Research Journal of Agricultural Sciences
An International Journal

Res. Jr. of Agril. Sci. **12**(2): 689–692

P- ISSN: 0976-1675 | **E**- ISSN: 2249-4538

www.rjas.org

Research Paper

Effect of VAM, Sulphur and Boron on Growth and Yield of Ragi (*Eleusine coracana* L. *Gaertn.*)

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Received: 28 Feb 2021 | Revised accepted: 20 Apr 2021 | Published online: 22 Apr 2021

A B S T R A C T

The field experiment was conducted at Achalvadi village, Harur block of Dharmapuri district during October 2019 – February 2020 to study the effect of VAM, sulphur and boron on growth and yield of ragi. The experimental plots were laid out in randomized block design with eleven treatments and three replications. The treatments consisted of T_1 - RDF alone (60:30:30 Kg of NPK ha^{-1}) / control, T_2 - T_1 + Farm yard manure @ 12.5 t ha^{-1}, T_3 - T_1+ Vermicompost @ 3 t ha^{-1}, T_4 - T_2 + Seed treatment with *Azospirillum* @ 600 g ha^{-1}, T_5 - T_3 + Seed treatment with *Azospirillum* @ 600 g ha^{-1}, T_6 - T_4 + Inoculation of VAM @ 12 kg ha^{-1}, T_7 - T_5 + Inoculation of VAM @ 12 kg ha^{-1}, T_8 - T_6 + Sulphur @ 40 kg ha^{-1} through gypsum, T_9 - T_7 + Sulphur @ 40 kg ha^{-1} through gypsum, T_{10} - T_8 + Foliar spray of Borax 0.5% twice at 30 and 45 DAT and T_{11} - T_9 + Foliar spray of Borax 0.5% twice at 30 and 45 DAT. The application of RDF (60:30:30 kgs of NPK ha^{-1}) + Vermicompost @ 3 t ha^{-1} + Seed treatment with *Azospirillum* @ 600 g ha^{-1} + Inoculation of VAM @ 12 kg ha^{-1} + Sulphur @ 40 kg ha^{-1} through gypsum + Foliar spray of Borax 0.5% twice at 30 and 45 DAT (T_{11}) recorded the maximum values for growth attributes viz., plant height (93.63 cm), number of leaves plant^{-1} (34.9), LAI (4.54), DMP (5860.00 kg ha^{-1}) and brings earliness in days to 50% flowering (57 days), yield attributes viz., number of tillers m^{-2} (123.00), number of productive tillers m^{-2} (116.33), number of ear heads m^{-2} (116.33), number of grains ear head^{-1} (921.33) and test weight (3.07 g) and yield viz., grain (2963.60 kg ha^{-1}) and straw yield (5414.43 kg ha^{-1}) of ragi. The lowest values of the growth attributes, yield attributes and yield were recorded under the control treatment (T_1).

***Key words*:** *Eleusine coracana* L., VAM, Sulphur, Boron, Growth, Yield

Finger millet (*Eleusine coracana* L. *Gaertn.*) popularly known as Ragi and African millet ranks first in area and production among the small millets in world. Ragi accounts for about 85% of production among the various minor millets cultivated in India [1]. In India Ragi is cultivated in an area of 11.9 lakh hectares with the production of 19.8 lakh tonnes and productivity of 1662 kg ha^{-1} [2]. As the nutritional value of ragi is superior to all other cereals and millets, owing to the socio-economic factors of the poor people, they depend on the millets for their food and nutritional security. One of such a valuable livelihood supporting crop is finger millet. Being a member of C_4 group of plants, finger millet sequesters carbon [3] which makes more opportunity for the higher productivity which also acts as a "famine reserve" crop.

Finger millet is known as low fertilizer input crop [4]. Indian soils are generally low in nitrogen, medium in phosphorus and high in potassium. Application of various biofertilizers increase the available nutrient in the soil. The application of Vesicular Arbuscular Mycorrhizal fungi mobilizes the soil unavailable phosphorus and makes it easily available to plants [5]. Application of the secondary macronutrient sulphur produces the better rooting, greater number of leaves, higher LAI, thus contribute towards higher net photosynthesizing area facilitating higher amount of dry matter accumulation [6]. Boron being vital for cell division, hormonal growth, seed formation and translocation of sugar, it plays an important role in terms of quantity of flowers and weight of seeds [7]. Thus, the present investigation was carried out to study the effect of VAM, sulphur and boron on growth and yield of ragi with an objective to increase its productivity.

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MATERIALS AND METHODS

The field experiment was conducted in farmer's field at Achalvadi village, Harur block of Dharmapuri district during October 2019 – February 2020 to study the "Effect of VAM, Sulphur and Boron on growth and yield of ragi". The experimental field was located at 11°59'56'' N latitude, 78°29'15'' E longitude with an altitude of 392 m above mean sea level. The experimental plots were laid out in randomized block design with eleven treatments and three replications. The cultivar Paiyur 2 was chosen for the study. The

treatments included in the experiment were T_1 - RDF alone (60:30:30 Kg of NPK ha^{-1}) / control, T_2 - T_1 + Farm yard manure @ 12.5 t ha^{-1}, T_3 - T_1+ Vermicompost @ 3 t ha^{-1}, T_4 - T_2 + Seed treatment with *Azospirillum* @ 600 g ha^{-1}, T_5 - T_3 + Seed treatment with *Azospirillum* @ 600 g ha^{-1}, T_6 - T_4 + Inoculation of VAM @ 12 kg ha^{-1}, T_7 - T_5 + Inoculation of VAM @ 12 kg ha^{-1}, T_8 - T_6 + Sulphur @ 40 kg ha^{-1} through gypsum, T_9 - T_7 + Sulphur @ 40 kg ha^{-1} through gypsum, T_{10} - T_8 + Foliar spray of Borax 0.5% twice at 30 and 45 DAT and T_{11} - T_9 + Foliar spray of Borax 0.5% twice at 30 and 45 DAT. The texture of the experimental field soil was sandy loam which was low in available nitrogen, medium in available phosphorus and potassium and low in available sulphur.

RESULTS AND DISCUSSION

Growth attributes

Application of VAM, sulphur and boron had a remarkable effect on the growth attributes at all the stages of crop growth. Among the various treatments implemented in the study, application of RDF (60:30:30 kgs of NPK ha^{-1}) + Vermicompost @ 3 t ha^{-1} + Seed treatment with *Azospirillum* @ 600 g ha^{-1} + Inoculation of VAM @ 12 kg ha^{-1} + Sulphur @ 40 kg ha^{-1} through gypsum + Foliar spray of Borax 0.5% twice at 30 and 45 DAT (T_{11}) recorded the highest values for growth attributes viz., plant height (93.63 cm), number of leaves plant^{-1} (34.9), LAI (4.54), DMP (5860.00 kg ha^{-1}) and less number of days to 50% flowering (57 days) and it was statistically on par with RDF (60:30:30 kgs of NPK ha^{-1}) + Farm yard manure @ 12.5 t ha^{-1} + Seed treatment with *Azospirillum* @ 600 g ha^{-1} + Inoculation of VAM @ 12 kg ha^{-1} + Sulphur @ 40 kg ha^{-1} through gypsum + Foliar spray of Borax 0.5% twice at 30 and 45 DAT (T_{10}). Inoculation of *Azospirillum* during seed treatment and application of VAM before transplanting might have fixed the atmospheric N_2 and mobilized the soil phosphorus respectively and make them easily available to plants for their normal growth and development. The optimum application of sulphur in soil results in vigorous crop growth [8] thus producing greater number of leaves, higher LAI, contributing towards higher net photosynthesizing area facilitating higher amount of dry matter accumulation [9]. Boron plays an important role in translocation of sugars, cell wall synthesis and maintenance of membrane integrity, RNA, Indole Acetic Acid (IAA) and phenol metabolism [10-11]. The earliness of days to 50% flowering under the treatment T_{11} might be due to increased pollen grain formation and its germination [12]. The lowest values of the growth attributes were recorded under the control treatment (T_1). This might be due to the application of only the recommended dosage of fertilizers [13-15].

Table 1 Effect of VAM, sulphur and boron on growth attributes of ragi

Treatment	Plant height (cm) at harvest	No. of leaves plant^{-1} at harvest	LAI at flowering stage	DMP (kg ha^{-1}) at harvest	Days to 50% flowering
T_1	74.63	19.5	1.47	3547.66	63.0
T_2	76.83	21.5	1.82	4354.33	62.33
T_3	77.16	21.7	1.82	4367.66	62.66
T_4	80.23	23.4	2.18	4498.66	61.66
T_5	80.83	24.3	2.22	4653.66	61.00
T_6	84.03	26.8	2.87	4926.33	60.00
T_7	84.90	27.6	2.79	5066.00	59.66
T_8	88.46	31.7	3.52	5166.00	58.66
T_9	89.10	32.4	3.69	5358.00	58.66
T_{10}	93.00	34.3	4.29	5855.33	57.33
T_{11}	93.63	34.9	4.54	5860.00	57.00
SEd	0.48	0.77	0.15	86.75	0.57
CD (p=0.05)	1.01	1.61	0.32	180.96	1.20

Yield attributes

Application of VAM, sulphur and boron had a spectacular effect on the yield attributes of ragi. Among the various treatments executed in the study, application of RDF (60:30:30 kgs of NPK ha^{-1}) + Vermicompost @ 3 t ha^{-1} + Seed treatment with *Azospirillum* @ 600 g ha^{-1} + Inoculation of VAM @ 12 kg ha^{-1} + Sulphur @ 40 kg ha^{-1} through gypsum + Foliar spray of Borax 0.5% twice at 30 and 45 DAT (T_{11}) recorded the superior values for yield attributes viz., number of tillers m^{-2} (123.00), number of productive tillers m^{-2} (116.33), number of ear heads m^{-2} (116.33), number of grains ear head^{-1} (921.33) and test weight (3.07) of ragi. It was followed by and statistically on par with RDF (60:30:30 kgs of NPK ha^{-1}) + Farm yard manure @ 12.5 t ha^{-1} + Seed treatment with *Azospirillum* @ 600 g ha^{-1} + Inoculation of VAM @ 12 kg ha^{-1} + Sulphur @ 40 kg ha^{-1} through gypsum + Foliar spray of Borax 0.5% twice at 30 and 45 DAT (T_{10}). This might be due to the combined application of various sources of nutrients that have provided the essential nutrients for the higher growth and development of crop. The increase in growth parameters of crop led to the increase in yield attributes which had further led to the higher yield of crop.

Sulphur plays an important role in carbohydrate metabolism due to its role in energy transformation and activation of carbon fixing enzymes. These favorable effects led to increased transformation of photosynthates towards sink and resulted in the formation of relatively bold grain and increased the yield [16]. Boron being vital for cell division, hormonal growth, seed formation and translocation of sugar, it plays an important role in terms of quantity of flowers and weight of seeds [17]. Foliar application of boron increased the grain yield of rice owing to substantial decrease in panicle sterility and increase in grain size [18]. The more number of grains ear head^{-1} and higher grain weight by B application might be due to improved panicle fertility of the crop [19]. The inferior values of yield attributes and yield were observed under the control (T_1) [20-21].

Table 2 Effect of VAM, sulphur and boron on yield attributes and yield of ragi

Treatment	No. of tillers m^{-2} at harvest stage	No. of productive tillers m^{-2}	Ear heads m^{-2}	Grains ear $head^{-1}$	Test weight (g)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
T_1	83.33	73.33	73.33	780.66	2.82	1301.51	3109.98
T_2	97.33	90.33	90.33	810.00	2.85	2009.19	3910.15
T_3	98.00	91.00	91.00	816.00	2.85	2044.31	3947.19
T_4	99.67	94.00	94.00	855.00	2.88	2049.70	4210.87
T_5	100.00	94.33	94.33	863.33	2.90	2075.21	4188.94
T_6	109.66	103.00	103.00	879.66	2.94	2245.95	4679.31
T_7	112.66	104.33	104.33	884.33	2.92	2306.23	4724.94
T_8	117.00	110.66	110.66	900.00	2.95	2517.82	4957.39
T_9	118.33	112.00	112.00	904.66	2.96	2540.10	4902.34
T_{10}	120.33	114.00	114.00	918.66	3.00	2873.77	5324.41
T_{11}	123.00	116.33	116.33	921.33	3.07	2963.60	5414.43
SEd	3.35	2.14	2.14	13.10	0.036	52.70	67.10
CD (p=0.05)	7.00	4.479	4.47	27.33	0.06	109.93	139.98

Yield

Application of VAM, sulphur and boron superiorly influenced the yield attributes of ragi. Among the various treatments imposed in the study, application of RDF (60:30:30 kgs of NPK ha^{-1}) + Vermicompost @ 3 t ha^{-1} + Seed treatment with *Azospirillum* @ 600 g ha^{-1} + Inoculation of VAM @ 12 kg ha^{-1} + Sulphur @ 40 kg ha^{-1} through gypsum + Foliar spray of Borax 0.5% twice at 30 and 45 DAT (T_{11}) produced the highest grain and straw yield of 2963.60 and 5414.43 kg ha^{-1}) and it was followed by RDF (60:30:30 kgs of NPK ha^{-1}) + Farm yard manure @ 12.5 t ha^{-1} + Seed treatment with *Azospirillum* @ 600 g ha^{-1} + Inoculation of VAM @ 12 kg ha^{-1} + Sulphur @ 40 kg ha^{-1} through gypsum + Foliar spray of Borax 0.5% twice at 30 and 45 DAT (T_{10}) but, both the treatments are on par with each other. The application of VAM, sulphur and boron along with the various organic and inorganic sources of nutrients produced the higher yield attributes of ragi. Thus, the increase in yield attributes have led to the increase in yield of crop. Compared to the control treatment (T_1) the grain and straw yield in the best treatment (T_{11}) were increased by 56.08 and 47.34 per cent. The highest yield from the treatment T_{11} might be due to the combined application of VAM, sulphur and boron along with the various other sources that have provided the essential nutrients for the higher growth and development of crop. The favorable effects of VAM, sulphur and boron have led to increase in transformation of photosynthates towards sink thereby resulting in formation of bold grain which increase the yield of crop [22]. The lowest grain and straw yield were recorded under the control treatment (T_1) [23-24].

CONCLUSION

Among the various treatments involved in the study, application of RDF (60:30:30 Kgs of NPK ha^{-1} + vermicompost @ 3 t ha^{-1} + seed treatment with *Azospirillum* @ 600 g ha^{-1} + inoculation of VAM @ 12 kg ha^{-1} + sulphur @ 40 kg ha^{-1} through gypsum + foliar spray of borax @ 0.5% twice at 30 and 45 DAT (T_{11}) has recorded the higher values for growth attributes, yield attributes and yield of ragi. Considering the light of above said facts, it can be concluded that application of RDF (60:30:30 kgs of NPK ha^{-1} + vermicompost @ 3 t ha^{-1} + seed treatment with *Azospirillum* @ 600 g ha^{-1} + inoculation of VAM @ 12 kg ha^{-1} + sulphur @ 40 kg ha^{-1} through gypsum + foliar spray of borax @ 0.5% twice at 30 and 45 DAT is agronomically sound and economically viable technology for enhancing the productivity and profitability of transplanted ragi.

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