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Soil Application of Sea Weed Extract Granules and Foliar Application of Nano ZnO to Bt Hybrid Cotton to *Vertic inceptisols*

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Author's contribution

The sole author designed, analyzed, interpreted and prepared the manuscript.

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ABSTRACT

Bt hybrid cotton was significantly benefitted by the soil application of Sagarika sea weed 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 stages. These treatments significantly enriched index leaf residual P and Zn content beyond 20 µg g^{-1} fresh weight during 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 alone 100% RDF in eroded *Vertic inceptisols* deficient in N, Mg, S, Zn and B. Excess rains at seedling and vegetative stage followed by drought at reproductive stages in both years, reduced the economic viability of seed treatment with bio-stimulants and foliar applications besides soil and foliar application of Zn, S, B alone or together to Bt hybrid cotton.

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1. INTRODUCTION

Vertic inceptisols occupies 40% of the 3.93 million hectares of rainfed cotton in Maharashtra state, India [1]. 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 with rain water conservation, harvesting and recycling for protective irrigations in case of intermittent droughts (Raju *et al*., 2011). Productivity of lint in these soils is just 250 kg lint ha^{-1}, which is economically not viable under present level of inputs [2]. Present productivity levels can be doubled easily with modern agro inputs and water resources development both with a capital investment to the tune of 1220 $ ha^{-2} farm [3,4]. Nutrients supply, uptake and utilization were key issues besides supplemental irrigations in improving the productivity of these soils as observed, tested and validated in different soils of Maharashtra state, India [5-7]. Optimum yields can be obtained if critical nutrient level is maintained in recently full matured cotton index leaf [8]. Critical level of N in Bt hybrid cotton is around 3 percent, if drops below, N deficiency symptoms appear and yield and quality is expected to decline, therefore an optimum of 4.0% N is to be maintained through adequate soil application of manures, fertilizers and through foliar correction [9]. P level in young cotton plants can be as high as 0.50 to 0.6 percent, but these high levels may reflect actual need. P deficiency occurs, due to a severe inadequacy of P in the soil solution. Phosphorus deficiencies normally occur early in the growth cycle of the plant when the P content goes below 0.2 percent [5-7]. Critical K in cotton leaf blades in mid to-late season is between 0.9 and 1.2% ([10,11], Snyder et al.,1991) and may be as low as 0.88% where significant decreases in leaf photosynthesis can occur [12]. Halevy and Markovitz [13] in Israel and Oosterhuis et al. [8, 14,15,16,17] in U.S.A., reported increased lint yield and average boll weight from foliar sprays containing N, P, K and S in locations where the soil fertility of K status is less than 125 ppm K. Foliar-applications of KNO_3 can increase yields and improve lint quality, i.e., by an average of 26 kg ha^{-1} compared to the standard soil K applications. Critical limit for S and Mg is 0.20 to 0.30 percent, deficiency symptoms occur in the older plant tissue. Soil and foliar applications of Mg may be needed in some cases to supply some of the Mg cotton requirement. Cotton optimum yields can be obtained by maintaining N:S ratio between 10:1 to 15:1. S is mobile element in the plant, deficiency symptoms tend to first appear in the upper or newly emerging leaf tissue. Critical levels of Fe, Zn, and B in Varamin, Iran sandy loam, irrigated calcareous soils were 5.5, 1.1, and 1.3 mg kg^{-1} soil [18]. Critical concentration for Pakistan saline, sity loam soils were Zn is 0.78 -1.0 µg g^{-1} and B 0.45 µg g^{-1} and was youngest leaves 35–43 mg kg^{-1} [19,20]. Nutrients supply, uptake and utilization were addressed through recommended dose of fertilizer nutrients, bio-stimulant sea weed extract condensed granules as soil application, seed treatment and foliar applications besides correcting deficiencies of nutrients using emulsifiable concentrate formulations of plant protection chemicals along with recommended dose of fertilizers.

2. MATERIALS AND METHODS

A field experiment was conducted for two years in *Vertic Inceptisols* with Twelve treatments and Four replications in RBD design during 2017, 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 consortia* as 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} yr^{-3} + Sulphur 20 kg ha^{-1} yr^{-3} + Borax 5 kg ha^{-1} yr^{-3} as soil application. T_5. T_3. + Zn solubilising bacteria (ZSB) seed treatment at 0.2% of seed weight. T_6. T_3. + Recommended dose of Zn sulphate 20 kg ha^{-1}yr^{-3} alone. T_7. T_3. + Borax 5 kg ha^{-1} yr^{-3} alone. T_8. T_3. + Bentonite Sulphur 20 kg ha^{-1} yr^{-3} 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} yr^{-1} alongwith basal dose of fertilizers. T_{12}. T_3. + 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 first urea top dressing in the month of August, 2017, 2018. Soil and plant samples were collected, processed and analyzed with standard protocols [21], before one week 10 days after foliar application to measure the residual value of nutrients 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 paper cup method.

3. 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, always caused a temporary flooding at lower end due to deposited clay. The soil fertility status was found to be 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) as observed, tested and confirmed by Raju and Deshmukh [22,23]. 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 rain on 12.6.2018. There was a rain gap of two weeks in 2018. A pot culture trial was also setup without external watering. Year 2017 and 2018 received 35 and 20% lower than that of the normal seasonal rainfall in 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 (Graph. 1) and excesses rains during vegetative stage (Graph 1 Table 1). Flowering stage in both the years received 33% less rainy days received 46% less rains in 2017 and received 60% less rains in 62% lesser rainy days during 2018 season. Pattern of excess rains during vegetative stage lead to 80% leaching of soluble nutrients creates and lower rains at reproductive stages producing less biomass and fruiting parts due to nutrient and moisture stress on developing bolls combined with higher biotic and abiotic stress during this period. This resulted in poor input response and non-viable input expenditure. Over all the rainfall deficit was 35% in 38% less rainy days 2017 and 19% less rainfall in 62% less rainy days in 2018 respectively producing sub optimal cotton lint yields despite of best investment on input technologies (Graph.1 Table 1). Therefore, the amount and distribution of rainfall was very crucial in realizing the input response to Bt hybrid cotton in *Vertic Inceptisols* as observed, tested and confirmed in Yeotmal (M.S) India by Raju and Thakare [5-7] and Nagpur (M.S) India district farmers fields by Raju and Deshmukh [22,23].

A pot culture trial was also conducted with the same soil, which found improved root length, lateral roots and biomass in a very low organic carbon, N, Mg, S, Zn, B deficient soil. It escaped more than 15 days drought in 2018 (Graph.1,Table 3) followed by confirmation of root study with paper cup seedling (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 annual application 25 kg ha^{-1} having Zn 60 ppm and GA_3 40 ppm applied alongwith basal dose of RDF 90:45:45 kg ha^{-1} N: P_2O_5: K_2O complex fertilizers. It is having comparable effect to that of liquid humic acid 0.02% also contains many root stimulating bio-chemicals as seed treatment both produced best phyto-tonic effect. It produced 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 seedling stage (Table 3).

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 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 alongwith 100% RDF improved yield by 33.0 kg ha^{-1} or 7% with net returns of ₹.5100 ha^{-1} and 5% improvement C: B ratio in shallow sloppy degraded *Vertisols* with *calcite* sub strata (Table 4). Lint yields improved by the treatments were met the minimum standard of popular agro economic standard followed by Indian cotton growers [24]. 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 very essential required to be supplemented in

Table 1. Monthly rainfall and rainy days in proportion to 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	0	0	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

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

S. No.	Soil content	Field No. A 18	Notices
1	pH	7.72	Neutral
2	EC(mmohs/cm)	3.85	
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

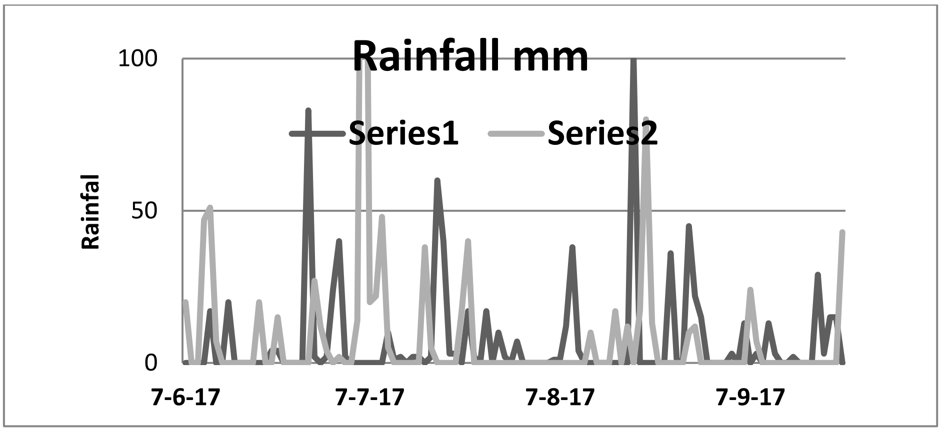
marginal soils to reduce the forth coming leaf reddening in mid September month when N, P, K, Mg and Zn falls below the critical limits either due to shortage in supply or diverted to more number of developing bolls (Table 4). Leaf reddening in Bt hybrid cotton was primarily due to early retention of higher boll numbers and fall in nutrient supply to demand with the onset of reduced root activity in early winter season as experienced by Oosterhuis et. al. [8], Ravinder and Thakare, [5,7] Ravinder, 2017. Current and forth coming deficiencies of N, P, K, Mg, S, Zn and B can also be met to some extent, through advanced soil and foliar application with Zn, Mg, B containing water soluble fertilizers salts at 0.5 to 0.3% along with emulsifiable concentrate formulations of plant protection chemicals or nano ZnO to a multi-nutrient deficient soils before the month of mid September at early reproductive stage can save from nutrient deficits besides boosting boll size, numbers and prevent leaf reddening as experienced and confirmed in the Midwest cotton by Oosterhuis et. al. [8,14,15,16,17,25,26] and Bt hybrid cotton in India by Raju and Thakare, [5-7], Raju and deshmukh, [22,23] with calcareous strata in station and onfarm trials.

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$\pm$ 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



Graph 1. Daily rain fall mm during 2017, 2018

Although Zn, S, B water soluble salts soil and three foliar applications costs 12 US $ ha $^{-1}$yr^{-1} in supplying deficient nutrients to the cotton crop and also found helpful in improving the nutrient status of the cotton crop. Foliar applications had relatively better agronomic adoptability in shallow and medium deep *Vertisols* with and without *calcareous* strata under rainfed conditions compared to limited soil application in deep *Vertisols* or under supplemental irrigations as observed, tested and validated in onfarm trials by Raju and Thakare, 2011, [5-7], Raju and Deshmukh, [22,23]. However, in sloppy, *Vertic Inceptisols*, having very low organic matter content, runoff and leaching losses are as high as 80% of applied N, K,S,Zn and B during July, August rainiest months at cotton vegetative stage (Table 1, Graph 1). The real deficits occur in the month of September, October during the early and late boll development stage in limiting the multi nutrient deficits made non-viable agro economic response of cotton lint yields, i.e., 35 kg lint ha^{-1}. These results were similar to those observed in validation by Oosterhuis et. al. [8], Raju and Thakare, [5-7], Raju and Deshmukh, [22,23] in different soils under rainfed and supplemental irrigations in onfarm trials of *Yeotmal* and Nagpur district of Maharashtra state, India [27-29].

Sagarika alone as seed treatments along with twice foliar spray applications at squaring to flowering stage did improved yield by 5.0% or 22 kg ha^{-1} , did not met the costs involved, in the prevailing shortage of rains during reproductive stage in both the years 2017 and 2018 (Table 1, Graph 1). Therefore, single applications are not viable and attractive to farmers in marginal soils under water deficits. Similarly, Zinc solubilizing bacteria or *Sagarika* as seed treatments, soil application of 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, 2011, [5-7], Raju and Deshmukh, [22,23].

4. 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 enriched P, Zn content in the index leaf. This improved P and Zn content in index leaf significantly improved lint yields 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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COMPETING INTERESTS

Author has declared that no competing interests exist.

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