane (*i.e.*, leaf azimuth distribution) can react filling empty spaces (e.g., intra-row or inter-row) due to plant spatial arrangement. Grain yield is a function of actual improvement in light

interception at silking stage in narrow row spaced plants (Andrade *et al.*, 2002). Plant population/unit land area plays an important role in the radiation use efficiency (RUE) and subsequently the grain yield. The grain yield is also determined by the number of kernels/plant and kernel weight during the grain filling period also substantially increase the grain yield by more translocation of assimilates especially at post silking period and this mostly depends on the intercepted photosynthetically active radiation (IPAR) and RUE (Borras *et al.*, 2003).

Very few researchers explored the benefits of square planting in maize. At flowering stage, corn grown under square pattern intercepted more PAR than rectangular arrangement (Acciaresi and Chidichimo, 2007) and also better resource utilization and lesser weed competition leads to higher grain yield. The productivity of maize is determined by several factors including nitrogen factor. Traditionally, N fertilizers have been applied uniformly across entire field while ignoring spatial variation in crop N needs within crop fields (Khosla *et al.*, 2010).

This resulted too little N reduces yields while too much N reduces nitrogen use efficiency. Application of higher level of N fertilizer is very common among Indian farmers, who attribute maize crop greenness and growth response to N application. Chlorophyll meter is expensive (US\$1200-1800/unit) to be owned by farmers in developing countries which restricts its wide spread use by farmers. The leaf colour chart was developed for rice and is also suitable for maize as indicated by spectral reflectance measurements performed on rice and maize leaves (Witt *et al.*, 2005).

LCC proves to be an effective tool in detecting the maize additional N need, giving higher yields and increased profit compared with fixed rates (Pasuquin *et al.*, 2012). There is need to investigate N management with tools like LCC for site specific nitrogen management in maize.

Information on the square planting pattern to explore the available resources and suitable N scheduling practices to maximize maize yield is meagre. Hence, this study has been contemplated on hybrid maize with various square crop geometry levels and N scheduling approaches with the following objectives include studying the effect of spatial pattern on yield attributes; to study the influence of spatial pattern on yield; and to evaluate nitrogen approaches on yield attributes.

Materials and Methods

The average maximum and the minimum temperature were 30.2°C and 21.1°C and 31.0°C and 21.5°C, respectively. The total rainfall received during the cropping period was 84.6 mm and 202.8 mm, the average relative humidity at 0722 hrs and 1422 hrs were 89.7 per cent, 57.2 per cent and 86.0 per cent and 50.7 per cent respectively, with an average bright sunshine hour of 6.3 and 6.5 hours with an evaporation of 3.9 and 4.8 mm day⁻¹. The mean solar radiation recorded was 356.3 and 355.9 Cal cm⁻² day⁻¹, respectively. The soil of the experimental site was clay loam in texture belonging to Irugur series and taxonomically known as Typic Ustropepts under USDA classification. Field experiments were laid out in split plot design and treatments were replicated thrice. Maize hybrid, NK 6240 was used as test crop. Main plot treatments were viz., M₁- 60 x 25, M₂- 30 x 30, M₃- 35 x 35, M₄- 40 x 40, 45 x 45 and 50 x 50 cm. Nitrogen scheduling approaches of Recommended dose of nitrogen (RDN) @ 150 kg ha⁻¹ in 3 splits as 25, 50 and 25 per cent at basal, 25 and 45 DAS, N₂- RDN @ 150 kg ha⁻¹ in 4 splits each 25 per cent at basal, 15, 30 and 45 DAS, Leaf colour chart (LCC) based nitrogen scheduling (whenever LCC critical value falls below 5, top dressing of N @ 30 kg ha⁻¹) were imposed. The recommended entire dose (75 kg ha⁻¹) of P₂O₅ was applied basally. The K₂O (75 kg ha⁻¹) was applied in two equal split doses viz., basal and with first top dressing of nitrogen.

The mean of grain rows cob⁻¹, of grains row⁻¹, of grains cob⁻¹ was counted from the cobs obtained from five sample plants and expressed in numbers cob⁻¹. The randomly selected 100 grains were air dried for each treatment (in three replications) and weight was recorded. The average was arrived and expressed in g. The cobs of the sample plants of the net plot area of each treatment were shelled separately. The grain weight to the

entire cob weight was computed and the mean for each treatment was expressed in percentage. The cobs from the net plot were harvested separately. The cobs were sun dried, shelled, cleaned and grain yield was recorded for individual treatment at 14 per cent seed moisture and expressed in kg ha^{-1} .

After the harvest of cobs, the stover in the net plot area were cut close to the ground level and left in the field for three days for sun drying. After drying, weight of stover from each plot was recorded and expressed in kg ha^{-1} . Harvest Index was calculated from the dry weight of grain and total dry weight using the formula of Yoshida *et al.*, (1972) as given below.

$$\text{HI} = \frac{\text{Economic yield (kg ha}^{-1}\text{)}}{\text{Biological yield (kg ha}^{-1}\text{)}}$$

The data collected were statistically analyzed as suggested by Gomez and Gomez (2010).

Results and Discussion

Maize crop planted at 35×35 cm registered more No. of rows cob^{-1} (15.1 and 15.4) during 2011 and 2012, respectively. Whereas, Spatial pattern of 50×50 cm recorded lucidly more of grains row^{-1} (34.04 and 34.53) and of grains cob^{-1} (522 and 531) than narrow pattern. Similarly, hundred grains weight also more (42.27 and 44.97 g) under this pattern. Nitrogen scheduling also significantly influenced the No. of rows cob^{-1} and higher values (14.7 and 15.0) were registered under LCC based N scheduling than other treatments. Similarly, N scheduling based on LCC recorded more of grains row^{-1} (32.03 and 32.51), of grains cob^{-1} (479 and 496) than other treatments.

The test weight of maize grain was also maximum (41.45 and 43.47 g) under this N

management strategy. Spatial pattern and N scheduling treatments had no significant effect on shelling percentage of maize cob. Interaction effect was not observed between spatial pattern and N scheduling with respect to yield attributes (Table 1).

Among the different spatial treatments, maize planted at 35×35 cm resulted in achieving higher maize grain yield (10337 and 10029 kg ha^{-1}) during 2011 and 2012, respectively and was superior over others (Tables 2 and 3). Maize crop nourished through LCC based N application recorded significantly higher grain yield (9253 and 9378 kg ha^{-1}) and it was significantly differed from the other treatments.

The interaction effect observed between crop geometry and N scheduling approaches was significant. The combination of LCC based N management and planted at 35×35 cm was found to record higher grain yields (11292 and 11558 kg ha^{-1}) than other combinations. Spatial pattern and N scheduling approaches significantly influenced the stover yield as that of grain yield. Higher stover yield (20666 and 20439 kg ha^{-1}) was recorded under crop geometry treatment of 30×30 cm and it was significantly differed from other treatments. Marked difference of maize stover yield was manifested due to nitrogen scheduling methods and higher yield (16778 and 16270 kg ha^{-1}) realized under LCC based N management.

The mean data pertaining to harvest index using grain and stover yields are shown in Tables 2 and 3. Higher HI value of 0.37 was recorded under crop geometry of 35×35 cm and it was significantly different from other treatments. Maize crop supplied with LCC based N resulted in achieving a higher HI (0.35 and 0.36) than others.

Table.1 Effect of spatial pattern and nitrogen scheduling on yield attributes of maize

Treatments	No. of grain rows cob ⁻¹		No. of grains row ⁻¹		No. of grains cob ⁻¹		Shelling percentage		100 grain weight (g)	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
Main plot: Spatial pattern										
M₁ - 60 × 25 cm	14.7	14.9	29.43	29.86	428	444	81.2	83.4	37.85	39.49
M₂ - 30 × 30 cm	13.5	13.7	27.33	27.71	382	405	80.3	82.3	36.65	38.89
M₃ - 35 × 35 cm	15.1	15.4	30.16	30.63	442	463	81.4	82.2	39.40	41.26
M₄ - 40 × 40 cm	14.6	14.8	31.70	32.18	477	491	81.1	81.8	40.97	43.04
M₅ - 45 × 45 cm	13.8	14.0	33.70	34.20	501	513	79.5	79.7	41.95	43.57
M₆ - 50 × 50 cm	13.7	13.9	34.04	34.53	522	531	79.1	80.1	42.27	44.97
SEm	0.3	0.3	0.88	0.89	11	12	2.3	1.4	1.14	1.24
C.D (P=0.05)	0.8	0.7	1.97	2.00	27	27	NS	NS	2.55	2.76
Sub plot: Nitrogen scheduling										
N₁	14.0	14.2	30.19	30.63	438	455	79.9	81.3	38.76	41.31
N₂	14.1	14.3	30.95	31.41	458	473	80.4	81.8	39.34	40.83
N₃	14.7	15.0	32.03	32.51	479	496	80.9	81.6	41.45	43.47
SEm	0.2	0.3	0.51	0.52	8.0	8	1.3	0.8	0.66	0.85
C.D (P=0.05)	0.5	0.6	1.06	1.08	17	17	NS	NS	1.36	1.76
Interaction (M x N)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

N₁- Recommended dose of nitrogen (RDN) @ 150 kg ha⁻¹ in 3 splits; N₂- RDN @ 150 kg ha⁻¹ in 4 splits, N₃- LCC based N application

Table.2 Grain yield (kg ha⁻¹), Stover yield (kg ha⁻¹) and Harvest index of maize as influenced by different spatial pattern and nitrogen scheduling approaches during 2011

Treatments	Grain yield (kg ha ⁻¹)				Stover yield (kg ha ⁻¹)				Harvest index			
	N ₁	N ₂	N ₃	Mean	N ₁	N ₂	N ₃	Mean	N ₁	N ₂	N ₃	Mean
M₁ - 60 × 25 cm	9278	9875	10829	9994	18333	17133	18333	17933	0.33	0.36	0.37	0.35
M₂ - 30 × 30 cm	7510	9097	8807	8471	20666	19333	22000	20666	0.26	0.32	0.28	0.29
M₃ - 35 × 35 cm	9544	10175	11292	10337	17000	16666	17668	17111	0.36	0.38	0.39	0.37
M₄ - 40 × 40 cm	7900	8462	9534	8632	15333	15333	15668	15445	0.34	0.35	0.38	0.35
M₅ - 45 × 45 cm	7779	6604	7855	7413	12000	12333	14335	12889	0.39	0.34	0.35	0.36
M₆ - 50 × 50 cm	6024	6107	7202	6444	11833	12000	12666	12166	0.33	0.33	0.36	0.34
Mean	8006	8387	9253		15861	15466	16778		0.33	0.35	0.35	
	M	N	M at N	N at M	M	N	M at N	N at M	M	N	M at N	N at M
SEm	376	191	536	467	577	311	848	761	0.004	0.002	0.007	0.006
CD (P=0.05)	837	394	1149	965	1286	642	NS	NS	0.011	0.005	0.015	0.013

N₁- Recommended dose of nitrogen (RDN) @ 150 kg ha⁻¹ in 3 splits, N₂- RDN @ 150 kg ha⁻¹ in 4 splits, N₃- LCC based N application

Table.3 Grain yield (kg ha⁻¹), Stover yield (kg ha⁻¹) and Harvest index of maize as influenced by different spatial pattern and nitrogen scheduling approaches during 2012

Treatments	Grain yield (kg ha ⁻¹)				Stover yield (kg ha ⁻¹)				Harvest index			
	N ₁	N ₂	N ₃	Mean	N ₁	N ₂	N ₃	Mean	N ₁	N ₂	N ₃	Mean
M₁ - 60 × 25 cm	8983	8821	11084	9629	15820	16382	17330	16511	0.36	0.35	0.39	0.36
M₂ - 30 × 30 cm	7936	7815	8383	8045	18202	20618	22497	20439	0.30	0.27	0.27	0.28
M₃ - 35 × 35 cm	8649	9879	11558	10029	17139	16476	17639	17084	0.33	0.37	0.39	0.36
M₄ - 40 × 40 cm	7185	8259	9379	8274	13214	12941	14158	13438	0.35	0.39	0.40	0.38
M₅ - 45 × 45 cm	7407	7396	8123	7642	13299	13370	13552	13407	0.35	0.35	0.37	0.36
M₆ - 50 × 50 cm	6628	7134	7740	7167	10830	11555	12445	11610	0.38	0.38	0.38	0.38
Mean	7798	8217	9378		14751	15224	16270		0.34	0.35	0.36	
	M	N	M at N	N at M	M	N	M at N	N at M	M	N	M at N	N at M
SEm	462	205	617	501	598	393	987	962	0.015	0.007	0.021	0.017
CD (P=0.05)	1029	422	1330	1035	1333	811	NS	NS	0.034	0.014	0.045	0.035

N₁- Recommended dose of nitrogen (RDN) @ 150 kg ha⁻¹ in 3 splits

N₂ - RDN @ 150 kg ha⁻¹ in 4 splits

N₃ - LCC based N application

Yield attributes

The spacing of 35 × 35 cm found to record more No. of grain rows cob⁻¹ compared to rest of the spacing levels on contrary, closer spacing of 30 × 30 cm recorded minimum number of grain rows cob⁻¹. This might be due to closer spacing reduced ear shoot growth which resulted fewer spikelet primordia transformed into functional florets by the time of flowering. The limited carbon and nitrogen supply to the ear stimulates young kernel abortion immediately after fertilization (Sangoi, 2001). Similar results were reported by Abuzar *et al.*, (2011) in maize. The No. of grains row⁻¹, No. of grains cob⁻¹ and hundred grain weight were significantly higher in 50 × 50 cm patter than other treatments. This could be attributed to lesser competition among plants within rows for light, water and nutrients which might have enhanced the availability of carbohydrate for the plant to set more grains ear⁻¹. The results are in agreement with Hamayun (2003).

The LCC based N scheduling recorded more No. of grain rows cob⁻¹, No. of grains row⁻¹, No. of grains cob⁻¹ and hundred grain weight compared to other recommended N scheduling practices. This was mainly due to increased N availability under LCC based application might have reduced grain abortion. This also could be attributed to increased availability of nitrogen from early to grain filling stages which increased the content and uptake of nitrogen which in turn increased the yield attributes. This is in corroborates with the findings of Singh (2010) in maize.

Yield

In the present study, higher grain yield was obtained under 35 × 35 cm spacing and it was 3.4 and 4.2 per cent higher over rectangular

planting during 2011 and 2012, respectively. The increased grain yield under square pattern was primarily due to decreased intra-plant competition for resources. This decreased competition lead to more uniform root and leaf distribution that promote more effective utilization of light (Sharratt and Mc Williams, 2005), particularly increased intercepted photosynthetically active radiation (IPAR) at flowering stage (Acciaresi and Chidichimo, 2007) and radiation interception during grain filling process (Andrade *et al.*, 2002). Stover yield was higher at closer spacing of 30 × 30 cm and it was 15.2 and 23.8 per cent higher than 60 × 25 cm. The stover yield was drastically reduced under wider spacing of 50 × 50 cm. The higher number of plants unit area⁻¹ contributed higher stover yield. Widdicombe and Thelen (2002) also observed that an increase in planting density increased the fodder yield linearly. This is in confirmity with the findings of Kumar (2009) and Shakarami and Rafiee (2009) in maize. The higher HI at 35 × 35 cm indicates that optimum density per unit area is efficiently converted the biological yield to economic yield.

Both the years, LCC based N scheduling strikingly increased grain yield of maize. The percentage increase of N₃ over N₂ (RDN @ 150 kg ha⁻¹ in 4 splits) was 10.3 and 14.1 and it was 15.6 and 20.3 per cent superior over N₁ (RDN @ 150 kg ha⁻¹ in 3 splits) during 2011 and 2012, respectively. The increased grain yield might be due to LCC based N application matched crop N demand which led to increased N uptake and improved the efficiency of applied N. The LCC treatment received higher quantity of N up to 180 kg ha⁻¹ based on LCC threshold value. Other favourable conditions under LCC threshold value 5 coincided with critical growth stages like 12th leaf stage (28 DAS), 15th leaf stage (35 DAS), 18th leaf stage (42 DAS) tasseling (49 DAS) and silking (56 DAS) stages,

respectively. The LCC based N application of N upto silking improved the vegetative and reproductive growth of maize and increased cob bearing plants. It is possible that late N application upto silking could provide an additional source for elevated rate of photosynthesis and transport of photo-assimilates during grain filling that resulted in the higher grain yield. This is in accordance with the findings of Pasuquin *et al.*, (2012) in maize. As that of grain, the stover yield was also higher with LCC based N scheduling. This is in conformity with the findings of Balaji and Jawahar (2007) reported that LCC-5 based N application increased straw yield.

Among the different combinations evaluated, spacing of 35 × 35 cm and maize crop nourished with N based on LCC value produced higher grain yield than other combinations. This corroborates with the findings of Biradar *et al.*, (2012) in maize. The increased grain yield might be due to increase in N accumulation associated with radiation interception and increased volume of soil made available for exploration by each plant than conventional spacing resulted in higher grain yield. Based on the experimental results it was concluded that wider spacing of 50 x 50 cm favoured yield attributes. Even though wider planting realized higher yield attributes the square planting of 35 x 35 cm found to be optimum for maximizing the yield. The LCC based N scheduling outperformed conventional approach in terms of yield and yield attributes. Integrated approach of 35 x 35 cm with LCC based N scheduling could sustain the productivity of maize and also it could avoid excess application of N and protect the environment.

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