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Effect of Biogenic Silica Soil Conditioner on Paddy Crop in India

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Abstract: Now-a-days various soil conditioners are being discovered and used in agriculture to increase soil fertility and crop productivity. Different soil conditioners are being used in this direction to improve the food production from the poor and medium soils. In this category, a new product, diatomaceous earth - Biogenic Silica, having the characteristics of good soil conditioner, is now studied in this article to improve the nutrient status and productivity of the soil of paddy field at Jabalpur, India. The results of one season field experiments showed significant improvement in the nutrient content of paddy field soil of medium fertility, and improvement in the yield attributes like plant population (119 plants/m^2), tillers (279/m^2), effective tillers (256/m^2), grains (163/panicle), test weight (21.28 g) and panicle length (24.42 cm). Similarly, grain yield (max. 45.74 q/ha) and straw yield (max. 92.49 q/ha) of rice were improved significantly by application of Biogenic Silica at the dose of 500 kg/ha separately both at transplantation stage and at full bloom stage of rice crop. The improvement in soil nutrients over initial values was up to maximum 2% in soil nitrogen, 42.25% in case of phosphorus and 3.2% in potassium content.

Key Words: Diatomaceous Earth, Paddy, Productivity, Soil Fertility

INTRODUCTION

Ever increasing population in the world, accompanied by decreasing per capita arable land, has ringed the bell to increase the production of food from the available land. Various technological interventions are being used to improve the yield of crop. Use of novel soil conditioners is one of these techniques to improve the fertility and quality of agricultural soils and to improve the productivity of land. Diatomaceous earth, which is Biogenic Silica (BS) derived from diatoms, has attracted the attention of a few researchers as potentially promising product for use in agriculture. Presently, it is being used in the garden as natural pest control substance. A few references are available on the use of BS as soil conditioner for turf grass growth and used as top dressing (Wehtje et al., 2003; Waltz and McCarty, 2000) while there is no reference on crops from India. Brown (2013) who has shown experimentally that diatomaceous earth spent cake from filters can be used as fertilizer to improve the growth of crops. He has reported that the BS has favorable physicochemical properties as soil conditioner. In this research paper, Biogenic Silica is used in India for the first time as novel soil conditioner for studying its favorable impact on soil fertility and growth and yield of paddy.

MATERIALS AND METHODS

The Biogenic Silica was securely collected from the mining area. The field experiment on paddy crop was carried out during 2014. The transplantation of paddy was carried out on 14th July 2014 (rainy season) at Jabalpur, India having black soil. In Experimental Set-1, the different doses of Biogenic Silica at 250 kg/ha, 375 kg/ha and 500 kg/ha were applied to paddy field soil before transplantation. In Experimental Set II, Biogenic Silica dose of 500 kg/ha was applied separately to the soil of rice field at each of three different stages of paddy crop. At Stage I (T1), Biogenic Silica was applied at the time of vegetative growth (VG) (30-35 days after sowing); at Stage II (T2), it was applied at the time of full bloom (FB) (Flowering stage) and; at Stage III (T3), it was applied at the time of development stage of grains in panicles. All the experimental plots of paddy field were also applied with recommended dose of fertilizer (RDF) (120:60:40 kg NPK/ha). The treatments were given in different experimental plots in the paddy field. Paddy variety IR-64 was selected as rice cultivar. The soil in the field was subjected to excessive dispersion during puddling, resulting into drastic change in their pore size distribution. The paddy crop was harvested on 12th November 2014.

A total of six treatments over 18 plots were arranged in a completely randomized design and each treatment was carried out in three replications (6x3=18). The gross and net plot sizes were 5m x 3.6 m and 4 m x 3.2 m respectively. The distance between the replications was kept at 1.5 m and the distance between the rows was kept at 20 cm. The powder form of Biogenic Silica was applied to paddy field soil at proper doses and mixed mechanically within 15 cm depth of the surface soil. The basal RDF dose applied into soil two days before rice transplanting was given as: nitrogen (50% dose), phosphorus (100% dose), and potash (100% dose). Each dose of top dressing fertilizer (nitrogen 25%) was added after one and two months of transplanting. Water level was controlled at around 5-7 cm depth during the cropping season and rice was harvested 150 days after transplantation. Soil was collected from the test field from 30 cm depth from three places from each treatment before sowing and after harvest, air dried, sieved (<10mm). Pre-sowing soil was analyzed for physicochemical parameters to evaluate the quality and nutrient content of soil. Post-harvest soil was analyzed for nutrient content (Jackson, 1973) to evaluate the effect of Biogenic Silica on nutrient content of soil wiz. available nitrogen (N), available phosphorus (P), and available potassium (K). At pre-harvest stage, the observations on crop were recorded on plant population/m^2 and number of tillers/m^2; and at Post-harvest stage on Effective tillers/m^2, number of grains /panicle, test weight (g), grain yield (q/ha), and straw yield (q/ha).

RESULTS AND DISCUSSION

Project Site

Jabalpur from Madhya Pradesh, India has humid subtropical climate. Summer starts in late March and lasts up to June. May is the hottest month with average temperatures reaching up to and beyond 45^0C. Summer is followed by monsoon season, which lasts until early October, with a total precipitation of nearly 55 inches (1386 mm). Winter starts in late November and lasts until early March. The cold peaks in January with average daily temperature near to 15^0C.

Biogenic Silica

The Biogenic Silica is naturally occurring, soft, chalk-like sedimentary rock that is easily crumbled into a fine white to off-white powder. It is very light due to its high porosity. It consists of fossilized remains of diatoms (Fresenberg, 1999), a type of hard-shelled algae, which is also heat-resistant. The diatoms pull silica acid of water and store large amount of crystallized silica in their outer walls. When diatoms die, much of silica dissolves back into water and rest of it collects in sediments to be recycled by geologic forces. Eventually some of the silica returns to the land in pure pockets. The silicates mined from these clean, rich deposits are useful for farmers, providing both water soluble and flowable silica in a form that is beneficial to plants and plant growth-promoting microorganisms.

Chemically, BS is like silica sand in that it consists of about 90% silica (SiO_2) with minor amounts of alumina (Al_2O_3) (Mannion, 1996). BS is porous, thus have low densities and can retain water up to 150% of its weight while draining fast and freely allowing high oxygen circulation within the growing medium and beneficial nutrient for plant growth. BS improves the uptake of water and minerals and adds an extra level of protection against fungal diseases such as powdery mildew. The BS has sharp edges that tear up insects crawling over them. BS is the reservoir of plant-available silica and nutrients and trace elements. Freshwater diatomite is typically food-grade due to its fine particle size and low silica content and is typically the variety used for consumption, health products and pest control. Saltwater BS should not be used in the same way due to its high silica content.

Paddy Field Soil Quality before Transplantation

The soil of experimental field before the transplantation of paddy seedlings was observed to be clayey in texture (however with excess clay) (Table I), with ideal electrical conductivity (EC) & pH; medium-low organic carbon, medium potassium; low nitrogen and very low phosphorus as per the guidelines for rating the soil fertility indicators in India (Table II) (Tandon, 2005) and also the guidelines given by Utah State University in cooperation with U.S. Department of Agriculture (Table III). It is concluded that the soil is of medium fertility level. This low content of P in the Jabalpur soil is in conformity with the report (Chandy, 2013) that medium black soils of semi-arid regions have a medium fertility level with respect to phosphorus. The reason for medium-low N is the medium organic carbon content of soil. Soil organic carbon has role in improving and maintaining soil fertility, structure, stability, nutrient retention & restricting soil erosion (Singh, 2008).

Improvement of Available Nutrients in Soil

The Experimental Set I screening experiment carried out on application of different doses of Biogenic Silica to paddy field at the time of transplantation showed encouraging results in improving the nutrient content of the paddy field soils over their initial value (Table IV, Figure 1 & 2). All the doses of Biogenic Silica improved the phosphorus content significantly ranging from 38.72% to 42.17%, highest being in 500 kg/ha dose. Similarly, percentage improvement in potassium content over initial was observed from 0.81% to 2.02%, and was in increasing order with increasing doses of Biogenic Silica, highest being in 500 kg/ha dose. In case of nitrogen content, 375 kg/ha dose of Biogenic Silica showed highest improvement by 1.08% over its initial value.

In Experimental Set II, the results of separate applications of 500 kg/ha Biogenic Silica at different stages of paddy crop life cycle (Table IV, Figure 1 & 2) showed highest improvement in the content of all nutrients when 500 kg/ha Biogenic Silica was applied at full bloom stage. The percentage improvement over initial value was 2.00% in nitrogen, 42.25% in phosphorus and 3.2% in case of potassium.

Similar results were obtained by Southern Cross University in Australia, where the moisture retention and nutrient level of the soil were significantly improved and leaching of any fertilizer was greatly reduced by BS application. It was also seen that addition of BS to soil amended with fertilizer may allow for more efficient use of fertilizer and reduce leaching of nutrients (Absorbent Products, info@absorbentproductsltd.com, browsed on 1st November 2015).

Improvement in Yield Attributes and Yield of Rice

The results of the Experimental Set I on effect of different doses of Biogenic Silica application in paddy field soil at the time of transplantation (Table V) showed that all the yield parameters of rice showed improvement in all doses of Biogenic Silica. The improvement was directly proportional to the increase in Biogenic Silica concentration; the range of improvement was observed as population (116 to 117 Plants/m2), tillers (251 to 261 tillers/m2), effective tillers (230 to 241 effective tillers/m2), grains (144 to 155 grains/panicle), test weight (19.86 g to 21.23 g) and panicle length (22.36 cm to 23.82 cm). These results showed that the Biogenic Silica dose of 500 kg/ha is optimum to increase the yield attributes of the rice.

The results of the Experimental Set II on the effect of Biogenic Silica dose of 500 kg/ha on the yield parameters are shown in Table V. It was observed that all the yield parameters were improved at application of 500 kg/ha Biogenic Silica at full bloom stage to the paddy field soil. The highest values of yield parameters at full bloom stage application were observed as plant population (119 plants/m2), tillers (279 tillers/m2), Effective tillers (256 effective tillers/m2), grains (163 grains/panicle), test weight (21.28 g) and panicle length (24.41 cm). It is also observed that the yield parameters were best improved at Biogenic Silica (500 kg/ha) application at transplantation stage which is next to application of Biogenic Silica (500 kg/ha) at bloom stage. Thus, it is evident that application of Biogenic Silica dose at 500 kg/ha at transplantation and at full bloom stage would give best results in improving yield attributes of paddy crop.

Similar trend of results were obtained in case of grain yield and straw yield of paddy crop (Table VI). Results of doses of Biogenic Silica application (Experimental Set I) at transplantation stage indicated gradual increase in the grain and straw yield of rice with increase in doses of Biogenic Silica from 250 kg/ha to 500 kg/ha. The highest yields at 500 kg/ha dose were 43.38 q/ha of grains and 90.37 q/ha of straw. Similarly, the application of Biogenic Silica at 500 kg/ha at full bloom stage (Experimental Set II) showed highest grain yield of 45.74 q/ha and straw yield of 92.49 q/ha. The yields Biogenic Silica (500 kg/ha) at transplantation stage and at full bloom stage are very much near to each other and highest among all treatments. Thus, application of Biogenic Silica (500 kg/ha) at transplantation stage and at full bloom stage is optimum to improve the yield attributes and grain and straw yield of paddy crop.

Conclusion

The results showed that the optimum dose of Biogenic Silica is 500 kg/ha for improvement of yield attributes and yield of paddy crop. This dose when applied at transplantation stage and at full bloom stage was observed to improve the nutrient content of paddy field soil especially the phosphorus content as well as the yield attributes and yield of paddy. The Biogenic Silica is observed to have good potential as soil conditioner at very low doses. More experiments are desirable to study the suitability of Biogenic Silica for different types of soils, different crops and under different climatic conditions.

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Table I: Qualitative Ratings of Soil Nutrients in Experimental Fields before Sowing

Description	Sand	Silt	Clay	Texture	pH	EC (dS/m)	Organic carbon (%)	Available plant nutrients (kg / ha)		
								N	**P**	**K**
Nutrient content	25.18	19.18	55.64	Clayey	7.1	0.31	0.54	266	12.45	293
Qualitative Ratings	Ideal	Ideal	Un-Accepta-ble	Accepta-ble	Ideal	Ideal	Medium Low	Low	Very Low	Medium

Table II: Soil Fertility Classification Followed in Maharashtra & Some Other States

Soil fertility level	Organic Carbon (%)	Available N (kg/ha)	Available P2O5 (kg/ha)	Available K2O (kg/ha)
Very High	>1.00	>700	>80.0	>360
High	0.81-1.00	561-700	64-80	301-360
Medium	0.61-0.80	421-560	48-64	241-300
Medium Low	0.41-0.60	281-420	32-48	181-240
Low	0.21-0.40	141-280	16-32	121-180
Very Low	<0.20	<140	<16.0	<120

Source: Tandon (2005)

Table III: Guidelines Category of Soil Parameters for the Growth of Crops

Category	Soluble Salts (EC) (dS/m or mmho/cm)	pH	Sand (%)	Silt (%)	Clay (%)	Texture Class*	Organic Matter (%)	% Coarse fragments (>2 mm in diameter)**	Sodium Adsorption Ratio (SAR)*
Ideal	<3	5.5 to 7.5	<70	<70	<30	L, SiL	≥2.0	≤ 2	<3 for any texture
Acceptable	<4	5.0 to 8.2	<70	<70	<30	SCL, SL, CL, SiCL	≥1.0	2.1 to 5.0	3 to 7 (SiL, SiCL, CL) 3 to 10 (SCL, SL, L)
Un-acceptable	>4	<5.0 or >8.3	>70	>70	>30	LS, SC, SiC, S, Si, C	<1.0	5.0	> 10 for any texture

Source: Utah State University Cooperation with the U.S. Department of Agriculture under Cooperative Extension Work (AG/SO-02, 2002) [S: Sand; Si: Silty; C: Clay; L: Loam; LS: Loamy Sand; SL: Sandy Loam; SCL: Sandy Clay Loam; CL: Clay Loam; SiCL: Silty Clay Loam; SC: Sandy Clay; SC: Silty Clay; SiC: Silty clay; SiL: Silty loam]

Table IV: Effect of Biogenic Silica Application on Soil Nutrient Content as Influenced by Different Doses of Biogenic Silica and Time of Application

Treatments	Dose/Time of Application	Nitrogen	Phosphorus	Potassium
		Nutrient content (kg/ha) and Percentage Increase / Decrease		
Pre-Sowing Content		266	12.45	293
Experimental Set I: Application of different Biogenic Silica doses at the time of transplantation	250 kg/ha	264.76 (-0.47%)	17.27 (38.72%)	295.37 (0.81%)
	375 kg/ha	268.86 (1.08%)	17.52 (40.72%0	297.13 (1.41%)
	500 kg/ha	267.5 (0.56%)	17.7 (42.17%)	298.91 (2.02)
SEm±		1.02	0.4	0.82
CD at 5%		3.08	NS	2.47
Experimental Set II: Separate application of Biogenic Silica at 500 kg/ha dose at different stages of crop life cycle	At vegetative growth stage	266.55 (0.21%)	17.67 (41.93%)	299.12 (2.09%)
	At full bloom stage	271.32 (2.00%)	17.71 (42.25%)	302.36 (3.20%)
	At grain development stage	263.25 (-1.03)	17.11 (37.43%)	289.94 (-1.04%)
SEm±		1.02	0.41	0.82
CD at 5%		3.08	NS	2.47

Table V: Effect of Biogenic Silica Application on Yield Attributes of Rice as Influenced by Different Doses of Biogenic Silica and Time of Application

Treatments		Plant Populat-ion / m2	Number of Tillers/ m2	Number of Effective Tillers/ m2	Number of Grains/ Panicle	Test Weight (g)	Panicle Length (cm)
Experimental Set I: Application of different Biogenic Silica doses at the time of transplantation	250 kg/ha	116	251	230	144	19.86	22.36
	375 kg/ha	117	257	237	152	20.43	23.06
	500 kg/ha	117	261	241	155	21.23	23.82
SEm±		2.29	2.08	2.25	1.24	0.24	0.31
CD at 5%		NS	6.24	6.74	3.72	0.71	0.93
Experimental Set II: Separate application of Biogenic Silica at 500 kg/ha dose at different stages of crop life cycle	At vegeta-tive growth stage	115	258	234	147	20.55	23.68
	At full bloom stage	119	279	256	163	21.28	24.41
	At grain develop-ment stage	116	236	218	142	19.69	21.61
SEm±		2.29	3.60	2.25	1.24	0.24	0.31
CD at 5%		NS	10.81	6.47	3.72	0.71	0.93

Table VI: Effect of Biogenic Silica Application on Yield of Rice as Influenced by Different Doses of Biogenic Silica and Time of Application

Treatments		Grain Yield (q/ha)	Straw Yield (q/ha)
Experimental Set I: Application of different Biogenic Silica doses at the time of transplantation	250 kg/ha	39.59	80.48
	375 kg/ha	42.06	86.92
	500 kg/ha	43.58	90.37
SEm±		1.02	1.92
CD at 5%		3.08	5.77
Experimental Set II: Separate application of Biogenic Silica at 500 kg/ha dose at different stages of crop life cycle	At vegetative growth stage	41.09	86.68
	At full bloom stage	45.74	92.49
	At grain development stage	38.40	78.59
SEm±		1.02	1.92
CD at 5%		3.08	5.77

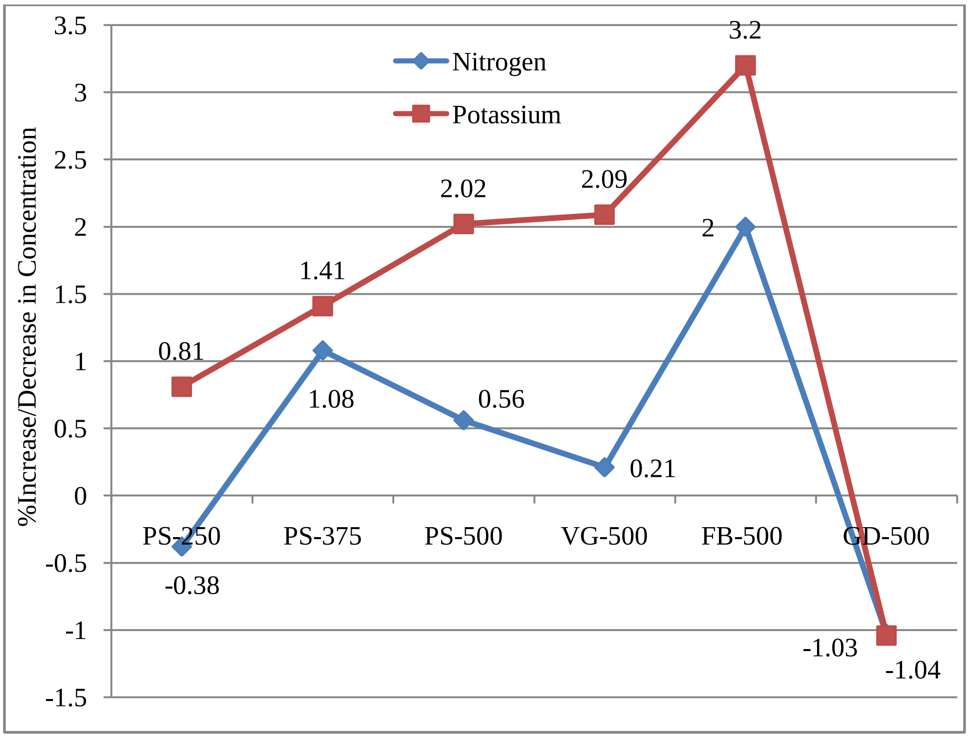

Figure 1: Percentage Increase / Decrease in the Concentration of Soil Nitrogen and Potassium in Treatments as Compared to Initial Concentration (PS: pre sowing; VG; vegetative stage; FB: full bloom stage; GD: grain development stage)

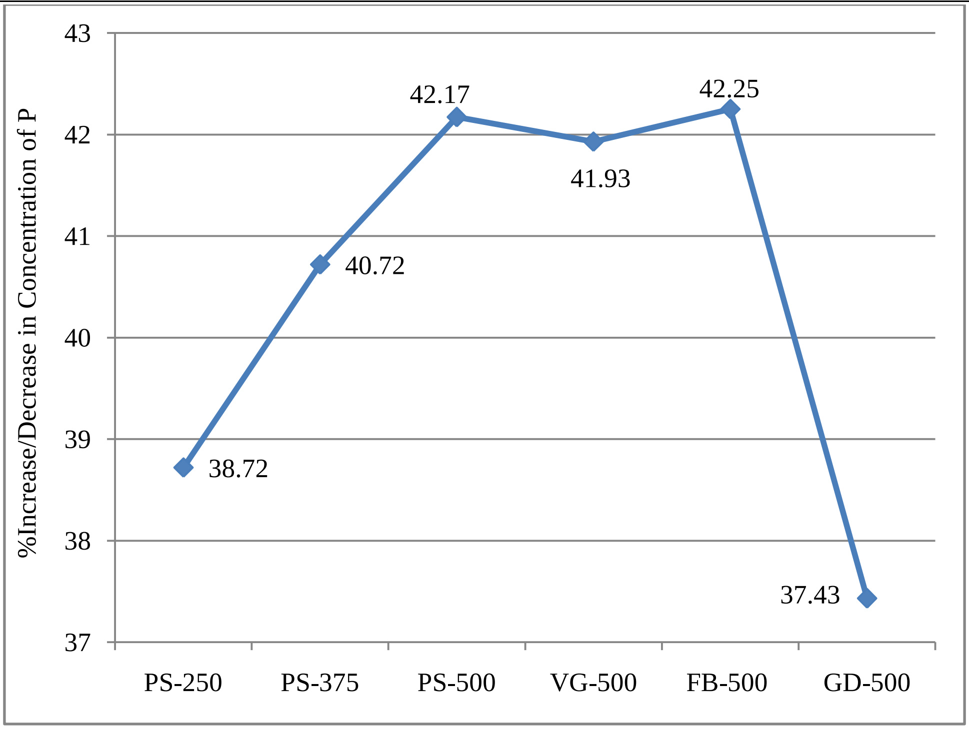

Figure 2: Percentage Increase / Decrease in the Concentration of Soil Phosphorus in Treatments as Compared to Initial Concentration (PS: pre sowing; VG; vegetative stage; FB: full bloom stage; GD: grain development stage)