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Effect of Arbuscular Mycorrhizal Fungi and Different Combination of Foliar Application of Nutrients on Nutrient Uptake and Yield of Aerobic Rice

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ABSTRACT

Background: In Aerobic rice cultivation, crop would faces water and nutrient deficiency; it would be a difficult for roots to reach in those situations. During that stress situation Arbuscular Mycorrhizal fungi helps to observe water along with essential nutrients results out of efficiently increases the nutrient uptake.

Methods: The field experiment was conducted during 2022 at wetland farms, Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore. The experiment consisted of thirteen treatments, which includes different recommended doses of VAM 50, 62.5 and 75 kg ha^{-1} together with different combinations of foliar application of 0.5% of urea, 0.5% of $ZnSO_4$ and 1% of $FeSO_4$.

Result: The experiment results concluded that the combined application of 150 % of recommended dose of VAM and foliar application of 0.5% urea + 0.5% of $ZnSO_4$ + 1% of $FeSO_4$ at 25 and 45 DAS, significantly increased the nutrient uptake, by improving the morphology of shoot and root biomass under upland condition.

Key words: Aerobic rice, Foliar nutrition, Nutrient uptake, VAM fungi.

INTRODUCTION

Rice (*Oryza sativa* L.) is main cereal grain crops. It feeds up more than half of the global population (Carrijo *et al*., 2017). Due to an over explosion in industrial and economic growth and rapid urbanization causes to meet the demand for food. It will be a great challenge in future food security (Fahad *et al*., 2017; Fukase and Martin, 2020). Since, it has been pointed out that global rice production want to be increase by approximately 20% by the year of 2030 and 30% before 2050 (Peng *et al*., 2009 and Shew *et al*., 2019). Currently, increases in labour rates, fertilizer costs and water requirements in conventional rice production methods result in lower profits (Nawaz *et al.,* 2022), which has a direct impact on the farmer life. So, to come over that, farmers would go for aerobic rice cultivation. Aerobic rice is a novel cultivating technology that will be used as an alternative to flooded agriculture. The nutrition factor is the critical one in the yield realization of the aerobic rice ecosystem. The major consequence of inadequate nutrients is reduced leaf area, thereby limiting the following factors such as light interception, photosynthesis, biomass growth, grain yield and water productivity. Nutrient use efficiency was very poor in aerobic rice cultivation method, the presence of AM (Vesicular Arbuscular Mycorrhiza) fungi plays an important role to mobilize the nutrients which increasing their availability and ensuring those nutrients to crop during all growth stages. AM fungi significantly increased the nutrient concentration in shoot and root, grain and straw yield of rice under aerobic condition (Li *et al*., 2011). Micronutrients such as iron and zinc deficiency is major nutritional deficiency have been found in aerobic rice cultivation. Therefore present study formulated to mitigate the nutrient deficiency at early stage of aerobic rice. AM fungi and foliar application of nutrients is an option to correct such nutritional deficiencies of iron and zinc in aerobic rice.

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MATERIALS AND METHODS

Experimental site

During the month of January 2022, the research trial was conducted in wetland Farms situated at Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore. The experimental site is geographically located at 11°N latitude and 77°E longitude at the height of 426.72 m above mean sea level. The soil type of the experimental site was clay loam in texture with– pH range of 7.84 and EC was 0.51 dsm^{-1}. The initial soil fertility status indicated low available $KMnO_4$ - N (225 kg ha^{-1}) (Asija and Subbiah, 1956), medium in available Olsen P (20.5 kg ha^{-1}) (Olsen, 1954) and high in available NH_4 O Ac - K (740 kg ha^{-1}) (Stanford *et al.,* 1949).

Experimental design and treatment

Rice variety CO 53 (Duration 115 to 120 days, average yield - 3.7 to 3.8 t ha^{-1}, white short bold rice) was used in this experiment. The research trial field was designed with 13 treatments that were replicated three times in a randomised block design. An individual plot sizes of 1 m × 1 m. The treatments include foliar applications of urea, iron ($FeSO_4$) and zinc ($ZnSO_4$), as well as soil applications of AM fungus (Table 1).

Crop management

Paddy seeds were directly sown in dry soil during *Navarai* season (Dec-Jan) with the spacing of 20 × 10 cm. Recommended dose of fertilizers (150: 50: 50 kg ha^{-1} of N, P and K) was given as a split application. N was given as four splits 20% at 15 DAS, 30% at tillering and panicle initiation stage and 20% at flowering. Full dose of P was given as basal application and K was given as 50 % at basal and 50% at panicle initiation stages. Foliar application of Urea, Iron (Fe) and Zinc (Zn) were given on 25th and 45th DAS. Application of 100%, 125%, 150% recommended dose of VAM spores (50, 62.5, 75 kg ha^{-1}) along with farmyard manure was basally applied on before sowing. Crop was irrigated twice in a week with depth of 3 - 4 cm. Weed, pest and disease management was done as per the TNAU CPG 2020.

Nutrient uptake analysis

Total nitrogen was estimated by Kjeldahl distillation (Jackson, 1973), total phosphorous by Spectrophotometer (Jackson, 1973), total potassium by Flame photometry (Jackson, 1973) and micronutrients (Lindsay and Norvell, 1978) by Inductively Coupled Plasma Optical Emission spectroscopy (ICP - OES).

Statistical analysis

Data were analysed for randomized block design by using SPSS 16.0. software to find the significance difference at 5 % level was used to test for significant differences among 13 treatment means. The relationship between total VAM colonization percentage with nutrient uptake of root and shoot of rice was assessed by Pearson correlation analysis using R software version 4.2.0 (RStudio 2022.02.3+492).

RESULTS AND DISCUSSION

Nutrient uptake in shoot biomass

Macro and micronutrients uptake was significantly affected by soil application of VAM and foliar application of urea, zinc and iron. At 30 DAS application of 150% VAM + foliar application of 0.5% urea + 0.5% $ZnSO_4$ + 1% $FeSO_4$ at 25 and 45 DAS (T_{13}) exhibited a positive impact on nutrients uptake of N (27.2 kg ha^{-1}), P (6.6 kg ha^{-1}), K (39.7 kg ha^{-1}), Fe (648 g ha^{-1}) and Zn (106 g ha^{-1}) of shoot biomass respectively (Table 2). Lowest nutrient uptake of macro and micronutrients were recorded in control. At 50 DAS the plot fertilized with 150% soil application of VAM combined with foliar application of 0.5% urea + 0.5% $ZnSO_4$ + 1% $FeSO_4$ at 25 and 45 DAS (T_{13}) increased the nutrients uptake of N (34.3 kg ha^{-1}), P (20.9 kg ha^{-1}), K (42.9 kg ha^{-1}), Fe (325 g ha^{-1}) and Zn (54 g ha^{-1}) of shoot biomass respectively. VAM fungi develop and spread through their external hyphae and cover the 8 cm area around the rhizosphere of the plant root system. Fungi expand the nutrient absorption range and surface area, which increase the nutrient uptake by plants. Primary nutrients (N, P and K), secondary nutrients (Ca and Mg) and micronutrients (Cu, Fe, Zn and Mn) can be more efficiently absorbed by plant root hairs when VAM fungi are present. These results line up with Abd-Alla *et al.* (2014). With respect to foliar application of 0.5% urea, 1% $FeSO_4$ and 0.5% $ZnSO_4$ at different growth stage in aerobic rice crop resulted in maximum iron and zinc uptake in shoot biomass. Soil application of $FeSO_4$ and $ZnSO_4$ results in adsorption to soil colloids and precipitation thereby reduced the availability of Zn and Fe (Recena *et al.*, 2021). Foliar application of nutrients alternate method of application, increased the Zn and Fe content and uptake (Phuphong *et al.*, 2018).

Nutrient uptake in root biomass

At 30 and 50 DAS application of 150% VAM + foliar application of 0.5% urea + 0.5% $ZnSO_4$ + 1% $FeSO_4$ at 25 and 45 DAS (T_{13}) exhibited a positive impact on nutrients uptake of N (9.6 and 15.7 kg ha^{-1}), P (4.0 and 12.3 kg ha^{-1})

Table 1: Treatment details.

Treatments	
T_1 -	Control
T_2 -	Recommended dose of VAM*
T_3 -	125% recommended dose of VAM
T_4 -	150% recommended dose of VAM
T_5 -	T_2 + foliar application of 0.5% urea at 25 and 45 DAS
T_6 -	T_3 + foliar application of 0.5% urea at 25 and 45 DAS
T_7 -	T_4 + foliar application of 0.5% urea at 25 and 45 DAS
T_8 -	T_5 + foliar application of 0.5% $ZnSO_4$ at 25 and 45 DAS
T_9 -	T_6 + foliar application 0.5% $ZnSO_4$ at 25 and 45 DAS
T_{10} -	T_7 + foliar application of 0.5% $ZnSO_4$ at 25 and 45 DAS
T_{11} -	T_8 + foliar application of 1% $FeSO_4$ at 25 and 45 DAS
T_{12} -	T_9 + foliar application of 1% $FeSO_4$ at 25 and 45 DAS
T_{13} -	T_{10} + foliar application of 1% $FeSO_4$ at 25 and 45 DAS

and K (9.9 and 15.0 kg ha^{-1}) of root biomass respectively (Table 3). Applying macro and micronutrients maximises the crop growth and output every time. When nutrients were abundant in the soil, plants were better able to absorb them, which had a major favourable impact on crop development and output. These findings match with results of (Bernardo *et al*., 2017). According to the current study, applying foliar nutrients and VAM fungus to the soil together boosted the rice crop's ability to absorb nutrients. Due to their symbiotic connection, VAM fungi aid in the greatest availability of nutrients by assisting plant roots in absorbing fertiliser. These results were consistent with those of Maiti *et al*. (2015) and Narwal *et al*. (2018). Saboor *et al*. (2021) and Okonji *et al*. (2018) stated that, soil having low pH level, Fe and Al activity, VAM fungi application significantly limits the nutrients absorption soil colloids. Prolonged application of VAM fungi ultimately improves the soil fertility status.

Yield traits

The yield traits *viz.,* number of filled grains $panicle^{-1}$ (164), grain yield (3702 kg ha^{-1}), straw yield (4608 kg ha^{-1}) and Harvest index were influenced by different doses of soil application of VAM coupled with foliar application of Urea, Iron (Fe) and Zinc (Zn) (Table 4). The yield traits increased with 150% of recommended dose of VAM + foliar application of 0.5% urea + 0.5% $ZnSO_4$ + 1% $FeSO_4$ at 25 and 45 DAS

Table 2: Effect of different dose of soil application of VAM and foliar application of nutrients on macro (kg ha^{-1}) and micro nutrients (g ha^{-1}) uptake in shoot biomass.

Treatments	30 DAS					50 DAS				
	N	P	K	Fe	Zn	N	P	K	Fe	Zn
T_1	6.9	0.5	10.8	131	28	8.9	1.6	13.4	189	39
T_2	8.5	0.8	12.5	148	36	11.4	2.3	16.7	219	45
T_3	10.9	0.9	14.6	162	43	13.7	3.0	18.7	274	51
T_4	12.0	1.4	16.9	178	49	15.4	4.3	21.4	313	59
T_5	13.8	1.7	18.6	193	56	18.9	5.7	23.9	361	66
T_6	15.2	1.7	21.0	213	61	20.3	7.5	24.7	398	69
T_7	17.1	2.1	23.5	235	67	22.7	8.9	26.5	448	73
T_8	19.3	2.9	26.7	243	71	23.1	10.1	28.1	469	79
T_9	21.7	3.8	29.3	259	76	25.8	12.9	31.5	498	83
T_{10}	22.5	4.0	32.4	267	79	27.3	14.7	34.8	538	89
T_{11}	23.9	4.8	34.2	281	84	28.8	16.5	37.3	569	95
T_{12}	25.4	5.3	36.7	296	88	31.4	19.0	39.9	603	99
T_{13}	27.2	6.6	39.7	325	94	34.3	20.9	42.9	648	106
SEd	0.2	0.1	0.5	5.2	1.2	0.5	0.1	0.6	7.4	1.5
CD	0.5	0.2	1.1	10.8	2.5	1.2	0.3	1.3	15.4	3.1

Table 3: Effect of different dose of soil application of VAM and foliar application of nutrients on macro nutrients uptake in root biomass (kg ha^{-1}).

Treatments	30 DAS			50 DAS		
	N	P	K	N	P	K
T_1	1.1	0.3	0.9	2.9	0.7	1.9
T_2	1.5	0.5	1.2	3.6	0.9	2.8
T_3	2.5	0.7	1.3	4.5	1.2	3.2
T_4	2.9	0.7	1.5	5.2	2.3	5.0
T_5	3.1	0.9	1.7	5.9	2.9	6.4
T_6	3.3	1.0	1.8	6.4	3.5	7.7
T_7	3.9	1.1	2.5	7.8	4.5	8.3
T_8	4.9	2.5	3.8	9.2	6.1	9.4
T_9	5.0	2.8	5.4	9.9	6.9	10.5
T_{10}	5.3	2.8	6.8	10.6	8.8	11.2
T_{11}	6.7	3.0	8.1	12.4	9.1	12.8
T_{12}	8.2	3.4	9.0	14.2	10.5	13.6
T_{13}	9.6	4.0	9.9	15.7	12.3	15.0
SEd	0.1	0.1	0.1	0.2	0.1	0.2
CD	0.2	0.1	0.2	0.4	0.2	0.4

Table 4: Effect of different dose of soil application of VAM and foliar application of nutrients on yield attributes and yield of aerobic rice.

Treatments	Number of filled grains panicle^{-1}	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index
T_1	70	1589	2454	0.39
T_2	86	1899	3004	0.39
T_3	93	1989	3156	0.39
T_4	102	2174	3267	0.40
T_5	110	2398	3591	0.40
T_6	113	2536	3656	0.41
T_7	120	2738	3735	0.42
T_8	124	2995	4067	0.42
T_9	129	3267	4279	0.43
T_{10}	135	3398	4489	0.43
T_{11}	142	3437	4500	0.43
T_{12}	153	3494	4589	0.43
T_{13}	164	3702	4608	0.45
SEd	3.0	61	79	0.01
CD	5.0	126	163	0.02

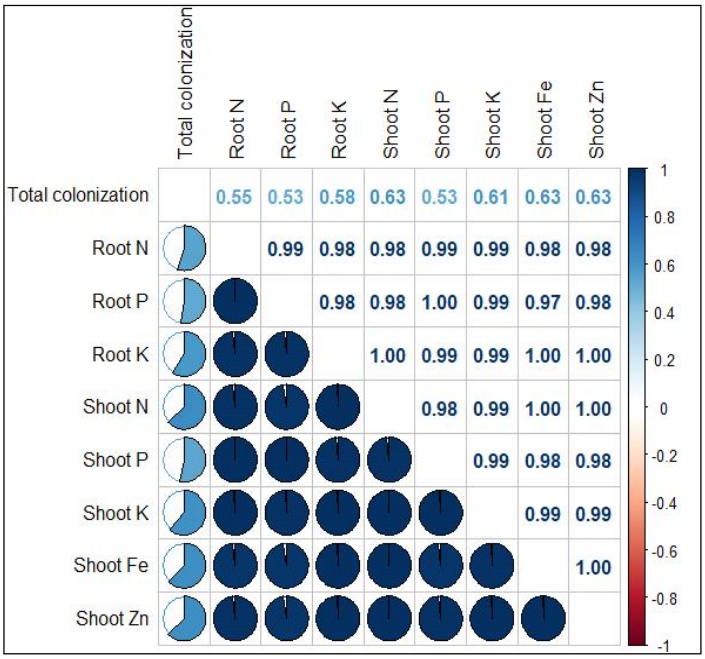

Fig 1: Correlation between total VAM colonization percentage and nutrient uptake of aerobic rice.

(T_{13}). However, straw yield and harvest index was on pair with T_{12}. The presence of VAM fungi and foliar feeding of nutrient alter nutrient availability and absorption of nutrients at all stages of the crop, resulting higher yield traits under aerobic condition. These results are in confirmation with the results of Khan *et al.* (2022); Aziez *et al.* (2022). The inoculation VAM fungi can assist the host plant in absorbing nutrients required for photosynthesis and boost the yield (Bahadur *et al*., 2019).

Correlation analysis

Correlation analysis was carried out for total VAM colonization percentage and nutrient uptake of the aerobic rice. Results showed that shoot uptake of nitrogen (0.63), phosphorous (0.53), potassium (0.61), iron (0.63) and zinc (0.63) of aerobic rice observed were positively correlated with total VAM colonization percentage. Similarly root uptake of nitrogen (0.55), phosphorous (0.53) and potassium (0.58) of aerobic recorded positive correlation with total VAM colonization percentage (Fig 1). Comparatively shoot uptake was highly positive correlation than root uptake of aerobic rice.

CONCLUSION

Based on the discussion, it can be concluded that application of 150% of the recommended dose of VAM

(75 kg ha^{-1}) along with foliar spray of 0.5% urea + 0.5% $ZnSO_4$ + 1% $FeSO_4$ at 25 and 45 greatly enhanced nutrient absorption and yield and yield traits under aerobic circumstances.

Conflict of interest

The authors declare that there is no conflict of interest.

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