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Effect of different sources of sulphur along with or without N, P, K and FYM in rapeseed-mungbean-rice crop sequence in the Gangetic West Bengal

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ABSTRACT

Field experiments was carried out during 2002 to 2005 in Entisol Soil of nearly neutral reaction (pH 6.8), sandy clay loam texture and having 0.05% N, 30.82 kg ha^{-1} available phosphorus, 147.84 kg ha^{-1} available potassium and 22.46 kg ha^{-1} available sulphur in a relatively upland situation with irrigation facility at the Instructional Farm of the Bidhan Chandra Krishi Viswavidyalaya, West Bengal, India to evaluate the relative performance of three different sources of sulphur (ammonium sulphate, gypsum and elemental sulpher) when applied along with recommended doses of fertilizer ($N_{80}P_{40}K_{40}$ kg ha^{-1}) and in combination with or without 5 t FYM to rapeseed crop under rapeseed mungbean-rice sequential cropping. Results revealed that in rapeseed mungbean-rice sequential cropping, total productivity (5.09 t ha^{-1} $yr.^{-1}$), total equivalent rice yield (9.16 t ha^{-1} $yr.^{-1}$) total uptake of NPK and S (733.29 kg ha^{-1} $yr.^{-1}$) and increment of soil nutrient status (6.9% N, 7.5% P, 5.4% K and 47.33% S) of the soil after harvesting of sixth crops in sequence were maximum in treatment where rapeseed crop received 40 kg S in the form of Gypsum along with $N_{80}P_{40}K_{40}$ + 5 t FYM ha^{-1} and rice crop was fertilized with 60 kg N, 30 kg P_2O_5 and 30 kg K_2O ha^{-1}. But the same crop sequence earned maximum net return (Rs 25,482/- ha $yr.^{-1}$) and return per rupee investment (Rs 1.78) when the rapeseed crop was manured with 40 kg S ha^{-1} in the form of ammonium sulphate along with $N_{80}P_{40}K_{40}$ and 5 t FYM ha^{-1} and rice crop was fertilized with 60 kg N, 30 kg P_2O_5 and 30 kg K_2O ha^{-1}. Under the same treatment combination the total productivity (4.88 t ha^{-1} $yr.^{-1}$), total equivalent rice yield (8.84 t ha^{-1} $yr.^{-1}$) total uptake of N, P, K and S (696.85 kg ha^{-1} $yr.^{-1}$) by rapeseed, mungbean and rice in the sequence per annum and increment of soil nutrient status (6.9% N, 7.9% P, 4.2% K, 31.8% S) were slightly lower than the previous treatment. Considering economic return and other factors this treatment may be recommended.

Key Words : Sources of sulphur, N, P, K and FYM, rapeseed-mungbean-rice crop sequence

Rice based cropping systems are the most popular in West Bengal as rice is the staple food crop for the people of there areas. In kharif season there is no alternative rather to grow rice. Since last two decades West Bengal was facing acute problems of protein deficiency in one hand and oil crisis on the other hand. For that the crops like mungbean and rapeseed were included in this rice based cropping system. Sulphur is essential for maximization of yield of rapeseed because of its many fold functions. Maximization of yield of crops is not possible with the application of inorganic fertilizer only. Organic manure is required both in terms of soil health and proper utilization of inorganic fertilizer. Considering all these points this experiment was planned to carry out.

MATERIALS AND METHODS

Field experiments were conducted at the Instructional Farm of the Bidhan Chandra Krishi Viswavidyalaya, West Bengal, India located at 22º56' N latitude, 88º32'E longitude at an elevation of 9.95 meters above sea level to study the integrated nutrient management under rapeseed – mungbean – rice crop sequence during 2002 – 03 to 2004 – 05. The experiment was conducted on a sandy loam entisol neutral soil (pH 6.8) having 0.058% total N, 0.554% organic carbon, 30.82 kg ha^{-1} available P_2O_5, and 147.84 kg ha^{-1} of available K_2O and 22.46 kg ha^{-1} of available sulpher. Initially experiment was laid out with Randomized Block Design having 9 manurial treatments to the first rapeseed (B – 9) crop (as in table 1) with three replications. After harvest of first season rapeseed crop first mungbean crop was taken as residual crop and thereafter all the plots were sub divided into two equal halves. Two fertilizer doses ($P_1 = N_{30}P_{15}K_{15}$ and $P_2 = N_{60}P_{30}K_{30}$ kg ha^{-1}) were randomly allotted to subsequent rice crop. So the data of third, fourth, fifth and sixth season crops were analyzed as per the split plot design considering allocation of manurial treatments to rapeseed crops in main plot (as in table 1) and fertilizer doses to rice crop in sub plot (as in table 1). The treatments were replicated thrice. The experiments were conducted for three consecutive years on the same field without disturbing the layout. Each small unit had net plot size of 5m x 3m.

Rapeseed and rice were fertilized as per treatment (as in table 1). Nutrient content of FYM used in the experiment in different years were 0.56, 0.60 and 0.58% N, 0.27, 0.28 and 0.27% P_2O_5, 0.46, 0.48 and 0.49% K_2O and 0.22, 0.24 and 0.23% S ha^{-1} in 2002 – 03, 2003 – 04 and 2004 – 05, respectively. Rapeseed crop was sown on 31.10.02, 05.11.03 and 29.10.04 and harvested on 31.01.03, 09.02.04 and 05.02.05. Mungbean crop was sown on 24.02.03 and 29.02.03 and harvested on 02.05.03 (1^{st} picking) and 12.05.03 (2^{nd} picking) and 05.05.04 (1^{st} picking) and 16.05.04 (2^{nd} picking). Rice crop was sown on 19.06.03 and 21.06.04 and harvested on 11.10.03 and 14.10.04. Variety B-9 (Binoy), B-1 (Sonali) and IET 4786 (Satabdi) were used for rapeseed, mungbean and rice crops, respectively.

RESULTS AND DISCUSSION

Productivity of crops under Rapeseed–Mungbean – Rice crop sequence

Crop yields in rapeseed–mungbean–rice sequence for consecutive three years varied significantly became of different fertilizer management schedule. Seed yield of rapeseed increased by 0.8% in second year and 10.8% in third year over first year (1.20 t ha^{-1}). This may be due to cumulative effect of manuring in each year (table 1). In every year maximum seed yield of rapeseed was recorded (1.33, 1.34, 1.49 t ha^{-1} in 1, 2 and 3rd year respectively) where the rapeseed crop received 80 kg N, 40 kg P_2O_5, 40 kg K_2O and 40 kg S as ammonium sulphate along with 5 t FYM ha^{-1}. It was observed that the rapeseed yield (average of three years) was increased by 1.5, 10.3 and 17.8% due to application of above mentioned treatment when composed with the treatments having NPK + S as ammonium sulphates, NPK + FYM and NPK alone, respectively. Performance of gypsum (1.33 t ha^{-1}) and elemental sulpher (1.29 t ha^{-1}) on seed yield (table 1) of rapeseed was slightly lower than that of ammonium sulphate (1.39 t ha^{-1}) as a source of sulphur when applied along with NPK to rapeseed crop. Sudhakar *et al.*, (2002) reported that S as ammonium sulphate with increasing rate (20, 40 or 60 kg S ha^{-1}) significantly improved the yield of irrigated mustard. Sharma *et al.*, (1992) opined alike. FYM when applied along with chemical fertilizer (NPK or NPKS) helped to increase yield (1.35 t ha^{-1}) as compared to that of chemical fertilizer alone (1.18 and 1.33 t ha^{-1} at $N_{80}P_{40}K_{40}$ or $N_{80}P_{40}K_{40}S_{40}$ kg ha^{-1} respectively). Mandal and Sinha (2004) reported the similar trend of result. In both 2nd and 3rd crops of rapeseed yielded better (1.23 and 1.35 t ha^{-1}, respectively) where the rice crop received 60 Kg N, 30 kg P_2O_5 and 30 kg K_2O ha^{-1} as compound to 30 kg N, 15 kg P_2O_5 and 15 Kg K_2O ha^{-1}.

Seed yield of mungbean was higher in second year (0.67 t ha^{-1}) than that of first year (0.53 t ha^{-1-}). When average seed yield of mungbean of two years was compared among different manurial treatments applied to preceding rapeseed crop, an increment of yield by 54% was observed with the application of $N_{80}P_{40}K_{40}$ + S_{40} as gypsum along with 5 t FYM ha^{-1} (0.77 t ha^{-1}) over that of $N_{80}P_{40}K_{40}$ along with 5 t FYM ha^{-1} (0.50 t ha^{-1}). Under similar condition when rapeseed crop received $N_{80}P_{40}K_{40}$ and S_{40} as ammonium sulphate or elemental sulphur along with 5 t FYM ha^{-1} the increment of seed yield of mungbean were 32% and 40%, respectively. The trend of results for individual year was very much similar to that of mean result (table 1). This was in line of harmony with the findings of Sreemannaryana and Raju (1993), Mondal *et al.*, (2002). Similarly mungbean yield was higher (6.15%) in fertility level of $N_{60}P_{30}K_{30}$ (0.69 t ha^{-1}) applied to preceding rice crop as compared to that of $N_{30}P_{15}K_{15}$ level (0.65 t ha^{-1}) in the second year of experiment.

Rice grain yield when averaged over two years, the application of 60 kg N, 30 kg P_2O_5 and 30 kg K_2O ha^{-1} to rice increased the grain yield of rice by 13.86% over that of 30 kg N, 15 kg P_2O_5 and 15 kg K_2O ha^{-1} (table 1). Same trend of result was noticed in both the years (table 1). This was in agreements with the findings of Masthan *et al.*, (1997).

When average grain yield of rice of two years was compared among different manurial treatments applied to preceding rapeseed crop, an increment of yield by 10.6% was observed with the application of 80 kg N, 40 kg P_2O_5, 40 kg K_2O and 40 kg S as gypsum along with 5 t FYM ha^{-1} over $N_{80}P_{40}K_{40}$ along with 5 t FYM ha^{-1}. Under similar condition when rapeseed crop received $N_{80}P_{40}K_{40}$ and S_{40} as ammonium sulphate or elemental sulphur along with 5 t FYM ha^{-1} rice yield increased by 4.9 and 7.7%, respectively. The results corroborated with the findings of Chandel *et al.*, (2002).

When system productivity was considered on per hectare and per annum basis, the maximum grain yield (5.09 t ha^{-1} $year^{-1}$) and maximum equivalent rice yield (9.16 t ha^{-1} $year^{-1}$) was recorded where the rapeseed crop received 80 kg N, 40 kg P_2O_5, 40 kg K_2O and 40 kg S as gypsum along with 5 t FYM ha^{-1} and rice crop was fertilized with 60 kg N, 30 kg P_2O_5 and 30 kg K_2O ha^{-1} (table 2). At this treatment combination (R_7P_2) yield of the system increased by 20% and 13.3% over that of $N_{80}P_{40}K_{40}$ and $N_{80}P_{40}K_{40}$ along with 5 t FYM ha^{-1}, respectively applied to rapeseed crop in combination with $N_{60}P_{30}K_{30}$ fertility level applied to rice (R_2P_2 and R_3P_2 respectively). On an average, total productivity of the sequence was increased by 14 to 18% due to addition of sulphur, irrespective of sources over that of $N_{80}P_{40}K_{40}$ alone and it was further increased by 15 to 20% due to addition of 5 t FYM along with $N_{80}P_{40}K_{40}$ + S_{40} over $N_{80}P_{40}K_{40}$ applied to rapeseed crop. Similarly, total yield increased by 9.7% due to application of $N_{60}P_{30}K_{30}$ over that of $3_{60}P_{15}K_{15}$ to the direct seeded rice.

The nutrient uptake by rapeseed – mungbean – rice crops in sequence.

The uptake of nutrients by rapeseed – mungbean – rice crops in sequence during different seasons were computed for two consecutive years

(2002 – 2003 and 2003 – 2004) and from the results is apparent that maximum uptake of nutrients (N, P, K and S) by rapeseed – mungbean – rice sequence was recorded (733.29 kg ha^{-1} $year^{-1}$) under the treatment where rapeseed crop received 80 kg N, 40 kg P_2O, 40 kg K_2O and 40 kg S in the form of gypsum along with 5 t FYM ha^{-1} and the rice was fertilized with 60 kg N, 30 kg P_2O_5 and 30 kg K_2O ha^{-1} (table 3). This might be due to the fact that the application of FYM in presence of inorganic fertilizers the nutrient becomes readily available to the crops. This result is confirmed with the findings of Chandel *et al.,* (2003).

Table 1 : Seed yield of rapeseed and mustard, mungbean and rice as affected by manuring during 2002-03 to 2004-05

Manuring to rapeseed crop	**2002-03**	**2003-2004**			**2004-2005**			**Mean of 3 yrs**
		P_1 = $N_{30}P_{15}K_{15}$	**P_2 = $N_{60}P_{30}K_{30}$**	**Mean**	**P_1 = $N_{30}P_{15}K_{15}$**	**P_2 = $N_{60}P_{30}K_{30}$**	**Mean**	
A. Seed yield of rapeseed crop (t ha^{-1})								
R_1=$N_0P_0K_0$	0.81	0.68	0.75	0.71	0.68	0.74	0.71	0.74
R_2=$N_{80}P_{40}K_{40}$	1.14	1.14	1.19	1.16	1.20	1.29	1.24	1.28
R_3=R_2+FYM(5t)	1.20	1.24	1.27	1.25	1.29	1.35	1.32	1.26
R_4=R_2+S_{40}(AS)	1.31	1.31	1.35	1.33	1.47	1.49	1.48	1.37
R_5=R_2+S_{40}(AS)+FYM(5t)	1.33	1.32	1.36	1.34	1.48	1.50	1.49	1.39
R_6=R_2+S_{40}(Gypsum)	1.26	1.28	1.31	1.29	1.44	1.46	1.45	1.33
R_7=R_2+S_{40}(Gyp)+FYM(5t)	1.29	1.31	1.34	1.32	1.45	1.48	1.47	1.36
R_8=R_2+S_{40}(EI S)	1.23	1.26	1.27	1.26	1.38	1.40	1.39	1.29
R_9=R_2+S_{40}(EI S)+FYM(5t)	1.24	1.26	1.29	1.27	1.43	1.44	1.43	1.31
Mean	1.20	1.19	1.23		1.31	1.35		
Effect of	**S.Em±**	**CD (P=0.05)**	**S.Em±**	**CD (P=0.05)**	**S.Em±**	**CD (P=0.05)**		
R (Rape Seed)	0.099	0.297	0.039	0.119	0.049	0.146		
P (Paddy)			0.011	0.032	0.020	NS		
R x P			0.033	NS	0.060	NS		
P x R			0.045	NS	0.060	NS		
B. Seed Yield of mungbean (t ha^{-1})								
R_1=$N_0P_0K_0$	0.31	0.28	0.33	0.33				0.31
R_2=$N_{80}P_{40}K_{40}$	0.38	0.53	0.55	0.54				0.46
R_3=R_2+FYM(5t)	0.40	0.58	0.62	0.60				0.50
R_4=R_2+S_{40}(AS)	0.54	0.71	0.75	0.73				0.64
R_5=R_2+S_{40}(AS)+FYM(5t)	0.57	0.72	0.77	0.74				0.66
R_6=R_2+S_{40}(Gypsum)	0.67	0.76	0.80	0.78				0.73
R_7=R_2+S_{40}(Gyp)+FYM(5t)	0.71	0.81	0.83	0.82				0.77
R_8=R_2+S_{40}(EI S)	0.62	0.73	0.78	0.75				0.69
R_9=R_2+S_{40}(EI S)+FYM(5t)	0.63	0.76	0.79	0.77				0.70
Mean	0.53	0.65	0.69					
Effect of	**S.Em±**	**CD (P=0.05)**	**S.Em±**	**CD (P=0.05)**				
R (Rape Seed)	0.032	0.095	0.086	0.260				
P (Paddy)			0.034	NS				
R x P			0.104	NS				
P x R			0.112	NS				

C. Grain yield of rice (t ha^{-1})	**2002-03**			**2003-04**			**Mean of two years**		
	P_1	**P_2**	**Mean**	**P_1**	**P_2**	**Mean**	**P_1**	**P_2**	**Mean**
R_1=$N_0P_0K_0$	2.15	2.38	2.26	2.21	2.48	2.34	2.18	2.43	2.31
R_2=$N_{80}P_{40}K_{40}$	2.23	2.48	2.35	2.23	2.51	2.37	2.23	2.50	2.37
R_3=R_2+FYM(5t)	2.26	2.50	2.38	2.39	2.65	2.52	2.33	2.58	2.46
R_4=R_2+S_{40}(AS)	2.29	2.67	2.48	2.50	2.78	2.64	2.40	2.73	2.57
R_5=R_2+S_{40}(AS)+FYM(5t)	2.29	2.69	2.49	2.51	2.80	2.65	2.40	2.75	2.58
R_6=R_2+S_{40}(Gypsum)	2.38	2.96	2.67	2.60	2.81	2.70	2.49	2.89	2.69
R_7=R_2+S_{40}(Gyp)+FYM(5t)	2.38	2.96	2.67	2.64	2.87	2.75	2.51	2.92	2.72
R_8=R_2+S_{40}(EI S)	2.34	2.76	2.55	2.55	2.80	2.67	2.45	2.78	2.62
R_9=R_2+S_{40}(EI S)+FYM(5t)	2.36	2.88	2.62	2.55	2.80	2.67	2.46	2.84	2.65
Mean	2.29	2.69		2.46	2.72		2.38	2.71	
Effect of	**S.Em±**	**CD (P=0.05)**		**S.Em±**	**CD (P=0.05)**				
R (Rape Seed)	0.134	NS		0.090	NS				
P (Paddy)	0.028	0.085		0.053	0.158				
R x P	0.159	NS		0.086	NS				
P x R	0.144	NS		0.146	NS				

Uptake of nutrient was increased by 32.36% and 23.39% due to application of the R_7 treatment ($N_{80}P_{40}K_{40}$ + S_{40} as gypsum + 5 t FYM ha^{-1} applied to rapeseed crop) over that of $N_{80}P_{40}K_{40}$ and $N_{80}P_{40}K_{40}$ along with 5 t FYM ha^{-1}, respectively. Treatment differences due to application of different source of sulphur was very much narrow (4 to 5%). Application of 60 kg N, 30 kg P_2O_5 and 30 kg K_2O ha^{-1} to the rice crop influenced to increase the uptake of nutrients in the system by 14.9% over that of 30 kg N, 15 kg P_2O_5 and 15 kg K_2O ha^{-1}.

Economic evaluation of the rapeseed-mungbean-rice sequential cropping

In crop management, a farmer is interested to produce more per unit of investment in inputs and that also from easily available resource. So it will be of great concern to evaluate the net profit per unit investment that was involved in rapeseed-mungbean-rice cropping sequence studied in this experiment. The maximum net return (Rs. 25,482.10) was earned when rapeseed crop was manured with 80 kg N, 40 kg P_2O_5, 40 kg K_2O and 40 kg S in the form of ammonium sulphate along with 5 t FYM ha^{-1} and succeeding rice crop was fertilized with 60 kg N, 30 kg P_2O_5 and 30 kg K_2O ha^{-1}. (Table 3).

Under the same treatment combination, return per rupee investment was Rs. 1.78 (table 3). Total productivity of crops in sequene and return per rupee investment were high where organic manure was added to the crop in conjunction with mineral fertilizers including sulphur as compared to those obtained under the crops fertilized only with inorganic fertilizers. This result is corroborated with the findings of Brahmachari (1996). The results thus confirmed that the country can ill afford to any reduction in the recommended dose of fertilizer application to increase the crop production through the use of modern varieties, unless the efficiency of fertilizer use can be further enhanced through judicious use of organic manures/matters in conjunction with mineral fertilizers. Return per rupee investment was increased by 0.6, 1.2 and 1.4% due to application of inorganic fertilizer viz. $N_{80}P_{40}K_{40}$ and S_{40} as ammonium sulphate or gypsum or elemental sulphur along with 5 t FYM ha^{-1} as

Table 2 : Effect of nutrient management on total productivity (t ha^{-1} yr^{-1}) and total equivalent rice yield

Manuring to rapeseed	Total productivity (t ha^{-1} yr^{-1}) Fertility levels to rice			Equivalent rice yield (t ha^{-1} yr^{-1}) Fertility levels to rice		
	$P_1(N_{30}P_{15}K_{15})$	$P_2(N_{60}P_{30}K_{30})$	Mean	$P_1(N_{30}P_{15}K_{15})$	$P_2(N_{60}P_{30}K_{30})$	Mean
$R_1=N_0P_0K_0$	3.14	3.51	3.33	4.86	5.34	5.10
$R_2=N_{80}P_{40}K_{40}$	3.90	4.24	4.07	6.97	7.38	7.18
$R_3=R_2$+FYM(5t)	4.15	4.47	4.31	7.47	7.87	7.67
$R_4=R_2+S_{40}$(AS)	4.42	4.83	4.63	8.29	8.73	8.51
$R_5=R_2+S_{40}$(AS)+FYM(5t)	4.44	4.88	4.66	8.35	8.84	8.60
$R_6=R_2+S_{40}$(Gypsum)	4.53	5.00	4.77	8.47	8.96	8.72
$R_7=R_2+S_{40}$(Gyp)+FYM(5t)	4.63	5.09	4.86	8.71	9.16	8.94
$R_8=R_2+S_{40}$(EI S)	4.44	4.83	4.64	8.23	8.67	8.45
$R_9=R_2+S_{40}$(EI S)+FYM(5t)	4.48	4.92	4.70	8.40	8.84	8.62
Mean	**4.22**	**4.63**		**7.75**	**8.20**	

Table 3 : Effect of nutrient management on total uptake of nutrients (N, P, K and S) and net return & return per rupee investment.

	Total uptake of N, P, K, S, (kg ha^{-1} yr^{-1})			Net return (Rs ha^{-1} yr^{-1})			Return $rupee^{-1}$ investment		
	P_1	P_2	Mean	P_1	P_2	Mean	P_1	P_2	Mean
R_1	370.67	452.97	411.82	4624.2	7636.4	6130.3	1.17	1.27	1.22
R_2	480.57	564.31	522.44	14746.8	17345.0	16045.9	1.48	1.55	1.52
R_3	516.49	604.44	560.47	17652.8	20154.5	18903.6	1.57	1.63	1.60
R_4	594.06	674.48	634.27	21890.9	24971.6	23431.2	1.69	1.77	1.73
R_5	613.82	696.85	655.34	22058.9	25482.1	23770.5	1.69	1.78	1.74
R_6	624.05	708.40	666.23	19589.6	23042.3	21315.9	1.56	1.64	1.60
R_7	649.72	733.29	691.51	20830.5	23877.3	22353.9	1.59	1.66	1.63
R_8	598.26	683.55	640.91	16068.9	19300.1	17684.5	1.43	1.51	1.47
R_9	620.02	705.72	662.87	16972.9	20078.6	18525.7	1.45	1.52	1.49
Mean	**563.07**	**647.11**		**17050.8**	**20155.2**		**1.51**	**1.59**	

compared to that of inorganic forms ($N_{80}P_{40}K_{40}$ and S_{40} through ammonium sulphate or gypsum or elemental sulphur, respectively) only.

Soil nutrient status after harvesting of sixth crop in the sequence

The nutrient status of soil after harvesting of sixth crop in the sequence and (N, P, K and S) from the soil as compared to their initial values in rapeseed-mungbean-rice cropping sequence with different forms and sources of fertilizer management along with organic manure have been summarized. It was clearly observed that total nitrogen decreased gradually in control a well as in treatment having $N_{80}P_{40}K_{40}$ due to continuous cropping of rapeseed, mungbean and rice crops in both the years (Fig. 1). In rest of the treatments (viz. where NPKS were applied with or without FYM) it was increased by 3 to 7% and 1.5 to 7% after first and second crop of rapeseed, respectively and by 1.7 to 3.5% and 8 to 10% in first and second crop of mungbean, respectively. In case of second crop of rice it was increased by 1.7 to 5% but it was decreased by 1.7% to 3.5% after harvest of first rice crop.

Available phosphorus and potassium content of soil (Fig. 2 & 3) were increased over initial level in all the treatments except in control plot after harvest of both the rapeseed crops. After harvest of first mungbean crop, decreasing trend of above nutrients was noticed but it was slightly reversed after harvest of second mungbean crop in treatments having NPKS along with FYM. After harvest of first rice crop both available phosphorus and potassium content of soil were decreased in most of the treatment combinations except in treatment having NPKS along with FYM. But improved trend of above nutrients content was noticed after second rice crop in treatments having NPKS with or without FYM (Fig. 4).

Sulphur content of soil was much higher than the initial value after harvesting of every crop in those treatments where sulphur was added along with NPK in conjunction with or without FYM.

At the end of sixth crop in rapeseed-mungbean-rice crop sequence, organic carbon, total nitrogen, available phosphorus, potassium and sulphur content of soil were increased over initial value by 3 to 7, 3 to 7, 7.3 to 9.4, 4 to 5 and 32 to 47% in treatment where rapeseed crop received 80 kg N, 40 kg P_2O_5, 40 kg K_2O and 40 kg S (irrespective of sources) along with FYM and rice crop was fertilized with 60 kg N, 30 kg P_2O_5 and 30 kg K_2O ha^{-1}. The corresponding nutrient contents were also showed maximum values where rice crop was fertilized with 60 kg N, 30 kg P_2O_5 and 30 kg K_2O ha^{-1} as compared to that of 30 kg N, 15 kg P_2O_5 and 15 kg K_2O ha^{-1}.

In rapeseed-mungbean-rice sequential cropping total productivity (5.09 t ha^{-1} yr^{-1}), total equivalent rice yield (9.16 t ha^{-1} yr^{-1}) total uptake of NPK and S (733.29 kg ha^{-1} yr^{-1}) and increment of soil nutrient status (6.9% N, 7.5% P, 5.4% K and 47.33% S) of the soil after sixth crop was the maximum in treatment where rapeseed crop received 40 kg S in the form of gypsum along with $N_{80}P_{40}K_{40}$ and 5 t FYM ha^{-1} and rice crop was fertilized with 60 kg N, 30 kg P_2O_5 and 30 kg K_2O ha^{-1}. But the same crop sequence earned maximum net return (Rs. 25,482/- ha^{-1} yr^{-1}) and return per rupee investment (Rs. 1.78) when the rapeseed crop was manured with 40 kg S ha^{-1} in the form of ammonium sulphate along with $N_{80}P_{40}K_{40}$ and 5 t FYM ha^{-1} and rice crop was fertilized with 60 kg N, 30 kg P_2O_5 and 30 kg K_2O ha^{-1}. Under the same treatment combination the total productivity (4.88 t ha^{-1} yr^{-1}), total equivalent rice yield (8.84 t ha^{-1} yr^{-1}), total uptake of nitrogen, phosphorus, potassium and sulphur (696.85 kg ha^{-1} yr^{-1}) by rapeseed, mungbean and rice in the sequence per annum and increment of soil nutrient status (6.9% N, 7.9% P, 4.2% K, 31.8% S) were slightly lower than that of former treatment (where gypsum was applied as a source of sulphur along with NPK and FYM). So, considering economic return and other factors application of 80 kg N, 40 kg P_2O_5, 40 kg K_2O and 40 kg S in the form of ammonium sulphate along with 5 t FYM ha^{-1} to rapeseed crop and 60 kg N, 30 kg P_2O_5 and 30 kg K_2O ha^{-1} to the direct seeded rice in rapeseed-mungbean-rice cropping sequence may be recommended for adoption by the farmers.

REFERENCES

Brahmachari, K. (1996). Nutrient management with special reference to potassium, sulphur and organic manure/matter on yield and quality development of crops in jute-rice-rapeseed sequence. Ph.D. Thesis, B.C.K.V., W.B.

Chandel, R. S.; Sudhakar, P. C.; Singh, Kabjasi and Singh, K. (2002). Effect of sulphur application on growth and yield of rice in rice-mustard cropping sequence. *Crop Res. Hissar*. **24** (2) : 261 – 265.

Chandel, R. S.; Kalyan Singh, A. K.; Sudhakar, P. C. and Singh, K. (2003). Effect of sulphur nutrition in rice and mustard grown in sequence. *Indian J. Plant Physiol*. **8** (2) : 155 – 159.

Mandal, K. G. and Sinha, A. C. (2004). Nutrient management effects on light interception, photosynthesis, growth, drymatter production and yield of Indian mustard. *J. Agron. Crop. Sci*., **190** (2) : 119 – 129.

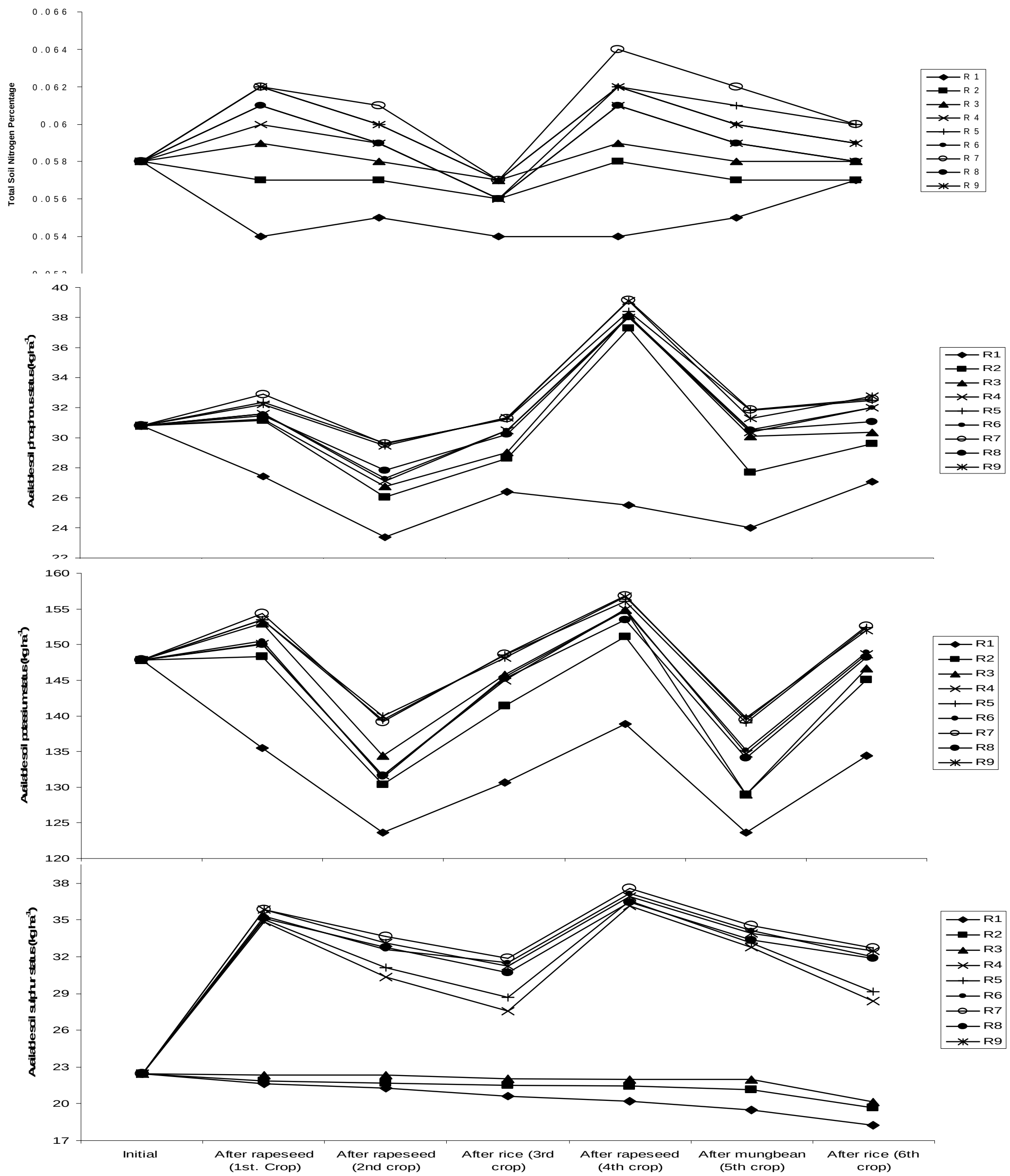

Fig. 1 - 4 : Total soils, nitrogen status (%), available soil, phosphorus, potasium and sulphur status (kg ha^{-1} during 2002 - 2003 and 2003 - 2004.

R_1-N_0 P_0K_0, R_2-$N_{80}P_{40}K_{40}$, R_3-R_2+FYM (5t), R_4-R_2+S_{40} (AS), R_5-R_2+S_{40} (AS)+FYM (5t), R_6-R_2+S_{40} (Gypsum), R_7-R_2+S_{40} (Gyp)+FYM (5t), R_8-R_2+S_{40} (El S), R_9-R_2+S_{40} (El S)+FYM (5t).

Masthan, S. C.; Reddy, S. N.; Mohammad, Shaik; Kumar, Vijay, B. and Mohammad, S. (1997). Possibilities of economizing phosphate fertilizer in rice-groundnut-greengram. *Int. J. Trop. Agric.*, **15** (1 – 4) : 223 – 228.

Mondal, S. S.; Mondal, S.; Sarkar, Sitangshu and Sarkar, S. (2002). Response of potato to sulphur bearing fertilizers and their residual effect on green gram in lower Gangetic plains of West Bengal. *Indian J. Agron*., **47** (2) : 181 – 186.

Sharma, D. N.; Khaddar, V. K.; Sharma, R. A. and Singh, D. (1992). Effect of different sources and levels of sulphur on nutrient uptake by mustard. *Crop Res. Hissar*., **5** (1) : 50 – 53.

Sreemannapayaha, B. and Raju, A. S. (1993). Direct and residual effect of applied sulphur in sunflower based cropping system. *Fertilizer News*. **38** (9) : 39 – 42.

Sudhakar, P. C.; Chandel, R. S.; Singh, Kalyan and Singh, K. (2002). Effect of sulphur, iron and silicon on the growth and yield of irrigated mustard. *Annals. Agric. Res*., **23** (3) : 483 – 485.