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Available soil moisture and yield of rainfed hybrid cotton (*Gossypium hirsutum*) as influenced by rainwater conservation practices

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ABSTRACT

To assess the effect of moisture conservation techniques for enhancement of soil moisture and yield of hybrid cotton (*Gossypium hirsutum* L.) under rainfed conditions, a field experiment was conducted during the rainy (*kharif*) seasons of three consecutive years 2004, 2005 and 2006 on vertisols, at Nagpur. The treatments comprised of six soil moisture conservation practices *viz.,* opening of furrows in each row, in alternate row, tied hoeing, three intercrops with cotton *viz.* soybean (*Glycine max* L.), blackgram (*Phaseolus mungo* L.) and greengram (*Phaseolus radiatus* L.) with one flat bed system (no moisture conservation). Three years study revealed that highest seed cotton yield (1.43 tonne/ha) and cotton equivalent yield (1.95 tonne/ha) with higher net returns of ₹26,491/ha and B:C ratio value of 2.92 was obtained with intercropping system of cotton + green gram compared to sole cotton on flat bed system with 1.20 tonne/ha seed cotton yield and net returns of ₹ 11550/ha). During the period of sowing to flowering stage of cotton, the available soil moisture were found higher at surface soil by 9% due to intercropping system as compared to flat bed system and declined to the increasing depth of soil.

Key words : Cotton, Intercrops, Moisture conservation, Rainfed

Cotton is one of the most important cash crops commercially grown in major rainfed areas of dry sub-humid agro-climate in central region of India. Rainfed cotton occupied an area of about 6.1 million ha out of total 9.1 million ha of cotton during 2006. Low productivity of cotton in this region is due to uncertain and poor distribution of rainfall. Available soil moisture at boll formation stage of cotton is very important and if it is less than 18% the plants get early senescence which reduces the cotton productivity (Sehgal *et al.,* 1992). The production was 17.1 million bales in rainfed area when compared with 10.9 million bales in irrigated areas (AICCIP, 2006). The surface and sub-surface moisture retention in soils can be enhanced by using appropriate agro-techniques like *in situ* moisture conservation by intercropping of short duration legumes with cotton having a row spacing of 90 cm. The effectiveness of *in situ* water conservation is a function of interaction between climate, soil and crop plant characteristics. Conventional method of making of furrows in between cotton rows and short duration intercrops in cotton help in enhancement of soil moisture (Singh *et al.,* 2004 and TMC, 2007). Growing of intercrops with cotton increase the seed cotton equivalent yield by increasing available soil moisture and reduce the weeds population (Mudholkar and Basu, 1995). Thus a study was undertaken to assess the effect of moisture conservation techniques for enhancement of soil moisture and yield of hybrid cotton under rainfed conditions.

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MATERIALS AND METHODS

Field experiments were conducted on hybrid cotton with different moisture conservation practices at Central Institute for Cotton Research, Farm, Nagpur (21^0 9' N latitude and 17^0 7' E longitude) for three consecutive years in rainy seasons of 2004, 2005 and 2006 under rainfed condition. The treatments consisted of six different moisture conservation practices with one no moisture conservation *viz.,* flat bed, opening of furrows in each row, opening of furrows in alternate row, tied hoeing, cotton + soybean, cotton + blackgram, and cotton + greengram. The experiment was laid out in randomized block design with 4 replications. Cotton crop was sown on flat bed system and furrows were opened at last intercultural operation as per treatments in the first week of September in each year. All intercrops viz., soybean ('JS 335'), blackgram ('TAU 1') and greengram ('Kopargaon') were sown on 10^{th} day after sowing of cotton with the system of 1:1 for soybean, and 1:2 for greengram and blackgram with cotton. Cotton 'NHH 44' was sown between 20 and 26 June in all the three years with spacing of 90 cm X 60 cm. The gross plot size was 7.2 m × 7.2 m. Furrows

were made by tying of nylon rope to the iron blade of 45 cm top width plough at last intercultural operation in cotton and the depth of open furrow was about 20 cm. Intercrops were harvested between 60 and 70 days after sowing of cotton and their residues was incorporated with soil through hoeing with bucker (plough) in the same plot. The fertilizer dose 150 kg N + 23 kg P + 41.5 kg K/ha was applied to cotton and no fertilizer was applied to any intercrop. Cotton crop was harvested (in 3 pickings) in the last week of November 2004, 2005 and 2006. Data on number of bolls harvested per plant (average of 5 plants per plot), boll weight (average of 10 bolls) and yield of crops were recorded.

Total rainfall during crop season was 648, 1042 and 940 mm in 2004, 2005 and 2006, respectively. Necessary plant-protection measures of systemic insecticides for sucking pests and 1spray each of quinolphos and synthetic pyrethroid for controlling of bollworms were applied to cotton. The soil of the experimental site was medium deep Vertisols (Typic *Heplusterts*), montmorillonite, high clay contents 55 to 57%, slightly alkaline in reaction (pH 8.1), low in organic carbon (0.46%), low in available nitrogen (154 kg/ha) and phosphorus (8.0 kg/ha) and rich in potassium (464 kg/ha). Weeds biomass (weight of weeds/m^2), water use efficiency and economic parameters like cost of cultivation, net returns and B:C ratio were worked out for each treatment.

RESULTS AND DISCUSSION

Rainfall distribution pattern

Most of the rainfall in central part of India is received from June to September. If low rainfall is received after first week of September in rainy season that occurs stress early in cotton then conservation practices of rainwater help in making of available soil moisture to crop. The amount of rainfall with normal distribution during crop season received in 2004 showed positive response on economic yield of cotton and intercrops (Fig.1). Higher amount of rainfall (1,042 mm) with normal distribution in September was received during crop season of 2005 resulted in good harvest of cotton and soybean crop. In 2006, the distribution of rainfall during crop growth period *i.e.* from 16th June to last week of August was more than normal distribution which resulted in higher biomass with less bolls setting and later rainfall received from 16 September to 30 November was very low (< 60 mm) this caused moisture stress and reduced seed cotton yield.

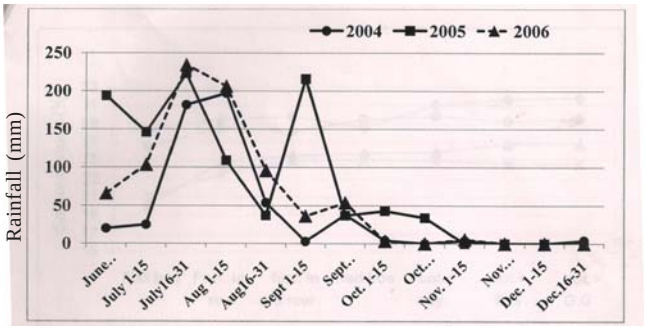

Fig. 1. Fortnightly rainfall (mm) distribution pattern during crop season at research farm, Nagpur.

Yield attributes

Biomass (dry matter) of hybrid cotton at initiation of boll formation stage *i.e.* at 110 days after sowing (DAS) in intercropping system (cotton+blackgram) was significantly higher over the biomass recorded in other intercropping and furrows systems in all the 3 years (Table 1). The cotton biomass accumulation in hybrid cotton was

Table 1. Effect of moisture conservation practices on cotton biomass, number of bolls and weed biomass

Treatment	Cotton biomass at 110 DAS (t/ha)			No of bolls /plant			Weed biomass at 70 DAS (g/m^2)		
	2004	2005	2006	2004	2005	2006	2004	2005	2006
Flat bed system	3.05	2.22	2.10	25.6 (3.5)	24.6 (3.4)	22.5 (3.4)	136.3	139.6	160.2
Furrow in each row	3.50	2.85	2.25	27.1 (3.8)	27.0 (3.5)	24.9 (3.5)	126.8	129.8	153.5
Furrow in alternate row	3.00	3.18	2.46	25.7 (3.7)	27.1 (3.6)	25.0 (3.5)	128.6	129.9	152.8
Tied hoeing	2.99	3.12	2.48	25.7 (3.9)	28.3 (3.4)	25.2 (3.5)	129.8	130.2	151.6
Cotton + soybean	2.48	3.03	2.47	22.6 (3.9)	24.8 (3.7)	24.8 (3.6)	58.6	44.1	53.5
Cotton + blackgram	3.72	3.72	2.84	27.2 (3.7)	30.5 (3.4)	26.8 (3.6)	53.2	54.6	55.3
Cotton + greengram	2.88	2.88	2.44	29.4 (3.7)	32.4 (3.7)	28.0 (3.6)	53.0	53.8	54.8
SEm±	0.02	0.19	0.09	0.92 (0.2)	0.63 (0.2)	0.94 (0.1)	11.61	11.53	4.95
CD (P=0.05)	0.05	0.54	0.25	2.77 (NS)	1.88 (NS)	2.80 (NS)	33.50	34.10	13.01

Figures in parentheses denotes the boll weight (g)
DAS, days after sowing

low in the third year of experimentation than first two years of experimentation at this boll development stage. However, higher biomass accumulation was recorded in moisture conservation plots compared to flat bed system which contributes to higher reproductive parts. In intercropping plots, the biomass accumulation of cotton at flowering stage *i.e.* at 70 DAS was observed comparably low than other treatments due to intercrops existence in cotton but it was non-significant. Similar observations were reported by Deshpande *et al.,* (1989) and Mudholkar and Basu (1995).

Weeds biomass

Weight of weeds collected at 70 DAS from each treatment is presented in Table 1. Total weeds per square meter unit area were collected after 3 intercultural operations and one manual weeding in the moisture conservation techniques *viz.,* flat bed, furrows in each row and alternate row and tied hoeing treatments, while only one manual weeding was done in the intercropping plots. If there was a more weeds in initial stage and not controlled by any means then weeds affect the growth and yield of cotton grown on vertisols. All the intercrops with cotton significantly reduced the biomass of weeds when compared to flat bed or furrows systems in all the 3 years. Biomass of weeds in different moisture conservation practices like opening of furrows systems was at par with each other but it was less than flat bed system. Hence the intervention of moisture conservation practices in rainfed cotton reduced weeds and helps in enhancement of growth and yield of cotton.

Seed cotton and grain yield

Three years data on yield of cotton and grain yield of intercrops viz., soybean, blackgram and greengram is presented in Table 2. Different moisture conservation techniques showed a positive response in producing higher yield of cotton and grain yield of greengram and blackgram with normal distribution of rainfall during crop season in 2004 even though rainfall was less as compared to rainfall received in 2005 and 2006. Significantly higher number of bolls per plant were recorded with moisture conservation practices as compared to no moisture conservation practice (flat bed system) in all the three years (Table 1). Boll weight did not differ significantly at any moisture conservation practice but slightly higher boll weight of hybrid cotton was recorded in intercropping plots. This increment in boll weight of an average of 28 to 30 bolls per plant contributed 0.18 to 0.20 tonne more seed cotton yield in 1 ha. Similar results corroborate with the findings of Mudholkar and Basu (1995) and Solaiappan and Dason (1998). Such response of a marginal increase in boll weight by 0.2 to 0.4 g through moisture conservation techniques over no conservation practice resulted in enhancement of seed cotton yield. Seed cotton yield was significantly influenced with alternate furrows practice over no moisture conservation treatment in all the three years. These results are in conformity with the findings of Singh *et al*., (2004) who reported an increase in seed cotton yield with the adoption of soil moisture conservation practices in different rainfed agro-eco-regions.

Maximum seed cotton yield of 1.59 tonne/ha was registered in cotton + greengram system followed by 1.55 tonne/ha in cotton + blackgram system and minimum yield

Table 2. Effect of moisture conservation practices on seed cotton yield and seed cotton equivalent yield

Treatment	Seed cotton yield (t/ha)			Seed cotton equivalent yield (t/ha)				Rain water-use efficiency (kg/ha-cm)			Cost of cultivation (₹/ha)	Net returns (₹/ha)	B:C ratio
	2004	2005	2006	2004	2005	2006	Pooled	2004	2005	2006			
Flat-bed system	1.31	1.25	1.04	1.31	1.25	1.04	1.20	20.2	11.9	11.1	13,250	11,550	1.87
Furrow in each row	1.41	1.25	1.17	1.41	1.26	1.17	1.28	21.8	12.0	12.4	13,960	12,494	1.89
Furrow in alternate row	1.40	1.53	1.26	1.40	1.50	1.26	1.39	21.7	15.2	13.4	14,260	14,467	2.01
Tied hoeing	1.37	1.34	1.19	1.37	1.34	1.19	1.30	21.1	12.8	12.6	14,360	12,507	1.87
Cotton+ soybean	1.35+ 0.20	1.24+ 1.52	1.12+ 0.82	1.47	2.15	1.67	1.76	20.8	11.8	11.9	13,720	22,654	2.64
Cotton + blackgram	1.55+ (0.46)	1.15+ (0.51)	1.29+ (0.45)	1.78	1.79	1.99	1.85	24.0	11.0	13.6	13,760	24,474	2.75
Cotton + greengram	1.59+ (0.44)	1.41+ (0.21)	1.30+ (0.57)	1.91	1.64	2.31	1.95	24.6	13.6	13.8	13,810	26,491	2.92
SEm ±	0.03	0.07	0.02	0.02	0.06	0.02	0.04	-	-	-	-	-	-
CD (P=0.05)	0.08	0.19	0.06	0.08	0.058	0.06	0.11	-	-	-	-	-	-

Figures in parentheses denote the grain yield of intercrop

Where Prices of crop: seed cotton @ ₹22,000/t, blackgram @ ₹11,000/t, geengram @ ₹16,000/t, soybean @ ₹13,000/t in 2004,
Seed cotton @ ₹ 20,000/t, blackgram @ ₹25,000/t, greengram @ ₹22,000/t, soybean @ ₹12,000/t in 2005,
Seed cotton @ ₹20,000/t, blackgram @ ₹30,000/t, greengram @ ₹35,000/t, soybean @ ₹13,000/t in 2006

of 1.31 tonne/ha in no moisture conservation treatment in the first year. This clearly showed that *in situ* moisture conservation practices through biomass of legumes incorporated in soil considered effective in increasing available soil moisture as well as yield of cotton. In the intercropping system, an additional yield of intercrops 0.20, 1.52 and 0.84 t/ha of soybean, 0.46, 0.51 and 0.46 t/ha of blackgram and 0.44, 0.21 and 0.57 t/ha of greengram over cotton yield was recorded in 2004, 2005 and 2006 respectively, which gave additional monetary benefits to the farmers. It showed that soybean as intercrop had more favourable weather when compared with greengram intercrop in 2005. Results of second year in 2005 indicated significant higher seed cotton yield 1.53 tonne/ha in an alternate furrows and 1.41 tonne/ha in cotton+greengram system over 1.25 t/ha seed cotton yield at no moisture conservation practice. An increase in seed cotton yield was observed by 13% in intercropping and 17% in alternate furrows over flat bed system in this year. These results are in conformity with the findings of Subramanian *et al.,* (1995). Similar trend related to grain yield of intercrops was observed in the third year in 2006 whereas number of bolls and seed cotton yields in all treatments were less when compared with 2004 and 2005 due to less rainfall received from mid-September to November when water requirement was more. In this year, there was no much difference in seed cotton yield in any moisture conservation treatments but they gave significantly higher yields of cotton over no moisture conservation practice. Higher grain yields of soybean 1.52 and 0.84 t/ha recorded in 2005 and 2006, respectively when compared with 0.20 t/ha in 2004. Similar findings corroborate with Rekha and Dhurua (2009).

Seed cotton equivalent yield

The prevailing market prices of seed cotton and intercrops were used for calculating seed cotton equivalent yield (SCEY). Data on cotton equivalent yield revealed that significant higher SCEY was observed in intercropping system *viz.,* cotton+ greengram (1.91, 1.64 and 2.31 tonne/ha), cotton+ blackgram (1.78, 1.79 and 1.99 tonne/ha) and cotton+ soybean (1.47, 2.15 and 1.67 tonne/ha) over the moisture conservation through alternate furrows system (1.40, 1.50 and1.26 tonne/ha) and no moisture conservation treatment (1.31,1.25 and 1.04 tonne/ha) during 2004, 2005 and 2006, respectively (Table 2). Rekha and Dhurua (2009) reported that legumes intercropped with cotton (1:1 row ratio) increased total productivity of the system in terms of seed cotton equivalent yield. The additional yields of intercrops over cotton yield has also been reported by Shekhawat and Singh (1985). Thus these intercrops acted as an cover crops in the early stage of cotton crop and protected the soil moisture from evaporation loss and reduce the weeds population in cotton up to the extent of 35% when compared with flat bed system which boost to produce higher seed cotton equivalent yield (SCEY).

Water use efficiency

Water use efficiency (WUE) was calculated based on yield of seed cotton obtained per unit of rainfall water (Table 2). Higher water use efficiency (WUE) was observed in 2004 when compared with 2005 and 2006 because of higher yield of seed cotton with best use of rainfall water in 2004 2005 and 2006. Maximum WUE of 24.6 kg seed cotton/ha-cm was found in greengram intercropping system followed by opening of furrows in cotton where this value was 21.7 kg seed cotton/ha-cm in first year. This indicated that short duration legumes as intercrop with hybrid cotton was found more useful over long duration intercrop like soybean. The values of WUE were found higher in furrows system as well as in intercropping system when compared with flat bed system of second and third year.

Available soil moisture

Data on available soil moisture at two depths, *viz.* 0 – 0.15 m and 0.15 – 0.30 m at different stage of cotton crop (Figs. 2, 3 and 4) indicated that the available soil moisture content were higher at surface soil (0 to 0.15 m) initially from June to August and declines to the increasing depth that to sub surface soil but after infiltration of water downward, the moisture was increased at sub surface soil profile (0.15 to 0.30 m) in the end of August. Intercropping system in initial period of crop or moisture conservation through different furrows systems at later stage of crop, maintained higher soil moisture contents at peak boll development stage in surface soil, which ranged from 23.2 to 24.8% when compared with 19% in no moisture conservation plots in 2004 (Singh *et al*., 2004). Higher soil moisture was recorded at early boll development (EBD) when compared with peak boll development (PBD) stage of cotton. Soil moisture contents were in the range of 25 to 27% in conservation practices when compared with no moisture conservation practice (20%) in 2005 and 2006. There was a more availability of moisture in soil (25% at surface and 34% at sub-surface) with the intercropping of greengram than flat bed (20%) at later stage of cotton crop in 2006. This clearly showed that the available soil moisture in moisture conservation practices was always higher when compared with no moisture conservation practice in sub surface soil where root of cotton plant was exists.

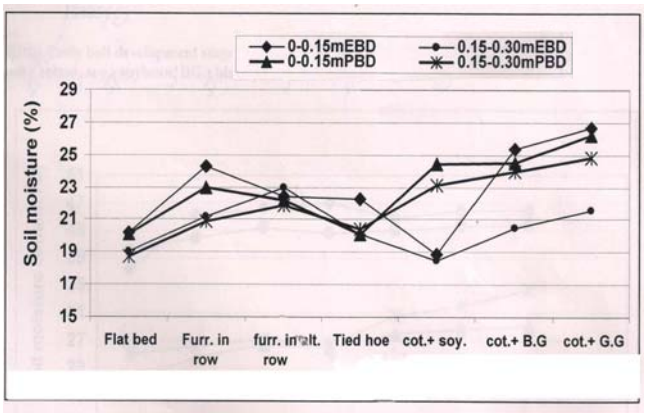

Fig. 2. Effect of moisture conservation practices on available soil moisture contents during 2004

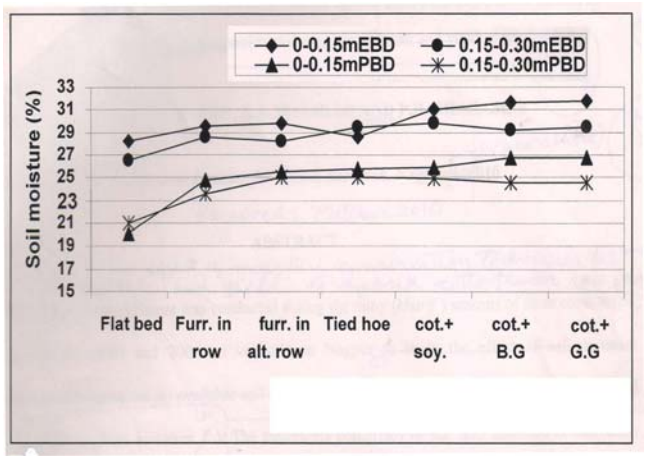

Fig. 3. Effect of moisture conservation practices on available soil moisture contents during 2005
EBD; Early boll development stage; PBD, Peak boll development stage. cot., cotton; soy, soybean; BG, blackgram, and GG, greengram

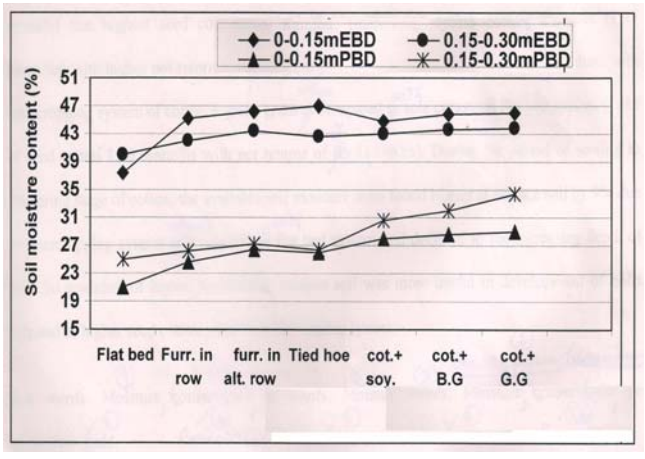

Fig. 4. Effect of moisture conservation practices on available soil moisture content during 2006

Economics

The benefit : cost (B:C) ratio as influenced by various moisture conservation practices (Table 3) revealed that the highest net returns of ₹26,491/ha and B:C ratio of 2.92 was observed in the intercropping system of cotton + greengram followed by cotton + black gram with net returns ₹24,474/ha and B:C ratio of 2.75 whereas minimum B:C ratio (1.87) was recorded in flat bed system. The net returns in alternate furrow in hybrid cotton was ₹ 14,467/ ha with a B:C ratio of 2.01 was comparably more than the furrows opened in each row of cotton.

It was concluded that the intercropping of two row of blackgram or greengram between two rows of hybrid cotton would be more effective and beneficial than opening of furrows or flat bed system to increase the income of farmers under rainfed condition. This system also helps in controlling weeds and cost of intercultural operations in fields during the crop season.

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