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# Effect of planting density and nitrogen levels on productivity and N-use efficiency of rainfed upland cotton (*Gossypium hirsutum*)

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## ABSTRACT

A field experiment was conducted during the rainy season of 1996 and 1997 on a shallow typic ustochrept to evaluate the response to N and plant density requirements for 'CNH 36' upland cotton (*Gossypium hirsutum.* L.). The experiment was conducted in split-plot design with 3 planting densities ($D_1$, 74,100; $D_2$, 49, 400; and $D_3$, 37,050 plants/ha) as main plots and 4 N (0, 50, 75, 100 kg N/ha) levels as subplots. At high plant population ($D_1$), significant response could be obtained up to 75 kg N/ha and interaction of D X N was significant. The economic optimum dose at $D_1$, $D_2$ and $D_3$ was 84, 88 and 62 kg N/ha respectively. The apparent recovery of applied N was highest with $D_1$ (31.3–47.6%), intermediate with $D_2$ (29.5–31.8%) and least with $D_3$ (17.8–26.8%). The petiole nitrate-nitrogen was low at higher planting densities.

***Key words*** : Upland cotton, *Gossypium hirsutum*, Plant density, N levels, N-use efficiency

In India, rainfed cotton is predominantly cultivated on Vertisols and related soil groups of varying depth. Although deep, well-drained soils are ideal for cotton cultivation (Bhaskar *et al.*, 1987), economic reasons compel farmers to grow cotton on shallow soils. Soil depth and profile soil-moisture storage capacity governs rainfed cotton yields (Bhaskar *et al.*, 1987). Since shallow soils have limited profile water storage, short–duration varieties are more suitable (Nimbole and Singh, 1993). Doble *et al.* (1990) reported that even under favourable rainfall situations, cotton yields were lower in shallow soils due to their low inherent fertility. There is an imperative need to modify the present recommendations considering the fragile nature of cotton cultivation on shallow soils. 'CNH 36', an early-maturing, superior medium-staple variety was recently released for cultivation in Maharashtra and Gujarat. The

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present investigation was aimed at evaluating N relationships and plant density requirements for this variety on shallow soil where restricted soil-moisture storage limits the expression of the genetic potential of the variety. The response patterns are discussed in relation to earliness, N-utilization efficiency yardsticks and petiole nitrate-N.

## MATERIALS AND METHODS

A field experiment was conducted on typic Ustochrepts with soil depth < 50 cm, containing 33–35% clay, and water-holding capacity of 140–145 mm during the rainy seasons of 1996–97 and 1997–98 under rainfed conditions. The soil of the experimental field was moderately alkaline (pH 8.1), low in organic carbon (0.36%), medium in available P (13.6 kg/ha) and high in available K (524 kg/ha). The monthly distribution of rainfall during 1996–97 and 1997–98 seasons was respectively 403 and 213 mm in July, 294 and 188 mm in August, 155 and 181 mm in September, 95 and 75 mm in October and 2 and 67 mm in November.

'CNH 36' was sown on 3 July during both the years. The treatments comprised 3 planting densities, viz. 74,100 ($D_1$); 49,400 ($D_2$); and 37,050 ($D_3$) plants/ha (obtained by dibbling at 45 cm × 30 cm, 45 cm × 45 cm and 45 cm × 60 cm spacing and thinned to 1 plant/hill) as main plots and 4 nitrogen levels, viz. 0 ($N_0$), 50 ($N_1$), 75 ($N_2$) and 100 ($N_3$) kg N/ha as subplots in split-plot design with 3 replications. Uniform recommended dose of 30 kg $P_2O_5$ and 30 kg $K_2O$) to all the treatments along with one-third dose of N (in $N_1$ to $N_3$) was drilled along marker lines at sowing. Remaining N was applied by spot placement method in 2 equal splits, at square-initiation and flowering stages. Above-ground dry matter was recorded 80 days after sowing (DAS), coinciding with peak flowering and at first picking (maturing stage). The latter samples were separated into leaf, stem, bur, seed and lint and analyzed colorimetrically for N content to compute N uptake. Petioles from the upper-most fully-expanded leaf from the top on the main stem nodes were randomly sampled in each plot at 50, 75, 90 and 140 days and analysed for nitrate-N, using phenol disulfonic acid method.

Seed-cotton yields, recorded picking-wise, were used to calculate earliness index (EI) using the formula proposed by Bartlett (1937).

Quadratic response equations were fitted to calculate economic optimum N dose at each density, assuming the cost of N through urea at Rs 7.30 /kg and value of seed cotton as Rs 21.00 /kg. The N-use efficiency yardsticks were graphically represented by method devised by de-Wit (1953). The apparent recovery (AR) of N was calculated using the formula:

$$AR = \frac{\text{N uptake in i}^{\text{th}}\text{ treatment (kg/ha)–N uptake in control (kg/ha)}}{\text{N applied in i}^{\text{th}}\text{ treatment (kg/ha)}} \times 100\text{ th}$$

## RESULTS AND DISCUSSION

### *Dry-matter production*

The dry-matter production increased with increasing plant density and the difference between $D_1$ and $D_2$ was significant at flowering stage (80 days), whereas the difference between $D_2$ and $D_3$

**Table 1.** Effect of plant densities and N levels on dry matter and seed-cotton yields

| Treatment | $N_0$ | $N_1$ | $N_2$ | $N_3$ | Mean |
|---|---|---|---|---|---|
| *Dry-matter yield at flowering stage (kg/ha)* | | | | | |
| $D_1$ | 731 | 1,584 | 2,075 | 2,291 | 1,670 |
| $D_2$ | 659 | 1,432 | 1,691 | 1,857 | 1,410 |
| $D_3$ | 678 | 1,413 | 1,594 | 1,821 | 1,337 |
| Mean | 689 | 1,476 | 1,787 | 1,990 | |
| LSD (P = (0.05) | | | | | |
| Planting density (D) | | | 202.5 | | |
| N levels (N) | | | 124.8 | | |
| D × N | | | NS | | |
| *Dry-matter yield at maturity (kg/ha)* | | | | | |
| $D_1$ | 2,162 | 4,162 | 4,383 | 4,592 | 3,819 |
| $D_2$ | 2,694 | 3,365 | 3,921 | 4,705 | 3,671 |
| $D_3$ | 2,100 | 3,115 | 3,360 | 3,433 | 3,002 |
| Mean | 2,319 | 3547 | 3,888 | 4,243 | |
| LSD (P = 0.05) | | | | | |
| Planting denisty (D) | | | 336.7 | | |
| N levels (N) | | | 319.9 | | |
| D × N | | | 554.1 | | |
| *Seed-cotton yield (kg/ha)* | | | | | |
| $D_1$ | 1,004 | 1,389 | 1,527 | 1,455 | 1,344 |
| $D_2$ | 1,005 | 1,405 | 1,507 | 1,495 | 1,353 |
| $D_3$ | 940 | 1,320 | 1,258 | 1,185 | 1,176 |
| Mean | 983 | 1,371 | 1,431 | 1,378 | |
| LSD (P = 0.05) | | | | | |
| Planting density (D) | | | 66.9 | | |
| N levels (N) | | | 70.4 | | |
| D × N | | | 121.8 | | |

was significant at maturity (Table 1). Similarly, the increase in dry matter with N application was significant up to the highest dose (100 kg N/ha) at both the stages. The D×N interaction for dry matter was significant at maturity stage.

### Yield, yield attributes and earliness

The seed-cotton yield was 15.0% higher with $D_2$ than that with $D_3$ and this increase was significant. This was owing to higher number of bolls/m$^2$ in the former. Averaged over the planting densities, the mean seed-cotton yield with 50 kg N/ha was significantly (39.5%) higher than the control ($N_0$), and beyond 50 kg N/ha there was no increase in yield (Table 1). However, the significant D×N interaction indicates that at the highest planting density, i.e. $D_1$ (74,100 plants/ha) significant response up to 75 kg N could be obtained while at lowest density, $D_3$ (37,050 plants/ha), the improvement in yield beyond 50 kg N/ha was not significant. Kharche and Deshpande (1989) reported density/dependent response of

**Table 2.** Effect of plant densities and N levels on yield attributes and earliness index

| Treatment | $N_0$ | $N_1$ | $N_2$ | $N_3$ | Mean |
|---|---|---|---|---|---|
| | | *Boll number/m²* | | | |
| $D_1$ | 50.1 | 62.2 | 69.4 | 67.7 | 62.3 |
| $D_2$ | 46.3 | 52.3 | 60.1 | 61.0 | 54.9 |
| $D_3$ | 31.0 | 41.3 | 42.1 | 42.1 | 39.1 |
| Mean | 42.5 | 51.9 | 57.2 | 56.9 | |
| LSD (P=0.05) | | | | | |
| Planting density (D) | | | 7.60 | | |
| N levels (N) | | | 3.92 | | |
| D × N | | | 6.18 | | |
| | | *Boll weight (g)* | | | |
| $D_1$ | 1.94 | 2.12 | 2.19 | 2.23 | 2.12 |
| $D_2$ | 2.03 | 2.20 | 2.23 | 2.28 | 2.19 |
| $D_3$ | 2.03 | 2.36 | 2.30 | 2.30 | 2.20 |
| Mean | 2.00 | 2.28 | 2.20 | 2.27 | |
| LSD (P=0.05) | | | | | |
| Planting density (D) | | | NS | | |
| N levels (N) | | | 0.110 | | |
| D × N | | | NS | | |
| | | *Earliness index* | | | |
| $D_1$ | 0.771 | 0.759 | 0.718 | 0.656 | 0.726 |
| $D_2$ | 0.717 | 0.677 | 0.666 | 0.635 | 0.674 |
| $D_3$ | 0.665 | 0.687 | 0.687 | 0.684 | 0.681 |
| Mean | 0.718 | 0.708 | 0.690 | 0.658 | |
| LSD (P = 0.05) | | | | | |
| Planting density (D) | | | 0.049 | | |
| N levels (N) | | | 0.038 | | |
| D × N | | | NS | | |

cotton to N application on rainfed Vertisols.

Economic optimum was obtained by fitting quadratic response equations for yield (y) as a function of N dose (x) at different densities:

$$D_1: y = 984 + 11.59 x - 0.067 x^2$$
$$D_2: y = 996 + 11.21 x - 0.061 x^2$$
$$D_3: y = 929 + 11.29 x - 0.088 x^2$$

Using the above equations the optimum N dose at $D_1$, $D_2$ and $D_3$ was 84, 88 and 62 kg N/ha respectively.

With closer planting and at higher N levels, the yield improvement was primarily owing to increased boll number per unit area (Table 2). The D × N interaction was significant for boll number, which increased significantly up to $N_2$ (75 kg N/ha)at $D_1$ and $D_2$, while at $D_3$, the increase beyond $N_1$ was not significant. Boll weight was significantly higher than the control at all N levels, while the differences among the different applied N levels were not significant. Joham (1986) opined that N has a direct bearing on growth, improves number of fruiting points but does not directly govern fruiting index.

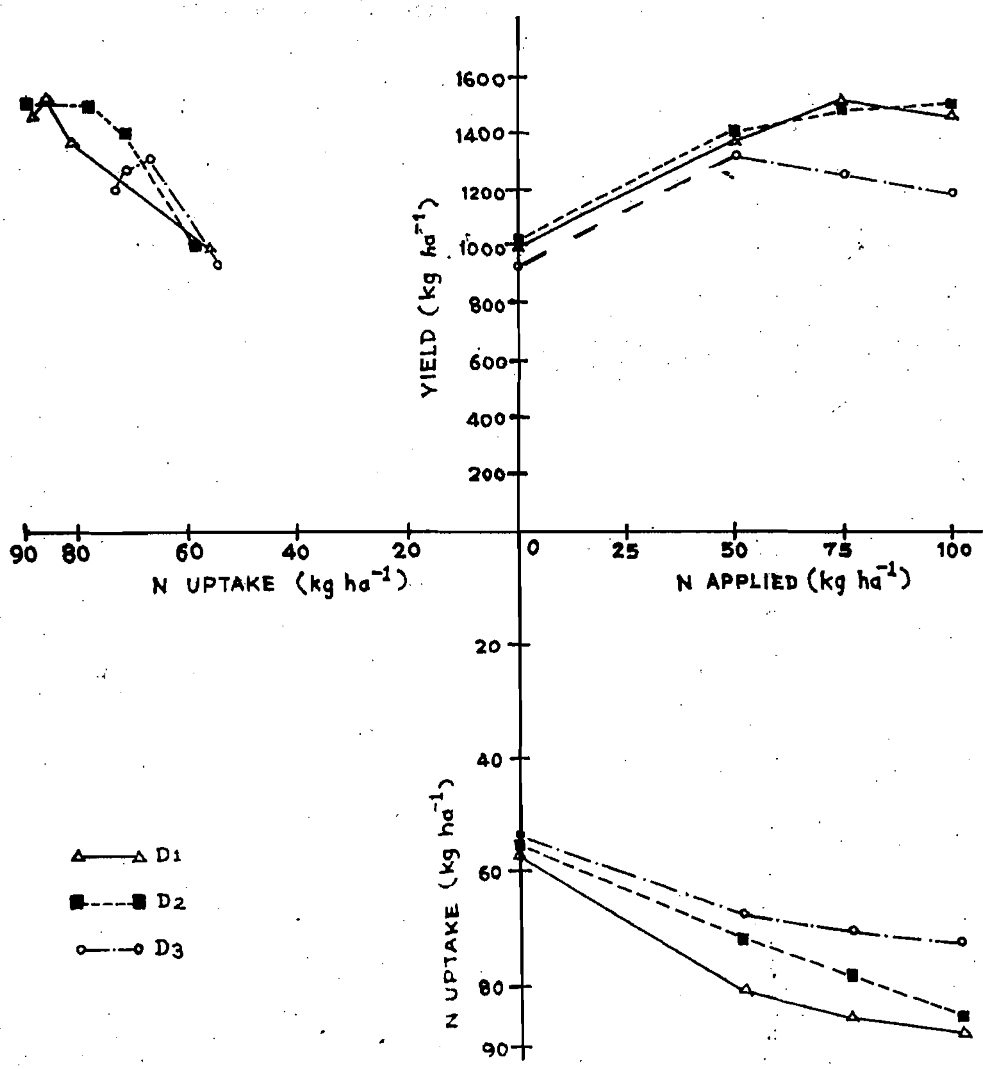


**Fig. 1.** Effect of planting density and N levels on nitrogen-use efficiency yardsticks (*a*, top right; *b*, bottom right; *c*, top left).

Earliness is an important factor influencing productivity on shallow soils where limited profile soil-moisture storage restricts growing period. Higher planting density ($D_1$) induced early fruiting at lower nodes, due to greater interplant competition within rows, resulting in higher earliness index (Table 2). When N dose was not limiting at $N_3$ (100 kg N/ha), maturity was delayed reducing the earliness index.

### *Nitrogen-use efficiency*

Response curves were fitted to depict yield as a function of applied N (quadrant a,

Fig. 1), yield as a function of N uptake (quadrant C, Fig 1) and N uptake as a function of N applied (quadrant b, Fig. 1). The conventional yield-fertilizer response (1, a) indicated similar response pattern with $D_1$ and $D_2$ which were significantly higher than $D_3$ at all N levels. This response is a product of recovery of applied N (1, b) and physiological N-utilization efficiency (Fig.1, c). The recovery of applied N was highest with $D_1$ intermediate with $D_2$ and lowest with $D_3$. The rate of recovery decreased with increase in N levels, irrespective of the density. Improved N recovery in $D_1$ and $D_2$ was due to a more rigorous growth and higher dry-matter production (Table 1), presumably causing increased N demand and absorption from a greater soil volume. The N utilization within the crop, varied little among the

**Table 3.** Effect of plant densities and N levels on petiole nitrate N × $10^3$ μg/g)

| Treatment | $N_0$ | $N_1$ | $N_2$ | $N_3$ | Mean |
|---|---|---|---|---|---|
| | | *50 days after sowing* | | | |
| $D_1$ | 13.20 | 15.60 | 16.00 | 16.00 | 15.2 |
| $D_2$ | 16.60 | 17.00 | 17.80 | 18.40 | 17.4 |
| $D_3$ | 16.80 | 17.10 | 17.60 | 18.20 | 17.4 |
| Mean | 15.53 | 16.50 | 17.13 | 17.53 | |
| LSD (P = 0.05) | | | | | |
| Planting density (D) | | | 1.82 | | |
| N levels (N) | | | 1.67 | | |
| | | *75 days after sowing* | | | |
| $D_1$ | 6.40 | 7.20 | 8.01 | 8.16 | 7.44 |
| $D_2$ | 8.20 | 9.42 | 9.67 | 11.01 | 9.58 |
| $D_3$ | 8.60 | 3.58 | 9.17 | 10.84 | 8.05 |
| Mean | 7.70 | 6.73 | 8.90 | 10.00 | |
| LSD (P = 0.05) | | | | | |
| Planting density (D) | | | 1.18 | | |
| N levels (N) | | | 0.92 | | |
| | | *90 days after sowing* | | | |
| $D_1$ | 1.60 | 1.90 | 2.50 | 2.20 | 2.05 |
| $D_2$ | 1.9 | 3.22 | 4.90 | 5.8 | 3.96 |
| $D_3$ | 2.10 | 3.58 | 4.60 | 5.80 | 4.02 |
| Mean | 1.80 | 2.90 | 4.00 | 4.60 | |
| LSD (P = 0.05) | | | | | |
| Planting density (D) | | | 0.46 | | |
| N levies (N) | | | 0.38 | | |
| | | *140 days after sowing* | | | |
| $D_1$ | 0.22 | 0.81 | 0.80 | 1.20 | 0.76 |
| $D_2$ | 0.34 | 1.22 | 2.10 | 2.41 | 1.51 |
| $D_3$ | 0.40 | 1.78 | 2.42 | 2.82 | 1.86 |
| Mean | 0.32 | 1.27 | 1.77 | 2.14 | |
| LSD (P = 0.05) | | | | | |
| Planting density (D) | | | 0.12 | | |
| N levels (N) | | | 0.09 | | |

planting densities (1,c), because no extraneous factor, including moisture, limited N utilization. The major contributor for improved agronomic response was improved apparent recovery (AR). The values for AR ranged from 31.3 to 47.6% at $D_1$, 29.5 to 31.8% at $D_2$ and 17.8 to 26.8% at $D_3$. Mean AR across planting densities was 35.4% with $N_1$, 30.1 with $N_2$ and 26.8% with $N_3$. The corresponding values in nutrient-utilization efficiency varied within a narrow range from 16.4 –17.5 in $D_1$ to 17.2–19.5 in $D_2$ and 16.3–19.3 in $D_3$.

### *Petiole nitrate-nitrogen*

The nitrate-N in the leaf petioles is an indicator of crop N status (Maples *et al.*, 1990). The petiole $NO_3$-N declined steadily with corp ontogeny, irrespective of the plant density and N levels applied (Table 3). Maples *et al.* (1990) attributed this phenomenon to increased boll N demand, decline in root activity and lower soil $NO_3$-N level. Within each sampling period, the nitrate-N was significantly lower in $D_1$ compared to $D_2$ or $D_3$. Sunderman *et al.* (1979) also observed a decline in $NO_3$-N with an increase in plant density. While all the N treatments recorded significantly higher $NO_3$-N than the control ($N_0$) at all stages, at 90 and 190 days after sowing. Petiole $NO_3$-N with $N_2$ (75 kg N/ha) and $N_3$ (100 kg N/ha) were significantly higher than with $N_1$ (50 kg N/ha). Earliness index was significantly, negatively correlated with petiole $NO_3$-N at 90 and 140 days with r values of –0.603 and–0.575 respectively, confirming that N stress due to increased planting density or low N doses-induced earliness.

Sunderman *et al.* (1979) concluded that petiole nitrate variation at flowering stage was correlated to yield. The following quadratic equations explained the relationship between seed-cotton yield (kg/ha) and petiole $NO_3$-N ($\mu$g/g) at flowering stage at different densities.

$$D_1: Y = -13{,}068 + 3.71\,X - 0.00024\,X^2 \quad R^2 = 0.97\ (6400 < X < 8{,}200)$$

$$D_2: Y = -10{,}478 + 2.31\,X - 0.00011\,X^2 \quad R^2 = 0.99\ (8200 < X < 11{,}000)$$

$$D_3: Y = 4{,}206 + 5.16\,X - 0.00026\,X^2 \quad R^2 = 0.98\ (8600 < X < 10{,}800)$$

It can be concluded that for cotton variety 'CNH 36', grown on shallow soil, 45 cm × 45 cm spacing with 49,400 plants/ha was optimum. The economic optimum N dose at this planting density was 88 kg N/ha. At higher planting density the increased agronomic response was due to a higher recovery of applied N.

## REFERENCES


Bartlett, M.S. 1937. Some examples of statistical methods for research in agriculture and applied biology. *Journal of Royal Statistical Society* **4** : (2) 137–183.

Bhaskar, K.S., Lal, S., Challa, O. and Madavi, S.H. 1987. Effect of soil depth on cotton yield. *Journal of Maharashtra Agricultural Universities* **12**(1) : 139–140.

Dewit, C.T. 1953. A physical theory on placement of fertilizers. *Versl Land Bowk. Onderz* **59** (4) : 1–71.

Doble, M.V., Giri, D.G., Pawar, B.R. and Patil, Y.D. 1990. Production of cotton varieties as influenced by different soil types. *Journal of Cotton Research and Development* 4(2) : 188–194.

Joham, H.E. 1986. Effects of nutrient elements on fruiting efficiency. (In) *Proceedings of Beltwide Cotton Production Research Confer-*

*ence*, National Cotton Council of America, Memphus, pp. 306–311.

Kharche, S.G. and Deshpande, P.M. 1989. Response of asiatic cotton to plant density and N levels under rainfed conditions in vertisols. *Annals of Plant Physiology* 3 (2) : 196–202.

Maples R.L., Miley, W.N. and Keisling, T.C. 1990. N recommendations for cotton based on petiole analysis : strengths and limitations pp. 33–39. (*In*) N nutrition for cotton : Practical Issues. Miley, W.N. and Oosterphious, D.M. (eds). American Society of Agronomy Inc. Madison.

Nimbole, N. and Singh, J.V. 1993. Performance of cotton varieties in relation to soil depths. (*In*) *Recent Advances in Dryland Agriculture*, pp. 181–185. Scientific Publishers, Jodhpur.

Sunderman, H.K., Onken, A.B. and Hossner, L.R. 1979. Nitrate concentration of cotton petioles as influenced by cultivars, row spacing and N application rate. *Agronomy Journal* **71** : 731–737.