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Standardization of agronomic requirements for early maturing cotton cultivars on shallow shrink-swell soil

M.V.VENUGOPALAN, P.TIWARY, S. CHATTERJI, O. CHALLA AND S.A. KALSARPE

National Bureau of Soil Survey and Land Use Planning
Amravati Road, Nagpur-440 033, India

Abstract : A field experiment was conducted to identify the optimum row spacing and fertilizer requirement for two early maturing cotton cultivars namely 120 MB and CNH 1001 under rainfed conditions on shallow Typic Haplustepts. Results indicated that although the productivity of both the cultivars were similar, cultivar 120 MB was early maturing with an Earliness Index of 0.78 as against 0.70 for CNH 1001 and was adaptable to a wider intra-row spacing. Although a spacing of 65 x 45 cm appears to be optimum for early maturing varieties on shallow black soils, genotype x environment interactions may necessitate cultivar specific recommendation. At a fertilizer dose of 90:45:45, the mean yield across cultivars and spacing was 10.1 per cent higher than with 60:30:30 dose. Reducing the intra-row spacing from 60 to 30 cm increased the Nitrogen Utilization Efficiency from 16.1 to 18 kg seed cotton per kg N. The variation in yield between years was analyzed and explained in terms of moisture stress and soil moisture depletion.

Additional key words: Moisture stress, row spacing, fertilizer dose, N utilization efficiency

Introduction

In India, cotton is cultivated under rainfed conditions in about 5.3 m ha (Hearn 1994). It is predominantly grown in shrink-swell soils of varying depth. Although, deep well drained soils are recommended (Sehgal and Yadav 1995), yet economic reasons compel farmers to grow cotton on shallow soils (Hajare *et al.* 1998). These soils, by virtue of reduced soil volume and in turn restricted root growth and moisture availability, limit the productivity of conventionally grown long duration cultivars. Under such situations, short duration varieties may offer an alternative to the conventional cultivars. For realizing optimum yield, it is necessary to standardize the agronomic parameters like row spacing and fertilizer dose according to the soil types (Mannikar *et al.* 1988; Venugopalan and Blaise 2001). This paper presents the results of an investigation undertaken to identify the optimum row spacing and fertilizer dose for two early maturing pre-release cotton cultivars under rainfed conditions on a shallow shrink-swell soil.

Materials and methods

Field experiments were conducted for two consecutive years (1998-99 and 1999-2000) on a shallow shrink-swell soil (Clayey, smectitic Typic Haplustepts) at Central Institute for Cotton Research (CICR), Nagpur. The site, a representative of AESR 10.2, is characterized by dry sub-humid tropical climate.

The experiment was laid out in a split-split plot design with four replications. The main plots comprised of two short duration cultivars *viz.* 120 MB (C_1) and CNH 1001(C_2). In the sub-plots, there were 3 intra-row spacings (S_1 = 60 x 30 cm, S_2 = 60 x 45 cm and S_3 = 60 x 60 cm). The two fertilizer (N: P_2O_5: K_2O) doses (F_1 = 60: 30: 30 and F_2 = 90: 45: 45) formed the sub-sub plots. Half the dose of N along with the entire P and K was applied at thinning and the remaining N at squaring stage. The crop was sown during the last week of June in both the years and raised following the recommended crop husbandry.

Petioles from the upper most fully expanded leaf were randomly sampled at first square, first flower, first open boll and maturity stage and analyzed for nitrate – N using phenol di-sulphonic acid method. Seed cotton yield recorded picking wise was used to calculate Earliness Index using the formula proposed by Bartlett (1937)

$$EI = \left[\frac{P_1}{T} + \frac{P_1 + P_2}{T} + \frac{P_1 + P_2 + P_3}{T} \right] \times \frac{1}{3}$$

where, P_1 P_2 and P_3 were the quantity of seed cotton obtained in 1st, 2nd and 3rd picking and $T = P_1 + P_2 + P_3$.

N concentration, in different plant parts at maturity stage, was estimated by Kjeldahl method for calculating N - uptake. Nutrient utilization efficiency (NUE) was calculated using the formula :

NUE = seed cotton yield / N uptake

Soil moisture content at two depths (0-20 and 20-40 cm) was monitored throughout the crop ontogeny. Cumulative water balance was estimated using weekly rainfall data and computed water requirement using the methodology outlined by Popov (1982). Weekly soil moisture stress was estimated using the expression

$$\text{Soil moisture stress} = \frac{\text{Deficit or Surplus soil moisture}}{\text{Crop water requirement}}$$

As the trend in yield and ancillary parameters were similar in both the years, pooled data was used for statistical analysis.

Results and discussion

Soil and climatic features

Some important physical and chemical properties of the soil are presented in

Table 1. Physical and chemical properties of the experimental soil

Horizon	Depth (cm)	Particle-size distribution Sand	Silt	Clay	Bulk density (Mgm^{-3})	Water retention (%) 33 kPa	1500 kPa	pH	Org. C	$CCaCO_3$	CEC [cmol (p+)kg-1]
		(%)							gkg^{-1}		
Ap	0-18	5.0	40.0	55.0	1.24	35.6	21.62	7.9	6.0	41.0	41.8
Bw_1	18-35	4.0	32.0	64.4	1.27	36.9	22.19	8.0	4.2	43.0	40.9
Bw_2	35-45	5.0	36.0	59.0	1.22	36.6	21.15	8.0	2.2	69.0	38.5

Table 2. Temperature and rainfall during the cropping seasons

Month	Mean maximum temperature (°C)		Mean minimum temperature (°C)		Total rainfall (mm)	
	1998-99	1999-00	1998-99	1999-00	1998-99	1999-00
June	38.6	36.7	27.7	25.7	140	82
July	32.2	31.4	25.0	24.6	172	265
August	31.3	30.5	24.5	23.7	346	335
September	31.1	29.9	24.1	23.7	167	234
October	32.4	31.8	22.4	21.1	80	77
November	28.9	31.1	17.0	15.6	86	-
December	28.4	28.2	10.9	11.4	-	-

Table 1. The soil was moderately alkaline with more than 55 per cent clay in all the horizons. Organic carbon was higher in the surface horizon and decreased with depth whereas $CaCO_3$ content followed a reverse trend. The rainfall during the cropping season was 991 and 993 mm respectively in 1998-99 and 1999-2000 and its month-wise distribution is presented in Table 2.

Dry matter yield

Increasing the intra-row spacing from 45 to 60 cm significantly decreased the dry matter production (Table 3). This indicates a sub-optimal use of the additional space available at the lowest planting density, (S_3). The dry matter yield was significantly higher (11.2 per cent) with 90: 45: 45 fertilizer dose (F_2) compared to the lower (60: 30: 30) dose (F_1).

Seed cotton yield, yield attributes and earliness

Averaged over the spacings and fertilizer doses, the seed cotton yields of the two cultivars *i.e.* 120 MB and CNH 1001 were not significantly different (Table 3). However, a significant response (10.1 per cent) was observed at F_2 over F_1 level of fertilizer. Decreasing intra-row spacing from 60 to 45 cm significantly increased the mean yield by 15.7 per cent. The enhanced yield at lower intra-row spacing and higher fertilizer dose was largely due to an increase in the number of bolls/m^2 (Table 3). Gerik *et al.* (1998) opined that adequate N supply increases the boll number by decreasing the bud and boll shedding at lower

Table 3. Effect of cultivars, intra-row spacings and fertilizer levels on yield and yield attributes, earliness and N - uptake

Treatment	Yield attributes: Boll number m^{-2}	Yield attributes: Boll weight (g)	Drymatter yield (Mean)	Seed Cotton Yield 1998-99	Seed Cotton Yield 1999-00	Mean	N - uptake (kg ha^{-1})	Earliness index
			Kg/ha					
Cultivars								
120 MB	105.6	2.38	4867	1771	1492	1631	94.0	0.78
CNH 1001	86.4	2.51	4770	1707	1528	1618	90.7	0.70
F	**	*	NS			NS	NS	**
CD (5%)	8.29	0.12	-			-	-	0.035
Intra-row spacings (cm)								
S_1 (60x30)	103.9	2.45	5043	1851	1667	1759	97.2	0.75
S_2 (60x45)	92.4	2.49	5029	1801	1540	1670	94.5	0.75
S_3 (60x60)	78.8	2.39	4384	1564	1324	1444	89.5	0.73
F	**	NS	**			**	*	*
CD (5%)	12.60	-	240.6			91.7	3.09	0.018
Fertilizer levels								
F_1(60:30:30)	87.4	2.48	4564	1671	1421	1546	88.2	0.75
F_2 (90:45:45)	96.0	2.41	5073	1805	1600	1702	96.6	0.73
F	*	NS	**			*	**	*
CD (5%)	7.69	-	320.4			106.9	4.08	0.015

**,* and NS denote significant at 1%, 5% and non-significant respectively

sympodial nodes. Higher retention of bolls at lower sympodial nodes is very essential on shallow soils where terminal soil moisture stress induces early cutout.

The interaction between cultivar and intra–row spacing was also significant (Table 4). Increasing the intra-row spacing from 30 to 45 cm decreased the yield significantly in CNH 1001, whereas the cultivar 120 MB was more plastic, producing similar yield at 30 and 45 cm row spacing. Similar plasticity over a wide range of planting densities was reported by Bonde and Raju (1996). Such genotype x row spacing interaction can be profitably exploited to reduce seed rate and cost of seed.

Table 4. Interaction effect of cultivars and intra-row spacings on seed cotton yield

	S_1 (60 x30 cm)	S_2 (60 x 45 cm)	S_3 (60 x 60 cm)
120 MB	1713	1743	1435
CNH 1001	1803	1597	1452

F * CD (5%) = 165

Cultivar 120 MB was more early maturing with an EI of 0.78 compared to CNH 1001 (Table 3). Reduced intra-row spacing (30 and 45 cm) induced early fruiting at lower sympodial nodes due to a greater inter – plant competition that resulted in higher EI.

Moisture stress and profile soil moisture

The difference in cotton productivity

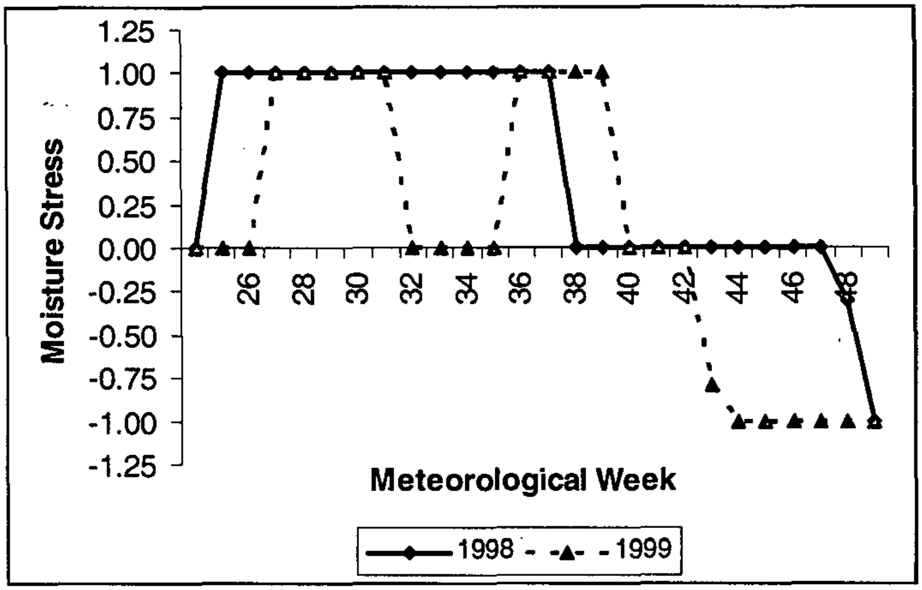

Fig. 1 Estimated moisture stress during crop growth in cultivar 120 MB

Table 5. Soil moisture (per cent by weight) content during the crop season

Met. week	27	31	35	37	39	41	44	46	48	50
					1998					
0-20 cm	33.6	34.2	35.7	35.5	33.6	31.8	34.7	28.7	22.2	20.2
20-40 cm	34.6	35.6	34.4	34.6	34.6	30.4	35.5	28.6	24.3	22.1
					1999					
0-20 cm	25.6	35.5	30.2	34.4	35.7	30.1	29.7	25.5	20.3	14.5
20-40 cm	27.7	36.6	33.2	34.7	36.6	32.2	30. 5	26.6	22.1	16.2

between years could partly be explained on the basis of soil moisture stress. The pattern of stress index (Figure 1) indicates that in 1999, low moisture stress set in early (44th metrological week) and prolonged for more than 6 weeks, causing a reduction in mean yield by 13.1 per cent compared to 1998. In 1998, no stress was observed upto the 48th week, but mild stress was set during the 49th – 50th week (boll opening period) which favoured higher yield realization. These observations were also substantiated by the behaviour of profile soil moisture (Table 5). In 1998-99, both the surface and sub-surface moisture was at least 90% of the field capacity upto the 44th meteorological week. In contrast, during 1999-2000, the decline started about 5 weeks earlier (39th week) and was steep reaching to around 15 per cent by the 50th meteorological week. Thus cumulative moisture stress can be used to explain the variation in productivity between years.

Petiole nitrate-N

Petiole nitrate is an indicator of the N levels in the xylem vessels and is an indirect indicator of soil and crop N status (Maples *et al.* 1990). Since petiole nitrate

Table 6. Petiole nitrate N (x 10^3 mg kg $^{-1}$) in fourth node leaf at different phenophases as influenced by planting density and fertilizer doses

Stage	S_1 (60 x30 cm)	S_2 (60 x 45 cm)	S_3 (60 x 60 cm)
Fertilizer dose		**60:30:30**	
First square	16.8	18.0	22.8
First white flower	10.6	11.6	12.7
First open boll	4.2	6.0	8.6
First picking	0.8	1.2	3.6
Fertilizer dose		**90:45:45**	
First square	20.2	19.8	25.6
First white flower	13.3	12.7	20.8
First open boll	4.0	7.8	9.2
First picking	0.9	1.2	4.7

N did not vary among cultivars, only mean figures are presented in Table 6. It declined with crop ontogeny at both fertility levels. Increasing intra – row spacing from 30 to 60 cm increased the petiole nitrate N at both fertility levels (F_1 and F_2) irrespective of the crop stage. At maturity stage, it was above the optimum level of 1000-1500 mg/kg in S_3 in both the fertility levels. This condition, lead to higher vegetative growth and delayed maturity with no concomitant gain in productivity in S_3. Sunderman *et al.* (1979) also observed increase in petiole nitrate N at higher intra-row spacing.

Nitrogen utilization efficiency (NUE)

There was no significant difference among cultivars or fertility levels in NUE (Fig 2). However, the NUE declined significantly at the highest intra-row spacing (60 cm). This was due to increased N – uptake and a less efficient mobilization of accumulated N for yield formation at 60 x 60 cm spacing. The increased N content induced fruiting but the rapid depletion in soil moisture resulted in an early cutout with many immature bolls.

Conclusions

Based on the study, it may be concluded that in shallow black soil (Typic Haplustepts), the productivity of both the cultivars *viz.* 120 MB and CNH 1001 were similar but the former was early maturing. Further, a spacing of 60 x 45 cm appears optimal, but genotype x environment interactions may necessitate cultivar specific recommendation. Cumulative moisture stress can be used to explain yield variation between years.

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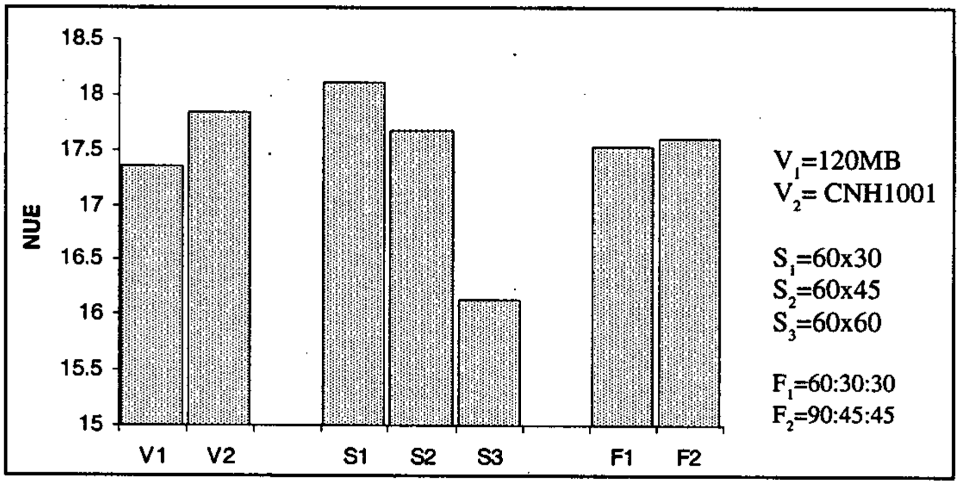

Treatment

Fig. 2 Effect of cultivars, planting densities and fertilizer doses on NUE

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