Soil application of seaweed extract granules and foliar application of nano ZnO to Bt hybrid cotton to *Vertic inceptisols*.

ABSTRACT

Bt hybrid cotton was significantly benefitted by the soil application of Sagarika seaweed extract granules at 25 kg ha^{-1} yr^{-1} along with the recommended basal fertilizers dose or foliar application of nano ZnO 4% at 0.04% at squaring and flowering stage. These treatments significantly enriched index leaf P and Zn content during the boll development stage and this resulted in significant improvement in lint yield by 7.5% i.e. 35 kg lint ha^{-1} yr^{-1}, C:B ratio by 5.0% and net returns to the tune of ₹. 5000 ha^{-1} over 100% RDF in eroded Vertic inceptisols deficient in Nitrogen, Magnesium, Sulphur, Zinc and Boron.

Keywords: Bio-stimulants, B:C ratio, Foliar application, Granules, Nano ZnO, Phosphorous, Seaweed extract, Seed treatment, *Vertic Inceptisols*, Zinc deficiency**.**

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Introduction

Vertic inceptisols occupy 40% of the 3.93 million hectares of rainfed cotton in Maharashtra state, India **(Sehgal,1991)**. These soils could have been better productive under short-duration, shallow-rooted, close-growing legumes under regular crop rotations under sustainable crop production. Bt hybrid cotton demands judicious application of bulky organic manures along with recommended dose of chemical fertilizers, rainwater conservation, harvesting and recycling as protective irrigations in case of intermittent droughts **(Raju *et al.*, 2011)**. The productivity of lint in these soils is just 250 kg lint ha^{-1}, which is economically not viable under the present set of inputs **(Aparna, 2014)**. Present productivity levels can be doubled easily with modern agro inputs and water resources development both with capital investment to the tune of Rs. one *lakh* ha^{-1} of a farm **(Ramasundaram and Gajbhiye, 2000; Ravinder *et al.*, 2011)**. Nutrient supply and uptake is one of the key issues besides supplemental irrigation in improving the productivity of these soils. Nutrients supply and uptake is addressed through bio-stimulant seaweed extract condensed granules as a soil application, seed treatment and foliar applications besides correcting deficiencies of nutrients using emulsifiable concentrate formulations of plant protection chemicals along with a recommended dose of fertilizers **(Raju and Thakare, 2012, 2013 and 2014).**

MATERIALS AND METHODS

A field experiment was conducted for two years in *Vertic Inceptisols* with Twelve treatments and Four replications in RBD design during the 2017, and 2018 seasons at ICAR, Central Institute for Cotton Research, Panjri farm, Nagpur (21.14, 79.01). Treatment details were T_1. Control. T_2. *Azotobacter* + *Azospirillum* and *Bacillus megatherium var. phosphaticum* IFFCO *consortia as a* seed treatment at 0.2% + 75% R D.F, i.e. 68: 34: 34 kg ha^{-1} N: P_2O_5: K_2O. T_3. RDF 100%, i.e., 90:45:45 kg ha^{-1} N: P_2O_5: K_2O. T_4. T_3. + Recommended dose of $ZnSO_4$ 20 kg ha^{-1} + Sulphur 20 kg ha^{-1} + Borax 5 kg ha^{-1} as soil application. T_5. T_3. + Zn solubilising bacteria (ZSB) IFFCO brand as *a* seed treatment at 0.2%. T_6. T_3. + Recommended dose of Zn sulphate 20 kg ha^{-1} alone. T_7. T_3. + Borax 5 kg ha^{-1} alone. T_8. T_3. + Bentonite Sulphur IFFCO brand 20 kg ha^{-1} soil application. T_9. T_3. + *Sagarika as* seed treatment. T_{10}. T_3. + *Sagarika as* seed treatment with two foliar applications at squaring and flowering stage at 2 ml L^{-1}. T_{11}. T_3. + Soil application of *Sagarika* granules 25 kg ha^{-1} along with basal dose of fertilizers. T_{12}. T_3. + IFFCO Nano ZnO 4% two foliar applications at 4 ml L^{-1} at squaring and flowering stages. Soil application of S, Zn, B in T_4., T_6., T_7. and T_8. were applied along with the first urea top dressing in August. Soil and plant samples were collected, processed and analyzed with standard protocols **(Estefan *et al.*, 2013)**, one week and 10 days after foliar application to measure the residual value in the index leaf after due absorption and translocation to developing bolls. A pot culture trial was also conducted in 2018 with similar treatments for root stimulation studies in response to moisture stress only during 2018 and confirmed under the paper cup method.

RESULTS AND DISCUSSION

Soil and climate during the seasons: Soil was slop~~p~~y, highly eroded, *Vertic inceptisols* with *Caliche* substrata below 45 cm soil depth, (Table 2) with very low in organic carbon, N, Mg, S, Zn, B and medium in available P_2O_5 and K_2O. Free calcium carbonate content was within the tolerable limits for Bt hybrid cotton (Table 2). The onset of monsoon was delayed in 2017, planting of Bt hybrid cotton was done only after receiving of 83 mm rain on 27.6.2017 and 98 mm of rain on 12.6.2018. There was a gap of 15 days in 2018. A pot culture trial was also set up without

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external watering. Years 2017 and 2018 received 35 and 20% lower than the normal seasonal rainfall 12% and 33% lesser number of normal rainy days (Table 1, Graph.1). Early seedling and vegetative stage of June and July months received 18 and 35% less rainfall in 33% less and 13% extra over and above of normal rainy days during 2017, while it was reverse in 2018 it was 14 and 40% more than normal rainfall in 8 and 27% lower number of rainy days made cotton to suffer both shortages and excesses rains during vegetative stage (Table 1). The flowering stage in both years received 33% fewer rainy days 46% less rains in 2017 and 60% less rains in 62% fewer rainy days during the 2018 season. The pattern of excess rains during vegetative and lower rains at reproductive stages producing less biomass and fruiting parts due to leaching of nutrients creates stress on developing bolls combined with higher biotic and abiotic stress resulting in poor input response pn non-viable input expenditure. Over all the rainfall deficit was 35% with 38% fewer rainy days in 2017 and 19% less rainfall on 62% fewer rainy days in 2018 respectively producing sub-optimal cotton lint yields despite of best investment in input technologies. Therefore, the amount and distribution of rainfall were very crucial in realizing the input response to Bt hybrid cotton (Table 1).

Table (1): Monthly rainfall and rainy days in proportion to the normal pattern.

Seasons--->	Rain (mm)	Rainy days	Rain (mm)	Rainy days	Rain (mm)	Rainy days	Proportion of normal Rain fall		Proportion of normal Rainy days	
Months	**2017**		**2018**		**Normal**		**2017**	**2018**	**2017**	**2018**
June	156	8	217	11	190	12	82	114	67	92
July	222	17	480	11	342	15	65	140	113	73
August	276	8	171	8	281	12	98	61	67	67
September	99	10	74	3	183	8	54	40	125	38
October	15	1	**?**	**?**	57	2	26	0	50	0
Seasonal	753	43	942	33	1166	49	65	81	88	67
Crop duration	612	36	725	22	1052	58	58	69	62	38

Graph (1): Daily rain fall mm during 2017, 2018

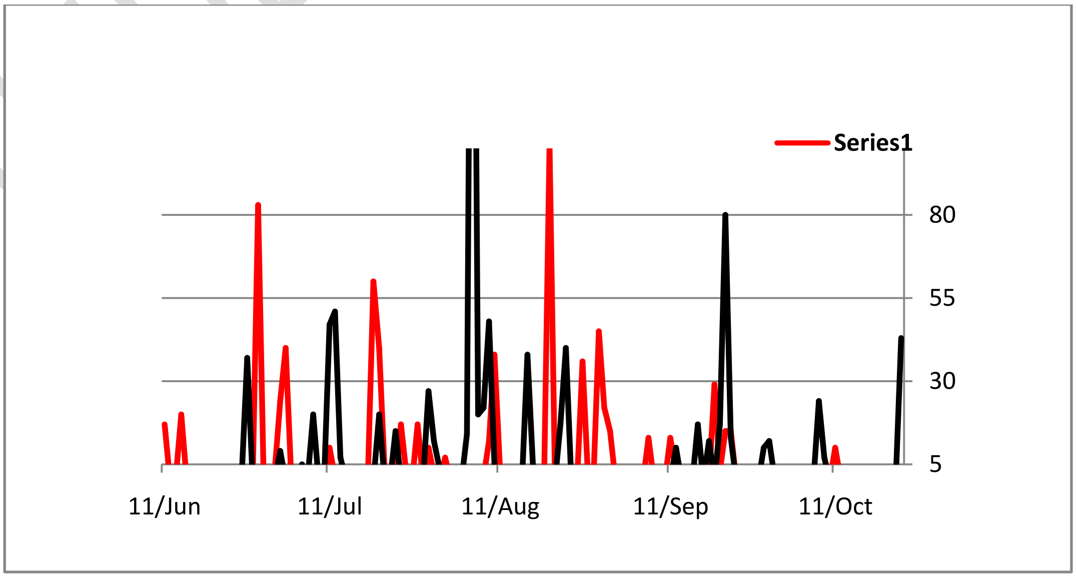

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Table (2): Soil fertility evaluation status before the start of the experimentation.

S. No.	Soil content	A 18	Notices
1	pH	7.72	Neutral
2	EC	3.85	(mmohs/cm)
3	Organic Carbon %	0.29	Low
4	Available Nitrogen kg ha^{-1}	113	Low
5	Available P_2O_5 kg ha^{-1}	26	Medium
6	Available K_2O kg ha^{-1}	462	Medium
7	Available Mg ppm	0.29	Very low
8	Available S ppm	0.58	Very low
9	Available Zinc ppm	0.84	Low
10	Available B ppm	0.49	Low
11	$CaCO_3$% equivalent	21.2	Medium

A pot culture trial was also conducted with the same soil, which found improved root length, lateral roots and biomass in very low organic carbon, N, Mg, S, Zn, and B deficient soil. It escaped more than 15 days of drought in 2018 (Graph.1, Table 3) followed by confirmation of root study with paper cup seedlings (13% higher shoot and root length 4% and 49% more lateral roots) and field studies by excavation at 30 days in *Vertic inceptisols*. *Sagarika* granules 25 kg ha^{-1} having Zn 60 ppm and GA_3 40 ppm applied along with a basal dose of RDF 90:45:45 kg ha^{-1} N: P_2O_5: K_2O complex fertilizers. It has having comparable effect to that of liquid humic acid 0.2% also contains many root-stimulating bio-chemicals as seed treatment both producing the best Phyto-tonic effect. It produced a higher number of dark green colour leaves, plant height and root length which meets the farmer's expectation as Bt hybrid cotton grows very slowly at the seedling stage (Table 3).

A significant economical mean cotton lint yield of 36.0 kg ha^{-1} or 7.8% was achieved with a net return ₹. 5000 ha^{-1} and with an improvement of 5.5% C: B ratio was realized with *Sagarika* granules 25 kg ha^{-1} soil application along with a basal dose of 100% R.D.F fertilizers or Nano ZnO 4% at 4 ml L^{-1} foliar spray twice at squaring and flowering stage along with 100% RDF improved yield by 33.0 kg ha^{-1} or 7.1% with net returns of ₹.5100 ha^{-1} and 5.0% improvement C: B ratio in shallow sloppy degraded *Vertisols* with *calcite* substrata (Table 4). Index leaf nutrient concentration at peak boll load on 12.10.18 was found deficient in P (<0.20%) and Zn (<20 ppm), which was increased by the soil application of *Sagarika* granules and foliar application nano ZnO 4% increased the residual index leaf Zn content to 18 and 21 ppm on 13.11.18, which was minimum equivalent to improve by soil and foliar application of recommended dose $ZnSO_4$ 20 kg ha^{-1} yr^{-3}. This is essential to be supplemented in marginal soils to reduce the forthcoming leaf reddening after September month when N, P, K, Mg and Zn fall below the critical limits either due to a shortage in supply or diverted to more developing bolls (Table 4). Current and forthcoming deficiencies of N, P, K, Mg, S, Zn and B can also be met to some extent,

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through advanced soil and foliar application with Zn, Mg, and B containing fertilizers salts compatible with WSF fertilizer salts at 0.3 to 0.5% along with emulsifiable concentrate formulations of plant protection chemicals or nano ZnO to multi-nutrient deficient soil before the month of mid-September at the early reproductive stage can save from nutrient deficits besides boosting boll size, numbers, and prevent leaf reddening as experienced in the Midwest cotton by **Mitchel *et al*. 1997, Raju and Thakare, 2012, 2013, 2014.**

Although Zn, S, B water-soluble salts soil application were relatively cheaper than foliar applications in supplying deficient nutrients to the cotton crop and also found helpful in improving the nutrient status of the cotton crop, with relatively better agronomic adaptability in medium and deep *Vertisols* (Rehman et al. 2018). However, in sloppy, *Vertic Inceptisols*, having very low organic matter content, runoff and leaching losses are very high during July, August rainiest month at the cotton vegetative stage (Table 1, Graph. 1). The real deficits occur in September, October during the early and late boll development stage in limiting the multi-nutrient deficits made the non-viable agro-economic response of cotton lint yields, i.e., 35 kg lint ha^{-1} **(Raju and Thakare, 2012, 2013,2014).**

Sagarika alone as seed treatments along with twice foliar spray applications at squaring to the flowering stage did improve yield by 5.0% or 22 kg ha^{-1}, but did not meet the costs involved, in the prevailing shortage of rains during a reproductive stage in both the years 2017 and 2018 (Table 1). Therefore, single applications are not viable. Similarly, Zinc solubilizing bacteria or *Sagarika* as seed treatments, soil application of Bentonite Sulphur 20 kg ha^{-1} or Borax 5 kg ha^{-1} alone or Zn, S, B together soil application produced marginal improvement in yield in a very low organic carbon soil, having very low nutrient holding capacity under adverse rainfall shortages at reproductive stage did not perform well to recover the costs involved in marginal soils as observed by **Raju and Thakare, 2013**.

CONCLUSION

On *Vertic inceptisols* with *caliche* sub strata having multiple nutrient deficiencies, soil application of *Sagarika* granules 25 kg ha^{-1} yr^{-1} along with basal fertilizers dose or nano ZnO 0.4% foliar application @ 0.04% at squaring and flowering stage ~~got~~ enriched P, Zn content in the index leaf. This improved lint yields significantly by 35 kg ha^{-1} yr^{-1}, improved-in C:B ratio by 5% and provided additional net returns of ₹ . 5000 ha^{-1} over 100% RDF alone.

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Table (3): Seedling growth 20 DAS in pot culture experiment in *Vertic Inceptisol*.

Treatments	Plant height (cm)	Primary root length (cm)	Lateral root numbers	Root: Shoot Ratio	Root length: Lateral root numbers	Number of Leaves
Control	18	20	5	1.1	4.4	7.5
RDF + Humic acid seed treatment + FS	33	38	15	1.1	2.5	12
RDF 90:45:45 kg ha^{-1}	27	35	11	1.3	3.1	9.0
NPK *consortia* seed treatment	24	35	8	1.5	4.5	7.5
Zn solubiliser as seed treatment	26	33	7	1.3	4.7	7.0
RDF + Zn solubiliser seed treatment	35	29	11	0.8	2.6	9.0
RDF + *Sagarika* granule 25 kg ha^{-1}	39	28	11	0.7	2.6	14
RDF + Humic acid seed treatment	34	26	14	0.8	1.8	8.0
RDF fertilizer + Humic acid mixture	25	24	11	0.9	2.1	9.7
RDF + *Sagarika* seed treatment	28	24	9	0.8	2.8	10
RDF +*Sagarika* seed treatment + FS	30	22	9	0.7	2.4	7.3
CD± 5 %	**5.5**	**9**	**NS**			**3.4**

Table (4): Impact of inputs nutrient content and mean lint yield *Vertic Inceptisols*.

Treatments	P%	K%		Zn ppm		Red Leaf	Boll load	Cotton lint		Net returns	C: B
	12/10	**12/10**	**13.11**	**12/10**	**13/11**	**%**	**No**	**kg ha^{-1}**	**FUE kg^{-1}**	**₹ 000**	**Ratio**
No fertilizers	0.36	2.4	0.30	10	22	84	21	205	0	1.1	1.04
NPK *consortia* seed treatment (tr)+ RDF 75%	0.50	3.0	0.34	14	29	63	25	418	1.6	39.5	2.23
RDF 100%NPK	0.50	2.6	0.44	18	18	30	40	464	1.4	36.1	1.83
RDF 100%+ Zn S B RD soil appn	0.66	2.9	0.43	18	43	26	30	412	1.2	26.4	1.59
RDF 100%+ ZnSB seed tr.	0.49	2.4	0.44	13	30	26	37	414	1.2	27.1	1.62
RDF 100%+ Zn sulphate 20 kg ha^{-1}	0.40	3.1	0.45	11	19	44	39	435	1.3	32.8	1.79
RDF 100%+ Borax 2.5 kg ha^{-1} soil	0.47	2.8	0.44	11	19	45	34	464	1.4	35.0	1.78
RDF 100%+ Sulphur 20 kg ha^{-1} soil	0.44	2.0	0.43	15	17	37	29	465	1.4	35.6	1.80
RDF 100%+ *Sagarika* seed treatment	0.39	2.3	0.45	9	23	46	34	412	1.2	27.3	1.63
RDF 100%+ *Sagarika* seed tr. +FS	0.31	2.2	0.45	9	22	42	31	486	1.6	38.0	1.83
RDF 100%+ *Sagarika* granules 25 kg ha^{-1}	0.42	2.0	0.45	10	31	49	39	500	1.6	41.1	1.93
RDF 100%+ nano ZnO two FS 4 ml L^{-1}	0.52	2.0	0.45	12	30	37	33	497	1.6	41.2	1.92
SE±5%	**0.49**	**0.8**	**0.69**	**0.4**	**0.16**	**0.14**	**0.4**		**0.3**		
CD±5%								**30**		**2.9**	**0.01**

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