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Yield and Economics of Finger Millet and Redgram Rotation as Influenced by Zinc, Boron and Biofertilizer Nutrition

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ABSTRACT

A field experiment was conducted at Dryland Agriculture Project, University of Agricultural Sciences, Bengaluru during *kharif* on response of finger millet and redgram rotation to zinc, boron and biofertilizer nutrition. The experiments were laid out in randomized complete block design having sixteen treatments and replicated thrice. The redgram (TTB-7) and finger millet (PR-202) was used as test crop. The amount of rainfall received during redgram period is 556.4 mm and 516.2 mm during finger millet crop season. Application of NPK+ $ZnSO_4$ @12.5 kg ha^{-1} + Borax @ 10 kg ha^{-1} + VAM + PSB + *Rhizobium* recorded significantly higher number of fingers / ear head (5.38), 1000 seed weight (3.72 g), grain yield (21.70 q ha^{-1}) and straw yield (31.65 q ha^{-1}) in finger millet as compared to other treatments. Higher B:C ratio (1.46) and micro nutrient efficiency (39.6 kg kg^{-1}) was obtained with application of NPK+ $ZnSO_4$ @12.5 kg ha^{-1} + VAM + PSB + *Rhizobium*. The treatment NPK + $ZnSO_4$ @ 12.5 kg ha^{-1} + Borax @10.0 kg ha^{-1} + VAM + PSB + *Rhizobium* recorded significantly higher number of pods / plant (87), 100 seed weight (11.9 g), grain yield (11.36 q ha^{-1}) and straw yield (4.29 t ha^{-1}) in redgram as compared to other treatments.

Keywords: Bio-fertilizer, boron, finger millet, redgram rotation, zinc

CROPPING system is a kind of sequence and arrangement of crops grown on a given area of land over a period of time. An ideal cropping system should use natural resources efficiently, provide stable and high returns and do not damage the ecological balance. It has attained great significance in intensified agriculture in India and experiments on cropping systems are the ultimate solution to overcome the drawbacks of monocropping system and attain food security. The continuous use of inorganic fertilizers under intensive cropping system has caused widespread deficiency of secondary and micro-nutrients in soil (Anon., 2005). Ragi + redgram intercropping system (8:2) under rainfed condition are common practices in southern Karnataka. It can be evaluated as an additive intercrop; redgram would increase the productivity of soil and cropping system besides helps to supply protein to the farmers.

Sustaining the supply of deficient micronutrients along with macronutrients in appreciate amount and right proportion is a key to maximize productivity gains from macronutrients. Micronutrients have received greater importance in recent years because of wide spread occurrence of their deficiencies from different parts of the country. Researchers have also reported significant responses of many crops to micronutrient fertilization. Zinc and boron are essential elements for plants, being involved in enzymatic reactions and are necessary for their growth and development.

Among micronutrients, zinc and boron deficiency accounts about 49 and 33 per cent, respectively in Indian soils, which reduce not only the yield but also the nutritional quality of the produce (Singh and Behera, 2011). Zinc is involved in auxin formation, activation of dehydrogenase enzymes; stabilization of ribosomal fractions (Afeez and Khanif, 2013) and boron is very important in cell division, pod and seed formation (Goldberg, 2007). Moreover, these two nutrients are found to have its residual impact on the successive crops, it is imperative that application of Zn and B containing fertilizers are needed to exploit the production potential of crops under cropping systems and also to mitigate the deficiencies of these nutrients. Addition of S + Zn + B in balanced fertilization schedule increased

N, P and K utilization efficiency which highlights the role of micronutrients in increasing macronutrient use efficiency (Shukla Aravind, 2011).

Finger millet based crop rotations or relay cropping are common cropping practices in south India. Crop rotation is important as residual fertility from the previous crop contributes to the next crop. It was observed by Ebanyat *et al*. (2010) that finger millet yields following legume crops (cowpea, green gram, groundnut, pigeonpea, and soybean) were higher compared to continuous finger millet cropping. However, the N benefits derived from the legume crop residues decreased as the season progressed. Therefore, selection of appropriate crops in finger millet based crop rotations is very important in order to utilize the residual nutrients and to obtain N credits for finger millet from the previous crop.

Material and Methods

A field experiment was conducted at DLAP, University of Agricultural Sciences, Bangalore, during *Kharif* in three years of crop rotation systems. The experiment was laid out in randomized complete block design having sixteen treatments and replicated thrice in red sandy loam soil with pH ranging from acidic to slightly acidic (4.65 to 5.65), low to medium in organic carbon (0.36-0.59%) and available nitrogen, high in both phosphorus and potassium. The content of sulphur, zinc, boron, and molybdenum were low, where as the soils were high in iron, manganese and copper status. The amount of rainfall received during redgram period is 556.4 mm and 516.2 mm during finger millet crop season. The treatments were used in experiment are T_1- Control (only NPK), T_2- NPK +$ZnSO_4$ @ 12.5 kg ha^{-1}(soil), T_3- NPK + Borax @ 10.0 kg ha^{-1} (soil),T_4- NPK + Rhizobium, T_5- NPK + PSB, T_6- NPK + VAM, T_7- NPK + $ZnSO_4$ @ 12.5 kg ha^{-1} + *Rhizobium*, T_8- NPK + $ZnSO_4$ @ 12.5 kg ha^{-1} + PSB, T_9- NPK + $ZnSO_4$ @ 12.5 kg ha^{-1} + VAM, T_{10}- NPK + Borax @ 10.0 kg ha^{-1} + *Rhizobium*, T_{11}- NPK + Borax @ 10.0 kg ha^{-1} + PSB, T_{12}- NPK + Borax @ 10.0 kg ha^{-1} + VAM, T_{13}- NPK + $ZnSO_4$ @ 12.5 kg ha^{-1} + Borax @10.0 kg ha^{-1}, T_{14}- NPK + $ZnSO_4$ @ 12.5 kg ha^{-1} + VAM + PSB + *Rhizobium*, T_{15}- NPK + Borax @ 10.0 kg ha^{-1} + VAM + PSB + *Rhizobium*, T_{16}- NPK + $ZnSO_4$ @ 12.5 kg ha^{-1} + Borax @10.0 kg ha^{-1} + VAM + PSB + *Rhizobium*.

Yield and its components were determined at maturity stage adopting standard procedure. The soil and plant samples were collected after harvest of each crop and were analyzed for macro and nutrients by adopting standard procedure. Micronutrient use efficiency and B:C ratio was calculated by using following formulae.

$$\text{Micronutrient Use Efficiency} = \frac{\text{Per unit of additional yield produced}}{\text{Per unit of micronutrient applied}}$$

$$\text{B:C ratio} = \frac{\text{Gross returns (Rs. ha}^{-1}\text{)}}{\text{Cost of cultivation (Rs. ha}^{-1}\text{)}}$$

All the data pertaining to the present investigation were statistically analyzed as per the method described by Panse and Sukhatme (1967). The level of significance used in 'F' and 't' test was p= 0.05.

Results and Discussion

Cropping system : Finger millet–Redgram

Crop : Finger millet

Significant differences were observed with respect to plant height and number of tillers / plant at different growth when compared to control. The application of NPK+ $ZnSO_4$ @12.5 kg ha^{-1}+ Borax @ 10 kg ha^{-1} + VAM + PSB + *Rhizobium* recorded significantly higher plant height (87.5 cm) and number of tillers/ plant (4.5) which was statistically on par with the application of NPK+ $ZnSO_4$ @12.5 kg ha^{-1} + VAM + PSB + *Rhizobium* (84.0 cm and 4.46), NPK+$ZnSO_4$ @12.5 kg ha^{-1} + Borax @ 10 kg ha^{-1} (83.2 cm and 4.42) and NPK + Borax @ 10 kg ha^{-1} + VAM + PSB + *Rhizobium* (82.0 cm and 4.40) and NPK+ $ZnSO_4$ @12.5 kg ha^{-1} + PSB (80.9 cm and 4.36), respectively at harvest of crop.

The effect of micronutrients (Zn & B) and bio-inoculants (VAM, PSB & *Rhizobium*) application of yield and yield attributes are presented in Table I and the results were found to be significant except in finger length. Application of NPK+ $ZnSO_4$ @12.5 kg ha^{-1} + Borax @ 10 kg ha^{-1} + VAM + PSB + *Rhizobium* recorded significantly higher number of fingers/ ear head (5.38), 1000 seed weight (3.73 g), grain yield (21.70 q ha^{-1}) and straw yield (31.65 q ha^{-1}) as

TABLE I

Effect of zinc, boron and biofertilizers on yield and yield attributes of finger millet in finger millet-redgram crop rotation

Treatment	Plant height (cm)	No. of tillers/ plant	No. of fingers / ear head	Finger lenght (cm)	1000 Grain weight (g)	Grain yield (qha^{-1})	Straw yield (qha^{-1})	MUE ($kg\ kg^{-1}$)	B:C ratio
T1- Control (only NPK)	71.5	3.73	4.28	4.90	3.10	18.91	26.51	-	1.20
T2- NPK+ZnSO4 @ 12.5 kg ha-1 (soil)	78.6	4.24	5.04	5.22	3.40	20.06	29.46	23.60	1.42
T3- NPK+Borax @ 10.0 kg ha-1 (soil) 73.3	3.91	4.54	4.93	3.20	19.42	27.16	5.10	1.15	
T4- NPK + Rhizobium	72.8	3.79	4.37	4.92	3.16	19.35	26.79	-	1.37
T5- NPK + PSB	74.0	4.00	4.60	4.96	3.25	19.50	27.34	-	1.42
T6- NPK + VAM	76.7	4.14	4.95	5.12	3.35	19.90	28.72	-	1.46
T7- NPK+ZnSO4 @ 12.5 kg ha-1+ Rhizobium	79.4	4.28	5.12	5.30	3.45	20.15	29.65	25.12	1.42
T8- NPK+ZnSO4 @ 12.5 kg ha-1+ PSB	80.9	4.36	5.20	5.40	3.52	20.52	30.33	30.56	1.46
T9- NPK+ZnSO4 @ 12.5 kg ha-1+ VAM	80.1	4.32	5.16	5.36	3.48	20.28	29.74	25.84	1.42
T10- NPK+Borax @ 10.0 kg ha-1+ Rhizobium	74.9	4.06	4.72	5.00	3.27	19.66	27.85	7.50	1.15
T11- NPK+Borax @ 10.0 kg ha-1+ PSB77.5	4.18	5.00	5.18	3.37	19.98	29.20	26.90	1.18	
T12- NPK+Borax @ 10.0 kg ha-1+ VAM75.6	4.10	4.79	5.05	3.30	19.82	28.30	17.90	1.16	
T13- NPK+ZnSO4 @ 12.5 kg ha-1+ Borax @10.0 kg/ha	83.2	4.42	5.25	5.45	3.62	21.05	30.90	35.12	1.24
T14- NPK+ZnSO4 @ 12.5 kg ha-1+ VAM + PSB + Rhizobium	84.0	4.46	5.30	5.48	3.68	21.35	31.46	39.60	1.47
T15- NPK+Borax @ 10.0 kg ha-1+ VAM + PSB + Rhizobium	82.0	4.40	5.20	5.42	3.57	20.77	30.34	38.30	1.22
T16- NPK+ZnSO4 @ 12.5 kg ha-1+ Borax @ 10.0 kg/ha + VAM + PSB + Rhizobium	87.5	4.50	5.38	5.52	3.73	21.70	31.65	22.84	1.23
S.Em±	1.45	0.16	0.23	0.18	0.05	0.30	0.55	-	-
CD @ 5 %	4.37	0.49	0.71	NS	0.16	0.92	1.65	-	-

MUE- Micronutrient Use Efficiency (kg of additional produce to an additional micronutrient applied)

compared to other treatments. This was on par with the application of NPK+ $ZnSO_4$ @12.5 kg ha^{-1} + VAM + PSB + *Rhizobium* (5.30, 3.68 g 21.35 & 31.46 q ha^{-1}), NPK+$ZnSO_4$ @12.5 kg ha^{-1} + Borax @ 10 kg ha^{-1} (5.25, 3.62 g, 21.05 & 30.90 q ha^{-1}) and NPK + Borax @ 10 kg ha^{-1} + VAM + PSB + *Rhizobium* (5.20, 3.57 g, 20.77 & 30.34 q ha^{-1}), respectively. Further it was noticed that a 12 per cent increase in yield with the application of $ZnSO_4$ @12.5 kg ha^{-1} + Borax @ 10 kg ha^{-1} was observed as compared to only NPK. Higher B:C ratio (1.47) and micro nutrient efficiency (39.6 kg kg^{-1}) was obtained with application of NPK+ $ZnSO_4$ @12.5 kg ha^{-1} + VAM + PSB + *Rhizobium*. In spite of dry spell, the crop performed well in micronutrient applied plots and proved the drought tolerance capacity due to application of micronutrients. Maitra *et al*. (2000) reported that application of NPK at a rate of 60:13.3:25 kg ha^{-1} maximized productivity and net return under finger millet-grain legume (pigeon pea and groundnut) cropping systems.

The increase in yield of finger millet may be due to increased growth attributes, leaf area expansion and dry matter accumulation. The combined application of zinc and boron at optimum level helped in fixation of atmospheric nitrogen due to increased nitrogenase enzyme activity, by zinc and boron helps in retention of flowers and improvement in grains setting resulted in higher yield (Lourduraj *et al*., 1998)

Cropping system: Finger millet – Redgram

Crop : Redgram

Significant difference was observed with respect to plant height and number of branches / plant at harvest. Application of recommended NPK+ $ZnSO_4$ @12.5 kg ha^{-1} + Borax @ 10 kg ha^{-1} + VAM + PSB + *Rhizobium* recorded significantly higher plant height (200.30 cm) and number of branches / plant (23.68) as compared to other treatments. Which was found to be statistically on par with the application of NPK+ $ZnSO_4$ @12.5 kg ha^{-1} + VAM + PSB + *Rhizobium* (198.32 cm and 23.45) and $ZnSO_4$ @12.5 kg ha^{-1} + Borax @ 10 kg ha^{-1} (195.24 cm and 21.95), respectively.

The effect of micronutrients (Zn & B) and bio-inoculants (VAM, PSB & *Rhizobium*) application of yield and yield attributes are presented in Table II and the results were found to be significant. Application of NPK+ $ZnSO_4$ @12.5 kg ha^{-1} + Borax @ 10 kg ha^{-1} + VAM + PSB + *Rhizobium* recorded significantly higher number of pods/ plant (87), 100 seed weight (11.9 g), seed yield (11.36 q ha^{-1}) and stalk yield (4.29 t ha^{-1}) as compared to other treatments. This was on par with the application of NPK+ $ZnSO_4$ @12.5 kg ha^{-1} + VAM + PSB + *Rhizobium*, NPK+$ZnSO_4$ @12.5 kg ha^{-1} + Borax @ 10 kg ha^{-1}, NPK+$ZnSO_4$ @12.5 kg ha^{-1} + PSB and NPK + Borax @ 10 kg ha^{-1} + VAM + PSB + *Rhizobium.* Further it was noticed that a 34 per cent increase in yield with the application of NPK+$ZnSO_4$ @12.5 kg ha^{-1} + Borax @ 10 kg ha^{-1} + VAM + PSB + *Rhizobium*, and 26.3 per cent with application of $ZnSO_4$ @12.5 kg ha^{-1} + Borax @ 10 kg ha^{-1} was observed as compared to only NPK. Higher B:C ratio (1.68) was obtained by application of NPK+ $ZnSO_4$ @12.5 kg ha^{-1} + VAM + PSB + *Rhizobium* and NPK+ $ZnSO_4$ @12.5 kg ha^{-1} + PSB. In spite of dry spell, the crop performed well in micronutrient applied plots and proved the drought tolerance capacity due to application of micronutrients.

The significant increase in yield by application of micro-nutrients and bio-inoculants may be attributed to positive response of redgram to zinc as it increased the nodulation and in fixation of atmospheric nitrogen due to increased nitrogenous enzyme activity and available soil N.

Further, boron facilitates synthesis of nucleic acids and hormones besides nitrogen and carbohydrate metabolism, which have enhanced the yield due to greater availability of nutrients and photosynthates. Whereas, the activity of nitrate reductase in conversion of nitrate in to nitrite and formation of proteins in the plants, is the process that primary involved in yield improvement due to molybdenum application. These results are in agreement with those of Lourduraj *et al*. (1998), Kathmale *et al*. (2000) and Subramaniyan *et al*. (2001). In addition to this, the combined inoculation of *Rhizobium*, PSB and VAM resulted in cumulative effects such as supply of nutrients to crop besides their role in production of growth promoting substances like auxin, gibberellins and cytokinin (Thakare and Rasal, 2000 and Kachot *et al*., 2001). Therefore, the increased yield was due to the positive

TABLE II

Effect of zinc, boron and biofertilizers on yield and yield attributes of redgram in finger millet-redgram crop rotation

Treatment	Plant height (cm)	No. of branches / plant	No. of Pods / Plant	100 Seed weight (g)	Seed yield (qha^{-1})	Stalk yield ($t\ ha^{-1}$)	MUE ($kg\ kg^{-1}$)	B:C ratio
T1- Control (only NPK)	173.00	19.66	63.00	9.56	8.55	3.37	-	1.37
T2- NPK+ZnSO4 @ 12.5 kg ha-1(soil)	190.21	21.20	79.00	11.03	9.37	3.86	6.56	1.33
T3- NPK+Borax @ 10.0 kg ha-1(soil)	177.01	20.00	68.00	10.10	9.00	3.48	4.50	1.20
T4- NPK + Rhizobium	176.56	19.81	64.00	9.91	8.75	3.46	-	1.41
T5- NPK + PSB	180.23	19.93	69.00	10.05	8.81	3.52	-	1.42
T6- NPK + VAM	178.40	19.70	65.00	9.85	8.67	3.41	-	1.38
T7- NPK+ZnSO4 @ 12.5 kg ha-1+ Rhizobium	188.60	21.00	75.00	10.84	9.07	3.84	4.16	1.57
T8- NPK+ZnSO4 @ 12.5 kg ha-1+ PSB	193.21	21.62	82.00	11.32	10.70	3.98	17.20	1.68
T9- NPK+ZnSO4 @ 12.5 kg ha-1+ VAM	185.70	20.85	74.00	10.62	9.86	3.66	10.48	1.52
T10- NPK+Borax @ 10.0 kg ha-1+ Rhizobium	182.32	20.32	72.00	10.8	9.45	3.60	9.00	1.25
T11- NPK+Borax @ 10.0 kg ha-1+ PSB	183.60	20.64	74.00	10.55	9.55	3.63	10.00	1.26
T12- NPK+Borax @ 10.0 kg ha-1+ VAM	182.00	20.26	69.00	10.33	9.23	3.57	6.80	1.20
T13- NPK+ZnSO4 @ 12.5 kg ha-1+ Borax @10.0 kg/ha	195.24	21.95	83.00	11.46	10.80	4.06	10.00	1.42
T14- NPK+ZnSO4 @ 12.5 kg ha-1+ VAM + PSB + Rhizobium	198.32	23.45	85.00	11.68	11.00	4.22	19.60	1.68
T15- NPK+Borax @ 10.0 kg ha-1+ VAM + PSB + Rhizobium	190.20	21.72	80.00	11.36	10.40	3.97	19.00	1.39
T16- NPK+ZnSO4 @ 12.5 kg ha-1+ Borax @ 10.0 kg/ha + VAM + PSB + Rhizobium	200.30	23.68	87.00	11.90	11.36	4.29	12.49	1.44
S.Em±	2.03	0.66	2.05	0.41	0.45	0.15	-	-
CD @ 5 %	6.10	1.99	6.15	1.25	1.36	0.45	-	-

MUE- Micronutrient Use Efficiency (kg of additional produce to an additional micronutrient applied)

role of bio-inoculants in the presence of major and micronutrients. Hence, the supply of required nutrients through organic and inorganic sources and bio-inoculants facilitated balanced nutrition to the crop which resulted in enhanced yield.

Application of NPK + zinc and borax along with the beneficial microorganisms (VAM + PSB + *Rhizobium*) recorded significantly higher yield and yield parameters while higher B:C ratio and micro nutrient efficiency was noticed with application of NPK + zinc along with the beneficial microorganisms in both crops.

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