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EFFECT OF SULPHUR NUTRITION IN RICE (*ORYZA SATIVA* L.) AND MUSTARD (*BRASSICA JUNCEA* L. CZERN AND COSS.) GROWN IN SEQUENCE

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SUMMARY

A field experiment was conducted to study the effect of sulphur nutrition on growth and sulphur content in rice and mustard grown in sequence. The experiment was laid out in split plot design with four sulphur levels (0, 15, 30 and 45 kg ha $^{-1}$) applied to rice as main plot treatments during rainy season and each plot was further divided into three subplots (0, 20 and 40 kg S ha $^{-1}$) applied to mustard during winter season. Increasing sulphur levels in rice significantly improved leaf area index, tiller number, dry matter production, harvest index and sulphur content in rice up to 45 kg S ha^{-1} and its residual effect on leaf area index, dry matter production, harvest index and sulphur content in mustard was also significant up to 45 kg S ha^{-1}. Sulphur application to mustard improved leaf area index, dry matter production, harvest index and sulphur content in mustard upto 40 kg ha^{-1} and its residual effect on succeeding rice crop was also significant upto 40 kg S ha^{-1} with respect to leaf area index, dry matter production, harvest index and sulphur content in rice grain and straw.

Key words: **Growth, mustard, rice, sulphur.**

INTRODUCTION

Sulphur is important for growth and development of plants, since it is a constituent of sulphur containing amino acids, enzymes and is required for the synthesis of protein, chlorophyll, oil and vitamins. The increased agricultural production per unit area is being emphasized through intensive cropping systems, which involve judicious use of high analysis fertilizers. The rice-mustard cropping system depletes sulphur status of the soil and thus results in soil health problems. Large portions of applied nutrients remain in soil and augment the succeeding crop yield (Islam *et al.* 1997). Considering the above facts, an experiment was planned to study the effect of sulphur nutrition in rice and mustard grown in sequence.

MATERIALS AND METHODS

The field experiment was conducted during 1997-98 and 1998-99 at the Research Farm, Department of Agronomy, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh. The soil of the experimental field was Gangetic alluvial with pH 7.3. It was moderately fertile being low in organic carbon (0.40%), available nitrogen (184.3 kg ha^{-1}) and sulphur (13.8 kg ha^{-1}) and medium in available phosphorus (18.5 kg ha^{-1}) and potassium (208.4 kg ha^{-1}). The experiment was laid out in split plot design keeping four sulphur levels (0, 15, 30 and 45 kg ha^{-1}) as main plot during the rainy season with rice (var. Pant 12) as test crop. Each main plot was further divided into three subplots (0, 20 and 40 kg S ha^{-1}) during winter season with mustard (var. Pusa Bold) as the test crop. Treatments were randomly allocated to main and sub plots separately and were replicated five times. The lay out of the experimental plots were not disturbed throughout the experimental period. Nutrients were applied @ 120, 60, 60 kg ha^{-1} and 90, 60, 40 kg ha^{-1} N, P_2O_5, K_2O to rice and mustard respectively through urea, diammonium phosphate (DAP) and muriate of potash. Sulphur was applied as per treatment through single super phosphate (SSP) and phosphorus added to soil through SSP was balanced accordingly by reducing the quantity of DAP in each SSP treated plots.

RESULTS AND DISCUSSION

Sulphur levels had pronounced effect on leaf area index and it increased with each increment of sulphur levels upto 45 kg ha^{-1} (Table 1). This can be attributed to the positive role of sulphur in vigorous leaf growth resulting in increased leaf area index (Sachdev *et al.* 1982). Leaf area index of rice also increased due to sulphur application to preceding crop mustard during second year only and 40 kg S ha^{-1} performed best indicating its residual effect on succeeding crop. Sulphur increased the tiller number in rice at all the stages of crop growth (Table 1). Application of 30 kg S ha^{-1} significantly increased tiller number over 15 kg S ha^{-1} and control, however, it was at par with 45 kg S ha^{-1}. Application of 40 kg S ha^{-1} to mustard significantly increased tiller number at all the growth stages as compared to 20 kg S ha^{-1} and control during second year only due to its residual effect.

Sulphur application significantly increased dry matter accumulation at all the crop growth stages (Table 2) and each increment in sulphur level upto 45 kg ha^{-1} accumulated significantly higher amount of dry matter than its lower levels. The increased dry matter production due to sulphur application might be due to increased leaf area index, which improves photosynthesis (Singh *et al.* 1993). Dry matter production in rice also increased with each increment of sulphur levels in mustard at all the growth stages. This may be due to residual sulphur and its effect on succeeding rice crop, thus the highest dry matter production was recorded with 40 kg S ha^{-1} applied to mustard while the lowest value was associated with control. Maximum harvest index was recorded with 45 kg S ha^{-1} while the lowest value was recorded with control (Table 2). Sulphur application to mustard significantly increased harvest index of rice over control only during second year. A higher value of harvest index indicated more efficient translocation of metabolites from source to sink and improvement in grain yield can be achieved entirely by increasing the harvest index without an increase in straw or total biological yield (Yoshida and Chaudhury 1979).

Table 1. Effect of sulphur levels on leaf area index and tiller number at different stages in rice.

Sulphur levels (kg ha^{-1})	Leaf area index						Tiller no. (m^{-2})					
	Tillering stage		Panicle initiation stage		Maturity stage		Tillering stage		Panicle initiation stage		Maturity stage	
	1997-98	1998-99	1997-98	1998-99	1997-98	1998-99	1997-98	1998-99	1997-98	1998-99	1997-98	1998-99
Main plots (Rice)												
R_0	2.37	2.04	3.74	3.40	2.41	2.20	354.80	374.40	379.60	395.40	312.40	352.40
R_{15}	2.64	2.33	4.59	4.16	2.94	2.59	396.00	386.80	398.40	405.20	344.80	367.60
R_{30}	2.86	2.54	5.18	5.06	3.33	3.16	410.80	410.00	420.60	421.40	358.40	375.80
R_{45}	3.29	2.75	5.81	5.39	3.72	3.40	421.80	416.00	425.60	429.80	364.80	380.60
SEM±	0.060	0.040	0.100	0.090	0.040	0.040	4.040	3.230	1.760	3.160	2.640	2.370
CD (P=0.05)	0.170	0.130	0.320	0.270	0.130	0.130	12.560	9.960	5.420	9.730	8.130	7.300
Sub plots (Mustard)												
M_0	2.78	2.39	4.81	4.48	3.09	2.79	395.25	395.60	405.10	411.00	358.65	358.90
M_{20}	2.79	2.41	4.83	4.50	3.10	2.84	395.85	396.80	406.65	412.95	395.10	369.20
M_{40}	2.80	2.44	4.86	4.52	3.12	2.88	396.45	398.00	406.40	414.90	360.55	379.20
SEM±	0.004	0.010	0.020	0.003	0.010	0.010	0.540	0.150	0.510	0.250	0.550	0.360
CD (P=0.5)	NS	0.020	NS	0.010	NS	0.020	NS	0.420	NS	0.710	NS	1.080

Table 2. Effect of sulphur levels on harvest index and dry matter accumulation at different stages in rice.

Sulphur levels ($kg\ ha^{-1}$)	Dry matter accumulation ($g\ hill^{-1}$) Tillering stage		Panicle initiation stage		Maturity stage		Harvest index (%)	
	1997-98	1998-99	1997-98	1998-99	1997-98	1998-99	1997-98	1998-99
Main plots								
(Rice)								
R_0	4.95	7.40	22.40	23.69	28.90	35.64	37.38	41.57
R_{15}	5.36	8.42	28.73	26.04	34.16	37.50	38.00	42.72
R_{30}	5.66	9.50	32.56	30.40	36.02	38.95	38.09	42.71
R_{45}	5.70	10.45	33.22	30.84	36.44	39.68	38.16	43.18
SEM±	0.090	0.190	1.050	0.330	0.520	0.370	0.200	0.330
CD (P=0.05)	0.270	0.580	3.220	1.010	1.600	1.160	0.620	1.020
Sub plots								
(Mustard)								
M_0	5.39	8.60	29.09	27.69	33.85	37.01	37.93	42.42
M_{20}	5.42	8.84	29.21	27.74	33.88	38.12	37.92	42.57
M_{40}	5.44	9.09	29.42	27.80	33.91	38.71	37.90	42.72
SEM±	0.010	0.080	0.120	0.010	0.040	0.120	0.020	0.050
CD (P=0.05)	NS	0.230	NS	0.02	NS	0.360	NS	0.160

Each increment in sulphur level significantly improved sulphur content in rice shoot at all the crop growth stages as well as at harvest (grain and straw) (Table 3). The sulphur content in rice shoot was initially higher at early growth stages while it decreased with the advancement in age of crop and reached its minimum level at crop harvest. It may be simply due to dilution effect (Singh *et al.* 1993). Sulphur content in rice also increased with increasing sulphur levels to mustard and the maximum content was obtained with the residual effect of 40 kg ha^{-1} sulphur applied to preceding mustard crop which was significantly superior to control.

In mustard leaf area index increased upto flowering stage and decreased thereafter irrespective of the treatment (Table 4). Increasing sulphur levels to mustard brought about marked increase in leaf area index at all the growth stages and sulphur application @ 40 kg ha^{-1} proved to be superior over its lower levels. Similar finding has also been reported by Jain *et al.* (1995). The effect on leaf area index due to residual effect of sulphur on mustard differed significantly and increase in leaf area index was significant upto 45 kg S ha^{-1} applied to preceding rice crop.

Sulphur application to mustard also differed significantly with respect to dry matter production and the best treatment was 40 kg S ha^{-1} (Table 4). Residual effect of sulphur applied to preceding rice on dry matter production of mustard also differed significantly among themselves during both the years except 45 and 30 kg ha^{-1} at bud formation and flowering stages during first year and at pod formation stages during both the years whereas, sulphur application @ 45 kg ha^{-1} was significantly superior to 30 kg ha^{-1} at harvest stage during both the years. The slow growth rate during initial stages of crop growth might be due to the lower assimilatory surface area leading to low photosynthetic rate and low dry matter accumulation (Dubey and Khan 1993 and Chandel *et al.* 2002). Harvest index increased with application of sulphur to rice and 45 kg S ha^{-1} registered significantly higher yield over control (Table 5). Application of 40 kg S ha^{-1} to mustard also significantly increased harvest index over control. In rapeseed also, increase in yield is closely linked to increase in the harvest index (Diepenbrock 2000) since it is related with the effective translocation of photosynthates to grain.

Table 3. Effect of sulphur levels on sulphur content (%) in shoot and grains in rice.

Sulphur levels (kg ha^{-1})	Tillering stage		Panicle initiation stage		Maturity stage Grain		Maturity stage Straw	
	1997-98	1998-99	1997-98	1998-99	1997-98	1998-99	1997-98	1998-99
Main plots								
(Rice)								
R_0	0.300	0.292	0.244	0.239	0.115	0.110	0.140	0.140
R_{15}	0.330	0.345	0.297	0.269	0.141	0.137	0.173	0.171
R_{30}	0.378	0.374	0.313	0.293	0.159	0.152	0.201	0.193
R_{45}	0.409	0.393	0.327	0.310	0.169	0.162	0.220	0.214
SEM±	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.001
CD (P=0.05)	0.002	0.005	0.004	0.003	0.002	0.002	0.006	0.003
Sub plots								
(Mustard)								
M_0	0.356	0.345	0.295	0.275	0.145	0.139	0.183	0.17
M_{20}	0.356	0.352	0.295	0.277	0.146	0.140	0.183	0.182
M_{40}	0.357	0.356	0.296	0.280	0.146	0.142	0.184	0.184
SEM±	0.001	0.001	0.0001	0.0002	0.0001	0.0003	0.0001	0.0002
CD (P=0.05)	NS	0.004	NS	0.0005	NS	0.0010	NS	0.0005

Table 4. Effect of sulphur levels on leaf area index and dry weight at different stages in mustard.

Sulphur levels (kg ha^{-1})	Leaf area index Bud formation		Leaf area index Flowering stage		Leaf area index Pod formation		Dry weight (g plant^{-1}) Bud formation		Dry weight (g plant^{-1}) Flowering stage		Dry weight (g plant^{-1}) Pod formation		Dry weight (g plant^{-1}) Maturity stage	
	97-98	98-99	97-98	98-99	97-98	98-99	97-98	98-99	97-98	98-99	97-98	98-99	97-98	98-99
Main plots														
(Rice)														
R_0	0.520	0.494	3.74	3.62	3.11	3.07	0.76	0.55	10.39	14.57	16.26	20.79	26.03	33.57
R_{15}	0.533	0.506	3.83	3.75	3.19	3.20	0.81	0.57	11.31	15.16	17.19	22.57	28.46	37.34
R_{30}	0.560	0.516	3.96	3.88	3.28	3.32	0.85	0.61	12.04	15.58	18.32	24.72	30.46	40.82
R_{45}	0.571	0.532	4.08	3.99	3.34	3.45	0.86	0.65	12.42	16.77	18.54	25.63	32.16	42.56
SEM±	0.001	0.001	0.027	0.011	0.011	0.040	0.018	0.043	0.162	0.136	0.293	0.393	0.521	0.526
CD (P=0.05)	0.004	0.003	0.084	0.029	0.035	0.122	0.056	NS	0.498	0.418	0.903	1.211	1.604	1.622
Sub plots														
(Mustard)														
M_0	0.502	0.492	3.60	3.43	2.97	3.00	0.76	0.54	10.42	13.53	16.12	21.34	25.50	32.58
M_{20}	0.538	0.509	3.87	3.72	3.22	3.23	0.83	0.60	11.72	16.18	17.72	23.66	30.04	38.03
M_{40}	0.589	0.535	4.27	4.28	3.51	3.59	0.88	0.65	12.47	16.86	18.81	25.29	32.06	45.10
SEM±	0.001	0.001	0.026	0.010	0.010	0.032	0.015	0.015	0.079	0.138	0.213	0.281	0.558	0.580
CD (P=0.05)	0.003	0.003	0.075	0.028	0.028	0.093	0.044	0.042	0.229	0.397	0.612	0.808	1.606	1.668

Table 5. Effect of sulphur levels on harvest index and sulphur content in shoot and seeds in mustard.

Sulphur levels (kg ha^{-1})	Harvest index (%)		Sulphur content (%) Bud formation		Flowering stage		Pod formation		Maturity stage Seed		Stover	
	97-98	98-99	97-98	98-99	97-98	98-99	97-98	98-99	97-98	98-99	97-98	98-99
Main plots (Rice)												
R_0	17.78	16.82	0.483	0.509	0.414	0.436	0.378	0.388	0.462	0.466	0.176	0.166
R_{15}	19.29	18.76	0.519	0.572	0.443	0.453	0.401	0.407	0.471	0.478	0.196	0.183
R_{30}	19.59	19.48	0.569	0.613	0.483	0.517	0.437	0.455	0.498	0.502	0.232	0.209
R_{45}	19.62	19.86	0.605	0.648	0.513	0.576	0.510	0.521	0.518	0.418	0.271	0.248
SEM±	0.115	0.163	0.002	0.004	0.001	0.001	0.001	0.001	0.003	0.001	0.0006	0.001
CD (P=0.05)	0.355	0.501	0.006	0.012	0.003	0.003	0.003	0.003	0.0011	0.003	0.0020	0.002
Sub plots (Mustard)												
M_0	18.39	17.60	0.459	0.506	0.408	0.428	0.332	0.359	0.441	0.462	0.134	0.136
M_{20}	19.24	19.18	0.556	0.589	0.461	0.502	0.443	0.446	0.475	0.492	0.227	0.201
M_{40}	19.58	19.41	0.618	0.612	0.520	0.557	0.519	0.523	0.533	0.520	0.296	0.268
SEM±	0.109	0.096	0.001	0.003	0.001	0.002	0.001	0.005	0.0003	0.001	0.004	0.001
CD (P=0.05)	0.313	0.275	0.003	0.011	0.003	0.010	0.002	0.017	0.0010	0.002	0.0011	0.002

It was observed that each additional dose of sulphur applied to mustard significantly increased sulphur content in seed and stover (Table 5) and the highest sulphur content was recorded with 40 kg S ha^{-1} at all the stages of mustard. Sulphur content in shoot at different stages of crop growth as well as at harvest (seed and stover) differed significantly due to residual effect of sulphur applied to preceding rice crop up to 45 kg S ha^{-1}. The maximum sulphur content in mustard plant was observed at early stage of crop growth and it decreased gradually with the advancement of crop growth stages (Singh and Singh 1984). At later stages lower sulphur content in shoot may be due to dilution effect of nutrients in plant parts (Tripathi and Sharma 1994).

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