

Interaction of thermal time and nitrogen levels on growth and productivity of cotton (*Gossypium hirsutum*)

A H PRAKASH¹, K K BANDYOPADHYAY², N GOPALAKRISHNAN³ and A ANDERSON AMALAN KUMAR⁴

Regional Station, Central Institute for Cotton Research, Coimbatore, Tamil Nadu 641 003

Received: 4 October 2009; Accepted: 25 May 2010

ABSTRACT

A field experiment was carried out at Coimbatore to study the interaction of date of sowing and N levels on growth, biomass partitioning and productivity of a popular 'LRA 5166' cotton (*Gossypium hirsutum* L.) under winter irrigated condition. The 8 August sown crop experienced the maximum cumulative growing degree days (1 560), whereas the 7 September sown crop experienced the minimum cumulative growing degree days (1489). The plant height and the number of sympodial branches decreased with the delay in sowing but increased with the increase in N levels. Nitrogen application improved the leaf area duration than the control and the maximum leaf area duration was recorded under 120 kg N/ha. Till 105 days after sowing, leaf was the major sink of photosynthates (28.8–38.1%), while seed cotton became the major sink of photosynthates after this period. There was significant decrease in the number of bolls/plant under late sowing (7 September) situation. However, with the increase in the N levels the number of bolls/plant increased significantly. Similar trend was observed with respect to seed cotton yield. Sowing of 'LRA 5166' can be delayed maximum up to 18 August which is the optimum time of sowing and sowing beyond this time leads to significant decline in seed cotton yield. The optimum dose of nitrogen for 'LRA 5166' was 60 kg N/ha for getting higher partial factor productivity of nitrogen but without significant yield reduction under the winter irrigated situation in Tamil Nadu.

Key words: Cotton, Date of sowing, Growing degree days, Nitrogen, Partial factor productivity of nitrogen

Sowing time plays an important role to realize maximum seed cotton yield as the potential optimizing yield is directly influenced by the accumulation of heat units and thermal time (Zhang *et al.* 2008, Nuti *et al.* 2006). Yield of cotton can be sufficiently increased if we know the optimum sowing time of cotton for a region. The importance of optimum sowing time of cotton on crop yield has been studied by different workers (O' Berry 2008, Wrather 2008). It has been observed that cotton sown earlier or later than its optimum time shows a rapid decline in its yield (Soomro *et al.* 2000). The early sown cotton gave significantly higher plant height, number of sympodial branches, number of bolls formed, seed cotton weight/plant and seed cotton yield/ha, whereas there was a remarkable decline in yield of late-sown crop (Arain *et al.* 2001).

It has been reported that nitrogen deficiency in cotton reduces vegetative and reproductive growth and induces premature senescence, thereby potentially reducing yields

whereas high N availability may shift the balance between the vegetative and reproductive growth towards excessive vegetative development, thus delaying maturity and reducing yield, harvesting and ginning percentage and promote boll shedding, disease and pest damage. Since nitrogen is expensive input, optimum dose of N should be used to increase its use-efficiency in cotton. Sometimes at farm level sowing gets delayed because of unpredictable weather situation and various unavoidable circumstances. It is hypothesized that the adverse effect of irregularities in the date of sowing can be minimized by proper nitrogen management practices through an optimum date of sowing and nitrogen interaction.

Keeping this in view, a field experiment was carried out at Coimbatore with the objective to study the interaction of date of sowing (thermal time) and N levels on growth, biomass partitioning and productivity of 'LRA 5166' cotton under winter irrigated condition.

MATERIALS AND METHODS

The field experiment was carried out during 2002–03 to 2004–05 in a mixed red and black calcareous soil (Vertic Ustropept) of Periyanaiken Palayam series at the Regional

¹Principal Scientist (email: prak_ah@rediffmail.com), ²Senior Scientist (email: kk.bandyopadhyay@gmail.com), ³Project Coordinator (AICCIP) and Head (email: gopalcotton@gmail.com), ⁴Research Associate (email: and_sand@rediffmail.com).

Station, Central Institute for Cotton Research, Coimbatore (11°N latitude and 77°E longitude and 426.7 m above mean sea level), Tamil Nadu. The soil was sandy clay loam in texture (31% clay) having bulk density of 1.35 Mg/m³ and soil water content on volume basis at 0.33 bar and 15 bar suction was 35.5% and 24.1%, respectively. The pH was 8.27 with 0.69% soil organic carbon and 0.186 dS/m electrical conductivity. The soil was low in available N (295 kg/ha) and available P (6.0 kg P/ha) but high in available K (625 kg K/ha). Coimbatore falls under semiarid zone with the normal weather condition (25 years mean) include a mean annual rainfall of 674.2 mm received in 49 rainy days. The mean maximum and minimum temperatures are 31.5°C and 21°C respectively. The mean relative humidity ranges from 58 to 63% and mean bright sunshine hours is 7.3 with mean solar radiation of 429.2 cal/cm²/day.

Growing degree days was calculated as:

$$\text{GDD} = \frac{T_{\text{max}} + T_{\text{min}}}{2} - 12.8 \quad \dots(1)$$

12.8°C is the base temperature for cotton.

Cumulative growing degree days was calculated as:

$$\text{CGDD} = \sum_1^n \text{GDD} \quad \dots(2)$$

The experiment was conducted in a split-plot design with 4 dates of sowing (ie D₁, Normal (8 August); D₂, 10 days after normal (18 August); D₃, 20 days after normal (28 August); D₄, 30 days after normal (7 September)) as main plot treatments and 4 N levels (N₁, control (no nitrogen); N₂, 60 kg N/ha; N₃, 90 kg N/ha; N₄, 120 kg N/ha) as sub-plot treatments. Nitrogen was applied as urea in 2 equal splits, ie 50% at basal and 50% as topdressing during the earthingup operation. Phosphorus and potassium were applied at the recommended dose, ie 45 kg P₂O₅/ha and 45 kg K₂O/ha as single superphosphate and muriate of potash, respectively, to all the plots. There were 4 replications and sub-plot was 5.4 m × 3.75 m.

Acid delinted good viable seed 'LRA 5166' was dibbled at a spacing of 75 cm × 45 cm @ 2 seeds/hill as per the sowing schedule. Then thinning was done at 15 days after sowing by retaining 1 seedling/hill. Plant protection and other cultural operations were taken up as and when required. The crop was grown under irrigated condition and the irrigation was given at critical growth stages. The crop was harvested in 3 pickings from the net plot after leaving boarder strip. The partial factor productivity of N was estimated as seed cotton yield/unit of N used.

In each treatment, 3 plants were randomly selected for collecting data at 15 days interval starting from 30 to 150 days after sowing for different physiological attributes, viz plant height, number of branches, leaf area index (LAI) and biomass partitioning to different plant parts. After partitioning of the biomass, these were dried in hot air oven at 65°C till constant weight and the dry weight was recorded. The leaf

area was measured in Windias package of image analysis system (M/s Delta T Inc.). From the leaf area index, the leaf area duration (LAD) was computed using the following formula.

$$\text{Total LAD} = [(LAI_{n-1} + LAI_n)/2] (t_n - t_{n-1}) \quad \dots(3)$$

where LAI_n, LAI at sampling time t_n and LAI_{n-1}, LAI at sampling time t_{n-1}

The statistical analysis of the data was carried out following the analysis of variance as outlined by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Effect of date of sowing

Thermal time experienced by the crop: At 30 days after sowing there was no significant difference in the growing degree days of the crop under different sowing dates. From 45 days after sowing onwards, the crop sown on 8 August (D1) experienced higher growing degree days than that of crop sown on 7 September (D4) till 120 days after sowing. However, from 135 days after sowing onwards, the late-sown (7 September) crop experienced higher growing degree days than the crop sown on earlier dates. The early-sown crop (8 August) experienced the maximum cumulative growing degree days (1 560), whereas the late-sown crop experienced the minimum cumulative growing degree days (1 489).

Plant height and number of sympodial branches: Results of 3-year study indicated decreased plant height and number of sympodia (fruit bearing branches)/plant with delay in sowing (Figs 1, 2). This finding is in agreement with the observations of Arain *et al.* (2001).

Leaf area index and leaf area duration: The temporal variation in the leaf area index under different days after sowing and N levels have been depicted in Table 1 for 2003–04 and 2004–05, respectively. It was observed that during 2003–04, the crop sown on 28 August (D3) registered the maximum leaf area index at 105 days after sowing. Whereas during 2004–05, the maximum leaf area index was recorded in the crop sown on 18 August (D2). In 2004–05, the leaf area index in D1 and D3 treatments showed an increasing trend even after 160 days after sowing, which may be attributed to development of new leaves.

The leaf area duration was more in 2004–05 than 2003–04 for all the dates of sowing except sowing on 28 August (D3) (Table 2). During 2003–04, the maximum leaf area duration was recorded for sowing on 28 August (D3), whereas during 2004–05, the maximum leaf area duration was recorded for sowing on 18 August (D2).

Biomass partitioning: Among the dates of sowing, the high dry matter accumulation 2003–04 was recorded for D2 (18 August) (5 362 kg/ha) and it was low for D4 (7 September) (3 052 kg/ha) (Fig 3). Till 105 days after sowing, leaf was the major sink of photosynthates (28.8–38.1%) and

Table 1 Temporal variation in the leaf area index of 'LRA 5166' cotton as influenced by the date of sowing and N levels during 2003–04

Treatment	Days after sowing												
	2003–04							2004–05					
	60	75	90	105	120	135	150	40	60	80	100	120	160
<i>Date of sowing</i>													
8 August	0.183	0.438	0.801	1.123	0.776	0.907	0.728	0.170	0.600	1.131	1.783	0.858	1.108
18 August	0.270	0.782	1.139	1.522	1.041	0.963	0.510	0.270	0.618	1.421	1.760	2.127	0.743
28 August	0.335	0.548	1.512	1.450	2.053	0.522	0.390	0.047	0.563	0.955	1.234	1.105	1.456
7 September	0.526	0.824	1.114	0.822	0.738	0.409	0.371	0.103	0.632	1.104	0.980	1.188	0.730
<i>N levels</i>													
Control	0.271	0.535	1.042	1.075	0.998	0.609	0.365	0.160	0.526	1.186	1.381	1.260	0.990
60 kg N/ha	0.314	0.699	1.177	1.172	1.198	0.740	0.501	0.162	0.617	1.153	1.357	1.286	0.845
90 kg N/ha	0.345	0.624	1.068	1.474	1.124	0.654	0.506	0.132	0.589	1.113	1.607	1.288	0.944
120 kg N/ha	0.294	0.593	0.846	0.810	0.702	0.616	0.501	0.135	0.677	1.160	1.418	1.446	1.257
LSD _{0.05} (DS)	0.069	0.116	0.130	0.034	0.063	0.071	0.088	0.037	0.129	0.267	0.265	0.389	0.321
LSD _{0.05} (N)	0.037	0.060	0.110	0.051	0.056	0.033	0.040	0.037	0.129	0.267	0.265	0.389	0.321
LSD _{0.05} (DS × N)	0.074	0.121	0.220	0.102	0.113	0.067	0.079	0.073	0.259	0.534	0.530	0.779	0.643

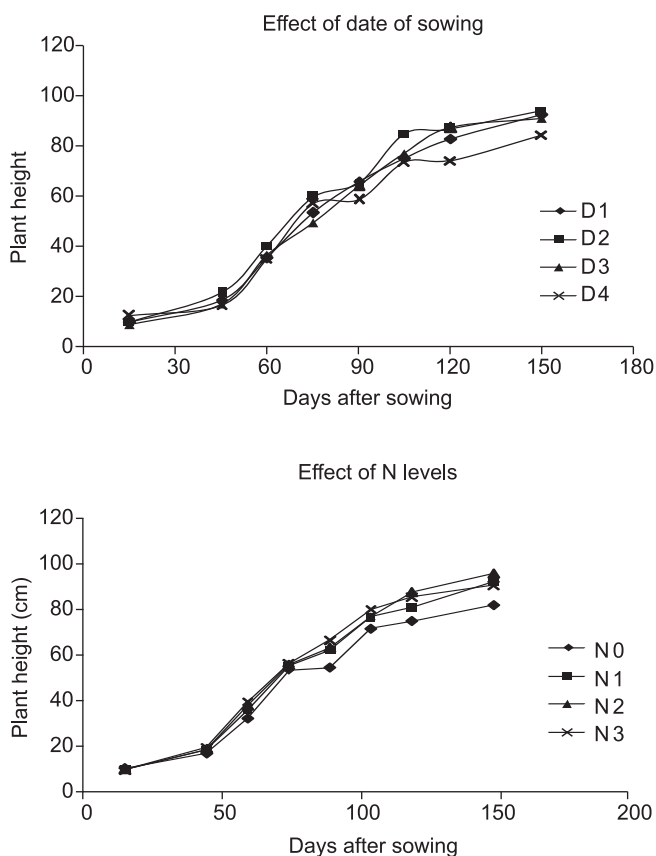


Fig 1 Effect of date of sowing and N levels on temporal variation in plant height of 'LRA 5166' cotton (pooled over 2002–03 to 2004–05)

after that, seed cotton became the major sink of photosynthates. This finding is in agreement with Prakash *et al.* (2008) who reported that the seed cotton became the major

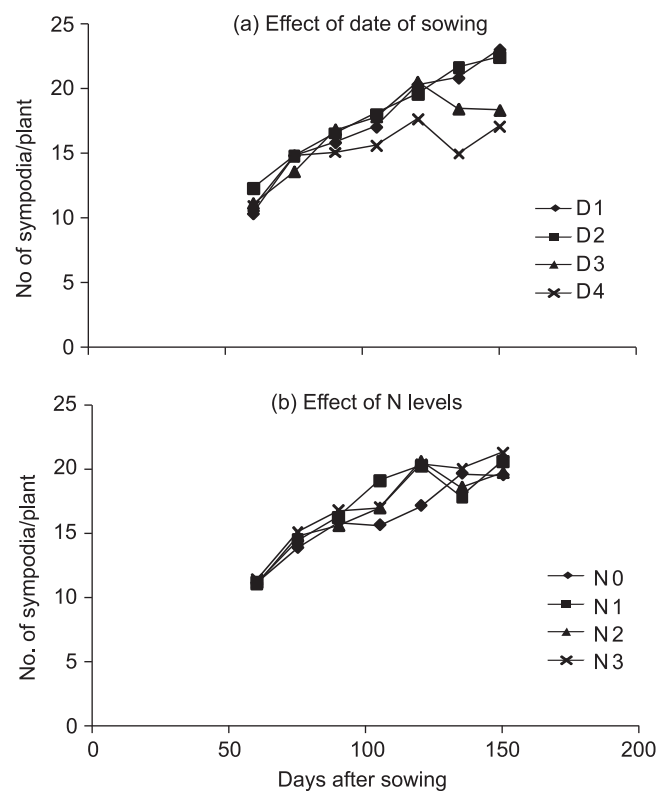


Fig 2 Effect of date of sowing and N levels on temporal variation in number of sympodial branches/cotton plant (cv LRA 5166) (pooled over 2002–03 and 2003–04)

sink of photosynthates from 120 days after sowing onwards in *Bt* cotton hybrid and from 135 days after sowing in non *Bt* cotton and prior to this, leaf was the major sink of photosynthates. At 150 days after sowing, the partitioning

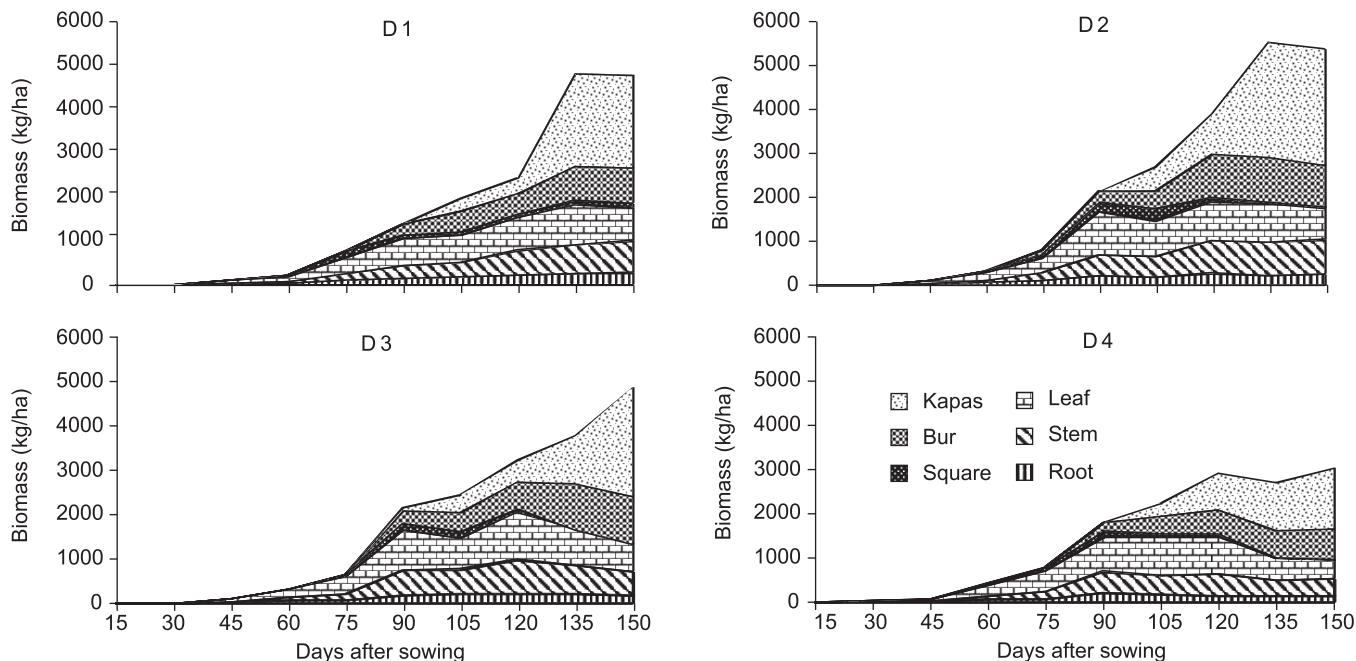


Fig 3 Temporal variation in biomass partitioning of cotton plant (cv ‘LRA 5166’) as influenced by date of sowing

Table 2 Total leaf area duration of ‘LRA 5166’ cotton as influenced by date of sowing and N levels

Treatment	2003–04	2004–05	Mean
<i>Date of sowing</i>			
8 August	68.90	98.74	83.82
18 August	89.59	126.85	108.22
28 August	103.42	86.65	95.04
7 September	72.41	83.70	78.05
<i>N levels</i>			
Control	72.27	96.11	84.19
60 kg N/ha	85.16	96.22	90.69
90 kg N/ha	84.94	99.74	92.34
120 kg N/ha	91.95	103.87	97.91

of biomass to seed cotton was maximum in D3 (28 August) (50.6%) and minimum for D1 (8 August).

Seed cotton yield and nitrogen-use efficiency: It was observed that there was significant decrease in the number of bolls/plant under late sowing (D4) situation (Table 3). Similar trend was noticed with respect to seed cotton yield (Table 3). The higher mean seed cotton yield was recorded for D2-18 August (2 238 kg/ha), which was statistically at par with D1-8 August (2 171 kg/ha) but significantly higher by 19.2% to D3- 8 August (1878 kg/ha) and by 92.3% to D4-7 September (1164 kg/ha). This finding is in agreement with that of Arain *et al.* (2001).

The partial factor productivity of N (PFPN) declined with delay in sowing (Table 4). It was maximum for D2 (18 August) and minimum for D4 (7 September) (Fig 5).

This is attributed to decline in seed cotton yield with delay in sowing.

Effect of nitrogen management

Plant height and number of Sympodial branches: With the increase in the N levels, the plant height (Fig 1) and the number of sympodial branches/plant (Fig 2) increased. This implies that growth of cotton plant shows positive response to nitrogen application.

Leaf area index and leaf area duration: In both the years 2003–04 and 2004–05, among the N management practices, the maximum leaf area index was recorded for 90 kg N/ha (Table 1). It can be seen that leaf area duration in 2004–05 was more than that of 2003–04 for the entire N levels (Table 2). Nitrogen application improved the leaf area duration than control in both the years. In both the years, maximum leaf area duration was recorded at 120 kg N/ha.

Biomass partitioning: It was observed that higher total dry matter accumulation was recorded for 120 kg N/ha (4959 kg/ha) and lower value was recorded under the control (3 873 kg/ha) (Fig 4). Leaf was the major sink of photosynthates till 120 days after sowing with the proportion varying from 27.7 to 28.9% and after 120 days after sowing, the seed cotton became the major sink of biomass. At 150 days after sowing, the biomass partitioned to seed cotton ranged from 46.6% in 90 kg N/ha to 48.6% in 60 kg N/ha.

Seed cotton yield and nitrogen-use efficiency: With the increase in the N levels the number of bolls/plant increased significantly (Table 3). Similar trend was observed in seed cotton yield. Nitrogen application significantly improved the

Table 3 Number of bolls/plant, seed cotton yield and partial factor productivity of Nitrogen of 'LRA 5166' cotton as influenced by date of sowing and N levels

Treatment	Bolls/plant				Seed cotton yield (kg/ha)				Partial factor productivity of nitrogen (kg yield/kg N)			
	2002–03	2003–04	2004–05	Mean	2002–03	2003–04	2004–05	Mean	2002–03	2003–04	2004–05	Mean
<i>Date of sowing</i>												
8 August	22.0	22.5	28.3	24.3	2 654	2 097	1 762	2 171	33.3	25.7	21.0	26.7
18 August	21.2	28.9	25.9	25.3	2 180	2 633	1 900	2 238	26.6	32.7	22.8	27.4
28 August	19.4	26.0	26.0	23.8	2 029	2 474	1 132	1 878	25.9	31.4	14.2	23.9
7 September	16.3	18.4	15.8	16.8	1 696	1 385	410	1 164	21.3	16.7	5.4	14.5
<i>N levels</i>												
Control	12.5	20.9	22.2	18.5	1 876	1 879	1 226	1 660				
60 kg N/ha	19.3	23.6	26.0	23.0	2 205	2 142	1 276	1 874	36.7	35.7	21.3	31.2
90 kg N/ha	23.4	25.0	24.5	24.3	2 227	2 234	1 382	1 948	24.7	24.8	15.4	21.6
120 kg N/ha	23.7	26.3	23.5	24.5	2 252	2 333	1 319	1 968	18.8	19.4	11.0	16.4
LSD _{0.05} (DS)	1.5	2.7	3.2		79.5	135	152					
LSD _{0.05} (N)	1.6	2.7	NS		21.2	96	NS					
LSD _{0.05} (DS × N)	NS	NS	NS		NS	NS	NS					

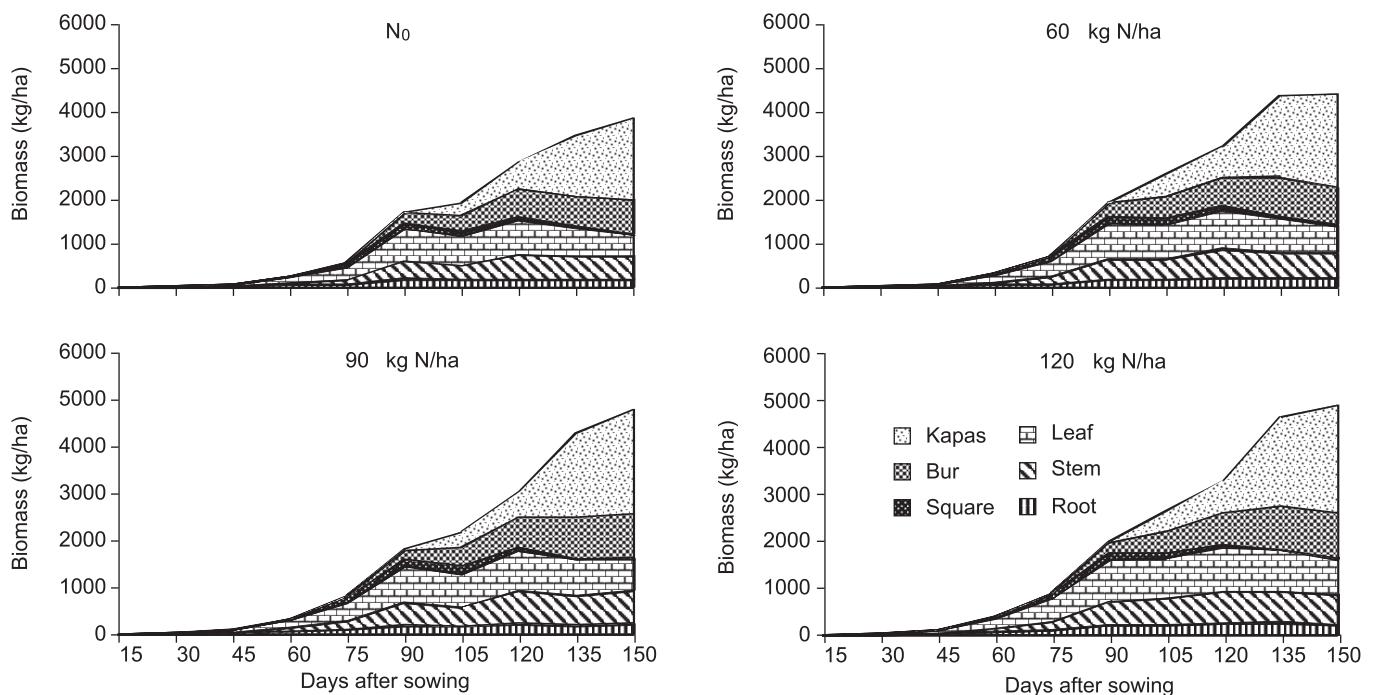


Fig 4 Temporal variation in biomass partitioning of cotton plant (cv 'LRA 5166') as influenced by N levels

seed cotton yield over control (Table 4). However, there was no significant difference in the seed cotton yield for 60 kg N/ha, 120 kg N/ha and 180 kg N/ha in all the years studied. With the increase in the N levels the partial factor productivity of nitrogen decreased from 31.2 kg/kg N under 60 kg N/ha to 16.4 kg/kg N under 120 kg N/ha (Table 4) (Fig. 5). This finding is in agreement with that of Bandyopadhyay *et al.* (2009). This may be attributed to losses of nitrogen at higher rate of application. Among the years, the maximum partial

factor productivity of nitrogen was recorded in 2002–03 and it decreased in the subsequent years.

Thus, from this study it may be concluded that sowing of 'LRA 5166' can be delayed maximum up to 18 August which is the optimum time of sowing for this variety and sowing beyond this date leads to significant decline in seed cotton yield. The optimum dose of nitrogen in 'LRA 5166' was 60 kg N/ha for getting higher partial factor productivity of nitrogen but without significant yield reduction compared

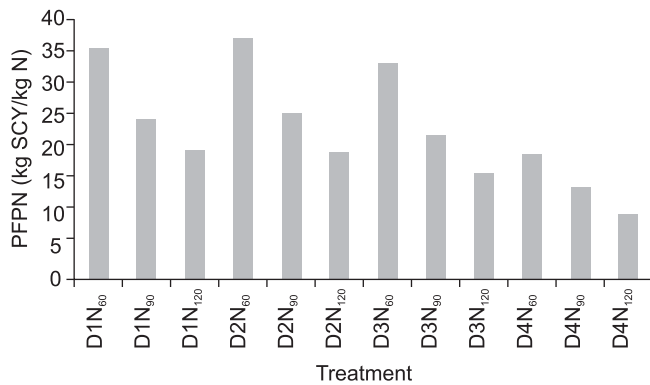


Fig 5 Partial factor productivity of nitrogen of 'LRA 5166' cotton as influenced by date of sowing and N levels (pooled over 2002–03 to 2004–05)

to higher doses of N under the winter irrigated situation of Tamil Nadu.

REFERENCES

- Ali M, Mohy-Ud-Din Q, Anjum Ali, M, Sabir S and Ali L. 2004. Cotton yield as influenced by different sowing dates under the climatic conditions of Vehari-Pakistan. *International Journal of Agricultural Biology* **6**(4): 644–6.
- Arain M H S, Arain S, Baloch M J, Kalwar G H and Memon A A. 2001. Performance of newly developed cotton strains under different sowing dates. *Pakistan Journal of Biological Sciences*. Supplementary Issue No. 1: 1–2.
- Bandyopadhyay K K, Prakash A H, Shankaranarayanan K, Dharajothi B and Gopalakrishnan N. 2009. Effect of irrigation and nitrogen on soil water dynamics, productivity and input use efficiency of Bt cotton (*Gossypium hirsutum* L.) in a Vertic Ustropept. *The Indian Journal of Agricultural Sciences* **79** (6): 448–53.
- Gomez K A and Gomez A A. 1984. *Statistical Procedures for Agricultural Research*, John Willey and Sons, New York.
- Nuti R C, Viator R P, Casteel S N, Edmisten K L and Wells R. 2006. Effect of planting date, mepiquat chloride, and glyphosate application to glyphosate resistant cotton. *Agronomy Journal* **98**: 1627–33.
- O' Berry N B, Faircloth J C, Edmisten K L, Collins G D, Stewart A M, Abaye A O, Herbert Jr D A and Haygood R A. 2008. Plant population and planting date effects on cotton (*Gossypium hirsutum* L.) growth and yield. *The Journal of Cotton Science* **12**: 178–87.
- Prakash A H, Bandyopadhyay K K and Gopalakrishnan N. 2008. Growth and biomass partitioning in Bt vs Non Bt cotton hybrids in winter irrigated situation in southern zone of India. *Journal of Indian Society of Cotton Improvement* December 129–42.
- Soomro A R, Channa M H, Channa A A, Kalwar G H, Dayo G N and Memon A H. 2000. The effect of different sowing dates on the yield of newly developed strain under climatic conditions of Ghotki, Sindh. *The Pakistan Cottons* **44**: 25–31.
- Zhang L, van der Werf W, Zhang S, Li B and Spiertz J H J. 2008. Temperature-mediated developmental delay may limit yield of cotton in relay intercrops with wheat. *Field Crops Research* **106** (3): 258–68.