between pod weight per plant and number pods per plant and total seed weight. Accordingly, predicted genetic advance as per cent of mean for these two traits was also high. Thus, it was found that due emphasis should be given to number of pods per plant and pod weight per plant during selection of genotypes to improve seed yield in cowpea.

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COST EFFECTIVE PHOSPHOROUS MANAGEMENT PRACTICES FOR RAINFED COTTON IN VERTISOLS

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ABSTRACT

A field experiment was conducted at Agricultural Research Station, Kovilpatti to study the effect of different P sources on the yield of Cotton (variety.MCU.10) and on soil fertility status of rainfed vertisol. The results showed that the seed cotton yield was significantly increased by the application of FYM enriched Mussorie rock phosphate at 20 $kgha^{-1}$ along withsoil application of phosphobacterium (2.0 $kgha^{-1}$). The same treatment significantly influenced the P uptake of the crop. Highest monetary return was realised with the application of FYM enriched Mussoorie rock phosphate along with the soil application of phosphobacterium.

KEY WORDS : P Management, Rainfed cotton, Vertisol.

Phosphorous plays a key role in the root development of any crop which is an important factor under dryfarming. Generally, the crop recovery of added chemical phosphatic fertilisers in vertisols seldom exceeds 20 to 30 per cent which might be due to the conversion of applied P sources into insoluble compounds. Consequent hike in the price of chemical fertilisers coupled with the low purchasing power of the rainfed farming community have resulted in the utilisation of natural resources such as organic and biofertilisers in crop production. Though the natural P sources, like Mussorie rock phosphate, is having the high nutrient content (20 percent P_2O_5) which is not readily available to the crop in time. To increase the use efficiency of added natural P sources, inclusion of organic mansures, and P solublizing microbes in the fertilizer schedule is necessary. Besides, the beneficial effect of substituting the mineral P sources with natural P sources like Mussoorie rock phosphate along with the phosphorous solubilizing micro organisms (PSM) not only reduced the fertilizer cost but also increased the use efficiency (Sarkar, 1996). An experiment was conducted to study the effect of inorganic and natural P sources along with microbial inoculum on the yield of rainfed cotton in vertisol.

MATERIALS AND METHODS

A field experiment was conducted in the black soil farm area of Agricultural Research Station, Kovilpatti during the rabi season of 1996-1997 in the rainfed vertisol using cotton (Variety MCU.10) as a test crop. The experimental soil had the following characteristics; texture - clayey; pH-8.5, EC-0.2 dSm^{-1} and organic carbon - 0.30%. The soil was low in available N (140$kgha^{-1}$), Olsen P (6.2$kgha^{-1}$) and high in available Potassium. The experiment was laid out in split plot design with three replications. The treatments viz., control and phosphobacterium were assigned to main plots and phosphorous sources were allotted to sub-plots. The treatment details were given below :-

Main Plot

M_1 - Control

M_2 - Phosphobacterium (PSM)

Sub plot

P_1 - Control

P_2 - Single superphosphate (SSP)

P_3 - Mussorie rock phosphate (MRP)

P_4 - FYM eriched SSP

P_5 - FYM enriched MRP.

The recommended dose of P at 20 kg P ha^{-1} was applied basally through various P sources viz., SSP and MRP which were applied individually and also in combination with enriched FYM. A uniform dose of 40kg N ha^{-1} as urea was supplied to all the plots. Phosphobacterium was applied at 2.0 $kgha^{-1}$. Necessary plant protection measures and intercultivation operations were carried out whenever needed. The crop was sown during October with the spacing of 40 x 30cm. The crop was harvested and seed cotton yield was recorded. The soil and plant samples collected at post harvest stage were analysed for their Olsen P status in soil and P content in Plant, by using standard procedures out lined by Olsen *et al* (1956) and Piper (1966). Uptake of nutrients was computed based on the nutrient content, and drymatter production. Economics of the treatments tried were estimated and reported.

RESULTS AND DISCUSSION

Seed cotton yield

In comparing the main plots inclusion of phosphobacterium in the fertiliser schedule increased the seed cotton yield. (Table 1). The highest mean seed cotton yield of 730 $kgha^{-1}$ was recorded with the soil application of phosphobacterium (2.0 $kgha^{-1}$) which was 11.6 percent increase over control (654 $kgha^{-1}$)

In the sub plot treatments, addition of phosphorous irrespective of the sources significantly increased the seed cotton yield than the control. The highest mean seed cotton yield of 759 $kgha^{-1}$ was registered by the application 20 kg P ha^{-1} as FYM enriched SSP (733 $kgha^{-1}$). The magnitude of yield increase was found to be 27 percent, as against unfertilised plots.

The interaction between various P sources and phosphobacterium was found to be significant. The application of 20 kg P as FYM enriched Mussorie rock phosphate recorded the highest seed cotton yield of 820 $kgha^{-1}$ as against the control (592 $kgha^{-1}$). The yield increased over control was found to be 38.7 percent. This was followed by the application of FYM enriched SSP (781 $kgha^{-1}$). Generally the enrichment of phosphorous with FYM significantly increased the seed cotton yield irrespective of the P sources.

The probable reason for getting the highest seed cotton yield with FYM enriched P sources and phosphate solubilising micro organisms (PSM) might be due to increased availability of P through solubilisation of insoluble compounds by the organic acid produced during decomposition (Vaishya *et al.*, 1996). Further, mineralisation through chelating effect of complex intermediate organic molecules again increased the P availability, which inturn increased the seed cotton yield (Trivedi *et al*, 1995, Sarkar, 1996)

Table 1. Effect of various phosphorus sources on seed cotton yield, root length and rain water use efficiency

Treat ments.	Seed cotton yield (Kgha^{-1}) Phosphorus sources. Control	SSP 20 Kg P ha^{-1}	MRP 20 Kg P ha^{-1}	EFYM SSP 20 Kg P ha^{-1}	EFYM MRP 20 Kg P ha^{-1}	Mean	Root Length (Cm) Phosphorus sources. Control	SSP 20 Kg P ha^{-1}	MRP 20 Kg P ha^{-1}	EFYM SSP 20 Kg P ha^{-1}	EFYM MRP 20 Kg P ha^{-1}	Mean
No Bio Fertilizer.	592	540	654	685	697	654	14.0	17.1	17.4	19.2	19.5	17.4
Phopho bacterium (PSM)	602	720	728	780	820	730	15.6	26.6	29.3	33.7	38.9	28.8
Mean.	597	680	692	733	759		14.8	21.8	23.3	26.4	29.2	
	Phospho (PSM)		Phosphorous source (P)		PSMXP	PXPSM	Phospho (PSM)		Phosphorus source (P)		PSMXP	PXPSM
CD (P=0.05)	4		25		31	35	1.4		1.6		2.4	2.3

Treat ments.	Rainwater use efficiency (Kgmm^{-1} ha^{-1}) Phosphorus sources. Control	SSP 20 Kg P ha^{-1}	MRP 20 Kg P ha^{-1}	EFYM SSP 20 Kg P ha^{-1}	EFYM MRP 20 Kg P ha^{-1}
No Bio Fertilizer.	1.1	1.2	1.2	1.3	1.3
Phopho bacterium (PSM)	1.1	1.3	1.3	1.4	1.5

SSP - SINGLE SUPER PHOSPHATE MRP - MUSSORIE ROCK PHOSPHATE.
EFYM SSP - FYM ENRICHED SINGLE SUPER PHOSPATE
EFYM MRP - FYM ENRICHED MUSSORIE ROCK PHOSPHATE.

Root length and Rain water use efficiency

Rain water received during the cropping period and its utilisation by the crop mainly depends upon the root length of the crop. Hence, the root length was recorded which was varied from 14.0 cm to 38.9 cm. The application of FYM enriched MRP along with phosphobacterium recorded the highest root length of 38.9 cm (Table 1), which was a three fold increase over control. Generally the soil application of phosphobacterium significantly increased the root length. The higher availability of phosphorous from the Mineral and natural P sources in the presence of FYM and phosphobacterium might be the reason for increased root lenght thus resuled in better use of soil moisture from the deeper layer (Trivedi *et al.* 1995, Sarkar, 1996). The result on rain water use efficiency showed that, the application of phosphorous enriched with FYM irrespective of the sources recorded the highest rain water use efficiency (Table 1). However, the application of FYM enriched MRP recorded the maximum RUE of 1.5 kgmm^{-1} ha^{-1} The minimum RUE value was noticed in the control. The higher rain water use efficiency might be due to higher root length which utilised the soil moisture fro deeper layers efficiently.

P availability and uptake

Significant build up in the availability of P status was observed due to treatments having

Table 2. Effect of various phosphorus sources on available P in the soil and P uptake by cotton crop.

Treatments.	Available P status of the soil (Kg ha^{-1})						Phosphorous uptake by cotton crop (kg ha^{-1})					
	Phosphorus sources.						Phosphorus sources.					
	Control	SSP 20 Kg P ha^{-1}	MRP 20 Kg P ha^{-1}	EFYM SSP 20 Kg P ha^{-1}	EFYM MRP 20 Kg P ha^{-1}	Mean	Control	SSP 20 Kg P ha^{-1}	MRP 20 Kg P ha^{-1}	EFYM SSP 20 Kg P ha^{-1}	EFYM MRP 20 Kg P ha^{-1}	Mean
No Bio Fertilizer.	6.2	8.1	8.6	9.5	9.6	8.4	0.5	1.2	1.2	1.4	1.5	1.2
Phosphobacterim (PSM)	8.4	9.8	9.6	10.1	10.3	9.6	0.5	2.2	2.4	2.7	3.3	2.2
Mean.	7.3	9.0	9.1	9.8	9.9		0.5	1.6	1.8	2.0	2.4	
	Phospho (PSM)		Phosphorous source (P)		PSMXP	PXPSM	Phospho (PSM)		Phosphorus source (P)		PSMXP	PXPSM.
CD (P=0.05)	0.2		0.3		0.4	0.4	0.3		0.4		0.6	0.6

SSP - SINGLE SUPER PHOSPHATE MRP - MUSSOORIE ROCK PHOSPHATE.
EFYM SSP - FYM ENRICHED SINGLE SUPER PHOSPATE
EFYM MRP - FYM ENRICHED MUSSORIE ROCK PHOSPHATE.

phosphorous when compared to control (Table 2). Among the P Sources tried, the FYM enriched P sources maximized the P availability when compared to the application of inorganic P sources. The application of FYM enriched MRP in the presence of phosphobacterium recorded the highest available P of 10.3 kg ha^{-1} as against the control which recorded 6.2 kg P ha^{-1} The increase over control was found to be 66 percent. The increased P availability might be due to the chelating effect of complex intermediate organic molecules formed during decomposition (Trivedi *et al.*, 1995). Further, the effect was enchanced by the addition of phosphobacterium which is having the ability to solubilise the insoluble P compounds fixed in the clay lattice with their secretion of aliphatic and aromatic acids coupled with enzymes such as phytases and phospholipases (Sarkar, 1996: Muthuvel *et al.*, 1977). Similar findings were reported by yaduvanshi *et al.*, (1985) and Trivedi *et al.*, (1995).

The uptake of P by the crop to added P sources was found to be significant. The application of PSM and FYM enrichment, showed a marked variation in the P uptake of cotton (Table 2). Among the two sources tried, addition of MRP performed better in increasing the crop nutrient uptake than the SSP. The values on crop nutrient uptake was ranged from 0.5 to 3.3 $kgha^{-1}$. The application of 20kg P ha^{-1} as FYM enriched MRP in the presence of phosphobacterium recorded the highest nutrient uptake of 3.3 $kgha^{-1}$ which was 22 percent increase over SSP. The absolute superiority of FYM and phosphobacterium in enhancing the P availability resulted in higher P uptake by the crop than the control (Chaudhry *et al.*, 1981 Kamala Kumari and Singaram, 1996).

Economics

The profitability of added inorganic and natural P sources were calculated and presented in Table 3. Highest monetary return of Rs. 6560 ha^{-1} and highest return per rupee spent on fertilizer (3.0) was realised with the apllication of 20kg P ha^{-1} as FYM enriched MRP along with phosphobacterium. This was followed by the application of FYM enriched SSP (Rs. 6248 ha^{-1}). The increase over control was found to be the highest of Rs. 1816 ha^{-1} for FYM enriched MRP along with phosphobacterium. The results indicated the beneficial effect of phosphorous application, through FYM enriched Mussorie rock phosphate along with soil application of phosphobacterium

Table 3. Profitability of different sources of phosphatic fertiliser use in cotton crop.

Treatment	Seed cotton yield (Kgha^{-1})	Cost of fertiliser (Rsha^{-1})	Monetary return (Rsha^{-1})	Increase over control (Rsha^{-1})	Return per Rupee spent on fertilizer (Rs.)
WITHOUT PHOSPHOBACTERIUM :					
No Fertilizer 'P'	592	-	4744	-	
SSP @ 20Kg Pha^{-1}	640	708	5120	376	0.5
MRP @ 20Kg Pha^{-1}	654	495	5232	488	1.0
EFYM SSP @ 20Kg Pha^{-1}	686	758	5488	744	1.0
EFYM MRP @ 20Kg Pha^{-1}	697	545	5576	832	1.5
WITH PHOSPHOBACTERIUM :					
No Fertilizer 'P'	602	63.	4816	72	1.1
SSP @ 20Kg Pha^{-1}	720	771	5760	1016	1.3
MRP @ 20Kg Pha^{-1}	729	558	5832	1088	1.9
FYM enriched SSP @ 20Kg Pha^{-1}	781	899	6248	1504	1.7
FYM enriched MRP @ 20Kg Pha^{-1}	820	608	6560	1816	3.0

SSP - SINGLE SUPER PHOSPHATE MRP - MUSSOORIE ROCK PHOSPHATE.

1) Unit cost of 'P' as SSP = Rs. 35.40

2) Unit cost of 'P' as MRP = Rs. 24.75

3) Unit cost of 'P' as EFYM SSP = Rs. 37.90

4) Unit cost of 'P' as EFYM MRP = Rs. 27.25

5) Unit cost of Phosphobacterium = Rs. 31.50

which increased the seed cotton yield significantly besides improving the available P status in the soil.

Thus it was concluded that the application of 2.0 kgha^{-1} phosphobacterium in soil and 20kg P ha^{-1} as FYM enriched Mussorie rock phosphate can be recommended to maximise the production of seed cotton yield with less cost of fertilizer.

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