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Effect of crop rotation on arbuscular mycorrhizal inoculum build up and infectivity status of soil

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Effect of crop rotation on native arbuscular mycorrhizal (AM) inoculum build up, infectivity status of soil and root infection intensity of crops was studied in a field experiment carried out with red gram (*Cajanus cajan* Milsp.), wheat (*Triticum aestivum* L.) and maize (*Zea mays* L.), grown respectively as *kharif* (August–November), *rabi* (December–March) and *pre-kharif* (April–July) crops for two consecutive years in a sandy loam soil of *terai* region of West Bengal without any chemical fertilizers. The crops were grown in single, double and triple crop sequences with weeded (i.e. clean) fallow during no-crop season in seven treatment combinations. Weeded and non-weeded fallow for all three seasons of two consecutive years were kept as two separate check treatments. AMF spore population in soil increased significantly with all crops and crop sequences as compared to weeded fallow treatment. Mean spore number of soil after two years was highest with triple cropping and lowest with weeded fallow treatment. Non-weeded fallow treatment gave significantly higher spore number for six consecutive seasons then any of the single crop sequences and also two of the double crop sequences (*Cajanus*–weeded fallow–maize and weeded fallow–wheat–maize). Wheat in *rabi* season gave the highest significant increase in spore number and maize during *pre-kharif* season gave the least, except when it followed wheat in either double or triple crop sequences. Mycorrhizal infectivity status of soil in different crop sequences, weeded and non-weeded fallow treatments showed similar trend as in case of spore number. High rainfall during *pre-kharif* season (seasonal mean 2132 mm for two years) was associated with lower spore number and consequent lower infectivity status of the soil after the single crop of maize. Root infection intensity of crops and native weeds was highest during *rabi* season and lowest during *pre-kharif* season. Wheat as a mycorrhiza responsive crop during *rabi* season can significantly improve mycorrhizal spore build up and infectivity status of soil but weeded fallowing even for a single season may drastically reduce the same. Maize, in spite of being mycorrhiza responsive, failed to stimulate AMF spore development most likely due to high soil moisture status duirng the *pre-kharif* season.

Key words : Crop rotation, fallowing, mycorrhiza

INTRODUCTION

Judicious selection of crops in rotation helps in maintaining soil fertility, multiplication of beneficial root and soil inhabiting microflora and suppresses the growth of weeds and harmful soil – borne plant pathogens. Arbuscular mycorrhizal fungi (AMF) are a group of such beneficial root inhabiting soil fungi, the population and species composition of which is also affected by the types and intensities of cropping (Harinikumar and Bagyaraj, 1988 ; Johnson *et al.,* 1991 ; Panja and Chaudhuri, 1998). AMF have been found as an invaluable biological tool for growth promotion of plants through mobilization of scarce soil nutrients, like phosphorus and improve plant water relations and tolerance to abiotic and biotic stresses in soil. Plant response to AM depends on the extent and earliness of infection, which in turn depends on the quantity of infective inoculum density and extent of extramatrical hyphal ramification in soil (Marschner, 1995). Augmentation of infective inoculum density in plant rhizosphere for sufficient root colonization of crop(s) can be done either through *in situ* muliplication of native inoculum or through the application of AM inoculum from

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external source. Multiplication of native AMF inoculum *in situ* through crops in rotation may be economically viable approach and may serve not only as an alternative to inoculum application but also as a reservoir of inoculum for root infection to the subsequent crops (Harinikumar and Bagyaraj, 1989).

A field experiment was conducted in West Bengal *Terai* Zone during 1998–2000 with maize as *pre-kharif* (April–July), red gram as *kharif* (August–November) and wheat as *rabi* (December–March) season mycorrhiza sensitive crops under single, double and triple crop sequences keeping weeded and non-weeded treatments as checks. The objective of the experiment was to see the effects of season specific crops in sequence and fallowing on mycorrhizal inoculum build up and infectivity status of soil.

MATERIALS AND METHODS

The experiment was conducted for two years (i.e. 2 × 3 seasons) during 1998–2000 in a sandy loam terai zone soil at the University Research Farm, Pundibari, Cooch Behar, with maize (*Zea mays* L., var., Vijay Composite) as *pre-kharif* (April–July), red gram (*Cajanas cajan* Milsp., var. TAT–10) as *kharif* (August–November) and wheat (*Triticum aestivum* L., var. UP – 262) as *rabi* season (December – March) mycorrhiza sensitive crops. Weeded and non –weeded fallow fields were kept as checks. Each experimental plot was 2.5 m × 2.0 m size. Nine treatments each with three replications were arranged in a completely randomized block design as per following schedule.

Cropping intensity	Treatments	Seasons		
		Kharif	*Rabi*	*Pre-kharif*
No crop	1. Weeded fallow (WF)	WF	WF	WF
	2. Non-weeded fallow (NWF)	NWF	NWF	NWF
Single cropping	3. *Cajanas*	*Cajanas*	WF	WF
	4. Wheat	WF	Wheat	WF
	5. Maize	WF	WF	Maize
Double cropping	6. *Cajanas* + Wheat + WF	*Cajanas*	Wheat	WF
	7. *Cajanas* + WF + Maize	*Cajanas*	WF	Maize
	8. WF + Wheat + Maize	WF	Wheat	Maize
Triple cropping	9. *Cajanas* + Wheat + Maize	*Cajanas*	Wheat	Maize

Except non-weeded fallow, all plots after single or double cropping were weeded manually. In non-weeded plots, *Ageratum conyzoides* L., *Commelina benghalensis* L., *Cynodon dactylon* Pers., *Tridax procumbans* L. and *Heliotropium indicum* L. as dominant weeds were allowed to grow. No chemical fertilizers were applied and only life saving irrigation was given to the crops as and when necessary. Each crop was allowed to grow for 120 days. Tratment wise soil and root samples were collected at the end of each season for assessment of root infection intensity of crops and weeds. AMF spore number and infective inoculum density of soil under the treatments were recorded. AM spores were isolated from soil by wet sieving and decanting method of Gerdemann and Nicolson (1963). Root samples were processed and stained following the method of Philips and Hayman (1970). For each treatment root infection intensity was estimated microscopically measuring the length of roots of at least 50 × 1 cm stained root pieces showing AM hyphae, vesicles, arbuscles etc. Mycorrhizal infectivity status was assessed by standard 10-fold dilution series technique (Powell, 1980), as most probable number (MPN) of infective propagules present in soil. The experimental soil had average inoculum density of 170 spores / 100 g and 16 infective propagules / g dry soil. Out of the four AM genera viz. *Gigaspora, Glomus, Acaulospora* and *Sclerocystis* isolated from the experimental soil, *Gigaspora* was predominant. AM fungi were identified as far as practicable from metrical and other characters of azygospores or chlamydospores according to the standard description (Schenck and Perez, 1990). Statistical analyses of metrical data were done following standard experimental design and analysis (Gomez and Gomez, 1983).

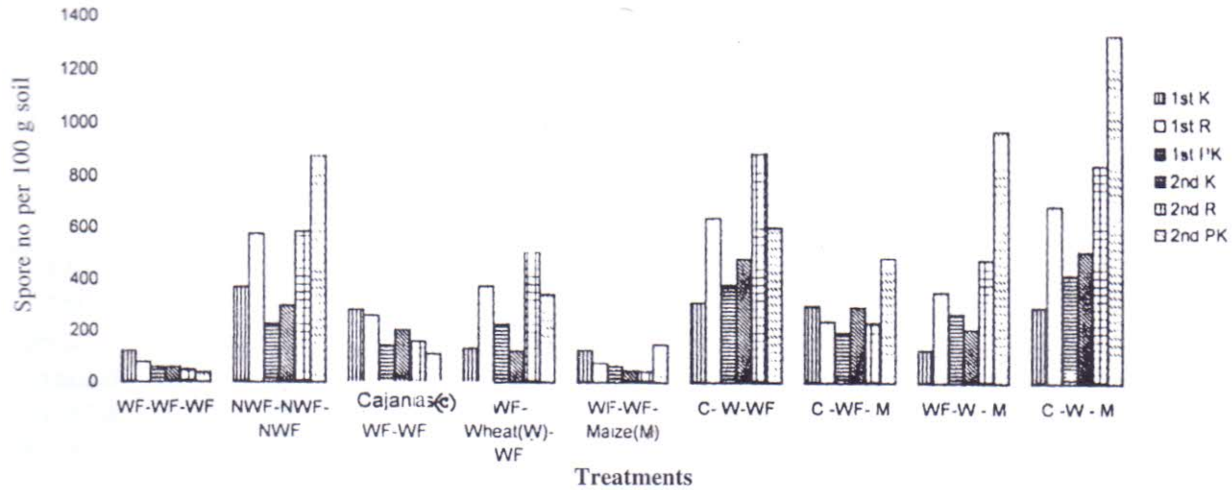
RESULTS AND DISCUSSION

Results (Table 1 and Fig. 1) of the experiment revealed gradual decline of AM spore number of soil kept as weeded fallow for six consecutive seasons in two years. Single cropping of *Cajanas* or wheat or maize in their respective seasons resulted significant increase in spore number from that of preceding fallow seasons. Among these three crops, wheat under single cropping in *rabi* season gave the highest stimulation of spore number whereas maize during *pre-kharif* season stimulated the least.

Double cropping of *Cajanas* and wheat or *Cajanas* and maize or wheat and maize with one season as weeded fallow in normal sequence resulted significantly higher mean spore number than that of single cropping of either of the three crops with two weeded fallow seasons preceding or succeeding the crops in sequence. Here again the promotional effect of wheat in sequence during *rabi* season on the mean spore number was more than that caused by the other two crops in sequence. Triple cropping with three crops in succession resulted the highest mean spore number among all treatments where the effect of wheat in *rabi* season was most pronounced. Extent of increase in spore number due to crops or weeds was related to the base spore number in the immediately preceding season with or without crops. In general, irrespecitve of the crops and seasons, stimulation of spore number with any of the crops was higher in the second year than the first year (Fig. 1)

promotional effect on AMF spore formation. Mean spore number produced after six seasons of non-weeded fallowing was significantly higher than that obtained with all the three crops in single cropping and the two maize based double crop sequences (Table 1).

Mean mycorrhizal root colonization intensity of crops in different seasons under different crop sequences was found highly variable (Table 1). Wheat during *rabi* season exhibited the highest root colonization intensity followed by *Cajanas* during *kharif* and maize during *pre-kharif* seasons. The effect of season specific climatic factors particularly rainfall seemed to have conditioning influence on root colonization intensity of the crops. Infection intensity of maize during *pre-kharif* season was the lowest, even when it followed wheat sequence that had left higher number of spores in soil.



K – Kharif R – Rabi PK – Pre-kharif

Fig. 1 : Variation in AM spore no. in soil in three successive seasons for two years under different cropping intensity with pre-kharif maize, kharif cajanus and rabi wheat

AMF spore production during *pre-kharif* season was found lower either in fallow or in maize treatments, except when maize followed wheat in double or triple crop sequences. Seasonal rainfall was exceptionally higher (average rainfall 2132 mm which spreads over 56 rainy days) in the *pre-kharif* season during the period of experimentation.

The non-weeded fallow treatment for six consecutive seasons also had significant

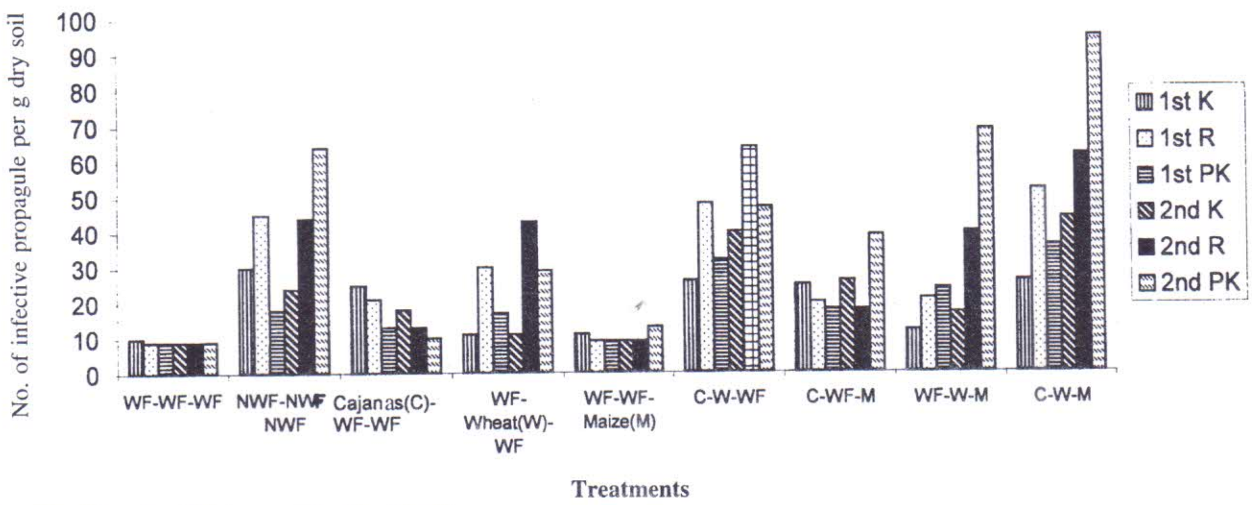
Mean mycorrihizal infectivity status of soil was variable according to the crops considered under rotation, cropping intensity and types of fallowing and exhibited the same trend as found in the variation of spore number in soil (Table 1 and Fig. 2).

Results of the field experiment with three season specific mycorrhiza sensitive crops in sequence of AMF potential of soil indicated that the crops and

Table 1 : Effect of single, double and triple cropping with cajanas, wheat and maize in sequence for two yers on mycorrhizal root colonization of crops, inoculum build up in and infectivity status of soil

Rotation	Cropping intensity	Cropping sequences			Mean spore no. (Av. of two Yrs.)			Mean spore no. (Av. of six seasons)	Mean % of mycorrhizal colonization (Av. of two yrs.)		
		Kharif	*Rabi*	*Pre-kharif*	*Kharif*	*Rabi*	*Pre-kharif*		*Kharif*	*Rabi*	*Pre-kharif*
Without crop		WF	WF	WF	92 (9.5)*	65 (9.0)	49 (9.0)	69 (9.2)			
		NWF	NWF	NWF	335 (27.0)	580 (44.5)	552 (41.0)	489 (37.5)	53.1	64.9	47.1
With crop	Single	*Cajanas*	WF	WF	245 (21.5)	210 (17.0)	128 (11.5)	194 (16.7)	72.1		
		WF	Wheat	WF	128 (11.0)	439 (36.5)	284 (23.0)	284 (23.5)		95.6	
		WF	WF	Maize	84 (10.0)	59 (9.0)	106 (11.0)	84 (10.0)			25.6
	Double	*Cajanas*	Wheat	WF	397 (33.0)	764 (56.0)	490 (39.5)	550 (42.8)	77.1	95.8	
		Cajanas	WF	Maize	298 (25.5)	238 (19.0)	341 (28.5)	292 (24.3)	75.8		36.9
		WF	Wheat	Maize	170 (14.5)	417 (30.5)	620 (46.5)	402 (30.5)		95.2	52.1
	Triple	*Cajanas*	Wheat	Maize	404 (35.0)	766 (57.0)	875 (65.5)	682 (52.8)	77.0	91.4	36.4
SEM								14(1.3)			
CD.05								42(4.0)			

Figure within parenthesis indicates no. of infective propagules per g of dry soil. WF = Weeded fallow NWF = Non-weeded fallow



K – Kharif R – Rabi PK – Pre-kharif

Fig. 2 : Variation of mycorrhizal infectivity status of soil in three successive seasons for two consecutive years under different cropping intensity with pre-kharif maize, kharif cajanas and rabi wheat

cropping intensity had pronounced multiplier effect on (i) AMF spore development in rhizosphere soil. (ii) root colonization intensity of the crops in sequence and (iii) infective inoculum density of soil. Among the three crops selected wheat as *rabi* season crop either single or double or triple crop sequences stimulated the AM potential of soil more than *Cajanas* as *kharif* and maize as *pre-kharif* season crop. The AMF spore and infective potential of the soil in single cropping was found less than that of double or triple cropping. The results of the experiment corroborated with the findings of

Harinikumar and Bagyaraj (1988, 1989) where they found spore production in monoculture was less than that of double or multiple cropping or even that of intercropped situation. AMF root colonization of the succeeding crops alongwith spore number and infective propagules of the soil were greatly determined by the mycorrhizal potential, influenced by types of crops and fallow considered of preceeding soil. AMF development in soil was known to be influenced by the system of cropping–rotations/sequences, cropping intensities, crop choice etc. (Black and Tinker, 1979 ; Sieverding and Leihner, 1984 ; Dodd *et al.,* 1990).

Results of the experiment also exhibited that if the land was kept as weeded fallow for seasons together or before or after cropping, it had significant effect on reduction of AM sporulation and inoculum potential of soil. Since new crop of spores are not produced in weeded fallowing situation, the population of AMF can decline gradually. Harinikumar and Bagyaraj (1988) reported the marked effect of fallowing on decreasing AM root colonization, sporulation, survival and inoculum potential in soil. Greater rate of decrease in spore number was evident in fallowed or non–host cropped soil. A year of fallow may reduce the AMF colonization level of the subsequent crop by half (Black and Tinker, 1979).

Characteristically, keeping the native weed cover undisturbed in non – weeded fallow treatment helped to augment and maintain AMF inoculum and infectivity status of the soil whereas weeded fallow even for short or long season drastically reduced them. So, native weeds play an important role not only to preserve inherent mycorrhizal spore number as well as infective potential of soil between intercropped periods but also to augment these further. The AM infected weed flora function as a natural repository and also serve as an important mode of perpetuation of native AMF from one season to others during intercropped period. Role of native weeds during crop free period for maintain AM potential's of soil were also indicated by Anwar and Jamaluddin (1994) and Maiti *et al.* (1996).

Besides the role of crop, cropping sequence, cropping intensity, native weeds on AM spore development, infective potential and root colonization, seasonal rainfall apeared to have considerable interactive effect on not only AMF spore production but also on soil infectivity status and mycorrhizal root colonization of crop. Higher rainfall during *pre-kharif* season was associated with lower spore number and infective propagules either in fallow or in maize treatments except when maize followed wheat in double or triple crop sequences. It seemed to have also deminishing influence on the AM root colonization intensity of the crop. Infection intensity of maize during *pre-kharif* season was the lowest, even when it followed wheat in sequence that had left higher number of spore in soil. High average rainfall during *pre-kharif* season elevated and maintained soil moisture level for longer period and which is very detrimental for mycorrhizal root colonization, sporulation and survival. Excessively high soil moisture potential due to high precipitation was known to decrease AM spore number in soil and root colonization of plants (Read and Bowen, 1979 ; Mohankumar and Mahadevan, 1987).

It may be concluded from the results of the present study that under low input cultivation system, choice of crops in sequence and cropping intensity and management of fallow lands during crop free period may be useful to exploit the inherent mycorrhizal potentials of soils.

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