



Effect of vam, sulphur and boron on chlorophyll content, root characters, yield and economics of ragi

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Abstract

The field investigation was carried out during October 2019 – February 2020 at Achalvadi village, Harur block in Dharmapuri district to study the effect of VAM, sulphur and boron on chlorophyll content, root characters, yield and economics of ragi. The present investigation consisted of eleven treatments and three replications and the experimental plots were laid out in randomized block design. The treatments of the investigation are T₁ - RDF alone (60:30:30 Kg of NPK ha⁻¹) / control, T₂ - T₁ + Farm yard manure @ 12.5 t ha⁻¹, T₃ - T₁ + Vermicompost @ 3 t ha⁻¹, T₄ - T₂ + Seed treatment with *Azospirillum* @ 600 g ha⁻¹, T₅ - T₃ + Seed treatment with *Azospirillum* @ 600 g ha⁻¹, T₆ - T₄ + Inoculation of VAM @ 12 kg ha⁻¹, T₇ - T₅ + Inoculation of VAM @ 12 kg ha⁻¹, T₈ - T₆ + Sulphur @ 40 kg ha⁻¹ through gypsum, T₉ - T₇ + Sulphur @ 40 kg ha⁻¹ through gypsum, T₁₀ - T₈ + Foliar spray of Borax 0.5% twice at 30 DAT and 45 DAT and T₁₁ - T₉ + Foliar spray of Borax 0.5% twice at 30 and 45 DAT. The results of the present investigation revealed 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 (T₁₁) predominantly influenced the chlorophyll content, root characters, grain and straw yield and economics of ragi. This treatment has produced the higher chlorophyll content index (6.96 and 8.98 at 30 and 60 DAT respectively), root characters viz., root length (15.90 cm), root volume (36.33 cc), grain and straw yield (2963.60 and 5414.43 kg ha⁻¹ respectively). The same treatment has recorded the highest mycorrhizal root colonization percentage (39.66) and it was on par with the other mycorrhizal inoculated treatments. With regard to the economics of ragi, application of RDF (60:30:30 kgs of NPK ha⁻¹) + Farm yard manure @ 12 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 (T₁₀) has recorded the higher values of net income (Rs. 51810.54) and return rupee⁻¹ investment (2.13) of ragi.

Keywords: Ragi, VAM, sulphur, boron, chlorophyll content index and mycorrhizal root colonization

Introduction

Ragi (*Eleusine coracana* L. Gaertn) is the staple food crop, grown in many hilly regions of Indian sub-continent. Ragi accounts for about 85% of production among the various minor millets cultivated in India (Sakamma *et al.*, 2018) [14]. In India it is widely cultivated in the states of Karnataka, Tamil Nadu, Assam, Andhra Pradesh, Orissa and Uttar Pradesh. Ragi covers 50% area and contributes 2/3rd production in global minor millets cultivation and production respectively. It ranks first in productivity among small millets. As ragi is nutritionally superior to all other cereals in terms of protein with essential amino acids, fat, minerals, ash, calcium, iron, phosphorus, vitamin A and B (Gopalan *et al.*, 2004) [5] it has a pride of place among the various millets. Owing to the socio economic factors of the poor people, they depend on the millets for their food and nutritional security. Compared to other crops, Ragi can tolerate the higher temperature and can grow in the soils with higher salinity. Indian soils are generally low in nitrogen, medium in phosphorus and high in potassium. The application of Vesicular Arbuscular Mycorrhizal fungi mobilizes the soil unavailable phosphorus and makes it easily available to plants. As sulphur is the main constituent of various enzymes it increases the enzymatic activity of plants which leads to the higher growth of plants and dry matter production (Vishwanath *et al.*, 2006) [19]. Boron a

non-metal micronutrient, necessary for anthesis, germination of pollen grains and its viability for pollination and to translocate the sugars from source to sink (Bolanos *et al.*, 2004) [1]. Thus the present investigation was conducted to study the effect of VAM, sulphur and boron on chlorophyll content, root characters, yield and economics of ragi.

Materials and Methods

The field investigation was conducted during October 2019 -February 2020 at Achalvadi village, Harur block in Dharmapuri district. The experimental field is located at 11°59'56'' N latitude, 78° 29' 15'' E longitude with altitude of 392 m above mean sea level in the North Western Agro-climatic zone of Tamil Nadu. The present investigation consisted of eleven treatments and it was replicated thrice. The experimental plots were laid out in randomized block design and the treatments were allotted randomly in each replication. The treatments consisted of T₁ - RDF alone (60:30:30 Kg of NPK ha⁻¹) / control, T₂ - T₁ + Farm yard manure @ 12.5 t ha⁻¹, T₃ - T₁ + Vermicompost @ 3 t ha⁻¹, T₄ - T₂ + Seed treatment with *Azospirillum* @ 600 g ha⁻¹, T₅ - T₃ + Seed treatment with *Azospirillum* @ 600 g ha⁻¹, T₆ - T₄ + Inoculation of VAM @ 12 kg ha⁻¹, T₇ - T₅ + Inoculation of VAM @ 12 kg ha⁻¹, T₈ - T₆ + Sulphur @ 40 kg ha⁻¹ through gypsum, T₉ - T₇ + Sulphur @ 40 kg ha⁻¹ through gypsum, T₁₀

- T₈ + Foliar spray of Borax 0.5% twice at 30 and 45 DAT and T₁₁ - T₉ + Foliar spray of Borax 0.5% twice at 30 and 45 DAT. The cultivar Paiyur 2 was chosen for the study. The chlorophyll content was measured with Chlorophyll Content Index (model CCM-200) and expressed as CCI. The root volume was measured with water displacement method as suggested by Karthikeyan (1999) [7] and mycorrhizal root colonization percentage was observed on 50 DAT as suggested by Phillips and Hayman (1970) [10].

Results and Discussion

Chlorophyll content (Table 1)

Application of VAM, sulphur and boron had a significant effect on the chlorophyll content index of the crop. Among the various treatments imposed, 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 (T₁₁) recorded the highest chlorophyll content index of 6.98 and 9.98 on 30 and 60 DAT respectively. It was followed by application of 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 (T₁₀) with the values of 6.98 and 9.97 at 30 and 60 DAT respectively, but it statistically on par with T₁₁. As sulphur is the constituent of succinyl CO A, a precursor of biosynthesis of chlorophyll (Jamal *et al.*, 2010) higher chlorophyll content in the leaves were observed due to sulphur application. The inoculation of mycorrhiza (Tyagi *et al.*, 2017) [18] and foliar application of boron (Duying qiong *et al.*, 2002) [4] significantly increased the chlorophyll content. With regard to the organic sources of nutrients, vermicompost consists of the higher nutrients content compared to the farm yard manure. Thus the application of vermicompost also have increased the chlorophyll content. Hence, the combined application of VAM, sulphur and boron along with the various organic and inorganic fertilizers increased the chlorophyll content of the crop. The lowest chlorophyll content index *viz.*, 4.20 and 6.58 at 30 and 60 DAT were observed under control (T₁).

Root characters (Table 1)

Application of VAM, sulphur and boron had a spectacular effect on the root length, root volume and mycorrhizal root colonization percentage of ragi. Among the various treatments tried, 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 (T₁₁) produced the lengthiest root (15.90 cm) and root volume (36.33 cc) of ragi. It was followed by 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 (T₁₀) and are on par with each other. The application of vermicompost might have provided the nutrients required for the growth and development of roots. With regard to mycorrhizal population, the highest mycorrhizal root colonization percentage (39.66) of ragi was observed under the treatment (T₁₁) and it was on par with other mycorrhizal inoculated

treatments. Root colonization by VAM can increase root length and surface area, allowing a large volume of soil to be explored to roots, thereby enhancing water and nutrient uptake (Marulanda *et al.*, 2006) [8]. As phosphorus is the essential primary nutrient that promote the root growth, mobilization of phosphorus through mycorrhiza might have helped in the root growth and development. Bama and Ramakrishnan (2010) [2] also indicated that higher root biomass and root length were observed under the combined inoculation of *Azospirillum* and mycorrhiza, which may be due to the provision of nitrogen and growth promoting substances (IAA and GA) by *Azospirillum* and mobilization of phosphorus by mycorrhiza. The minimum root colonization percentage of 10.67 was observed under control, which may be due to the native soil mycorrhiza. Similar findings were reported earlier by (Bhagyaraj, 2014) [3] and Saharan *et al.* (2018) [15].

Yield (Table 1)

The data regarding the grain and straw yield indicated that application of VAM, sulphur and boron achieved a markedly significant influence on it. Among the various treatments tried, maximum grain and straw yield of 2963.60 and 5414.43 kg ha⁻¹ were achieved through 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 (T₁₁). It was closely followed by application of 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 (T₁₀), but both are on par with each other. The lowest grain yield of 1301.51 kg ha⁻¹ was obtained under control (T₁). The higher yield attributes and yield from the treatment T₁₁ might be due to the combined application of various sources of nutrients such as *Azospirillum*, vermicompost, VAM, RDF, gypsum and borax that have provided the essential nutrients for the higher growth and development of crop. The soil application of VAM have mobilized the soil unavailable phosphorus and make it available for the plants which is necessary for the development of grains. As sulphur plays an important role in carbohydrate metabolism, it plays a major role in energy transformation and activation of carbon fixing enzymes. These favorable effects have led to increased transformation of photosynthates towards sink and resulted in the formation of relatively bold grain and increased the yield (Rahman, 2007) [11]. Boron application significantly increased the chlorophyll content and dry matter accumulation of plants which led to advance flowering and promoted the transport of photosynthates from vegetative organs to the reproductive organs, thus resulting in significant improvement of yield (Duying qiong *et al.*, 2002) [4]. Rani and Latha (2017) [12] reported that addition of boron alone increased the yield by 45% in rice 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. Similar findings were reported earlier by Shankar *et al.* (2018) and Prashantha *et al.* (2019) [9].

Economics (Table 2)

Among the various treatments imposed in study, application of 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 (T₁₀) recorded the highest net return and return per rupee invested of Rs. 51810.54 and 2.13 respectively. This was followed by application of 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 (T₁₁). Though the highest gross return was recorded in T₁₁ due to the higher grain yield of crop, highest net return and return

rupee⁻¹ invested were registered under T₁₀. This was due to the higher cost of vermicompost which has resulted in the higher cost of cultivation.

The lowest gross income, net income and return per rupee invested of Rs. 44758.30, Rs. 15756.2 and 1.54 were registered under control (T₁). The reasons attributed to lowest economic values under the treatment T₁ might be due to poor grain yield recorded under the control treatment. Similar findings were reported earlier by Roy *et al.* (2018) and Thimmegowda *et al.* (2018) [16, 17].

Table 1: Effect of VAM, sulphur and boron on chlorophyll content, root characters and yield of ragi

Treatment	Chlorophyll Content Index (CCI)		Root length (cm)	Root volume (cc)	Mycorrhizal root colonization percentage	Grain yield (Kg ha ⁻¹)	Straw yield (Kg ha ⁻¹)
	30 DAT	60 DAT					
T ₁	4.20	6.58	9.96	26.36	10.67	1301.51	3109.98
T ₂	4.65	6.67	11.43	27.76	12.66	2009.19	3910.15
T ₃	4.76	6.74	11.44	27.96	12.00	2044.31	3947.19
T ₄	4.93	6.77	11.44	29.93	13.00	2049.70	4210.87
T ₅	4.89	7.00	11.93	30.10	13.33	2075.21	4188.94
T ₆	5.54	7.52	13.06	32.70	37.67	2245.95	4679.31
T ₇	5.64	7.79	13.23	32.96	38.66	2306.23	4724.94
T ₈	6.86	8.88	15.23	35.76	39.33	2517.82	4957.39
T ₉	6.75	8.88	15.36	35.96	38.00	2540.10	4902.34
T ₁₀	6.98	8.97	15.60	36.13	38.33	2873.77	5324.41
T ₁₁	6.96	8.98	15.90	36.33	39.66	2963.60	5414.43
SEd	0.31	0.32	0.74	0.37	2.08	52.70	67.10
CD (p=0.05)	0.64	0.67	1.56	0.78	4.35	109.93	139.98

Table 2: Effect of VAM, sulphur and boron on economics of ragi

Treatment	Gross income (Rs. ha ⁻¹)	Net income (Rs. ha ⁻¹)	Return rupee ⁻¹ invested
T ₁	44758.30	15756.2	1.54
T ₂	68204.23	27951.72	1.69
T ₃	69365.11	24612.60	1.55
T ₄	69801.27	29518.76	1.73
T ₅	70595.76	25813.25	1.58
T ₆	76549.82	35667.31	1.87
T ₇	78524.41	33141.90	1.73
T ₈	85527.60	41453.12	1.94
T ₉	86341.44	37673.54	1.77
T ₁₀	97285.05	51810.54	2.13
T ₁₁	100249.63	48514.87	2.00

Conclusion

Application of VAM, sulphur and boron a greatly influenced the chlorophyll content, root characters, yield and economics of ragi. Though the highest chlorophyll content, root characters and yield were recorded under 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 (T₁₁), with regard to the economics of the crop it can be concluded that application of 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 (T₁₀) is an efficient treatment for obtaining the higher yield and monetary returns.

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