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Yield and soil properties influenced by levels of phosphorous and silica under submerged rice

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Abstract
The study aimed to determine the effect of silica and phosphorous levels on soil properties and yield of rice crop during kharif season, 2019. The experiment was laid out in factorial randomized block design with total fifteen treatment combinations. Phosphorus was applied at levels of 0, 25, 50, and 75 kg ha^{-1} and silica was applied at four levels i.e. 0, 50, 100, 150 kg ha^{-1}. Result of the experiment revealed that, the grain and straw yield of rice recorded highest due to sole and combine application of phosphorous @ 75 kg ha^{-1} and silica @ 150 kg ha^{-1}. The available phosphorous and silica content significantly increased by phosphorous application @ 75 kg ha^{-1}. Thus it is concluded that, application of phosphorous @ 75 kg ha^{-1} along with silica @ 150 kg ha^{-1} is effective for beneficial improvement in yield and soil properties under rice crop.

Keywords: silica, phosphorus, rice, available nutrients and yield

Introduction
Rice based agriculture is the main and largest source of livelihood of majority of rural peoples in Konkan which lies along the Arabian seacoast at the extreme western part of the Indian peninsula. In Maharashtra, Konkan region having about 80 per cent of rice crop is under low land, spreading over a 40-60 km in width and about 700 km stretching to a length all along the west-coast. The yields are highly variable due to inconsistency in weather like intermittent dry spell, late onset of monsoon, heavy continuous rains and heavy rains at the time of harvesting etc. The Konkan region occupies an area of about 0.39 million hectares under rice with production of about 253 million tonnes and productivity around 2.93 t ha^{-1} (Anonymous, 2018) [1].

Silica is in abundant quantity in earth crust, but only monosilisic form of silicon is available to the plants. In soils, silicon is generally grouped into three different fractions; they are liquid phase, adsorbed phase and solid phase. The largest fraction of silicon in the solid phase is the crystalline forms that occur primarily as primary and secondary silicates and silica materials. The fractions of dissolved silicic acid in the soil solution are adsorbed onto a variety of solid phases in soils, including clay particles and Fe and Al hydroxides. A minimal reduction in the concentration of silicon in the soil solution is attributed to the adsorption by secondary clay minerals.

The Fe and Al hydroxides have strong adsorption capacity, which can remove significant amounts of dissolved silicon from the soil solution (Tubana and Heckman 2015) [12] Silica mainly accumulated in the epidermal tissues of roots and leaves known as phytoliths. This thickened epidermal silicon cellulose layer supports the mechanical stability of plants, which gives resistance to lodging. Light receiving posture of the plant also get increased. Leaves were reported to be darker green, stiffer and slower to senesce, increasing their potential for photosynthesis and hence growth (Epstein, 1994) [5].

Phosphorus deficiency is one of the major constraints to crop production. It is the second most required primary nutrient in plants after nitrogen. The unique feature of P is its low availability due to slow diffusion and high fixation in soils P can be one of the major limiting factors for plant growth. Information on P fertility status of soils is of great importance, because of the high P fixation capacity of soil.

Thus, the present investigation was undertaken with an objective to assess the effect of silicon nutrition along with phosphorous on rice yield. The field experiment was carried out in submerged soil condition, with an objective to determine the effects of applications of silica and phosphorous on available nutrient status in soil at various crop intervals.

Material and Method

The experiment was conducted at experimental farm of department of soil science and agricultural chemistry, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth Dapoli. The study area is located at 17^0 45' 02" North latitude and 73^0 10' 55" East longitude. The climate of the area is hot humid to per humid with mean annual rainfall is 3500 mm, of which about 90 per cent is received during the months of June to October. Generally total 95 to 100 rainy days are in the most of years. The experimental soil was lateritic in nature and classify as Alfisol. The initial experimental soil was well-drained, sandy clay loam in texture, acidic in reaction with low electrical conductivity and very high organic carbon content. It was very high in available N and K_2O and low in available P_2O_5. The soil used for the experiment examined and showed following initial status listed in table 1.

Table. 1: Initial status of different soil properties used in the experiment

Sr.	Soil properties	Initial Status
1	pH (1:2.5)	6.52
2	Electrical conductivity (dSm^{-1})	0.056
3	Organic carbon (g kg^{-1})	18.9
4	Available N (kg ha^{-1})	357.15
5	Available P_2O_5 (kg ha^{-1})	19.20
6	Available K_2O (kg ha^{-1})	316.24
7	Available Si (Calcium chloride extractable) (kg ha^{-1})	54.28

Treatment details

The experiment was laid out in factorial randomized block design with 3 replications. The four levels of phosphorus and silica application *viz.* P_0 – 0 kg P ha^{-1}, P_1 – 25 kg P ha^{-1}, P_2 – 50 kg P ha^{-1},P_3 – 75 kg P ha^{-1} through single super phosphate and Si_0 - 0 kg Si ha^{-1}, Si_1 - 50 kg Si ha^{-1}, Si_2 - 100 kg Si ha^{-1} and Si_3 - 150 kg Si ha^{-1} through potassium silicate were examined.

Soil analysis

The changes occur in the soil reaction, Electrical conductivity, organic carbon contain as well as available nitrogen, phosphorus, potassium and silica were determined at 30 days after transplanting (30 DAT), 60 days after transplanting (60 DAS) and at harvest stage respectively. The soil reaction and electrical conductivity was determined by potentiometric and conductometric method, respectively (1:2.5 soil: water suspension ratio w/v) described by Jackson, (1973) [6]. The organic carbon content in the soil was estimated by Walkley and Black's wet oxidation method (Black, 1965). Available nitrogen was determined by Alkaline permanganate (0.32% $KMnO_4$) method described by Subbiah and Asija, 1956, whereas available phosphorous determined by Brays No. 1 method and available potassium was estimated by flame Photometer as described by Bray and Kurtz (1945) [3] and Jackson, 1973 [6] respectively. Available silica was extracted by 0.01 M $CaCl_2$ and determined according Korndorfer *et al.* (2001) [7]. The data generated from present experiment was statistically analyzed by methods suggested by Panse and Sukhatme (1985).

Result and Discussion

Grain yield and straw yield

Application phosphorous @ 75 kg ha^{-1} produced the highest grain and straw yield (42.75q ha^{-1} and 51.64 q ha^{-1}) over remaining phosphorus levels. Application of different levels of silica significantly influenced the grain and straw yield of rice. The significantly highest grain yield (31.21q ha^{-1}) and straw yield (47.52q ha^{-1}) were recorded with application of 150 Kg Si ha^{-1} through potassium silicate. The application of different treatment combinations showed significant effect with respect to grain and straw yield. The highest grain and straw yield (42.75 and 56.00 q ha^{-1}) recorded by treatment combination P_3Si_3 in which 75 kg P ha^{-1} was applied with 150 kg Si ha^{-1}.

Higher yield associated with higher levels of phosphorus are may be due to better root growth and increased uptake of nutrients (Archana *et al.*, 2016) [2]. Increased amount of phosphorus resulted enhanced photosynthetic rate, biomass production and sink formation which increased grain yield of rice. Wang *et al.* (2014) [14] reported that application of silicate increases the percentage of ripened grains in rice. In lateritic soils of Konkan (pH 6.2), Talashilkar *et al.* (1996) [11] noted that the application of calcium silicate slag in combination with the N and P sources significantly increased grain yield of rice.

Table 2: Effect of phosphorus and silica levels on grain and straw yield (q ha^{-1}) of rice.

Phosphorus levels	Grain yield	Straw yield	Silica levels	Grain yield	Straw yield
P_0 0 kg ha^{-1}	31.48	38.34	Si_0 0 kg ha^{-1}	34.85	43.22
P_1 25 kg ha^{-1}	35.09	43.71	Si_1 50 kg ha^{-1}	35.35	44.17
P_2 50 kg ha^{-1}	37.62	47.49	Si_2 100 kg ha^{-1}	36.66	46.26
P_3 75 kg ha^{-1}	39.94	51.64	Si_3 150 kg ha^{-1}	37.27	47.52
S.Em. (±)	0.213	0.265	S.Em. (±)	0.213	0.265
C.D. at 5%	0.616	0.767	C.D. at 5%	0.607	0.755

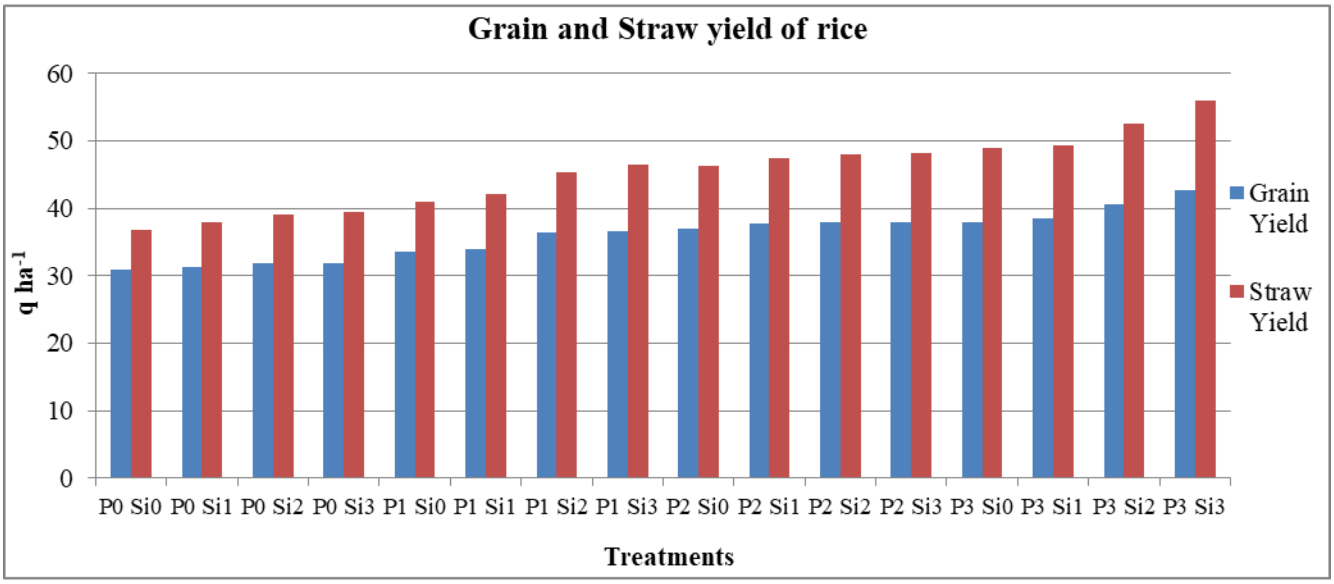

Fig 1: Effect of different treatment combination on grain and straw yield (q ha^{-1}) of rice.

Soil properties

Available nitrogen

The effect of application of different levels of phosphorus reported to be non significant regarding available nitrogen content in soil at 30 days after transplanting, 60 days after transplanting and at harvest stage of rice.

The significant effect was noticed due to the application of different silica levels with respect to available nitrogen content in soil at 30 DAT, 60 DAT and at harvest stage. The maximum nitrogen recorded by the treatment receiving silica @ 150 kg ha^{-1} at 30 DAT(402.81 kg ha^{-1}) and 60 DAT (305.59 kg ha^{-1}), respectively. However, at harvest stage of rice, maximum nitrogen was recorded by application of silica @ 50 kg ha^{-1}. With increased level of silica, available nitrogen found to be increased. This might be due to synergistic effect between nitrogen and silica application (Das *et al.*, 2013) [4]. Similar findings were obtained by Selvakumari *et al.* (2000) [9].

The interaction effect between phosphorous and silica application did not reach the level of significance at all growth stages of rice.

Table 3: Effect of different levels of phosphorous application on available nitrogen, phosphorous, potassium and silica at various growth stages of rice.

Treatment	Available Nitrogen (kg ha^{-1})			Available Phosphorus (kg ha^{-1})			Available Potassium (kg ha^{-1})			Available Silica (kg ha^{-1})		
	30 DAT	60 DAT	At Harvest	30 DAT	60 DAT	At Harvest	30 DAT	60 DAT	At Harvest	30 DAT	60 DAT	At Harvest
P_0 0 kg ha^{-1}	379.46	277.27	239.82	18.33	14.65	11.78	371.08	287.97	262.02	53.16	41.00	40.15
P_1 25 kg ha^{-1}	374.46	295.34	251.48	19.63	15.94	13.08	370.07	289.64	268.17	54.03	41.80	40.42
P_2 50 kg ha^{-1}	393.43	291.57	251.60	21.30	16.90	14.03	378.69	294.65	269.66	54.61	41.78	40.36
P_3 75 kg ha^{-1}	403.35	293.17	246.50	22.20	18.13	15.27	383.52	295.26	274.55	56.30	42.57	41.06
S.Em. (±)	8.322	8.221	3.326	0.07	0.10	0.10	4.736	4.776	4.789	0.12	0.20	0.13
C.D. at 5%	NS	NS	NS	0.20	0.30	0.30	NS	NS	NS	0.36	0.56	0.38

Table 4: Effect of different levels of silica application on available nitrogen, phosphorous, potassium and silica at various growth stages of rice.

Treatment	Available Nitrogen (kg ha^{-1})			Available Phosphorus (kg ha^{-1})			Available Potassium (kg ha^{-1})			Available Silica (kg ha^{-1})		
	30 DAT	60 DAT	At Harvest	30 DAT	60 DAT	At Harvest	30 DAT	60 DAT	At Harvest	30 DAT	60 DAT	At Harvest
Si_0 0 kg ha^{-1}	364.30	282.92	246.83	19.36	15.83	12.96	363.32	277.54	254.26	52.81	41.14	39.53
Si_1 50 kg ha^{-1}	386.72	270.97	255.67	20.26	16.12	13.25	371.51	289.17	264.10	54.27	41.68	40.17
Si_2 100 kg ha^{-1}	396.86	297.87	246.12	20.76	16.65	13.78	382.06	295.95	276.38	55.21	42.46	40.86
Si_3 150 kg ha^{-1}	402.81	305.59	240.78	21.08	17.03	14.17	386.48	304.85	279.66	55.81	42.86	41.43
S.Em. (±)	8.32	8.22	3.32	0.07	0.10	0.10	4.73	4.89	4.81	0.12	0.20	0.13
C.D. at 5%	23.68	23.39	9.46	0.20	0.29	0.29	13.46	13.91	13.70	0.36	0.56	0.38

Available phosphorous

The highest phosphorous content in soil was associated with highest level of the phosphorous application that is treatment P_3 receiving phosphorous @ 75 kg ha^{-1} at all growth stages of the crop growth. Significantly highest phosphorous at 30 DAT (22.20 kg ha^{-1}), 60 DAT(18.13 kg ha^{-1}) and at harvest stage (15.27 kg ha^{-1}) of rice was observed due to P_3 treatment and found superior over rest of the treatments.

Similarly, by application of highest silica level (150 kg ha^{-1}); available phosphorous influenced significantly superior over all treatments. The highest available P i.e. 21.08 kg ha^{-1}, 17.03 kg ha-^{1} and 14.17 kg ha^{-1}was reported at 30 DAT, 60 DAT and at harvest stage, respectively. Over initial phosphorus status and control, the available phosphorus content of soil was significantly increased with the increasing levels of silicon. Increased concentration of monosilisic acids in soil solution due to silicon application displaces phosphorus from ligand exchange sites. This results into transformation of fixed and slightly soluble phosphorus into plant available phosphorus. Also, by process of adsorption, leaching of phosphorus reduces due to silicon application (Das *et al.*, 2013 and Selvakumari *et al.*, 2000) [4, 9].

The highest phosphorus (22.93 kg ha^{-1}) was recorded for treatment combination Si_3P_3receiving 150 kg Si ha^{-1} and 75 kg P ha^{-1} at 30 DAT; whereas, at 60 DAT and at harvest interaction effect was non-significant.

Available potassium

The data in relation to available potassium content in soil noticed to be non-significant at 30 DAT, 60 DAT and at harvest stage of rice due to application of the levels of phosphorous and combine application of P and Si.

The treatment Si_3 consisting application of silica @150 kg ha^{-1} recorded significantly highest available potassium at 30 DAT (386.48 kg ha^{-1}), 60 DAT (304.85 kg ha^{-1}) and at harvest (279.66 kg ha^{-1}) stage of rice. In general, with advancement of submergence, available K tended to decline. This decrease in K_2O content with submergence may probably be due to leaching of soluble K fractions. In this connection, in some soils, non-exchangeable K becomes available as the exchangeable and solution K^+ are removed by cropping or lost by leaching were reported by Tisdale *et al*. (1995). The available potassium content was significantly increased with increased levels of silicon and this could be the result of positive interaction of silicon with potassium and reduction in its leaching (Das *et al*., 2013) [4]. These findings are tune with Wader (2012) [13].

Available silica

The significantly superior effect was achieved by treatment P_3 receiving phosphorous @ 75 kg ha^{-1} at all sampling stages regarding available silica content in soil. The available silica observed 56.30 kg ha^{-1} 42.57 kg ha^{-1} and 41.06 kg ha^{-1} at 30 DAT, 60 DAT and at harvest stage respectively.

The maximum silica content in soil was noted 55.81 kg ha^{-1}, 42.86 kg ha^{-1} and 41.43 kg ha^{-1} at 30 DAT, 60 DAT and at harvest stage, respectively. The Si_3 treatment comprising application of silica @ 150 kg ha^{-1} which found significantly superior at 30 DAT and at harvest; while significantly highest at 60 DAT. The available Si trend remains increasing in all three stages it may be due to added silicate material might have contributed for release of soluble Si to the soil.

The interaction effect between the application of different levels of silica and phosphorus recorded non-significant.

Soil reaction (pH), Electrical conductivity and Organic carbon

The impact of application of different levels of phosphorous and silica as well as interaction effect between silica and phosphorous found to be non significant at all sampling intervals.

Table 5: Effect of different levels of phosphorous application on soil reaction, electrical conductivity and organic carbon content at various growth stages of rice.

Treatment	Soil reaction (pH)			Electrical conductivity (dSm^{-1})			Organic Carbon (g kg^{-1})		
	30 DAT	60 DAT	At Harvest	30 DAT	60 DAT	At Harvest	30 DAT	60 DAT	At Harvest
P_0 0 kg ha^{-1}	6.81	5.13	5.71	0.19	0.14	0.06	14.57	16.85	19.44
P_1 25 kg ha^{-1}	6.87	5.07	5.98	0.12	0.13	0.07	14.84	16.10	17.15
P_2 50 kg ha^{-1}	6.72	5.14	5.68	0.16	0.11	0.06	14.82	16.33	18.92
P_3 75 kg ha^{-1}	6.78	5.02	5.57	0.15	0.13	0.06	15.98	15.95	21.43
S.Em. (±)	0.05	0.06	0.14	0.03	0.008	0.006	0.37	0.60	0.46
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	1.33

Table 6: Effect of different levels of silica application on soil reaction, electrical conductivity and organic carbon content at various growth stages of rice.

Treatment	Soil reaction (pH)			Electrical conductivity (dSm^{-1})			Organic Carbon (g kg^{-1})		
	30 DAT	60 DAT	At Harvest	30 DAT	60 DAT	At Harvest	30 DAT	60 DAT	At Harvest
Si_0 0 kg ha^{-1}	6.83	5.08	6.00	0.12	0.11	0.07	15.08	16.10	19.26
Si_1 50 kg ha^{-1}	6.78	5.14	5.48	0.13	0.13	0.06	14.82	16.63	20.15
Si_2 100 kg ha^{-1}	6.73	4.99	5.76	0.19	0.14	0.06	15.08	16.38	18.18
Si_3 150 kg ha^{-1}	6.83	5.15	5.69	0.18	0.14	0.07	15.22	16.13	19.35
S.Em. (±)	0.05	0.06	0.14	0.03	0.008	0.006	0.37	0.60	0.46
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	1.31

Conclusion

From the present investigation it is concluded that, sole application of phosphorous @ 75 kg ha^{-1} and silica @ 150 kg ha^{-1} as well as combine application of phosphorous @ 75 kg ha^{-1} and silica @ 150 kg ha^{-1} significantly influenced the grain and straw yield of rice. The available phosphorous and silica significantly improved by application of 75 kg ha^{-1} phosphorous through SSP. The application of silica @ 150 kg ha^{-1} enhanced available nitrogen, phosphorous, potassium and silica content in soil. Thus overall study indicated that, application of phosphorous @ 75 kg ha^{-1} along with silica @ 150 kg ha^{-1} is effective for beneficial improvement in yield and soil properties under rice crop.

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