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Interactive effect of moisture conservation and integrated nutrient management on yield and nutrient utilization efficiency of rainfed *Bt* cotton (*Gossypium hirsutum*)

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ABSTRACT

A continuous decline in rainfall in the area of rain dependant crop like cotton, there remains a critical need for much more appropriate water conservation research with integrated nutrient as viable option. A field experiment was conducted during *kharif* season of 2007, 2008 and 2009 to study the effect of different rainwater conservation practices with integrated nutrient through different sources on seed cotton yield and nutrient utilization efficiency (NUE) of *Bt* cotton (*Gossypium hirsutum* L.). Results of three years revealed that the intercropping system in *Bt* cotton hybrid with greengram (*Phaseolus radiatus* L.) enhanced the seed cotton as well as seed cotton equivalent yield significantly over sole cotton. Higher seed cotton equivalent yield (2.07 tonnes/ha) was also recorded with cotton intercropped with greengram followed by *in-situ* mulching of sunnhemp (*Crotolaria juncea*) and opening of furrows in alternate row of cotton (1.68 tonnes/ha) as compared to conventional method (1.33 tonnes/ha). Higher available soil moisture was recorded in intercropping and mulching system resulted in higher seed cotton and NUE. Among the different N sources, *Bt* cotton produced the highest seed cotton yield with 75% N through inorganic+ 25% N through FYM and 100% N through inorganic + micronutrients over 100% N through inorganic only. Bt cotton with greengram intercrop recorded higher production efficiency (12.16 kg/ha/day), net returns (30 842/ha) with B: C ratio of 2.35 when compared to flat bed system production efficiency 7.82 kg/ha/day, net returns 12 054/ha, and B: C ratio 1.54.

Key words: Bt cotton, *In-situ* moisture conservation, Intercrop, Integrated nutrient, Nutrient utilization efficiency, Yield

Bt cotton (*Gossypium histutum* L.) not only give higher productivity, but also higher net income over conventional cotton, due to reduction in expenditure on insecticide on this crop. At present *Bt* cotton occupied 7.60 million ha out of 9.37 million ha in 2008 had highest productivity of cotton (560 kg/ha) in India (ICAC 2009). The production of *Bt* cotton hybrids was 1.17 tonne/ha against 0.87 tonne/ha in the conventional hybrids grown in central region of India (Ramasundaram *et al.* 2007).

Despite an increase in productivity of cotton due to commercialization of *Bt* hybrids the productivity of rainfed cotton in central zone is still low as compared to irrigated cotton owing to several factors including erratic rainfall, shallow soils, low permeability and AWC. Cotton hybrids sown of wider row spacing provide space for cultivation of short duration intercrops which conserve rainwater and stabilizes the productivity besides improving income. Secondly most of the rainfall was received in the month of July and August and later period recedes when water demand is more to cotton, for which moisture conservation practice may be very useful to enhance the yield of rainfed cotton. Hence, to harness the benefits of *Bt* cotton hybrids and to sustain the yield potential, the suitable agro-practices for rainwater conservation with nitrogen management through organic manure are most essential for rainfed region of India. Looking to the large area under *Bt* cotton, intercropping, water conservation and integrated nutrient management (INM) are best opportunity for achieving higher cotton yield (Shankarnarayanan *et al.* 2004). The present field study was therefore, conducted to study the effect of different rainwater conservation practices in combination with integrated nutrient supply on the production of *Bt* cotton in rainfed area.

MATERIALS AND METHODS

Field experiment was conducted at Central Institute for Cotton Research, Nagpur, during *kharif* seasons of 2007, 2008 and 2009. The region is characterised as dry sub humid climate with an annual rainfall of 900 to 1150 mm. The soil of experimental site was medium deep black (Typic *Haplustert*) with slightly alkaline in reaction (pH 8.1) having

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field capacity 29.9%, low in organic carbon (0.36%), low in available nitrogen (110 kg/ha) and phosphorus (7.9 kg/ha), low in boron (0.2 ppm) and iron (Fe 5.45 ppm) and rich in available potassium (526 kg/ha). Treatments consisted of three soil moisture conservation practices (M_1: Opening of furrows in alternate row of cotton, M_2: intercropping of greengram with cotton, M_3: mulching of sunnhemp *in-situ,* with one conventional practice, M_4 i.e. flat bed system) as main plot factors and six integrated nutrient treatments (F_1:100% recommended dose of N as inorganic (RDN), F_2: 75% RDN + 25% N through FYM, F_3:75% RDN+ 25% N through vermicompost, F_4:50% RDN + 50% N through FYM, F_5:50% RDN + 50% N through vermicompost and F_6:100% RDN + micronutrients as Fe + B each @ 10 kg/ha) as sub plot factors. Experiment was laid out in a split plot design with 3 replications. Recommended dose of NPK fertilizer adjusted on soil test basis was 112:25:40 kg /ha and full dose of P and K as inorganic was applied at the time of sowing and N as inorganic in 3 splits applied to cotton. No fertilizer was given to intercrop. *Bt* cotton hybrid NCS 145 (intra-specific *hirsutum* hybrid) was sown on 24, 21 and 22 June during 2007, 2008 and 2009 respectively. Two seeds of *Bt* were dibbled at 90cm x 60cm and after its emergence of seedlings, one cotton plant per dibble was retained for study. Intercrop sunnhemp (*Crotalaria juncea* L.) of locally available and greengram (*Phaseolus radiatus* L.) Kopergoan was sown in between cotton rows (1:1 system) after one week of emergence of cotton. The total biomass of sunnhemp at 45 days and residues of greengram (after harvest of pods) was mulched *in-situ*. Recommended plant protection measures were taken to control sucking pests of cotton. Crop was harvested in 3 pickings during November to first week of December. The mineral contents in manures used in experiment are presented in Table 1. Observations on yield and yield attributing parameters were recorded. Effective rainfall water utilized by cotton on the basis of evaporation rate during crop season was 654, 455 and 608 mm in 2007, 2008 and 2009 respectively. Water use efficiency was calculated on the basis of yield (kg/ha) divided by the amount of effective rainfall water. Standard procedures were used for chemical analysis of NPK nutrients (Jackson 1967). Data was statistically analysed and least significant difference (LSD) at 5% probability was used to separate out the treatments difference.

Table 1 Nutrient composition index in organic and green manure on dry weight basis

Materials	N (%)	P (%)	K (%)	Zn (%)	B (%)	Mg (%)
Farmyard manure						
(Cow dung)	0.6	0.2	1.8	0.05	0.01	0.3
Vermicompost	2.5	2	3.5	0.11	0.06	0.2
Greengram	3.5	1.7	2.5	0.1	0.01	0.4
Sunnhemp	3.6	0.3	2.1	0.01	0.16	0.3

RESULTS AND DISCUSSION

Effect of seasons on productivity

The total precipitation received during the crop season was 934, 569 and 810 mm in 2007, 2008 and 2009, respectively. The distribution pattern of rainfall in 2007 during July, August and September was more uniform as compared to 2008 and 2009, resulted in higher seed cotton yield in 2007. Rainfall received in 2008 was less than 2007 and 2009 so most of the rainwater utilised by cotton was fairly good as compared to high rainfall received in July and August in 2009 which had positive impact on filling of bolls resulted in increase of seed cotton yield. High intensity of rainfall received during July 2009, adversely affects the growth and formation of fruiting parts which ultimately affect the yield. The rainfall received during September if very low then it affects the filling of bolls therefore, the suitable moisture conservation practice may help to sustain soil moisture up to some more time than conventional practice.

EFFECT OF MOISTURE CONSERVATION PRACTICES AND INM

Biomass, sympodia and opened bolls

The influence of moisture conservation practices on dry matter yield was significant over no moisture conservation practice at both the stages of cotton. The maximum dry matter (1.8 tonnes/ha) was recorded in *in-situ* mulching plots followed by intercropping plots (1.6 tonnes/ha) as compared to flat bed plots (1.3 tonnes/ha) at 70 DAS. Significant higher dry matter was recorded in intercropping system as compared to flat bed and furrows system at 110 DAS. Increase in biomass of rainfed *Bt* cotton is an important factor which provides good harvest of seed cotton. The reduction in biomass of *Bt* than non *Bt* counterpart due to genetic modification has been reported earlier by Singh *et al*. (2004). Yield attributing parameters such as number of sympodia and opened bolls per plant differed significantly due to moisture conservation treatment over flat-bed (Table 2). Highest number of mean sympodia (23.7), total opened bolls (36.7) per plant and good boll weight (3.75g) was recorded in intercropping system followed by sunnhemp mulching (sympodia 22.1, bolls 32.2 per plant and boll weight 3.67g. Marginal increase in boll weight by 0.47, 0.43 and 0.80g per boll in 2007, 2008 and 2009 respectively, in intercropping system contributed to maximum yield as compared to sole cotton. The positive impact of intercrop like greengram owing to its ability of N contribution and reduces weeds in between cotton rows followed in increase of yield attributes lead to higher seed cotton yield. These results are in close agreement with the findings of Shankarnarayanan *et al.* (2004) and Shinde *et al.* (2009).

Different manurial treatments had non-significant effect

Table 2 Yield attributing parameters as influenced by different moisture conservation practices and integrated nutrients

Treatment	Number of sympodia/plant				Average boll weight (g)				Opened bolls/plant			
	2007	2008	2009	Mean	2007	2008	2009	Mean	2007	2008	2009	Mean
Moisture conservation practices												
M_1	22.0	22.1	19.1	21.1	3.78	2.80	3.62	3.40	35.7	34.3	24.6	31.5
M_2	24.6	24.2	22.3	23.7	4.10	3.48	3.68	3.75	43.1	36.1	30.8	36.7
M_3	23.8	22.4	20.2	22.1	3.96	3.48	3.57	3.67	36.9	36.1	23.6	32.2
M_4	20.5	18.5	16.5	18.5	3.30	3.05	3.21	3.19	24.1	26.0	22.4	24.2
SE m ±	0.4	0.4	1.4	0.4	0.5	0.4	0.2	0.4	2.0	0.7	1.3	1.3
CD(P=0.05)	1.4	1.3	3.2	1.4	NS	NS	NS	NS	4.7	1.8	3.2	3.3
Integrated nutrients												
F_1	19.4	19.2	15.0	17.9	3.28	2.95	3.05	3.09	32.7	30.2	22.7	28.5
F_2	24.8	24.3	22.0	23.7	4.20	3.67	3.57	3.81	34.0	35.7	27.3	32.3
F_3	22.9	21.3	21.0	21.7	3.98	3.26	3.63	3.62	36.0	31.6	26.1	31.2
F_4	22.6	21.6	19.5	21.2	3.68	3.27	3.65	3.57	36.3	34.5	25.1	32.0
F_5	22.5	21.6	19.5	21.2	3.60	3.03	3.53	3.39	34.9	31.9	25.8	30.9
F_6	23.8	22.8	21.5	22.7	4.14	3.71	3.43	3.76	35.7	34.8	25.4	32.0
SE m ±	0.4	0.6	1.4	0.8	0.5	0.6	0.3	0.5	0.8	1.3	1.5	1.2
CD(P=0.05)	1.2	1.2	3.6	2.0	NS	NS	NS	NS	1.2	2.6	NS	2.7

Details of treatments are mentioned in the text

on dry matter recorded at 70 and 100 DAS. A substitute of 25% N through FYM with 75% RDN inorganic (F_2) influenced in achieving higher dry matter yield of cotton than 100% RDN inorganic (F_1). Combined application of organic and inorganic nutrients in different proportions influenced significantly the yield attributing parameters over to F_1 in all the three years (Table 2). Maximum bolls /plant and boll weight was recorded by F_2 and F_6 treatments as compared to F_1. Similar findings were in confirmation with Blaise (2006). Increase in boll weight of *Bt* cotton with different INM treatments was reported by Narayana *et al.* (2011). With a little variations in growth periods to achieve reproductive phase of crop was also influenced by organic treatments. Thus, the *Bt* cotton under organic manures produced more output in terms of seed cotton yield.

Yield of seed cotton and grain yield of intercrop

Variation in seed cotton yield at three moisture conservation practices was observed in different years due to variation in rainfall distribution patterns. Influence of years on seed cotton yield revealed that significantly higher bolls and boll weight led to realization of highest yield during 2007 due to favourable climate. Data on seed cotton yield (SCY) revealed that all moisture conservation practices, i.e. opening of furrows (M_1), intercropping (M_2) and *in-situ* mulching (M_3) were found equally effective and produced significantly highest SCY over flat bed practice (M_4) in first year but the magnitude of yield difference between M_2 M_1/ M_3 increased in subsequent years (Table 3). Highest SCY in M_2 was observed due to mulching effect of residues and more available soil moisture from boll formation to maturity stage (Shankarnarayanan *et al.* 2004 and Narayana *et al.* 2011). Economic yield of intercrop, i.e. greengram was 0.22, 0.11 and 0.12 tonne/ha in 2007, 2008 and 2009 respectively, in addition to the seed cotton yield of *Bt* in M_2. When green manure or intercrop residue applied, the soil moisture was improved resulted in release of nutrients following mineralization of organic sources and increased seed cotton yield by 16-20 % (Venugopal *et al*.1999, Kimetu *et al.* 2004). Experimental trials in western Maharashtra, at Rahuri, revealed that sunnhemp grown as green manure and incorporated *in-situ* improved productivity of widely spaced hybrid cotton.

Application of nitrogen in the form of organic manures and inorganic fertilizer in different proportions increased SCY significantly over F_1 (Table 3). Highest SCY recorded at different INM treatments in 2007 indicates the maximum utilization of nutrients from manures as well as uniform distribution of rainfall in first year than the remaining two years of experimentation. Treatments difference with respect to SCY was narrow in 2009 as compared to 2007 and 2008, it may be residual and cumulative effect of organic manures. Highest SCY (2.16, 1.65 and 1.43 tonnes/ha) was recorded in F_6 treatment followed by F_2 (2.15, 1.59 and 1.43 tonnes/ ha) in the year of 2007, 2008 and 2009, respectively. When the integrated use of fertilizer and manures coupled with moisture conservation practices it further improves the yield and water productivity of pigeonpea in Tamil Nadu (Ramesh and Devasenapathy 2007).

Seed cotton equivalent yield

Intercropping of greengram produced cotton equivalent

Table 3 Seed cotton yield (tonnes/ha), production efficiency and economics under moisture conservation and integrated nutrient treatments

Treatment	2007-08	2008-09	2009-10	pooled	PE (kg/ha/day)	GR (/ha)	NR (/ha)	B:C ratio
Moisture conservation practices								
M_1	2.2	1.66	1.18	1.68	9.87	43 628	21 128	1.94
M_2	2.29	1.63	1.57	1.83	12.16	53 742	30 842	2.35
	–2.52	–1.87	–1.82	–2.07				
M_3	2.22	1.56	1.28	1.68	9.87	43 888	21 288	1.94
M_4	1.47	1.35	1.17	1.33	7.82	34 554	12 054	1.54
SEm ±	0.07	0.09	0.1	0.09				
	–0.08	–0.06	–0.1	–0.07				
CD(P=0.05)	0.18	0.22	0.25	0.22				
	–0.2	–0.14	–0.25	–0.17				
Integrated nutrients								
F_1	1.78	1.4	1.21	1.46	8.96	39 598	17 098	1.76
	–1.84	–1.46	–1.27	–1.52				
F_2	2.15	1.59	1.43	1.72	10.57	46 722	23 222	1.99
	–2.2	–1.71	–1.48	–1.8				
F_3	2.02	1.59	1.25	1.62	9.83	43 446	19 446	1.81
	–2.08	–1.62	–1.31	–1.67				
F_4	2.14	1.53	1.27	1.65	9.93	43 888	20 888	1.91
	–2.13	–1.6	–1.34	–1.69				
F_5	2	1.54	1.19	1.58	9.62	42 536	19 036	1.81
	–2.05	–1.6	–1.26	–1.64				
F_6	2.16	1.65	1.43	1.75	10.75	47 502	24 602	2.07
	–2.22	–1.77	–1.5	–1.83				
SEm ±	0.07	0.05	0.05	0.06				
	–0.07	–0.04	–0.05	–0.04				
CD(P=0.05)	0.13	0.09	0.1	0.11				
	–0.2	–0.09	–0.1	–0.08				

* Figures in parenthesis indicate the seed cotton equivalent yield, PE: production efficiency. To calculate SCEY the following prevailing minimum support prices were considered seed cotton and greengram @ ± ₹ 24 500/tonne and ₹ 25 000/ tonne in 2007, seed cotton and greengram @ ± ₹ 33 000/tonne and ₹ 50 000/ tonne in 2008 and seed cotton and greengram @ ± ₹ 29 000/tonne and ₹ 60 000 /tonne in 2009

yield of 0.22, 0.24 and 0.25 tonne/ha in 2007, 2008 and 2009, respectively in addition to the seed cotton yield, received in the same plot (Table 3). These values were added to the yield obtained in intercropping plots to describe seed cotton equivalent yield (SCEY). Higher SCEY was registered in M_2 as compared to seed cotton yield in other plots. Pooled data of three years revealed that significant higher SCEY in M_2 and SCY in M_1/M_3 were recorded over the flat bed system (M_4). Average across the years, SCEY was significantly greater in all moisture conservation treatments than the flat bed. The results are in agreement with those of Shinde *et al.* (2009) and Narayana *et al*. (2011).

Effect of addition of micronutrient with 100% RDN (F_6) and substitution of 25% N through organic manure (F_2) significantly influenced SCEY as compared to F_1 (Table 3). An increase in SCEY by 20, 21 and 17% in 2007, 2008 and 2009, respectively was observed in F_6 when compared to F_1. Sub plot treatments difference was narrow in SCEY in 2009 as compared to 2007, because of cumulative effect of organic manures. Further increase in substitution of nitrogen through organic manures with inorganic fertilizer proved to be counterproductive. Pooled data of three years on SCEY showed that INM treatments (F_2 and F_6) had significant effect on increase of SCEY over 100% RDN inorganic. Similar results were also reported by Kimetu *et al.* (2004), Ramesh and Devasenapathy (2007) and Narayana *et al*. (2011). Interaction effect of nutrients and soil moisture conservation treatments was non-significant in all the three years.

Water use efficiency

Water-use efficiency (WUE) from effective rainfall during crop season was highest in M_2 and M_3 than M_1 and M_4 in *Bt* cotton (Table 4). When there was a less rainfall, highest WUE (29.2 kg /ha-cm) was recorded in M_1 than M_2 (28.7 kg /ha-cm) and M_3 (27.5 kg /ha-cm) which reflects higher yield

Table 4 WUE (kg seed cotton/ha-cm) and NUE (kg seed cotton/kg nutrient uptake) under different moisture conservation and integrated nutrient treatments

Treatment	WUE			NUE			
	2007-08	2008-09	2009-10	Pooled	N_{UE}	P_{UE}	K_{UE}
Moisture conservation practices							
M_1	23.6	29.2	14.5	22.4	25.80	59.38	29.92
M_2	24.6	28.7	19.3	24.2	28.10	65.52	30.81
M_3	23.8	27.5	15.8	22.4	26.39	65.78	32.20
M_4	15.7	23.8	14.4	18.0	22.41	50.41	30.04
SEm ±					0.79	3.13	1.77
CD (P=0.05)					1.93	7.67	NS
Integrated nutrients							
F_1	19.1	24.6	14.9	19.5	24.42	55.64	26.20
F_2	23.0	27.9	17.6	22.8	26.50	62.10	30.14
F_3	21.6	27.9	15.4	21.7	24.91	59.22	29.94
F_4	23.2	27.0	15.7	22.0	24.20	60.53	29.01
F_5	21.4	27.2	14.7	21.1	26.40	59.76	28.90
F_6	23.2	29.0	17.7	23.3	27.60	64.40	31.22
SE m ±					1.01	1.87	1.07
CD (P=0.05)					2.03	3.79	2.17

in this system in 2008. Lowest amount of rainwater utilization was observed in M_4 in all the three years. This showed that rainwater conservation practices are more beneficial than flat bed system for rainfed *Bt* cotton. These results are in conformity with the findings of Singh *et al.* (2004) and Sivanappan (2004). Pooled data indicated that treatment M_2 had WUE (24.2 kg/hacm) followed by M_1 and M_3 as compared to M_4. Among the different manurial treatments the substitute of 25 to 50 % N through organic manures enhanced WUE as compared to 100% RDN inorganic because of increase in number of bolls resulted in higher SCY. Pooled data revealed that the inorganic fertilizer coupled with organic manure in different proportions improved rainwater use efficiency as compared to inorganic fertilizer applied alone.

Nutrient utilization efficiency

Nutrient utilization efficiency (NUE in kg seed cotton per kg uptake) in *Bt* cotton was derived from mean seed cotton yield of three years divided by total uptake of each nutrient (Table 4). Maximum utilization of nutrient NPK was observed at all conservation practices as compared to flat bed system. Highest NUE_N (28.10) was observed in intercropping system while NUE_P (65.8) and NUE_K (32.20) was in mulching plots as compared to conventional practice (Venugopalan and Tarhalkar 2003). The efficiency of P utilization was high as compared to utilization of N and K might be due to higher soil P mineralization to its available form with the addition of manures which retained more moisture for more times than open space in sole cotton sown at wider spacing. The combination of organic manures and inorganic fertilizer in different proportions increased the utilization efficiency of nutrients in *Bt* cotton as compared to 100% RDN (F_1). The utilization efficiency values of P and K of different INM treatments were at par while NUE_N was significantly higher in treatment F_2 and F_7 in which highest SCY was recorded over F_1, F_3 and F_4. Data on utilization of nutrients in INM treatments clearly indicates the higher nutrient utilization over 100 % RDN (F_1).

Available soil moisture

Effect of *in-situ* conservation of rainwater through intercropping or land configuration treatment in cotton on available soil moisture (ASM) was determined at 16 days interval after second week of August coinciding with the normal period of recession of rains. Among the different *in-situ* moisture conservation practices, M_2 and M_3 retained high soil moisture as compared to M_1 and M_4 during the period of 12 August to 30 September while at later stage of crop, ASM was more in M_1. This indicates that intercropping as well as *in-situ* mulching preserved more moisture in soil during active growth period to boll formation stage of cotton. Venugopalan and Tarhalkar (2003) reported that legume crop as an intercrop in cotton not only protects the soil from the impact of rain drops and reduce erosion but also improves soil water storage and thus productivity. However, under low rainfall situation the ASM was effectively utilized by fast growing crop like greengram or sunnhemp which decrease the temperature as compared to opened space as reported by several workers. ASM at surface soil was higher in conservation treatments at that time cotton crop needs more moisture for development of productive parts of cotton. While soil moisture in M_4 was near to permanent wilting

point (PWP) at peak boll development stage that will adversely affect the development of productive parts in second phase (harvest stage) of cotton. The ASM in moisture conservation plots was more in last soil samples as compared to M_4, it was due to 10-15 mm rainfall received during third week of November.

Economics

Economics of different moisture conservation practices described from the pooled data of SCEY is presented in Table 3. The economics of *Bt* cotton due to intervention of conservation practices indicates cotton+ greengram system on an average fetched 30842/ha as higher net returns and higher B:C ratio (2.35) when compared to the economics of flat bed system (net returns of 12054/ha and B:C ratio of 1.54). Maximum returns are due to addition of intercrop yield and higher support market price of greengram. Economics of other two rainwater conservation practices as opening of furrow in alternate rows and *in-situ* mulching were found to be at par but higher than flat bed system (Singh *et al.* 2004). Among different manurial treatments, maximum net returns (24602/ha) and B: C ratio (2.07) was found with addition of micronutrients to 100% RDN as compared to other INM treatments when seed cotton equivalent yield was to be considered for economic analysis (Shinde *et al*. 2009). The study indicated that wherever feasible green manuring or organic manure could offer a viable option for higher productivity and higher net returns to the farmers. Similar observations were also made by Blaise and Ravindran (2003).

Thus, it can be concluded that *in-situ* moisture conservation practices with short duration crop of greengram in *Bt* cotton utilizing open space between cotton rows, was found beneficial over conventional method (flat bed system) for rainfed *Bt* cotton hybrid. Addition of micronutrients with recommended dose of fertilizer to those soils belong to low in their availability and with substitution of 25% of N through organic manure was found biologically and economically sustainable cropping system for *Bt* cotton hybrids.

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REFERENCES

Blaise D. 2006. Balanced fertilization for high yield and quality of cotton. *Extended summaries Vol. 1. International Symposium on Balanced fertilization for sustaining Crop Productivity*, PAU, Ludhiana, India, during 22-25, Nov. 255–3.

Blaise D and Ravindran C D. 2003. Influence of tillage and residue management on growth and yield of cotton grown on Vertisols over 5 years in semi-arid region of India. *Soil and Tillage Research* **70**: 163–73.

ICAC. 2009. Biotech cotton and technology. ICAC Recorder **27**: 4–8.

Jackson M L.1967. *Soil Chemical Analysis.* Prentice Hall India Pvt Ltd, New Delhi.

Kimetu J M, Mungedi D N, Palm C A, Mutus P K, Gachungo C N, Bationo A, Nandwa S and Kungu J. 2004. Nitrogen fertilizer equivalencies by organics of differing quality and optimum combinations with organic nitrogen source in Central Kenya. *Nutrient Cycling in Agro-ecosystem* **68**:127–35

Narayana E, Aparna D and George M. 2011. Response of *Bt* cotton (G. *hirsutum* L) for integrated rainwater and nutrient management. *Journal of Cotton Research and Development* **25**: 68–70.

Ramesh T and Devasenapathy P. 2007. Natural resources management on sustainability of rainfed pigeonpea (*Cajanus cajan L.*) *Research Journal of Agricultural and Biological Science*s **3** (3):124–8.

Ramsundram P, Vennila S and Ingale R K. 2007. *Bt* cotton performance and constrains in Central India. *Outlook in Agriculture* **36** (3): 175–80.

Shankarnarayanan K, Praharaj C S, Nalayini P and Dharajothi B. 2004. Studies on intercropping in *Bt* cotton hybrid. *(in) proceedings of Abstract, National Symposium on Changing World Order Cotton Research, Development and Policy in Context,* ANGRAU, Hyderabad, pp 42.

Sivanappan R K. 2004. Irrigation and rainwater management for improving water use efficiency and production in cotton crop. *(in) International Symposium on Strategies for Sustainable Cotton Production - A Global Vision,* UAS, Dharwad. pp 7–14.

Shinde V S, Deshmukh L S, Shinde S A and Zade K K. 2009. Influence of rainwater management through different agro practices on yield, yield attributing characters and economics of cotton. *Journal of Cotton Research and Development* **23**: 5.

Singh Jagvir, Blaise D, Veerbhadra Rao, Patil B C, Dhawan A S and Deshmukh M S. 2004. On-farm evaluation of integrated nutrient management and moisture conservation practices on rainfed upland cotton (*Gossypium hirsutum*). *Indian Journal of Agricultural Sciences* **74**: 649–53.

Venugopalan M V and Tarhalkar P P. 2003. Evaluation of organic recycling practices in improving the productivity of rainfed cotton on marginal soils. *Tropical Agriculture* **80**: 163–7.