Fertilization of High Density, Rainfed Cotton Grown on Vertisols of India

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Despite large tracts of irrigated cotton, rainfed systems remain the most important option for improving cotton production in India. Within rainfed fields, the potential effects of adopting high plant population with adequate NPK fertilizer management offer a good opportunity to increase crop productivity.

India has the largest area in the world under cotton at 10.1 M ha and is the second largest producer in the world at 31 M bales. However, India's average cotton productivity is 478 kg lint yield /ha, combining both irrigated and rainfed fields, and this is low compared to other countries like China (1,311 kg lint/ha), Brazil (2,027 kg lint/ha), U.S. (945 kg lint/ha) as well as the world average yield of 763 kg lint/ha (ICAC, 2011).

Rainfed cotton occupies 7 M ha (70%) with an average productivity of 230 kg/ha in India. The majority (90%) of cotton in the State of Maharashtra is rainfed, and this area is expected to increase in the coming years. A system of high density planting (HDP) leading to more rapid canopy closure and decreased soil water evaporation, is becoming popular to address water scarcity challenges. In many countries, narrow row plantings have been adopted after showing improvement in cotton productivity (Ali et al., 2010). The adoption of HDP, along with good fertilizer management and better genotypes, is a viable approach to break the current trend of stagnating yields under primarily rainfed *hirsutum* (upland) cotton growing areas.

Experimental Sites and Design

Four sites (Nagpur, Akola, Parbhani, and Nandyal) were selected during the *kharif* (rainy) season of 2010-11. The commercial varieties grown at these sites included NH 615, NH 452, and PKV 081 at Nagpur, AKH 081, NH 615, and NH 630 at Akola, NH 545, NH 452, and AKH 081 at Parbhani, and NDLH 1938 at Nandyal. The varieties were sown at the onset of the monsoons during the last week of June at Nagpur and Akola, and in the second week of July at Parbhani and Nandyal. Each sub-plot contained ten rows of cotton, 5.4 m long. A plant spacing of 0.45 m x 0.15 m produced a high density population of 14.9 plants/m^2. The traditional plant population is 5.5 plants/m^2.

In Maharashtra and Andhra Pradesh, the climate is hot, dry, and sub-humid. Soils are dominated by Vertisols and Vertic intergrades. Soils at the experimental sites were medium deep black, slightly alkaline (pH 7.8 to 8.4), low-to-medium in available N and P, and high in K status (**Table 1**).

A split-plot design with three replications was used with the main plots being three upland varieties and the sub-plots being four levels (75, 100, 125, and 150% RDF) of NPK fertilizers. Data were collected for seed cotton yield, yield components, and biological yield. Total heat unit during the crop period was estimated on the basis of weekly maximum and minimum temperatures using this equation:

Total Heat Unit=(Max.Temp+Min.Temp)÷2 - Base Temp. (15 °C)

Common abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium; C = carbon; RDF = recommended dose of fertilizer; GR = Gross returns; NR = net returns; B:C ratio = benefit:cost ratio; M = million.

Table 1. Physiochemical properties of selected soils and their respective fertilizer recommendations (100% RDF).

Particulars	Nagpur	Akola	Parbhani	Nandyal
Clay, %	53	48	54	50
Available N, kg/ha	111	218	116	127
Available P_2O_5, kg/ha	18	23	26	87
Available K_2O, kg/ha	481	365	675	591
Organic C, g/kg	3.5	3.7	4.1	4.0
100% RDF, N:P:K	60:13:26	50:20:0	84:18:36	40:9:18

Available N, P_2O_5, and K_2O values reported were determined using the Kjeldahl, Olsen, and 1 N ammonium acetate extraction methods, respectively.

Results and Discussion

Seed cotton yield varied greatly among locations (**Table 2**). Mean seed cotton yield recorded at Nandyal was 13% more than the yield obtained at Akola and >70% higher than yields obtained at Nagpur and Parbhani. From the last week of June through the last week of December (the growing period of cotton), the observed average maximum and minimum temperatures were 30.2 and 21.1 °C at Nagpur, 32.2 and 21.2 °C at Akola, 31.1 and 20.3 °C at Parbhani, and 31.6 and 22.8 °C at Nandyal, respectively. Precipitation was high in the months of July and August at Nagpur and Parbhani, which reduced the growth and yield components. Precipitation during the period from flowering to early boll development (65 to 100 days after planting) is crucial for rainfed cotton. This amount was 339, 225, 222 and 198 mm at Parbhani, Akola, Nagpur, and Nandyal, respectively. During the crop period, Nandyal recorded higher heat units (360.5 °C) as compared to Akola (350.5 °C) and Parbhani (324.1 °C), which might have led to the differences in yields among locations.

No significant difference in seed cotton yield was found between the three varieties used at Nagpur, Akola, and Parbhani. However, variety NDLH 1938 recorded highest yield with the highest bolls per square meter (139.8 BPM) compared to NH 630 (125.5 BPM) under HDP. Seed cotton yield and yield components like plant height, bolls, sympodia, and biomass of upland cotton were increased by 125% NPK fertilization at all four locations. Seed cotton yield recorded with 125 and 150% RDF were significantly higher than that with 75% and 100% RDF. This indicates that fertilizer requirement is most likely to be higher under HDP (Jost and Cothren, 2000; Ali et al., 2007). Interaction effects between main plot and sub plot treatments were not significant for yield and BPM at all the locations.

Total nutrient (N, P, and K) uptake per hectare was higher

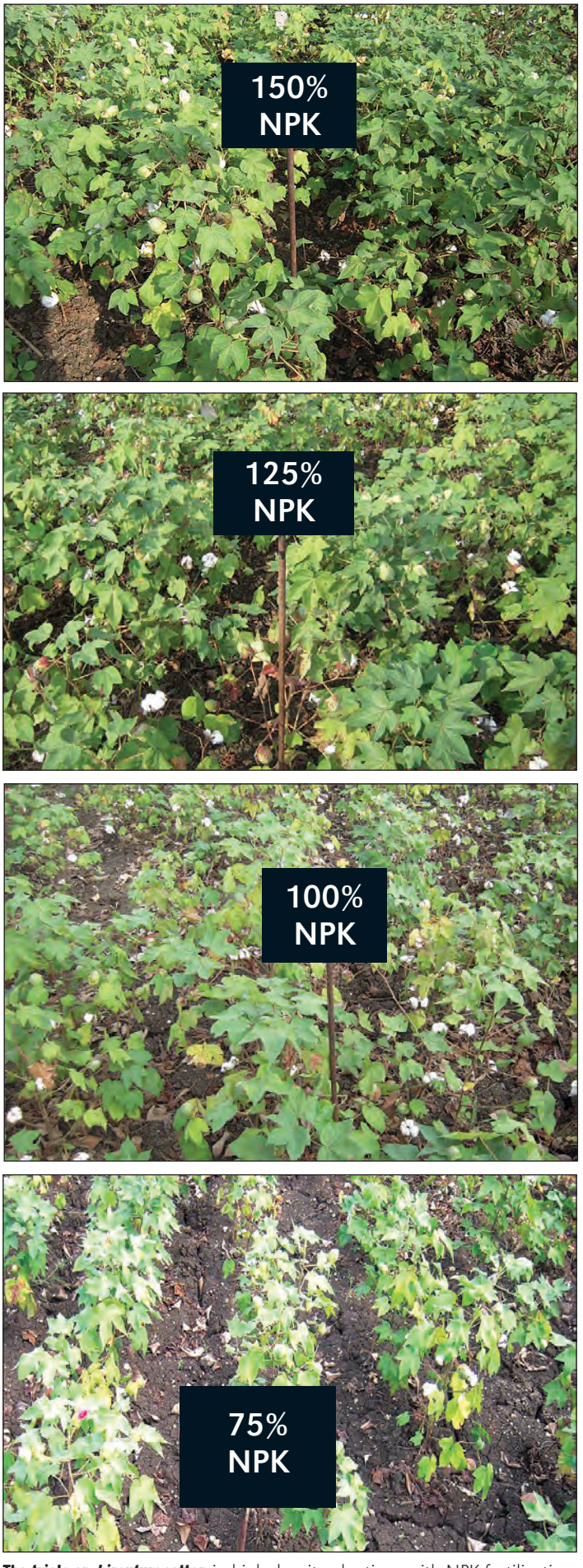
Table 2. Seed cotton yield and yield attributes of cotton in HDP at four experimental locations.

Treatment	Plant height, cm	Sympodia/ plant	Biomass/ plant, g	Open bolls/m²	Yield, kg/ha	Treatment	Plant height, cm	Sympodia/ plant	Biomass/ plant, g	Open bolls/m²	Yield, kg/ha
Nandyal						Akola					
Variety (V)						Variety (V)					
Narasimha	59.3	11.0	36.0	116.7	1,848	AKH 081	66.2	15.4	53.7	93.9	1,731
Sivanandi	65.8	11.7	42.9	121.6	1,868	NH 615	65.6	16.4	51.9	100.8	1,819
NDLH 1938	69.6	14.0	44.7	139.8	2,511	NH 630	75.1	17.6	64.6	125.5	1,917
Mean	64.9	12.2	41.2	126.1	2,076	Mean	68.8	16.5	56.7	106.7	1,822
RDF (F: NPK)						RDF (F: NPK)					
75%	56.0	11.8	33.5	104.3	2,026	75%	65.0	15.9	51.4	104.4	1,698
100%	64.2	12.5	33.8	123.7	2,060	100%	68.2	16.4	54.3	103.5	1,796
125%	63.9	12.8	35.0	126.6	2,133	125%	69.9	16.6	57.8	113.8	1,921
150%	65.7	11.9	34.3	125.2	2,082	150%	72.1	17.0	63.3	112.9	1,873
LSD (0.05) V	9.3	NS	14.9	19.6	313.0	LSD (0.05) V	7.4	1.3	1.45	17.7	NS
LSD (0.05) F	8.3	2.0	2.1	NS	NS	LSD (0.05) F	3.7	NS	4.9	NS	117.0
Parbhani						Nagpur					
Variety (V)						Variety (V)					
NH 545	64.7	6.9	33.1	125.2	1,286	NH 615	71.0	14.5	46.7	96.4	1,156
NH 452	61.5	6.6	31.5	116.2	1,221	NH 452	67.2	16.0	43.5	95.4	1,149
AKH 081	62.4	6.7	31.9	119.2	1,239	PKV 081	60.0	15.0	45.5	104.3	1,309
Mean	62.9	6.7	32.2	119.2	1,249	Mean	66.1	15.4	45.2	98.7	1,205
RDF (F: NPK)						RDF (F: NPK					
75%	59.4	6.4	30.4	119.2	1,179	75%	59.0	14.0	42.7	78.8	972
100%	60.9	6.5	31.2	123.7	1,210	100%	64.2	15.1	46.8	104.3	1,182
125%	67.5	7.2	34.6	125.2	1,341	125%	69.9	16.8	46.2	106.3	1,353
150%	63.6	6.8	32.6	129.6	1,263	150%	74.1	17.0	45.8	105.8	1,311
LSD (0.05) V	1.3	0.1	0.7	NS	NS	LSD (0.05) V	7.8	1.2	2.6	NS	NS
LSD (0.05) F	4.4	0.1	2.2	10.4	71.0	LSD (0.05) F	4.2	1.3	NS	20.1	136.0

Table 3. Nutrient requirement and economics of cotton at different NPK fertilizer levels.

NPK fertilizer levels	Yield, kg/ha	Nutrient uptake, kg/ha			Nutrient use per 100 kg yield, kg			Gross returns,* INR/ha	Net returns, INR/ha	B:C
		N	P	K	N	P	K			
Nandyal										
75%	2,026	101.5	17.6	124.9	5.0	0.9	6.2	100,700	75,700	4.02
100%	2,060	117.3	17.5	124.1	5.7	0.8	6.0	108,100	82,980	4.30
125%	2,133	122.4	19.0	120.5	5.7	0.9	5.6	108,750	83,510	4.30
150%	2,082	118.9	18.5	133.6	5.7	0.9	6.4	108,550	83,190	4.28
Akola										
75%	1,698	71.2	11.8	89.7	4.2	0.7	5.3	75,221	50,241	3.01
100%	1,796	78.8	13.8	99.3	4.4	0.8	5.5	79,563	54,055	3.12
125%	1,921	95.4	16.2	99.6	5.0	0.8	5.4	85,100	59,191	3.28
150%	1,873	84.6	18.7	103.9	5.1	1.0	5.5	82,974	56,423	3.12
Parbhani										
75%	1,179	53.0	12.9	79.6	4.5	1.1	6.8	56,599	35,155	1.64
100%	1,210	54.7	13.4	82.1	4.5	1.1	6.8	58,089	36,406	1.68
125%	1,341	60.2	14.7	88.2	4.5	1.1	6.6	64,373	42,450	1.94
150%	1,263	69.0	15.7	88.5	5.5	1.2	7.0	60,616	38,215	1.71
Nagpur										
75%	972	48.4	8.3	64.6	5.0	0.9	6.6	39,240	21,240	2.18
100%	1,182	65.1	9.6	85.0	5.5	0.8	7.2	48,690	30,290	2.65
125%	1,353	68.5	10.2	96.6	5.1	0.8	7.1	56,385	37,485	2.98
150%	1,311	70.3	9.9	94.6	5.4	0.8	7.2	54,540	35,140	2.81

*Cost of cotton cultivation for recommended practice (INR = Indian Rupee): Nandyal: INR 25,120/ha, Akola: INR 25,508/ha, Parbhani: INR 21,683/ha, and Nagpur: INR 18,400/ha. Cost of nutrients: INR 12/kg N, INR 7/kg SSP (single superphosphate), and INR 5.5/kg MOP (Muriate of Potash or Potassium Chloride)



The trials on *hirsutum* cotton in high density plantings with NPK fertilization.

with higher NPK levels at all the four locations (**Table 3**). The nutrient use in upland cotton was high at Nandyal, which might explain higher seed cotton yield here compared to other locations. Plant P utilization was the least at Nagpur, which might have led to lower yield at this site. These results suggest high nutrient uptake is required for improved yield and numbers of bolls per m^2. The cotton plants had similar N and K uptakes (4.5 to 5.7 kg and 5.5 to 7.2 kg, respectively), while P uptake was 1.0 kg for every 100 kg seed cotton produced at all locations. Although plant nutrient uptake does not differentiate between soil and fertilizer sources, it does give some indication whether inadequate, sufficient, or excessive amounts of fertilizers were applied (Rochster et al., 2009). The higher requirement of NPK was attributed to higher seed cotton yield in HDP, which was needed to improve productivity of upland cotton (Jost and Cothren, 2000). As with the results for yields and nutrient uptake, maximum GR, NR, and B:C ratio were again recorded at 125% fertilizer application levels for Nandyal > Akola > Parbhani = Nagpur.

Summary

Cotton yields in upland, rainfed regions can be increased by higher plant populations that optimize numbers of bolls per plant and boll weight, while lowering cost of cultivation (as straight varieties of upland cotton require less fertilizer compared to hybrid cotton). Application of 25% more NPK fertilizer than the RDF within a 14.9 plant/m^2 stand achieved a maximum seed cotton yield. Cotton productivity can be improved through adequate fertilization of high-yielding, straight varieties of cotton suitable for high density planting. BC

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