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Influence of rice-legumes intercropping on native vesicular-arbuscular mycorrhizal association in rice

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Rice is one of the major food grain crops of the rainfed upland farmers, practicing mostly subsistence farming. Drought and consequent poor nutrients uptake are the major constraints for low rice productivity in this fragile ecosystem. The symbiotic association of Vesicular-arbuscular mycorrhiza (VAM) is known to facilitate water and nutrients uptake in plants. Water and nutrient uptake in mycorrhizal plants are improved predominantly by increasing effective root surface area of plants through extramatrical mycelial network of VAM fungi leading to greater exploration of soil beyond root hairs (1). The soils of the target ecosystem were found to harbor VAM fungi (*Glomus* being predominant genus) and upland rice was observed to be colonized by native VAMF (6). VAM dependency of upland rice for phosphorus acquisition had also been reported (7). Thus, enhancing native VAM association in upland rice could partially mitigate drought and improve nutrients acquisition. The preliminary study revealed that, colonization of native VAMF in upland rice was enhanced when intercropped with legumes (6). Having this information, systematic efforts were made in the present study to investigate the possible role of rice – legumes intercropping systems to enhance native VAM association in upland rice and also to evaluate different rice – legumes intercropping systems for identifying suitable systems that would induce higher VAM association in upland rice.

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The experiment was conducted in the research farm. The following four (T_2-T_5) rice based intercropping systems, suitable for rainfed uplands, were evaluated and compared with rice monocropping in field with 3 replications following RBD design during wet seasons of 1998 and 99: (1) T_1 = Rice (R) sole; (2) T_2 = R + pigeon pea (PP; *Cajanus cajan*) intercropping (4:1; R:PP row ratio); (3) T_3 = R + groundnut (GN; *Arachis hypogea*) intercropping (4:2; R:GN); (4) T_4 = R + black gram (BG; *Phaseolus mungo*) intercropping (4:1; R:BG) and (5) T_5 = R + green gram (GG; *P. aureus*) intercropping (4:1; R:GG)

The row ratios were followed as per recommendations. The crop varieties used were; R = Vandana, PP = Birsa Arhar, GN = BG 3-6, BG = Pant U 19, GG = Sunayana. Rice and intercrops were sown directly in lines 20 cm apart (seed rate; R = 100 kg/ha, PP, GG = 20 kg/ha, BG = 15 kg/ha, GN = 110 kg/ha; seed rates adjusted in intercropping systems). Fertilizers were applied @ 20+20:30:20; N:P:K kg/ha (adjusted full dose of N of intercrops as basal) in the form of urea, SSP and MOP respectively.

Root samples of rice and the legumes were taken at 20, 40 and 60 days after emergence (DAE) of rice as per standard technique (3 samples/plot). Sampling of rice roots in each plot was done from 3 sampling areas (pre-fixed rice rows) from the adjacent (row 1) and second row (row 2) of rice to the intercrops separately. Root pieces (1-2 cm) after washing with tap water were cut into pieces (1-2 cm) and were fixed in FAA solution (formalin : acetic acid : 70% alcohol; 5 : 5 : 90; v/v) . Extent of root colonization was estimated by systematic gridline-intersect method (3) using stereo-zoom microscope (STEMI 2000C; Carl Zeiss) after staining (5) fixed roots.

Soil sampling (5-20 cm soil depth) was done from each plot (1 pooled sample of 5 sub-samples/ plot) at initial (prior to crop sowing) and final (just after rice harvest) stages. The native VAMF spore population from the soil samples was estimated using the wet sieving and decanting method (2).

All the intercropping systems led to higher root colonization by native VAMF in rice over rice sole at 60 DAE in both the years (Table 1). Significantly highest colonization percentage was noticed in R+GN system. This was followed by figurative increase in R+PP, R+BG, R+GG over rice sole. Gradual increase in root colonization in rice, irrespective of cropping system, was noticed with increase in time of emergence. Up to 40 DAE, only figurative increase was noticed in rice under the 4 intercropping systems, over rice sole in both the years. Colonization in the legumes, however, was less as compared to rice. This indicated that higher colonization in rice under intercropping systems was due to increased root density per volume of soil in intercropping systems which favoured the spread of the symbiotic fungi (4). When the effects of spatial distance of rice roots from the roots of the intercrops (row 1- nearest to intercrops; row 2- distant from intercrops) in soil,

Table 1. Influence of legumenous intercrops on root colonization by native VAM in upland rice under rice based intercropping systems as a function of time

Cropping systems[1]	% root colonization[2]					
	1998			1999		
	DAE[3]			DAE[3]		
	20	40	60	20	40	60
R sole						
Row 1	14.2 def	18.1 a	32.8 cde	21.0 a	25.5 ab	29.1 f
Row 2	14.6 def	18.1 a	32.6 cde	18.8 ab	23.7 ab	29.2 f
R+PP						
R Row 1	16.2 c-f	23.4 a	43.2 bc	20.4 a	28.0 ab	46.9 b
R Row 2	15.0 def	25.7 a	44.6 bc	18.2 ab	24.7 ab	41.5 bcd
PP	10.6 f	23.0 a	23.9 de	8.3 c	19.1 bcd	20.3 g
R+GN						
R Row 1	39.3 a	30.4 a	62.7 a	24.8 a	29.5 a	60.2 a
R Row 2	36.3 ab	21.1 a	50.5 ab	25.7 a	23.8 ab	45.5 bc
GN	26.2 a-d	28.5 a	24.6 de	18.4 ab	23.4 ab	32.9 def
R+BG						
R Row 1	24.0 b-e	21.0 a	48.7 abc	21.7 a	24.3 ab	48.3 b
R Row 2	29.4 abc	24.5 a	44.2 bc	12.7 bc	21.8 abc	42.9 bcd
BG	11.5 ef	16.7 a	27.4 de	7.2 c	12.7 d	20.8 g
R+GG						
R Row 1	17.9 c-f	27.6 a	37.4 bcd	17.6 ab	24.2 ab	31.1 ef
R Row 2	14.4 def	23.2 a	36.9 bcd	18.9 ab	26.9 ab	36.4 c-f
GG	17.0 c-f	21.7 a	20.9 e	11.6 bc	15.1 cd	19.3 g

[1]Cropping systems: R=rice, PP=pigeon pea, GN=groundnut, BG=black gram, GG=green gram, Row 1=adjascent rice row to I/C, Row 2=2nd rice row to I/C;

[2] mean of 3 samples and 3 replications; [3]Days after rice emergence

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT; Statistical analysis done with Arcsine transformed data

Table 2. Influence of upland rice-legumes intercropping systems on native VAMF spore population in soil

Cropping systems[1]	Number of chlamydospores (#/100 g soil)[2]					
	1998 [3]			1999 [3]		
	Initiat	Final	Difference[4]	Initiat	Final	Difference[4]
Glomus spp.						
R sole	417.5 a	315.9 a	ns	313.9 a	465.5 ab	*
R+PP	392.0 a	305.5 a	ns	330.7 a	390.8 b	ns
R+GN	313.5 a	344.2 a	ns	420.8 a	421.8 b	ns
R+BG	333.1 a	442.7 a	ns	352.6 a	584.9 a	**
R+GG	283.1 a	359.9 a	ns	344.9 a	496.3 ab	*
LSD (5%); stage x CS		132.2			131.6	
Total						
R sole	465.1 a	325.6 ab	ns	331.8 a	480.5 ab	*
R+PP	433.1 a	382.5 b	ns	345.4 a	405.2 b	ns
R+GN	386.8 a	353.6 ab	ns	445.0 a	431.6 b	ns
R+BG	379.7 a	467.5 a	ns	368.9 a	592.3 a	**
R+GG	315.7 a	372.1 ab	ns	361.2 a	506.4 ab	*
LSD (5%); stage x CS		155.1			133.5	

[1]Cropping systems:, R=rice, PP=pigeon pea, GN=ground nut, BG=black gram, GG=green gram

[2] mean of 3 replications, [3]Inital=prior to sowing, Final=after harvest, [4]ns=not significant, *&**=significant at 5% & 1% level

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT

on extent of native VAMF colonization (rice roots) was observed, the nearest rows (row 1) showed figuratively higher colonization over row 2 in all intercropping systems. Such difference was significantly higher in R+GN system (Table 1). R+GN system (4:2 row ratio) expected to have higher root density of GN per volume of soil as compared to other systems (4:1 row ratio) leading to higher intimate interaction with rice roots. This indicated direct influence of intimate interaction of roots of intercrops (legumes) with rice roots on encouraging native VAM association in rice.

The estimation of spore population of native VAMF indicated that, on an average (both years), about 94% VAMF spores were of genus *Glomus* (Table 2) in the eco-system, confirming the earlier findings (6). On the other hand, none of the cropping systems, except R+BG, influenced much on native VAMF spore population in soil. The trend of spore population dynamics was different in two years. In 1999, all the cropping systems, except R+GN increased VAMF population. The trend was reversed in 1998 except in R+BG and R+GG. General reduction in population in 1998 could be attributed to less rainfall [total rainfall during crop growth period (June to September) was 896.1 mm in 1998 as compared to 1186.5 mm in 1999] leading to less soil moisture regime during crop growth period. Irrespective of increasing or decreasing spore population, all rice-legumes intercropping systems encouraged higher VAMF colonization in rice. This further indicated that higher colonization in rice under rice-legumes intercropping systems was due to interactive effects of roots of rice with the intercrops. It is concluded that intercropping upland rice with legumes induced higher native VAMF association in rice through their intimate interaction with rice roots.

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