Validation of seed treatment, soil and foliar application of bio-stimulants and nano inputs on flood affected Bt hybrid cotton.

ABSTRACT:

Excess rains caused water logging for more than a week inJuly, August, September months of 2021 in*Vertisols* and with *Calcareous*substratasoils reduced the biomass, boll number and seed cotton yields to more than 50% due to prevailing anaerobic condition besides leaching of split soil applied fertilizer nutrients. Floods caused reduction of index leaf N,P,K,Zn and B nutrient status below the threshold levels except fibre properties. Flooded soil resilient technologies validated were soil application of Zn and B once in three years alone or seed treatment formulation with NPK Bio-inoculant *consortia* along with Nano ZnO0.004%+CuO0.001%as seed treatment at the time of sowing with or without foliar application of WSF N, P, K 2%, Zn0.5%, B 0.3% and nano formulations0.04% of ZnOUrea, DAP alongwith the common insecticides and fungicidal sprays significantly improved index leaf nutrient status, biomass, boll number and seed cotton yields in both the soils.Validation of these results in stationtrials during 2022-23 found the need for two foliar application of nutrientseachnano ZnO+ DAP +K followed by nano Urea+ ZnO+K alternately at the mid and end September and October months essential for increasing seed **K, Zn**content with 117 kg additional seed cotton yield ha^{-1} by nano DAP over Urea + ZnO + K three times foliar application at squaring, flowering and boll formation stage.

KEYWORDS: Boron,Floods,Foliar application, Leaching losses, Nano fertilizers, NPK, Water logging, Water soluble fertilizers,Zinc Oxide.

Introduction

Cottonfarmers are interested in improving their average seed cotton yields with minimum investment on deficient nutrients.Soil testing for theavailable nutrient status is not easily accessible to the farmers despite of huge spending by the government on soil health cards. However, this GPS tagged soil test helped in mapping of soil nutrient status across the country.These mapshelps more the administrators than the practicing cotton farmers(IISS, 2022).Cotton lint yield response to added Zn, B was considerably higher magnitude on low available Zn and B soil status. Boron deficiencies are also very common in marginalsoilsor high pH calcareous soils when the available soil boron is less than 0.50 ug^{-1} g of soil(**Gupta, 1980, Raju, 2022**). Zn and B deficiencies were found in more than 50% of the area of the cotton growing states in India (**IISS, 2022**). Critical levels of available Zn 0.90 $mgkg^{-1}$in soil and concentration of Zn in cotton 4^{th} leaf 58mg kg^{-1}at 30 daysand 25 mg kg^{-1}at maturity were found to be adequate(**Berger and Truog,1939**)for cotton crop(**Lindsay and Norwell,1978, Polara*et.aL.*,2010**).Zinc(Zn) and boron(B)applications were recommended for both*Vertisols*and calcareous soils (chelated) as soiland foliar applicationsalongwith other agro-chemicalsinorder to correct anticipating Zn and B deficiencies(**Singh and Blaise,2000, Raju, 2022**).Zn and B both are essential throughout the crop growth and immobile inside the plant. They are highly soluble and subjected to leaching, runoff and fixation on clay. Azomethine-H method was the most sensitive in determining extractable B content of soils and also in plant tissues(**Sarkar *et al.*,2014**).Application of zinc and boron along with 90: 45:45 and 120:60:60 kg ha^{-1}N:P_2O_5:$K_2$0was found to be beneficial in *Vertisol*and associated seriesin improving the productivity of rainfed and supplemental or drip irrigated Bt hybrid cotton respectively (Ghabhne*et al.,* 2011; Raju and Thakare, 2012, Raju, 2018, 2022).

Central India had facedexcess rains since 2019due to more frequent depressions formed fortnightly in either Bay of Bengal or Arabian ocean during July, August and September months (Table 1,2, Fig.1)as expected gave 40% extra rains in 20% more rainy days in interior or rain shadow areas (Table 1,2, Fig.1). However, often they also stalled and disturbedthe progress of south west monsoonfrom Arabian ocean during June to September months adversely affecting the rainfall dependent activities in interiorareas of India.

Soil and water conservation measures developed and tested for semi arid tropics worldwide were adopted and worked satisfactorily to conservea mean rainfall of 80 to 120 mm of rainfallonbroad beds (BBF) and ridges and furrows (R&F) respectively at 0.6-1.0% slope (**Raju *et al*., 2009**). High intensityof rainfall exceeding 60 mm rain per day, on steep slope may breaks ridges very easily with high speed runoff,carrying mudand stones lead to severe soil erosionand submergenceof low lying cotton fields and silting of runoff harvesting ponds to the tune of >10 tonnes $ha^{-1}yr^{-1}$(**Raju*et al.*,2011**). Although the best agro-techniques adjudged for wet monsoon areas were planting of cotton on broad bed and furrows (BBF) or advance planted cotton with opening of BBFat 0.6 to 1.0% slopeon or before 2nd intercultural operation. However, this was never adopted by the cotton farmers even uptothe last 4 wet monsoon years.Weak starting of south west monsoon also adversely affectedthe monsoon sown cotton germinationand seedling growth by delayed starter fertilizer application due to moisture stress. Sub-sequent heavy down pour in July and August months also did not permitted intercultural operations resulted in either heavy consumption of post emergence herbicidesor poor young seedling growth with conventional weed management system (**Nalyaniand Raju.,2010; Rajuand Raju *et al.*,2018**).Heavy rains in the month of July did'nt permit timely application of herbicidesand fertilizersresulted in reduced seed cotton yields in verydeep,deep and medium deep clay soils i.e. *Vertisols*(Table 2, Fig.1). Excessrains beyond 60 mm leads to water logging,shortage of oxygen supply and leaching of soluble nutrientsfrom the root zone (**Rochester, 2007a**). Repeated situation once in September and October monthsreduced plant growthand total shedding of first two flushes of fruiting parts besides rotting of young unopened bolls (**Rochester, 2007 b; Nagrale*et al*., 2020**).However, there was also improved productivity in *VerticInceptisols* and *Calcisols* due to better soil moisture storage and enhanced water and nutrient supplies ensured by the excess rains. However, the increase in yields in these soils did not compensated the loss of yield from *Vertisols*, which was visible in the lint productivity decline of 100 kg ha^{-1}(**CAB, 2023**).Therefore, the highest price realized in *Jalgaon*market was two and half to three times what used to be paid per quintal by traders *via* ginners to cotton farmers in India (**Aras, 2022; Arya, 2022**). However, this price realization contradicts with the area, production and productivitydata of tradeand agriculturedepartment(**Aras, 2022**). Traders claim that textile manufacturing will become non viable once it exceeds Rs.50/- kg^{-1}seed cotton, which they used to pay to the cotton farmers anything excess will be passed on to the customers, which was reflected in 10% increase in the whole sale prices in the cotton yarn, textiles and apparels market (**Aras,2022,Anon2022a,b**), with a excellent opportunities for 19 billion US$ export markets. However, the big challenge is in the shortage of raw materials and skyracketing of input costs,labour wages, power and transportation incurring a losses to the tune of 25 to 50 kg^{-1} yarn (**Aras, 2022**). Now,there is an urgent need to test the existing and new nutrient formulationtechnologies to suit under challengingwet climatic conditions to produce cotton.Therefore, this experiment was planned on soils having different drainage, water and nutrient holding capacities to test wide range of nutrients and their formulations to meet these unforeseen challenges.

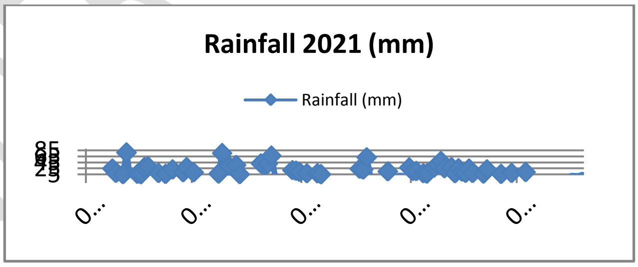
Table 1 Rainfall mm and number of rainy days 2016-2022.

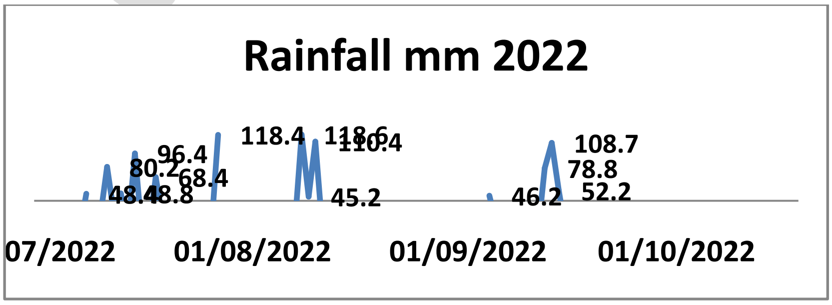
	2016		2017		2018		2019		2020		2021		2022		Mean	
	Rain	Days	Rain	Days	Rain	Days	Rain	Days	Rain	Days	Rain	Days	Rain	Days	Rainfall	Days
June	126	6	132	7	217	11	131	5	234	13	283	17	123	7	208	11
July	455	17	246	18	480	11	308	16	318	17	383	16	695	22	481	20
August	60	3	276	8	171	8	317	12	515	22	181	9	362	11	314	12
September	92	9	99	10	74	3	299	13	201	12	356	19	246	8	228	12
October	42	3	15	1		0		4	86	5	22	3			27	3
SED+5%	171	6	107	6	174	5	89	5	160	6	147	7	246	7	182	6
Total	**775**	**38**	**768**	**44**	**942**	**33**	**1055**	**50**	**1354**	**69**	**1225**	**64**	**1426**	**48**	**1257**	**58**

Table 2 Rainfall (mm), distribution and number of rainy days during 2021.

Months	2021	Total rain	>5mm	>25mm	60mm
June	Rainfall	283	76.8	106.2	76.8
June	Rainy days	20	7	5	1
July	Rainfall	371	150	293	141.3
July	Rainy days	19	9	4	2
August	Rainfall	150	120.6	59.2	61.4
August	Rainy days	14	5	3	1
September	Rainfall	329.4	76.4	216.3	0
September	Rainy days	22	5	7	0

Fig 1 Monthwise rainfall amount and distribution during 2021 & 2022





Materials and Methods:

Two field experiments were sown on 23.6.2021 in very deep typical *Vertisols* and medium deep calcareous soils at ICAR-Central Institute for Cotton ResearchFarm, Nagpur (N 21.2, E 79.1) Maharashtra state, India.Soil application of soluble Zn can be easily precipitated in *Vertisols* with shallow calcareous sub soils, renders unavailable to crop due to high pH and more than 30% $CaCO_3$. Therefore, only foliar applications of micronutrientsthree times at squaring, flowering and boll formation stageswere tested, confirmed andvalidated in high rainfall humid tropics of Nagpur. Micronutrient $ZnSO_4$ 0.5% alongwith potassium nitrate (13:0:45) 2.0 % and B 0.25%, chelated 0.5% and nano Zinc 0.04% with mono potassium phosphate (0:52:34),were applied on a baseline status of available Zn content was low 0.58-0.69 ug g^{-1}B 0.2 ug g^{-1}soil. Treatments under testing were **T_1:**Control.**T_2:**Three times foliar application of Zinc sulphate 0.5% at 45,66,87 days (squaring,flowering and boll development stages); **T_3:** Three times foliar application of chelated Zinc sulphate 0.5%; **T_4:** Three times foliar application of nano Zinc oxide 0.04%; **T_5:** Three times foliar application of Boron 0.3%; **T_6:** Three times foliar application of nano Zinc oxide 0.04% + Boron 0.3%; T_7: Seed pelletizationof nano ZnO0.004% + nano CuO0.001% with N, P, K bio-inoculants*consortia* and three times foliar application nano ZnO;T_8: Seed pelletization of nano ZnO0.004%+ nano CuO0.001% with Zn solubilizer and three times foliar application of nano ZnO0.04%;T_9: High Zn 0.54% B 0.33% three foliar sprays T_{10}.Medium Zn 0.36% B 0.2% three foliar sprays T_{11}. Low Zn 0.18% B 0.1% three foliar sprays T_{12}.Nano DAP three foliar sprays.

Soil and foliar application of Zn and B alongwith nano formulations of Zn, DAP were validated in *Vertisols* with base line available Zn was 0.48-0.69 ug g^{-1}B 0.2 ug g^{-1}soil.Treatment details were **T_1:**Control.**T_2:**Three times foliar application of Zinc sulphate 0.5% at 45,66,87 days; **T_3:**Three times foliar application of chelated Zinc sulphate 0.5%; **T_4:** Three times foliar application of nano Zinc oxide 0.04%; **T_5:**Three times foliar application of Boron 0.3%; T_6: Three times foliar application of nano ZnO 0.04% + Boron 0.3%; T_7: Soil application of $ZnSO_4$ 20 kg ha^{-1} 30 days; T_8: Soil application of Borax 5 kg ha^{-1} in borate form30 DAS.; T_9: Soil application of 20 $kgha^{-1}$$ZnSO_4$ and 5 $kgha^{-1}$ Borax in borate form30 days; T_{10}: Soil and three times foliar application of $ZnSO_4$ form B in borate form;T_{11}:Soil and foliar application of chelated Zn B in borate and solubor form; T_{12}: Seed pelletization of nano Zn 0.004% + nano Cu0.001% with Zn solubilizer and three times foliar application of nano ZnO;**T_{13}:** Seed pelletizationof nano ZnO0.004% + nano CuO0.001% with N, P, K *consortia* and three times foliar application nano ZnO0.004% **T_{14}:**Lower dose of 3.24 g L^{-1} $ZnSO_4$ and 0.32 g L^{-1} Boron three times foliar application;**T_{15}:**Medium dose of 4.86 g L^{-1} $ZnSO_4$ and 0.65g L^{-1} Boronthree times foliar application;**T_{16}:**High dose of 6.48 g L^{-1} $ZnSO_4$and 0.97 g L^{-1}

Boronthree times foliar applicationwas applied to Bt hybrid cotton to supplement the initial soil status of available Zinc. RCH-659 Boll guard II hybrid cotton was planted at 90x90 cm spacing on 23.6.2022 followed by the farmers with recommended dose of fertilizer(90:45:45 kg ha^{-1} N:P_2O_5:K_2O) in basal dose of complex fertilizer and twice urea top dressing. Post emergence herbicides *Pyrithiobac*sodium alongwith graminicides were applied followed by twice hoeingfollowed by hand weeding to remove resistant weeds. Although need based plant protection measures were ensured but they were less effective in epizootic conditions of bollworm complex. Plot wise soilsamples were analyzed for available Zinc status by Atomic Absorption Spectrophotometerwith D.T.P.A.extractant. Bt hybrid cotton index leaf samples were collected before and after the spray to monitor the macro and micronutrients level with standard analytical procedures and data were subjected to ANOVAs and interpretedwith prevailing soil and weather conditions. Nano materials for experimentation were supplied by Ms. IFFCO, New Delhi, of commercial grade.

Results and Discussion

Flooded*Vertisols*:

A rainfall of more than 60 mm on every 1st week of June,July,August and September,2021 months in *Vertisols*caused severe runoff followed by flooding of cotton fields and rain water harvesting ponds (Table 2, Fig.1). These results were in agreement with those observed by Raju *et al*., 2011 about probability of excess rains and their consequences on decreasing the yield of Bt hybrid cotton in longterm rainwater harvesting validation studies in humid tropics. Sub-merged cotton fields caused leaching of soil applied N,P,K fertilizers from the flooded cotton fields, which haddepleted index leaf N during September and October months to less than 50% of bare minimum (ICAC, 2015). Top dressing soil fertilizer application in this saturated soilsis also mere impossible except foliar application of NPK alongwith fungicides against the spread of wilts (Nagrale*et al.,* 2020). Water soluble fertilizermono potassium phosphate i.e.**0:52:34**N:P_2O_5:K_2Oalongwith micronutrients foliar applicationwhich does'nt have nitrogen, helped to maintain significantly higher levels of index leaf P content at all concentrations and forms, of Zn and B both as soil and foliar applications during early and late October months(Raju and Thakare, 2012, ICAC, 2015)**.** Soil application of zinc sulphate,chelated Zn and seed pelletization with N, P, K *consortia* or Zn solubilisersalongwith nano ZnO 0.004% and CuO 0.001% followed by three times foliar application of nano ZnO 0.04% alongwith water soluble fertilizer potassium nitrate i.e. **13:0:45**N:P_2O_5:K_2O could maintain significantly higher cotton index leaf K during months September and October, 2021. These results were in agreement with those observed by Basavanneppa*et al.,* 2015 in Bt hybrid cotton.Significantly higher K was maintained in the seeds formed by all the soil and three times foliar application of low, medium, higher concentration of Zn and B due to combined foliar application of water soluble fertilizer potassium nitrate i.e. **13:0:45**

$N:P_2O_5:K_2O$ alongwithmicronutrients, insecticides and fungicides(Table 4). Flooding of Bt hybrid cotton depleted cotton root, shoot and index leaf nutrient content in September, 2021 month reduced cotton index leaf N, P, K in September, October months,which adversely affected phosphorous content of seeds formed during this time.Thisnecessitated to supply of the**$N:P_2O_5:K_2O$**through water soluble fertilizersas foliar application having compatibility with non chelated Zinc**13:0:45**and **0:52:34** with nano and chelated Zinc alongwith insecticides and fungicides to maintain optimum nutrient content in the index leaf (GSFC, 2022,IFFCO, 2022;Table 3).

Conclusion

In flooded *Vertisols*maintenance of index leaf N, P, K nutrients concentration at reproductive stage through water soluble fertilizersis crucial with compatible Zinc forms alone or together in conjunction with compatible pesticides (Chloripyriphos/Corazen/Imamection benzoate with Carbendazim and Mancozeb) application. Boron or chelated Zn or nano ZnO combined with combination of Mono ammonium(12:61:0$N:P_2O_5:K_2O$) and or potassium phosphate (0:52:34$N:P_2O_5:K_2O$) alone or together 2% and alternated fortnightly with alone potassium nitrate2% (13:0:45$N:P_2O_5:K_2O$)or Urea 2% combined with Zinc sulphate 0.5% and Boron 0.3% sprays may be helpful to Bt hybrid cotton during reproductive stage for flood affected Bt hybrid cotton.These results were in agreement with**Basavanneppa*et al*., 2015 , IFFCO and GSFC, 2022** in maintaining N,P, K, Zn, B status of Bt hybrid cotton with compatible insecticides and fungicides. The confirmatory lab, field and OFTs found very encouraging results in the similar situation in 2022-23 season with three times heavy floods, significant reduction of leaf reddening and square drop werealso observed besides meeting the target.

Table 3. Nutrient content of flooded Bt hybrid cotton in *Vertisols*.

	Seed nutrients			Index leaf NPK before and after flooding										
	N	P	K	Nitrogen%				Phosphorous%			Potash%			
Vertisols	%	%	%	18/8.	18/9	8/10	29/10	18/9	8/10	29/10	N18/8	N18/9	N8/10	N29/10
Control	3.79	0.36	0.96	4.28	2.24	2.75	3.60	0.41	0.47	0.41	1.69	0.43	0.71	1.18
Zn 3 foliar sprays	4.75	0.37	0.91	4.26	3.04	2.88	3.03	0.36	0.62	0.55	1.56	0.47	0.65	1.21
Chel Zn 3 foliar sprays	3.84	0.41	0.95	4.40	2.55	2.54	3.60	0.47	0.58	0.46	1.55	0.42	0.67	1.40
Nano ZnO 3 foliar sprays	3.91	0.29	1.03	4.13	2.62	2.60	3.86	0.43	0.57	0.48	1.56	0.39	0.68	1.22
Boron 3 foliar sprays	4.28	0.30	1.03	4.10	3.33	2.27	3.36	0.46	0.46	0.48	1.46	0.45	0.49	1.14
Boron+NanoZnO 3 foliar sprays	4.73	0.38	1.09	4.32	2.18	2.89	3.38	0.45	0.43	0.59	1.48	0.32	0.66	1.27
Soil application of Zn	4.77	0.35	1.37	4.57	2.15	4.23	4.02	0.41	0.69	0.61	1.63	0.35	1.00	1.31
Soil application of B	4.97	0.42	1.37	4.12	2.03	3.63	3.78	0.45	0.72	0.59	1.50	0.34	0.89	1.37
Soil application of Zn B	4.66	0.35	1.37	3.28	2.49	3.07	3.51	0.46	0.61	0.59	1.33	0.37	0.87	1.09
Soil application of ZnBfoliar sprays	4.11	0.43	1.38	4.41	2.40	2.61	4.11	0.45	0.62	0.64	1.60	0.34	0.90	1.22
Soil application of chel Zn B	4.25	0.33	1.38	4.23	2.07	3.14	3.68	0.42	0.61	0.51	1.45	0.36	0.96	1.16
Seed Tr ZnSol nano Zn Cu + Nano ZnO foliar sprays	4.26	0.44	0.68	4.44	2.62	3.41	3.38	0.37	0.51	0.44	1.61	0.71	0.74	1.43
Seed Tr NPK *consortia* nano ZnO+ CuO+ 3 foliar sprays ZnO	4.12	0.44	0.72	4.80	2.25	2.66	3.22	0.37	0.47	0.40	1.71	0.62	0.69	1.20
Low Zn 0.3% B 0.1% foliar sprays	4.94	0.36	1.44	4.25	2.36	2.25	3.69	0.50	0.58	0.58	2.18	0.36	0.89	1.26
Medium Zn 0.4% B 0.2% foliar sprays	4.65	0.35	1.38	4.34	2.18	3.33	3.52	0.46	0.65	0.58	1.30	0.34	0.91	1.26
High Zn 0.5% B 0.3% foliar sprays	4.61	0.39	2.16	4.41	1.84	2.70	3.81	0.45	0.53	0.50	1.56	0.27	0.84	1.26
SE±5%	0.21	0.03	0.15	0.38	0.16	0.27	0.20	0.02	0.04	0.04	0.15	0.05	0.07	0.05
CD ±5%	NS	NS	0.43	NS	NS	NS	NS	NS	0.10	0.10	NS	0.14	NS	0.15

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As the soil available Zn content was low0.48-0.69 ug g^{-1}B 0.2 ug g^{-1}soil,despite of prevailing flooded condition with higher leaching, runoff, weed growth, epizootic conditions of sucking pests and boll worms significant improvement in biomass production (Table 4) by all the existing recommendations for *Vertisols*and associated series. This validation of micronutrient Zn is in agreement with the field studies made by **Lindsay and Noerwell,1978, Sarkar *et al*.,2012**. Soil application of alone or both Zn4.0 kgha^{-1}yr^{-3} + B2.0 kg ha^{-1}yr^{-3}and new interventions like chelated Zn 0.4 kg ha^{-1}yr^{-3} + B 2.0 kg ha^{-1}yr^{-3} and seed pelletization of N, P, K solubilisers*consortia* and nano ZnO 0.004%+CuO 0.001% along with three foliar sprays of nano ZnO 0.04% at the time of squaring, flowering and boll developmentstages. In *Vertisols*,therefore,flood resilient micronutrient technology is either soil application, seed pelletization with NPK solubilisers*consortia*alongwith nano ZnO+CuO or combination of compatible water soluble fertilizers together with three foliar applications of nano ZnO 0.004%. However, the fiber quality was unaffected by the Zn and B soil or foliar applications except micronaire, which was low from the last flush of squares formed to bolls in the month of October, 2021 (Table 8).

Table 4. Yield attributes and economics of the micronutrient advices in *Vertisols*.

Vertisols	Biomass tonne ha^{-1}	Boll No's plant^{-1}	Lint yield ha^{-1}	Net returns ₹000	C B Ratio	Index leaf zinc ppm		
						31/8	18/9	29/10
Control	3.4	27.3	199	18	1.69	126	136	94
Zn 3 foliar sprays	3.0	34.0	231	31	2.05	110	134	93
Chel Zn 3 foliar sprays	3.5	34.3	259	27	2.08	117	150	92
Nano ZnO 3 foliar sprays	4.0	28.7	191	13	1.52	98	144	95
Boron 3 foliar sprays	4.4	43.3	266	24	2.06	104	146	82
Boron+NanoZnO 3 foliar sprays	4.2	31.3	219	13	1.63	109	143	90
Soil application of Zn	3.3	42.0	264	39	2.36	133	150	84
Soil application of B	3.3	42.0	277	32	2.27	115	158	83
Soil application of Zn B	**3.9**	**43.0**	**390**	**54**	**3.16**	**130**	**146**	**85**
Soil application of Zn Bfoliar sprays	4.0	44.3	255	28	2.07	125	153	87
Soil application of chel Zn B	3.4	33.7	339	21	2.28	145	134	85
Seed Tr Zn solubilisers nano ZnO +CuOthree foliar spraysNano ZnO	3.7	38.0	272	28	2.15	176	147	96
Seed Tr NPK *consortia* nano ZnO+ CuO+ 3 foliar sprays ZnO	3.9	15.7	299	37	2.42	111	137	87
Low Zn 0.3 B 0.1 foliar sprays	4.4	13.7	269	31	2.20	153	128	86
Medium Zn 0.4 B 0.2 foliar sprays	3.9	45.3	276	26	2.13	155	141	83
High Zn 0.5 B 0.3 foliar sprays	4.5	28.0	269	31	2.19	154	149	86
SE$\pm$5%	0.2	5.1	32	5.0	0.19	15	8	5
CD $\pm$5%	0.6	15	NS	14.1	0.55	42		

Flooded *Vertisols* with calcareous substratasoils:

Bt hybrid cotton was submerged in the month of September, 2021(Fig.1) for nearly two weeks. Although the calcareous sub soils produced lint yields 1.5 times of their normal capacity, which was more than double of *Vertisols*. This was possible due to higher porosity and relative better drainage by sub soil calcareous strata. N,P, K content of index leaves in September, 2021 flooding was reduced to more than 50% compared to before flooding nullifying the impact of all soil applications of N, P and K fertilizers due to leaching losses**.** Three times foliar application of nano D.A.P., produced highest K and Zn content in index leaf before flooding despite of lower yield was due to very high weed intensity in some of these plots. Although, the biomass produced was non significantly differed highest was produced in three foliar applications of nano Zn + B, medium concentration of Zn and B followed by chelated Zn confirms the significance of Zn foliar application needs in calcareous soils. Significantly highest number of bolls were produced in three foliar applications of Zn while the yield per hectare was produced in three foliar applications of nano Zn + B. However, statistically similar seed cotton yields were produced in three foliar applications of lower concentration level of Zn+ B and nano D.A.P.Economical returns with better C:B ratio were observed with three foliar applications nano Zn, Zn and chelated ZnO at squaring, flowering and boll development stages with or without seed pelletization with bio-inoculants and nano ZnO+ CuO. Flooding did not influence fibre properties in both the soils except late formed immature bolls reduced micronaire. These results were in agreement with sample fibre test done by ICAR-CIRCOT, GTC, Nagpur during this season in the entire cotton area.

Table 5. Nutrient content of flood affected Bt hybrid cotton in Calcareous soils.

Calcareous soils	**Index leaf NPK Squaring &Boll formation**					
	N%	N%	P%	P%	K%	K%
Treatments	31-8	8-10	31-8	8-10	31-8	8-10
1.Control	4.53	2.79	0.56	0.22	1.84	0.87
2.Zn three foliar sprays	4.82	2.43	0.53	0.19	1.91	0.76
3.Chel Zn three foliar sprays	4.54	2.19	0.48	0.21	1.89	0.74
4.Nano ZnO 0.04%three foliar sprays	4.38	2.41	0.61	0.22	1.87	0.75
5.Boron 0.3%three foliar sprays	4.58	2.62	0.47	0.23	2.09	0.75
6.Nano ZnO B three foliar sprays	4.56	2.60	0.51	0.21	1.86	0.78
7.Seed Tr NPK Con Nano ZnO+CuO ZnOthree foliar sprays	4.69	2.95	0.55	0.22	2.05	0.69
8.Seed Tr ZnsolubiliserNanoZnO+ CuO ZnOthree foliar sprays	4.53	3.09	0.52	0.22	1.90	0.76
9.High Zn 0.54 B 0.33 three foliar sprays	5.04	2.63	0.61	0.21	1.84	0.83
10.Medium Zn 0.36 B 0.2 three foliar sprays	4.53	3.02	0.51	0.40	0.83	**0.70**
11. Low Zn 0.18 B 0.1 three foliar sprays	4.87	2.59	0.59	0.23	0.73	0.83
12.Nano DAP three foliar sprays	4.78	2.89	0.54		0.66	0.95
SE+	0.17	0.27	0.05	0.01	0.13	0.05
CD 5%	0.37	NS	NS	NS	NS	0.13

Table 6. Index leaf Zn yield, biomass and economics of the micronutrient advices in calcareous soils

	BM	**Boll**	**Lint**	**NR**	**C B**	**Index leaf Zn ppm**		
Calcareous	**Ton**	**Plant**	**Yield**	**₹ 000**	**Ratio**	**31-08**	**18-09**	**29-10**
Control	4.00	18	350	47	2.0	126	94	149
Zn three foliar sprays	3.89	60	583	79	2.8	110	93	152
Chel Zn three foliar sprays	4.11	40	513	75	2.5	117	92	179
Nano ZnO 0.04% three foliar sprays	3.61	46	513	66	2.5	98	95	141
Boron 0.3% three foliar sprays	3.81	39	497	65	2.5	104	82	132

Nano ZnO B three foliar sprays	4.24	37	643	89	2.9	109	90	140
Seed Tr NPK *Con* Nano ZnO+CuO ZnO three foliar sprays	3.91	47	558	89	2.6	133	84	133
Seed Tr Zn solubiliser NanoZnO+ CuO ZnO three foliar sprays	3.65	44	527	68	2.6	115	83	153
High Zn 0.54 B 0.33 three foliar sprays	3.77	26	488	62	2.5	130	85	144
Medium Zn 0.36 B 0.2 three foliar sprays	4.20	42	535	70	2.7	125	87	162
Low Zn 0.18 B 0.1 three foliar sprays	3.88	36	411	49	2.2	145	85	124
Nano DAP three foliar sprays	3.93	16	371	51	2.0	176	96	157
SE±5%	0.2	9	56	9	0.2	15	5	13
CD± 5%	NS	NS	159	26	0.49	42	NS	NS

Table 7. Fibre properties of flood affected Bt hybrid cotton by micronutrient advices

	Calcareous soils						*Vertisols.*					
Tr	**UHML mm**	**UI%**	**MIC ug/ inch**	**Bundle Strength g tex**	**El %**	Tr	**UHML mm**	**UI%**	**MIC ug/ inch**	**Bundle Strength g tex**	**El %**
0	27.2	83.0	3.47	26.1	4.9	0	26.5	81.3	2.6	25.6	4.73
T1	27.2	83.8	3.52	26.4	4.5	T1	26.4	82.3	2.8	25.0	4.80
T2	27.4	82.7	3.37	26.3	5.0	T 2	27.4	82.3	2.7	26.4	4.90
T3	**26.8**	83.2	3.63	25.8	5.0	T 3	27.0	82.3	2.9	25.7	4.70
T4	27.5	83.7	3.33	26.5	4.7	T 4	26.8	82.0	2.7	25.8	4.77
T5	27.7	83.5	3.52	26.0	4.8	T 5	26.7	81.3	2.5	26.0	4.80
T6	27.1	83.0	3.23	25.4	4.8	T 6	27.5	83.0	2.8	26.3	4.85
T7	27.5	82.7	3.50	25.9	4.8	T 7	27.3	82.3	2.8	25.8	4.78
T8	27.4	83.0	3.47	26.0	5.0	T 8	27.0	82.0	2.8	26.3	4.80
T9	27.9	83.3	3.48	26.3	4.8	T 9	26.6	81.8	2.6	25.8	4.88
T10	27.3	83.2	3.48	26.2	5.0	T 10	26.8	81.8	2.8	25.5	5.05
T11	27.9	83.5	3.10	26.5	4.7	T11	27.2	81.0	2.6	25.4	4.88
						T 12	26.6	80.8	2.6	25.4	4.88
						T 13	26.5	81.8	2.6	25.5	4.78
						T 14	27.0	82.0	2.8	26.3	4.86
						T15	27.0	82.2	2.8	26.0	4.96
SE±5%	0.3	6.1	0.11	0.3	0.2	SE±5%	0.32	0.44	0.11	0.5	0.15
Sig	NS	NS	NS	NS	NS	Sig	NS	NS	NS	NS	NS

Table 8. Validation of Bio-stimulants as seed treatment and foliar application of nano Urea, DAP, Zn, K on yield, FUE, B:C ratio 2023.

	Validation of interventions in high rainfall condition					
Treatments	Yield kg ha^{-1}	B:C Ratio	FUE kg Kgfert	Yield g $plant^{-1}$	Boll No $plant^{-1}$	Bpll Wt.g
RDF 10:26:26	776	2.87	4.25	67	13	4.2
RDF 20:20:0:13 + Seed Tr NPK Zn sol *consortia* +3 foliar sprays of nano Urea+K and ZnO+K	830	2.40	3.05	52	14	4.1
RDF 20:20:0:13 + Seed Tr NPK Zn sol *consortia*+ 3 foliar sprays of nano DAP+ ZnO+ K	893	2.54	3.12	72	10	4.8
SE±5%	157		1.09	13	3	0.4
CD±5%	453		NS	39	7	1.1

Table 9. Validation of Bio-stimulants as seed treatment and foliar application of nano Urea, DAP, Zn, K on index leaf NPK content 2023.

	Index Leaf pooled content		Index leaf P% 10days after foliar correction					
Treatments	N%	K%	6th Sept	27thSept	20-thOct	2nd Nov	2.nd Dec	Pooled
RDF 10:26:26	3.94	1.32	0.22	0.17	0.06	0.30	0.19	0.19
RDF 20:20:0:13 + Seed Tr NPK Zn sol *consortia* +3 foliar sprays of nanoUrea+K and ZnO+K	4.07	1.31	0.26	0.19	0.09	0.29	0.16	0.20
RDF 20:20:0:13 + Seed Tr NPK Zn sol *consortia*+ 3 foliar sprays of nano DAP+ ZnO+ K	4.06	1.34	0.21	0.19	0.07	0.30	0.18	0.19
SE±5%	0.24	0.03	0.02	0.02	0.01	0.02	0.17	0.01
CD±5%	NS	0.08	NS	NS	NS	19	NS	NS

Table 10. Validation of Bio-stimulants as seed treatment and foliar application of nano Urea, DAP, Zn, K on seed nutrient and index leaf Zn content 2023.

	Seed nutrient content				Index leaf Zn content					
Treatments	N%	P%	K%	Zn ppm	6th Sept	27th Sept	20th -Oct	2nd Nov	2nd Dec	Pool
RDF 10:26:26	3.2	0.54	1.0	63	73	95	85	121	103	93
RDF 20:20:0:13 + Seed Tr NPK Zn sol *consortia* +3 foliar sprays of nano Urea +K and ZnO + K	3.1	0.53	0.88	69	81	120	90	146	96	109
RDF 20:20:0:13 + Seed Tr NPK Zn sol *consortia*+ 3 foliar sprays of nano DAP+ ZnO + K	3.2	0.54	0.90	79	74	110	88	115	101	97
SE±5%	NS	0.02	0.06	15	NS	20	NS	NS	20	NS

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