Productivity and Nutrient Content Enhancement Through Agronomic Bio-Fortification In Pearl Millet

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ABSTRACT: Indian agriculture has secured food availability and is now aiming to ensure nutritional adequacy by promoting crops that supply essential nutrients and enhancing the nutrient content of major consumed crops. However, current intensive agricultural practices prioritize higher productivity over nutritional security. Fortification, which can take the form of bio-fortification, agronomic fortification, or industrial fortification, offers a means to boost nutrient levels. Agronomic bio-fortification involves agricultural practices that not only increase productivity but also enhance nutrient content. A study conducted over 2022 and 2023(two years) in red sandy loam soil during the *Kharif* season focused to determine effective sources and methods for applying micronutrients to boost iron (Fe) and zinc (Zn) levels in pearl millet, thereby developing a comprehensive technology of agronomic bio-fortification. The research followed a Factorial Randomized Design with three replications. Treatments included different types, quantities, and application methods of Fe and Zn, along with two types of pearl millet. Growth, yield and yield contributing factors, nutrient content in grain and post harvest soil and economics were studied. The study found that external application of Zn and Fe through both soil and foliar methods is crucial for achieving optimal nutrient levels in bio-fortified pearl millet hybrids. The cultivation of a specific type of pearl millet, CO 10 composite, responded particularly well to applied micronutrients. Cultivating CO 10 composite with recommended doses of NPK and Zn SO4@25kg/ha, along with foliar applications of Zn SO4(0.5%) and FeSO4(0.5%) and nano urea(5ml/litre), led to higher yields(3254 kg ha^{-1}), net income (Rs.50879 ha^{-1}), and Benefit Cost Ratio(2.51), accompanied by increased Zn and Fe content in the grains. In conclusion, supplementing micronutrients through agronomic bio-fortification is essential for enhancing nutrient levels in crops. This approach not only improves yield and income but also contributes to achieving higher nutritional standards

Key words: *Agronomic bio-fortification; Fe ; nutrient content; productivity; Zn*

I. INTRODUCTION

The production of food crops has significantly increased since the Green Revolution. Yet, the nutritious value of crops could not keep up with the population's increasing needs. Malnutrition, the monster of hidden hunger has already attained the status of the utmost significance through the interventions of Millennium Development Goals (MDGs) and Sustainable Development Goals (SDGs)[1]. According to World Health Statistics, 2022, around 45 percent of mortality occurred within the age of five is caused by malnutrition. One of the many micronutrients necessary for optimum health is zinc, which is typically insufficient in the average person's diet. Zn deficiency can cause immune system dysfunction, growth restrictions in children, and negative pregnancy outcomes in women [2]. Similarly, anaemia and neurological disorders are just two examples of the physiological issues brought on by a diet low in Fe [3].

Until recently, production of crop has primarily focused on boosting yield of crops and agricultural productivity compared to increasing nutritional security. Intensive agriculture stimulated micro nutrient deficiencies in the soil. Micronutrient deficiencies in plants can result in micronutrient deficiencies in individuals through consumption of plant parts and value added products as a food. Zinc (Zn) is vital trace element needed by both humans and plants. Zinc is an essential micronutrient required for the growth and development of plants, synthesis of chlorophyll and plays a role in the regulation of plant growth hormones, synthesis of enzymes and proteins required for plant growth. Zinc helps in the formation of seeds and their maturation. Iron (Fe) role is essential in both humans also in plants. Iron played on chlorophyll production and provides green colour needed for photosynthesis. Iron also plays a role in the production of enzymes that are involved in plant growth and metabolism.

Bio fortification and agronomic fortification is the ways to enhance the nutrient content in the plant and enhance the availability to the human through the consumption of mineral enriched millets. The important limitations of bio-fortification through conventional plant breeding or genetic engineering include the need for a lengthy gestation period, sufficient funding, and the fact that the products are not globally recognized. Agronomic bio-fortification is the simplest, quickest, and most frequently acknowledged method to enrich the nutrient content in the millets and to reach the rural people mineral requirement who are the most impoverished and to provide foods rich in micronutrients, vitamins, Folic acids, etc. Agronomic bio-fortification involves enhancing the concentration of nutrients, vitamins, and minerals in crops through the implementation of suitable agricultural practices. This method serves as an effective strategy for supplementing micronutrient powders and improving dietary variety [1]. Employing agronomic methods for bio-fortifying food crops is a practical and economical approach [4]. Overall, agronomic bio-fortification has the potential to improve the healthy life of millions of people around the world, mainly susceptible group needs of micronutrient. With this background agronomic bio-fortification study was conducted in pearl millet with the objectives to enhance the productivity and to increase the nutrient level of pearl millet cultivation under irrigated condition.

II. RESEARCH MATERIALS AND METHODS

Experimental design

The experiment was conducted two years (2022 and 2023) at Agricultural College and Research Institute, Tamil Nadu Agricultural University, Madurai, Tamil Nadu-625104 with the objectives to standardize the source and method of application of micro nutrient to enhance the mineral content (Fe& Zn) in Pearl millet and to develop a compendium technology for enhancement of Fe & Zn in pearl millet through agronomic bio fortification.

The research was executed in Factorial Randomized Block Design with the treatments combinations of composite (CO 10) and hybrids (ICMH 1202) as main factor and sources, forms and quantity of Zn and Fe as sub factors and replicated thrice. The two main factor and eight sub factors combination consists of CO 10 with 100 %RQ of Zn through CF of $ZnSO_4$ @25 kg/ha(**T_1**), CO 10 with 125%RQ of Zn through CF of $ZnSO_4$ @31.25 kg/ha(**T_2**), CO 10 with 100 %RQ of Zn through CF of $ZnSO_4$ @25 kg/ha+0.5 % spray of

FeSO4 +BF (*Bacillus megaterium* @ 500 ml/ha) through soil application(**T_3**), CO 10 with 125%RQ of Zn through CF of $ZnSO_4$ @31.25 kg/ha+0.5 % spray of FeSO4 +BF (*Bacillus megaterium* @ 500 ml /ha) through soil application(**T_4**), CO 10 with 100 %RQ of Zn CF of $ZnSO_4$ @25 kg/ha through soil and foliar application $ZnSo_4$ @0.5 % + 0.5 % spray of FeSO4(**T_5**) , CO 10 with 100 %RQ of Zn CF of $ZnSO_4$ @25 kg/ha through soil and foliar application $ZnSo_4$ @0.5 % +BF through soil application +0.5 % spray of FeSO4(**T_6**), 100 %RQ of Zn through chemical form $ZnSO_4$ @25 kg/ha through soil and foliar application $ZnSo_4$ @0.5 % + 0.5 % spray of FeSO4 +Nano urea foliar spray(@5 ml/litre of water)(**T_7**) and CO 10 with Foliar application $ZnSo_4$ @0.5 % + 0.5 % spray of FeSO4 + Nano urea foliar spray(@5 ml/litre of water)(**T_8**),ICMH 1202 with 100 %RQ of Zn through CF of $ZnSO_4$ @25 kg/ha(**T_9**), ICMH 1202 with 125%RQ of Zn through CF of $ZnSO_4$ @31.25 kg/ha(**T_{10}**), ICMH 1202 with 100 %RQ of Zn through CF of $ZnSO_4$ @25 kg/ha+0.5 % spray of FeSO4 +BF (*Bacillus megaterium* @ 500 ml/ha) through soil application(**T_{11}**), ICMH 1202 with 125%RQ of Zn through CF of $ZnSO_4$ @31.25 kg/ha+0.5 % spray of FeSO4 +BF (*Bacillus megaterium* @ 500 ml /ha) through soil application(**T_{12}**), ICMH 1202 with 100 %RQ of Zn CF of $ZnSO_4$ @25 kg/ha through soil and foliar application $ZnSo_4$ @0.5 % + 0.5 % spray of FeSO4(**T_{13}**) , ICMH 1202 with 100 %RQ of Zn CF of $ZnSO_4$ @25 kg/ha through soil and foliar application $ZnSo_4$ @0.5 % +BF through soil application +0.5 % spray of FeSO4(**T_{14}**), ICMH 1202 with 100 %RQ of Zn through chemical form $ZnSO_4$ @25 kg/ha through soil and foliar application $ZnSo_4$ @0.5 % + 0.5 % spray of FeSO4 +Nano urea foliar spray(@5 ml/litre of water)(**T_{15}**) and ICMH1202 with Foliar application $ZnSo_4$ @0.5 % + 0.5 % spray of FeSO4 + Nano urea foliar spray(@5 ml/litre of water)(**T_{16}**)

Crop management

The experimental soil contain Zn(13.68 ppm) and Fe (21.12 ppm) at low, with the texture of Red Sandy loam and low nitrogen and medium phosphorus and potassium status. Field was prepared to the level of fine tilth and layouts were formed and seeds of main factor were dippled and irrigated, Pre emergence herbicide of Pendimethalin was applied @1.1 kg/ha. The recommended fertilizer dose of 70:35:35 N, P_2O_5, K_2O kg / ha was applied in all the treatments by adopting split application of 25 percent of Nitrogen and 100% of phosphorus and potassium as basal, 75% of N was top dressed at 15 DAS and 30 DAS. Irrigated the field based on the crop appearance and weather condition without any moisture stress. Preventive measures were taken to control the pest and disease.

Data analysis methods

Initial soil and post harvest soil was analysed. The growth and yield and yield parameters were observed at different stages. Nutrient content in grain was analyzed and presented.

III. RESULTS AND DISCUSSION

Growth and yield parameters

The parameters of growth and yield were presented in Table 1. Among main factors, CO 10 was performed the higher growth, yield and yield factors. Among sub factors, 100 %RQ of Zn through chemical form $ZnSO_4$ @25 kg/ha through soil and foliar application $ZnSo_4$ @0.5 % + 0.5 % spray of FeSO4 +Nano urea foliar spray(@5 ml/litre of water) recorded the higher performance on growth, yield and yield factors. The treatment combination of CO 10+ 100 %RQ of Zn through chemical form $ZnSO_4$ @25 kg/ha through soil and foliar application $ZnSo_4$ @0.5 % + 0.5 % spray of FeSO4 +Nano urea foliar spray(@5 ml/litre of water) recorded the higher growth and yield (3254 kg/ha). This might be due to the enhancement of required nutrient availability to the crop. The increase in yield was matched by notable rises in the potassium and zinc levels in the grain when it reached maturity[5]. Both applying zinc to the soil and priming the seeds with zinc led to significant boosts in grain zinc concentration. When these methods were used together, the grain zinc concentration reached 27 mg kg^{-1}, a notable increase compared to the control. These results indicate that applying zinc to the soil is a more effective method for enhancing both wheat yield and zinc concentration. Wheat crops treated with 40 kg of FeSO4 ha^{-1} showed increased yield of grain (2975 kg ha^{-1}) and iron concentration of (432.23 mg kg^{-1}) compared to untreated crops.

Similarly, applying 40 kg of ZnSO4 ha^{-1} resulted in higher grain yield (2971 kg ha^{-1})[6].

Table 1 Effect of combination treatment on plant growth and yield parameters and yield of Pearl millet.

Treatments	Plant height at 50 % flowering (cm)	Flower initiation (DAS)	Plant height at harvest (cm)	Number of tillers	Grain yield(kg/ha)	Straw yield (kg/ha)
T_1	136	47	188	4.02	2446	5612
T_2	142	47	197	4.19	2582	5694
T_3	146	46	198	4.34	2632	5886
T_4	148	46	201	4.36	2891	5954
T_5	149	48	206	4.91	2930	5786
T_6	152	48	208	5.12	3096	5896
T_7	156	49	214	5.46	3254	6152
T_8	148	48	207	5.24	3076	6021
T_9	94	45	124	2.71	2076	5142
T_{10}	92	45	128	2.74	2221	5312
T_{11}	95	45	129	2.84	2276	5462
T_{12}	98	45	131	2.87	2432	5691
T_{13}	101	47	139	3.09	2546	5328
T_{14}	99	45	142	3.12	2881	5672
T_{15}	114	46	145	3.15	2938	5924
T_{16}	109	45	138	2.94	2762	5842
SEd	4	NS	3	0.42	24	32
CD(P=0.05)	9		7	0.91	53	67

Economics:

Cost of cultivation, gross return, net return and BCR was calculated and presented in Table 2. Among the main factors, CO 10, recorded the highest gross income(Rs.74438 ha^{-1}), net income(Rs.40670 ha^{-1}) and BCR(2.20) compared to ICMH 1202. Among the sub factors, 100 %RQ of Zn through chemical form $ZnSO_4$ @25 kg/ha through soil and foliar application $ZnSo_4$ @0.5 % + 0.5 % spray of FeSO4 +Nano urea foliar spray(@5 ml/litre of water) recorded the highest net income (Rs.46554ha^{-1})and BCR(2.37).

Treatment combination of CO 10+ 100 %RQ of Zn through chemical form $ZnSO_4$ @25 kg/ha through soil and foliar application $ZnSo_4$ @0.5 % + 0.5 % spray of FeSO4 +Nano urea foliar spray(@5 ml/litre of water) resulted in the net income of Rs.50879 ha^{-1} with the BCR of 2.51. Agronomic fortification with Zn and Fe positively influenced the growth, yield parameters and yield [7].

Table 3: Effect of treatment combinations on Economics

Treatments	Grain yield(kg/ha)	Gross income (Rs./ha)	Cost of cultivation (Rs./ha)	Net income (Rs./ha)	BCR (Rs./ha)
T_1	2446	63596	32200	31396	1.98
T_2	2582	67132	34075	33057	1.97
T_3	2632	68432	33475	34957	2.04
T_4	2891	75166	34775	40391	2.16
T_5	2930	76180	33075	43105	2.30
T_6	3096	80496	33425	47071	2.41
T_7	3254	84604	33725	50879	2.51
T_8	3076	79976	33675	46301	2.37
T_9	2076	53976	32020	21956	1.69
T_{10}	2221	57746	33895	23851	1.70
T_{11}	2276	59176	33295	25881	1.78
T_{12}	2432	63232	34595	28637	1.83
T_{13}	2546	66196	32895	33301	2.01
T_{14}	2881	74906	33065	41841	2.27
T_{15}	2938	76388	33545	42843	2.28
T_{16}	2762	71812	33495	38317	2.14

Nutrient Content:

ICMH 1202 with the combination of 100 %RQ of Zn through chemical form $ZnSO_4$ @25 kg/ha through soil and foliar application $ZnSo_4$ @0.5 % + 0.5 % spray of FeSO4 +Nano urea foliar spray(@5 ml/litre of water enhanced the level of Fe (178.11ppm)and Zn(49.76 ppm) in the grain. Similarly, CO 10 composite with the combination of 100 %RQ of Zn through chemical form $ZnSO_4$ @25 kg/ha through soil and foliar application $ZnSo_4$ @0.5 % + 0.5 % spray of FeSO4 +Nano urea foliar spray(@5 ml/litre of water enhanced the level of Fe (119.85 ppm)and Zn(39.49 ppm) in the grain. External application of Zinc and Fe is important to achieve the potential level of nutrient content in bio-fortified hybrid under deficit soil. Increase in level of Zinc and Iron application enhanced total content of Zinc and Iron in grain of Pearl millet. Addition of Fe and Zn enhance the level of nutrient content in the grain. Bio-fortified hybrid supported to achieve higher level of nutrient content. Under the application of zinc to the flag leaf, grain zinc concentration increased by 17–33%, while under spike zinc application, it increased by 30–37%. Absorption was responsible for 68–90% and 88–99% of the applied zinc, respectively[8]. Iron-enhanced pearl millet boosted iron absorption by 65%, diminishing iron deficiency, while zinc-enhanced wheat amplified zinc intake by 70% [9].

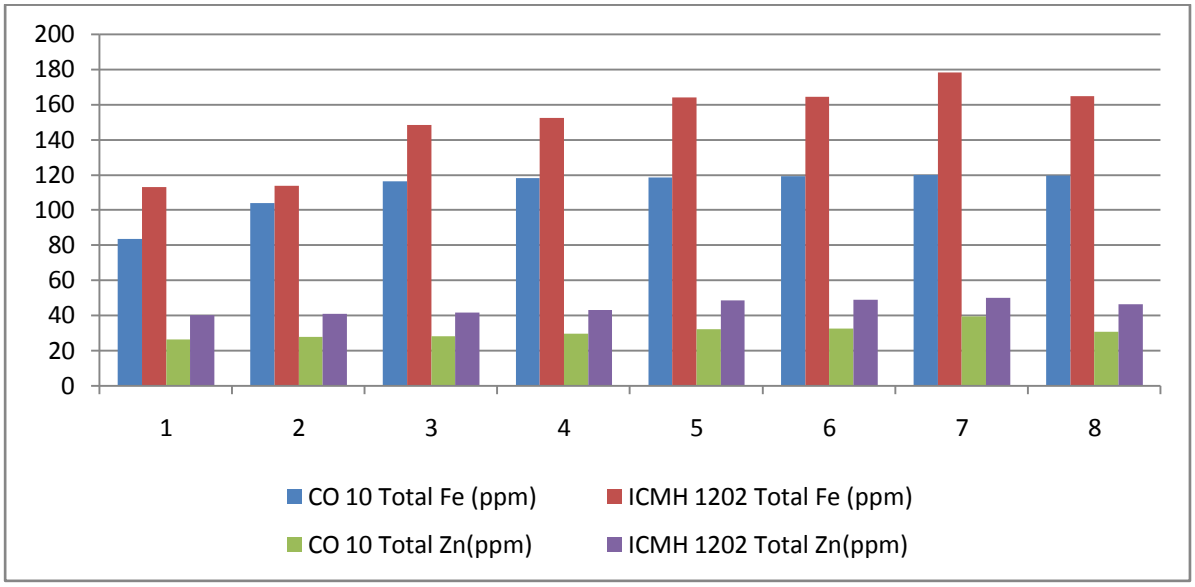

Fig1: Effect of treatment combinations on Fe and Zn nutrient content of grain

IV. Conclusion and Recommendation

Conclusion

Higher growth and yield(3254 kg ha^{-1}), net income (Rs.50879 ha^{-1})and BCR(2.51) recorded in the treatment combination of CO 10 cultivation with 100 % recommended quantity of Zn through chemical form as $ZnSO_4$ @25 kg/ha through soil and foliar application $ZnSo_4$ @0.5 % + 0.5 % spray of FeSO4 +Nano urea foliar spray(@5 ml/litre of water). The same trend also observed in the application of 100 % recommended quantity of Zn through chemical form $ZnSO_4$ @25 kg/ha through soil and foliar application $ZnSo_4$ @0.5 % + 0.5 % spray of FeSO4 +Nano urea foliar spray(@5 ml/litre of water) on enhancement in the nutrient content of Fe and Zn in Pearl millet. Application of Nano urea favoured for the uptake of nutrient and higher Zn content in the grain. Among two composite and hybrids, ICMH 1202 responded at higher level to the application of Zn when compared to CO 10.

Recommendation

Cultivation of pearl millet with the supplementation of micronutrient along with recommended fertilizer dose is important to protect the soil fertility without deterioration in addition to the production of micro nutrient enriched produce to protect the nutritional security.

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