Thus, the sandalwood tree is unique in many aspects. Unlike majority of tropical trees, this tree flowers and disperses seeds twice a year. The seeds are devoid of seed coat. The dicot seed contains a large endosperm and a tiny embryonic axis with 'underdeveloped' plumule and radicle. The seeds exhibit morphophysiological dormancy. The endospermous seeds demonstrate epigeal germination. During germination, the rudimentary cotyledonary leaf emerges at the base of the split stalk of the endosperm and protrudes out of the seed through the micropyle, alongside the split stalk to form the shoot system. After few months of growth, the seedlings of *S. album* connect with host plants through the haustoria to suck essential nutrients, demonstrating their hemiparasitic nature of survival. The wood of the mature *S. album* trees is the second most valued timber on earth. The natural populations are being decimated due to uncontrolled illegal felling and smuggling. Therefore the species has been declared 'vulnerable' and enlisted in the IUCN Red List.

There is a need to undertake further botanical and eco-physiological studies on the sandal species to unravel their uniqueness with respect to correlation among tree phenology, seed development, seed structure and dormancy, germination morphology, hemiparasitic nature and development of unique wood characteristics.

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Potential of integrated approach of zinc fortification in maize

Attention towards the major nutrients than secondary and micronutrients is more for achieving the targeted yields. Zinc (Zn) nutrition plays a pivotal role in plant metabolism and yield potential of maize. Indiscriminate use of high-analysis straight fertilizers coupled with negligible or no application of organics has resulted in imbalanced soil nutrient status and micronutrients deficiency across the globe, and zinc in particular[1]. Zinc deficiency in human nutrition is widespread, after iron, vitamin A and iodine deficiencies. Nearly 49% of the global adult population does not get its daily recommended intake of 15 mg day^{-1} of zinc. This is one of the leading risk factors associated with diseases such as diarrhoea and retarded growth contributing to the death of about 800,000 people each year[2]. Negative correlation between irrigation and phosphorus was observed with Zn uptake which leads to the low Zn content in kernels, a major cause of Zn malnutrition among maize consumers[3].

Zinc enrichment in maize could be achieved using various agronomic strategies. Although application of inorganic sources alone is the common method adopted, integrated approaches (organics and inorganics) involving techniques like seed pelleting, solubilizing bacteria, enriched compost along with foliar spray at critical crop growth stages are cost-effective and sustainable options in the long run. It is also the way forward to enhance the availability of zinc from native soil reserves and to render better availability to the plants and translocation towards the sink.

A field experiment on zinc enrichment in maize was carried out at the College Farm, College of Agriculture, Professor Jayashankar Telangana State Agricultural University (PJTSAU), Rajendranagar, Hyderabad during *kharif* 2019. The geographical location of the experimental site is 17°19′19.2″N lat., 78°24′39.2″E long. and altitude of 542.3 m amsl. Agro-climatologically the area is classified as Southern Telangana Agro-Climatic Zone. The total rainfall received during the cropping period was 680.8 mm. The soil of the experimental site was sandy loam type, slightly acidic in pH (6.30), non-saline in electrical conductivity (EC) (0.21 dSm^{-1}), low in organic carbon (0.42%), low in available nitrogen (230.60 kg ha^{-1}), medium in available phosphorus (24.30 kg ha^{-1}), high in available potassium (388.40 kg ha^{-1}) and low in available Zn (0.54 ppm).

The experiment was laid out in randomized block design with ten treatments and replicated thrice (Table 1). Recommended dose of fertilizer (RDF) 200 : 60 : 50–N : P_2O_5 : K_2O kg ha^{-1}) N was applied in three equal splits (at sowing, knee-high and tasselling stage), total P was applied as basal and K was applied in two equal splits (at sowing and tasselling stage respectively). Farmyard manure (FYM) was enriched with zinc solubilizing bacteria (ZSB) @ 1 kg per 100 kg FYM for 22 days before sowing (T_2 and T_7 treatments). Seed pelleting was done by dissolving 3.6 g of $ZnSO_4$ in water. Polymer was added to above solution and made into a slurry by thorough stirring. The slurry was added to 1 kg seed in a polythene cover and thoroughly mixed for 4–5 min and shade-dried (T_4 and T_9). Enriched FYM was prepared by adding $ZnSO_4$ @ 50 kg ha^{-1} with 25 t FYM ha^{-1} 22 days before sowing (T_5 and T_{10}). Maize hybrid NK-6240 @ 20 kg ha^{-1} was sown adopting a spacing of 60 cm × 20 cm.

Table 1. Effect of integrated approach of zinc fortification in maize

Treatment	Crude protein (%)	ZSB count (CFU × 10^4 g^{-1} soil)	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Zinc content in grain (ppm)	Gross returns (₹ ha^{-1})	Net returns (₹ ha^{-1})	B : C ratio
T_1 – Recommended dose of fertilizer (RDF) alone (control) [N : P_2O_5 : K_2O – 200 : 60 : 50 kg ha^{-1}]	4.98	7.66	3,020	6,021	16.55	59,179	30,519	1.06
T_2 – RDF + zinc solubilizing bacteria (ZSB @ 1 kg/100 kg FYM)	7.36	15.00	4,686	8,570	23.45	91,043	55,383	1.55
T_3 – RDF + FYM (25 t ha^{-1})	6.44	14.00	4,506	8,218	22.15	87,523	53,863	1.60
T_4 – RDF + seed pelleting (3.6 g $ZnSO_4$ kg^{-1} seed)	6.93	8.33	3,930	7,894	22.93	77,074	47,214	1.58
T_5 – RDF + FYM enrichment with 50 kg $ZnSO_4$ ha^{-1}	6.92	12.33	6,053	9,084	26.42	115,616	81,756	2.41
T_6 – RDF + 0.2% foliar spray of $ZnSO_4$ (knee-high and tasselling stages)	5.35	9.00	3,129	6,402	17.94	61,473	32,713	1.14
T_7 – RDF + ZSB (1 kg/100 kg FYM) + 0.2% foliar spray of $ZnSO_4$ (knee-high and tasselling stages)	7.92	17.00	5,631	8,883	25.99	107,994	72,234	2.02
T_8 – RDF + FYM (25 t ha^{-1}) + 0.2% foliar spray of $ZnSO_4$ (knee-high and tasselling stages)	5.90	15.00	4,418	7,988	21.39	85,750	51,990	1.54
T_9 – RDF + seed pelleting + 0.2% foliar spray of $ZnSO_4$ (knee-high and tasselling stages)	8.05	9.33	3,919	7,532	21.68	76,507	46,547	1.55
T_{10} – RDF + FYM enrichment with 50 kg $ZnSO_4$ ha^{-1} + 0.2% foliar spray of $ZnSO_4$ (knee-high and tasselling stages)	6.33	12.00	4,821	8,823	25.65	93,673	59,713	1.76
SEm±	0.36	0.54	337	369	0.70	5,953	5,953	–
CD (P = 0.05)	1.07	1.61	1,010	1,107	2.07	17,827	17,826	–

Initial population of ZSB in soil was 7.00 CFU × 10^4 g^{-1} soil. Initial zinc content in maize grain was 16.20 ppm.

The results revealed that significantly higher crude protein content (8.05%) was recorded with T_9 compared to all other treatments, except T_2 and T_7 which were comparable with T_9 (Table 1). The lowest crude protein content (4.98%) was recorded with T_1. Improved grain protein content was due to the role of zinc in the synthesis of RNA polymerase enzyme involved in the transformation of amino acids into proteins. The grains of the plants which were devoid of zinc application recorded the lowest protein content[4,5].

Perusal of data on microbial population at harvest revealed that it was highest (17.00×10^4 CFU g^{-1} soil) with the integrated approach; RDF + ZSB (1 kg/100 kg FYM) + 0.2% foliar spray of $ZnSO_4$ (knee-high and tasselling stages) compared to rest of the treatments. Highest microbial population in this treatment might be due to the conjunctive application of ZSB enriched with FYM that increase the activity of microbial count compared to rest of the treatments[6]. Lowest microbial population (7.66×10^4 CFU g^{-1} soil) was registered with application of inorganics alone.

The grain and stover yields (6053 and 9084 kg ha^{-1} respectively) were significantly high with T_7. Improved yield in this treatment was due to the enhanced chlorophyll content and adequate nutrient supply to crop. Further, enrichment process also favoured formation of stable organometallic micronutrient complexes[7,8] and prevented nutrient loss and improved nutrient use efficiency[9–11].

Grain zinc content was highest (26.42 ppm) in T_5. It was on par with T_7 and T_{10}, but significantly higher compared to rest of the treatments. Lowest zinc content (16.55 ppm) was registered with T_1. Improved zinc content in integrated approach was due to the enhanced plant metabolism processes (development of cell wall, respiration, carbohydrate metabolism and microbial activity) that enabled steady availability of zinc throughout the crop growth period over inorganic sources alone[12,13]. Monetary returns (gross, net returns and B : C ratio) were higher with integrated approach of zinc fortification, T_5 and T_7 due to higher grain and stover yields compared to rest of the treatments[14–16].

From the present study in maize, it can be concluded that the integrated method of zinc fortification with enriched FYM, ZSB along with RDF and foliar spray of 0.2% $ZnSO_4$ is a sound and sustainable option to overcome the problem of malnutrition by enhancing the quality and also ensuring higher economic returns.

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