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Participatory evaluation of technologies for improving the profitability of *Bt* hybrid cotton based cropping systems in calcareous soils

A. RAVINDER RAJU*, N. ANURADHA, RACHANA DESHMUKH AND SHILPA BABAR

ICAR-Central Institute for Cotton Research, Nagpur 440010.

**E-mail: bumaraju@gmail.com; AR.Raju@icar.gov.in*

ABSTRACT: Although cotton is semi tolerant to calcareous soils, yield reductions to the extent of 30-40 per cent were observed with a productivity as low as 5q/ ha at 40 per cent $CaCO_3$ and as high as 22 q/ha at 20 per cent $CaCO_3$ with fertigation in farmer's fields. *Dolichus purpureus* without any fertilizers, fortnightly insecticidal spray against pod borer and 3-4 supplemental irrigations was most economical with a net profitability of ₹ 37.4 to ₹ 50,000/- compared to ₹ 25,000/ha with rainfed *Bt* hybrid cotton where average $CaCO_3$ content was exceeding 40 per cent. Spraying humic acid/ growth stimulants, micronutrients and application of sulphur containing complex phosphorous fertilizers 25-35 per cent higher than RDP in 2-3 split applications, 80 per cent RDN nitrogen are most common practices followed by the rainfed *Bt* hybrid cotton farmer's. Present investigation found 125 per cent RDP and 100 per cent RDK applications were very essential to improve seed cotton yields respectively under rainfed and supplemental irrigations in calcareous soils. Rainfed *Bt* hybrid cotton with and without nutrient management package produced 11.5 and 8.5 q/ha in farmer's fields. *Bt* hybrid cotton with two supplemental irrigations and fertigation produced seed cotton yield of 15 and 25 q/ha respectively.

Key words : *Bt* hybrid cotton, calcareous soils, cropping systems, nutrient deficiencies, supplemental irrigation

Thirty per centage of Indian soils and seventy per centage of the Indian *Vertisols* are calcareous. *Bt* hybrid cotton is being semi tolerant grown as one of the major rotational crop in 36 per centage of Maharashtra state soils. Highly calcareous soils with >8.5 pH and 15-85 per cent $CaCO_3$ in the semi arid tropics severely interferes with *Bt* hybrid cotton Phosphorous (P), Potassium (K), Magnesium (Mg), Iron(Fe) and Zinc (Zn) nutrition causing hidden hunger, besides severe soil moisture stress causing terminal droughts and reduces the seed cotton yield to 1/3rd to that of non calcareous soils (Patricia, 2000; Pal *et al.*, 2012). Inadequate organic carbon in the rhizosphere quickly looses the soil moisture within two weeks after the cessation of the monsoon rains limiting the growing period of crops 120-140 days. Impermeable hard pan (*Caliche*) below 1.5-2' depth, is not a limiting factor for productivity in rainfed *Bt* hybrid cotton. Rainfed *Bt* hybrid cotton in highly calcareous soils expressed clear cut deficiencies of P, K, Mg and Zn. However, did not responded to foliar application of the same without any measurable yield improvement in a year of drought with fewer, and small sized bolls with prematured boll

bursting. However, seed cotton yields were not limited under two to three supplemental irrigations with adequate P, Mg, K, Zn and Fe application. Limited researches were conducted in groundnut and other crops, results were never validated in farmer's fields. Farmers were surviving on trial and error basis in the absence of adequate understanding of the chemistry of complex calcareous soils interactions with essential nutrients and agro advisory services. Therefore, present participatory investigations is the outcome of prestigious *Mera Gaon Mera Gaurav* PMO's programme in the adopted Kalmeshwar cluster of ICAR-Central Institute for Cotton Research, Nagpur by the author alongwith the team members.

MATERIALS AND METHODS:

A field experiment was conducted with *Bt* hybrid cotton Boll Guard II Ankur 3028 and PKV 081 non *Bt* variety during 2016-2017 and 2017-2018 in moderate calcareous soil at ICAR-Central Institute for Cotton Research Farm, Nagpur in RBD design with four replications. Soil profile characters, pH, $CaCO_3$ content and micronutrient availability is given in Table 1 and in OFTs at appropriate data Tables in the respective village sites. Onfarm trials were also conducted simultaneously to better understand

Table 1. Soil profile characteristics of the experimental site and available micronutrients status

Soil horizon (cm)	Soil colour (Moist)	pH -	EC (mmhos/ cm)	OC (%)	$CaCO_3$ (%)	Cu	Zn	Mn	Fe
						(mg/kg)			
Ap- 00-24	10YR 4/2	8.35	0.14	0.38	60	1.23	0.09	3.22	2.47
Ck1- 24-56	Rubbed 10YR 6/2	8.39	0.14	0.14	76.5	0.87	0.06	3.03	2.26
Ck2- 56-82	Rubbed 10YR 6/2	8.37	0.14	0.1	73.8	1.03	0.1	2.44	2.68
2Bw -82-102	Rubbed 10YR 6/1	8.35	0.14	0.07	53	1.01	0.02	1.95	3.79
3C-102-112	Sand layer Rubbed 10YR 5/2	8.4	0.12	0.07	37	0.7	0	2.29	3.69
Bw2 -112-133	Rubbed 10YR 5/2	8.29	0.13	0.07	53.2	1.35	0.06	2.37	3.77
Bed Rock >133		8.37	0.13	0.04	68.5	0.93	0.05	2.51	3.06

the outcomes of some of the known researches and farmer's experiences in vogue such as humic acid seed and fertilizer treatment, foliar application of water soluble NPK fertilizers and micronutrients besides validation of the station trial results. Different *Bt* hybrid cotton genotypes, American improved varieties and *desi* cotton varieties were also introduced for farmers acceptability and agronomical performance with descriptive statistics and computational economics for input validation.

Soil profile and productivity constraints : Lower organic carbon content, very high $CaCO_3$ and pH more than 8.3 resulting in very high P fixation and lower available K, Mg and precipitation of soil native or applied micronutrients *viz.,* Zn, Fe to cotton, besides terminal drought, are the main limitations in calcareous soils (Table 1). To overcome these constraints application of sufficient quantity of organic manures, crop residue recycling, F.Y.M., compost, tank silt, pressmud, bagasse, sulphur,

protective irrigations application, higher dose of P_2O_5, K, Mg and tolerant crops were suggested by the researchers for different crops in calcareous soils at different locations for field application (Patricia, 2000; Howaldar, 2014; FAO, 2016).

RESULTS AND DISCUSSION

Station trial: Two years station trial in moderate to high calcareous soil (Table 1) had confirmed that seed treatment with biofertilizers consortia (*Azotobacter/ Azospirillum* + PSB + *Trichoderma*) or humic acid treated fertilizers (0.02%) could buffer the rhizosphere P fixation when 125 per cent RDF (NPK) fertilizers and deficient micronutrients (Fe, Mn, Zn, B) were applied as per soil test (Table 2) which improved seed cotton yield. Opening of ridges and furrows after 1st interculture are optional for further reducing the impact of terminal droughts on seed cotton yield and improving the seed cotton yield to the tune of 20 per cent. Magnesium (Mg) and sulphur (S) each 10 kg/ha soil application can give sweetening effect in the rhizosphere and delays the P fixation and improves the availability of other pH sensitive soil applied

Table 2. Effect of input management on seed cotton yield under rainfed black calcareous soil at CICR, Nagpur

Treatment	Seed cotton yield (kg/ha)	Ankur 3028		PKV 081	
		2016-2017	2017-2018	2016-2017	2017-2018
T_1	Control (100%) RDF + Zn 12.5 kg/ha + B 5 kg/ha+ opening of ridges and furrows after 1st interculture	1700	1376	1482	1187
T_2	Seed treatment with biofertilizers + (125%) RDF (NPK)+ Mg, S each 10 kg/ha+Fe, Mn, Zn, B as per soil test + opening of ridges and furrows after 1st interculture	1893	**1532**	1397	1540
T_3	T_2+(100%) basal+ 25% P, K, Mg split soil application @ 45 DAS	2110	1321	1935	1641
T_4	T_2 + MN's 0.05 % B+ (0.5%) Fe + 0.3 % Mn + (0.5%) Zn sulphates @ 45 DAS+P 2 % DAP @ 75 DAS foliar spray	1679	1321	1941	1536
T_5	T_2 + Chelated MN's 2 kg/hasoil application @45 DAS	1790	1441	1563	1746
T_6	T_2 + Chelated MN's (0.5%) foliar spray @45 DAS	1815	1467	1388	1445
T_7	T_2 + Animal manure in root zone 2 t/ha+ MN's soil application 15 kg/ha hybrid 12 kg/ha for variety	1880	1205	1966	1075
T_8	T_2+ Humic acid treated fertilizers (0.02%) + MN's soil application 15 kg/hahybrid 12 kg/hafor variety	1834	**1519**	2494	1424
T_9	T_2+ Humic acid (0.02%) seed treatment chelated MN soil application 2 kg/ha	1676	1447	1382	1619
T_{10}	T_6+ Humic acid 0.02% treatment chelated MN (0.5%) foliar spray	1581	1399	2172	1463
	S.E D +(p=0.05)	205	194	348	250
	CD + (p=0.05)	NS	399*	730*	NS
	CV (%)	14.0	18	24.0	21.2

micro nutrients such as Zn and Fe. Similar results were observed by Haroon, *et al.*, 2010; Heydarnezhad *et al.,* 2012.

Cotton genotype selection :

Rainfed condition: *G. arboreum* cotton *Phule dhanwantary* was also planted in ½ (soybean) to 2.5 ac (cotton) and compared with rotational soybean JS 335 with RDF fertilizers was compared with *Bt* hybrid cotton Boll Guard II Ankur 3028 and Polaris in highly calcareous sols of *Sonegaon* village, *Kalmeshwar* Tq., Nagpur Dt. (M.S) a village under ICAR-CICR, Nagpur *Mera Gaon Mera Gaurav* programme under rainfed condition (Table 3). All the crops/varieties growth, boll/pod number, boll/grain weight,

Table 3. Genotype selection for rainfed calcareous soils directly under supervision of scientist at *Sonegaon, Khiri, Kalmeshwar* Tq.Nagpur Dt.

S. No.	Crop/Variety	Boll/pod plant	Yield (q/ha)
1	Soybean JS 335	25	6.25
2	*Phule dhanwantary*	30	6.5
3	*Polaris*	25	6.5
4	Ankur 3028	25	7.5

Table 4. Cotton genotype selection for rainfed condition moderate black calcareous soils Wathoda, Tq.Kalmeshwar, Dt.Nagpur

	Yield (q/ha)		Net returns US $/ ha	Cost: Benefit Ratio	Bolls/ plant	Fertilizer nutrients applied (kg/ha)				
	Seed cotton	Pigeon pea				N	P_2O_5	K_2O	Total	S
RCH 639	19	5	2900	3.3	80	73	60	95	228	17.5
Ankur 3028	16	2.5	2513	3	35	85	88	85	255	
Ankur 651	16	2.5	1969	2.6	25	108	43	18	168	42.5
GK 202	13	5	1881	2.7	55	113	70	70	253	
Hy 6 BG-II	11	7.5	1963	2.7	40	103	80	95	278	17.5
Phule Dhanwantari	10	7.5	1956	3	25	73	60	20	153	17.5
GK -202	13	0	1294	2.3	35	58	50	25	133	17.5
CD (p=0.05)	2.8	2.5	472	0.3	18	20	15	33	53	14

Table 5. Calcium carbonate and available P content in Linga series, Kalmeshwar, Nagpur, India

Name of the farmer	*Bt* hybrid	Irrigations	pH	Ca CO_3 (%)	Soil P (kg/ha)	Seed cotton yield (kg/ha)
Narayan Bansode	Prabhav Flax	3	8.3	34	4.3	16
Narayan Bansode	Bayer First class	3	8.3	34	4.3	15
Ashok Ambule organic	US 4647	3	7.9	14	4.1	15
Ashok Ambule irrigated	US 4647	3	7.8	7	4	13
Kauduji Sitaram Adle 1	Ankur 3028	3	8.2	10.5	4.1	11
Ukandrao Namdar	Ankur 3028	3	8.4	17	7.7	10
Narayan Bansode	Ankur 3028	3	8.3	34	4.3	10
Rahul Ambule	Polaris	3	8.0	14	4.1	10
Kauduji Sitaram Adle 2	Ankur 216	0	8.5	12.5	6.4	5
Kauduji Sitaram Adle 3	Polaris	0	8.4	16	4.6	5

Table 6. One protective irrigation in calcareous soils

	Bt hybrids		Pigeon pea yield (kg/ha)	Net returns	
	Seed cotton yield (kg/ha)	Bolls/ plant		US$	C:B
Ankur 3028	22	70	5	483	3.8
Ajit 111	19	60	5	450	3.6
Brahma	16	55	5	418	3.3
Hy 6	16	70	5	418	3.5
Hy 6	8.8	50	7.5	348	3
Phule dhanwantari	13	25	5	385	3.1
Phule dhanwantari	11	25	5	373	3
CD (p=0.05)	4.3		0.8	223	0.3

Bt hybrids with OFTs 55:30:28=123 N:P_2O_5:K_2O Kg /ha

Table 7. Two-Three supplemental irrigations in calcareous soils

	Bt hybrids			Pigeon pea yield (kg/ha)	Fertilizers applied kg/ha			**TOTAL**	Net returns Economics	
	Irriga-tions	Yield (kg/ha)	Bolls/ plant		N	P_2O_5	K_2O		US $	C:B
Ankur 3028	3	16	55	4	78	93	0	**169**	903	3
	2	16	55	5	165	213	73	**448**	1028	3
	2	16	35	5	165	213	73	**448**	1028	3
Ajit 155	3	16	55	4	78	93	0	**170**	903	3
Kaveri ATM	3	16	55	4	78	93	0	**170**	903	3
Hy 6	3	16	50	3	58	40	0	**98**	810	3
Hy 8	2	16	55	6	115	40	75	**230**	983	3
Vithal Gold [1]		16	35	5	83	65	65	**213**	915	3
Bhaskar drip[2]	4	22	55	8	120	115	63	**298**	1825	4
Ankur 3028 [3]	3	24	60	6	80	43	13	**135**	1468	4
Ankur 3028 [4]	6	25	120		120	60	60	**280**	1500	4
CD (p=0.05)		2	8	1	22	37	17	**71**	194	0

Note: 1. Deep black soil. 2. Red shallow soils 3 4. Calcareous soil: Nutrient corrections were made with soil and Foliar sprays of Mg SO_4, 19:19:19 and chelated micronutrients 5-6 times.

yields were limited to 60 per cent only to that of non calcareous medium deep black soil yields besides affected by terminal drought where ridges and furrows were not adopted by the farmer (Table 3). Although yield differences not much in the ruling Ankur 3028 had marginal yield advantage of one quintal per hectare. Severe limitation of soil moisture, available P, micronutrients Zn, Mn, Fe reduced the growth, biomass and yield in both soybean and cotton. However, farmer was more than happy with the recovery of his capital investments to produce even that much yield in an abandoned bushy and grassy field due to high calcareousness.

The most appropriate genotype, its duration and management were found to be

Table 8. Profitability of irrigated calcareous silty loams in Sonegaon, Khiri, Village

Bt hybrids	Seed cotton yield (kg/ha)	Irriga-tions	Cost of culti-vation (US $)	Net returns (US $)	Cost: Benefit Ratio	Fertilizer nutrients applied (kg/ha)				
						N	P_2O_5	K_2O	**Total**	Sulphur
Ankur 3028	14	3	468	556	1:2.19	107	28	12	**146**	18
Ankur Suvarna	14	3	468	556	1:2.19	107	28	12	**146**	18
Ankur 4252	14	3	468	556	1:2.19	107	28	12	**146**	18
Wheat	25	5	421	498	1:2.18	140	65	65	**270**	18

Table 9. Profitability of irrigated silty loams with calcareous substrata in Linga series Linga, Village

Bt hybrids	Seed cotton yield (kg /ha)	Pigeon pea yield (kg /ha)	Irriga-tions	Cost of Cultiv-ation (US $)	Net returns (US $)	Cost: Benefit ratio	Fertilizer nutrients applied kg/ ha						
							N	P_2O_5	K_2O	**Total**	Sulphur	Mg SO_4	Zn SO_4
Ankur3028	16	4	3	529	903	2.71	76	93	0	**169**	18	125	25
Ajit155	16	4	3	529	903	2.71	76	93	0	**169**	18	125	25
Kaveri ATM	16	4	3	529	903	2.71	76	93	0	**169**	18	125	25

Note: Nutrient corrections were made with 5-6 Foliar sprays of Mg SO_4, Biozyme, WSF 19:19:19 and chelated micronutrients.

Rashi 659 and Ankur 3028 due to their medium duration compared to long duration GK 202 *Bt* hybrid (Table 4). They produced more than 2.5 C:B ratio and very good profits of >1.75-2.0 [1] *lakhs* /ha which could not be maintained in subsequent year of seedling and terminal drought in the absence of ridges and furrows for *insitu* conserving soil moisture in rhizosphere.

Therefore, it is confirmed from the station trials and farmers fields that although farmers were reluctant to adopt rain water conservation measures, which atleast could have saved 20 per cent seed cotton yield reduction. Application of sub optimal P, K and sulphur containing fertilizers are key yield limiting factors observed despite of irrigation water in highly calcareous soils (Table 5) when soil application of Zn was ineffective with poor seed cotton yields and gave good results for foliar application of chelated micronutrients were achieved (Table 5).

Supplemental irrigation : Calcareous soils are porous, well drained with good percolation, best endowed often with gravitational wells for supplemental irrigations**.** Farmer's provide 1-3 irrigations or terminating the crop early to accommodate late planting of wheat/ summer groundnut /vegetables is not uncommon (FAO, 2016). Sub optimal fertilizer (<35%RDF) application is one of the common cause of non remunerative/ non significant response returns from calcareous soils under protective irrigations by surface or drip irrigation systems (Table 5-8).

Fertilizer nutrient application was ranging from 58-83 N kg/ ha; 40-93 P_2O_5 kg/ha, K_2O 0-75 kg/ha total together N:P_2O_5:K_2O 98 -

230 kg/ha produced yields similar to that of normal rainfed cotton despite of 2-3 irrigations clearly indicating a yield limiting factor of Zn, Mg, Fe, K deficiencies as hidden hunger (Table 5, 6). Application of balanced fertilizer and micronutrients in soil and foliar correction lead to improvement in seed cotton yields by 6-8 q/ha by progressive farmer's achieved to that of normal black, red and calcareous soils with fertigation of sulphur containing water soluble fertilizers (WSF) lead to sweetening of the rhizosphere and buffering with chelated micronutrients (Table 7).

Soil and foliar application of water soluble fertilizers, Zn, Mg improved 2q/ ha productivity (Howaldar, 2014, Lakshmi *et al.,* 2017) even with sub optimal fertilizers with the same management clearly indicate the narrow genetic base of hybrids adopted by the farmers in the influence of /dealer marketing influence producing similar yields in calcareous soils (Table 8, 9). Highly calcareous soils in *Kini* village Nagpur (2 ha farm) advance planted with Ankur 3028 under bed and furrow drip irrigation system at 1.2 x 0.4m fertilized with normal fertilizers produced 25-30 q/ha seed cotton yields.

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