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Effect of nutrient and beneficial sources on yield, nutrient content and uptake of rice

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Abstract
The pot culture experiment was carried out to examine the impact of different nutrient and beneficial sources application on yield, nutrient content and uptake of rice. Total 15 treatment combination were evaluated and laid out in factorial randomized block design with 3 replications. Recommended dose of fertilizer (100:50:50 $N:P_2O_5:K_2O$ kg ha^{-1}) through chemical fertilizers, 100 kg N through vermicompost and application of Konkan Anapurna Briquette (34:14:6 $N:P_2O_5:K_2O$) represented the first factor while second factor consisted control, silica @ 150 kg ha^{-1}, azolla @ 1 ton ha^{-1}, rice husk biochar @ 5 ton ha^{-1} and potassium sulphate @ 50 kg ha^{-1} application. The results regarding yield nutrient content and uptake of rice denoted that, application of 100:50:50 $N:P_2O_5:K_2O$ kg ha^{-1} through chemical fertilizers and silica @ 150 kg ha^{-1} significantly improved grain yield while rice husk biochar @ 5 ton ha^{-1} straw yield. The phosphorous, potassium and silicon content was significantly influenced by application of 100:50:50 $N:P_2O_5:K_2O$ kg ha^{-1} through chemical fertilizers in rice grain, while by Konkan Annapurna Briquette in rice straw. The phosphorous and potassium content in grain increased by Azolla application, and nitrogen content in straw and silicon content in straw by silica application. The 100:50:50 $N:P_2O_5:K_2O$ kg ha^{-1} through chemical fertilizers application significantly improved total uptake of phosphorous, potassium and silicon; however total nitrogen uptake by briquette application. Azolla application improved total uptake of phosphorous and potassium; while total nitrogen and silicon uptake by silica and biochar application respectively.

Keywords: rice, nutrient source, beneficial source, silicon, uptake

Introduction
Rice is the staple food for more than half of the world's population. Increasing population results in greater demand for food grain results need of grater production and productivity from limited land resources. For increment such production and productivity sustainable intensification are required. It is also important to minimize the solely dependence on external inputs (e.g. chemical fertilizers) in crop production and thus have to use beneficial sources which improves the utilization of primary and secondary applied nutrients.
Silicon (Si) is second most abundant element in the earth's crust and which gives several beneficial effects on crop growth, especially crops like Rice and Sugarcane. Silicon in enhances the rice yield through managing biotic and abiotic stress conditions viz. insect, diseases, pests, drought, salinity and heavy metals (Epstein, 2001) [7]. Silicon make available in the form of monosilicic acid. The higher P content and uptake by the plants by Si application might be due to replacement of phosphate anions released from Fe and Al phosphate by monosilicic acid anions released from silicon sources and improves P uptake from 26 to 34 per cent (Tavakkoli *et al*., 2011) [23]. Rao, (2017) [18] demonstated that silicon fertilization also increases the pH in acid soils which will release P from Fe-P and Al-P complexes. Silicon has synergistic interaction with applied K in soil and promotes the release of K from the exchange sites in soil solution.
Azolla is an aquatic fern that is free-floating and rapidly raises its biomass over 3 to 5 days. by establishing a symbiotic relationship with the blue-green algae azolla fixes atmospheric nitrogen in the soil. Azolla releases 56% to 80% of its ammonia nitrogen because it quickly breaks down in the soil at 3 and 8 weeks (Khan, 1983) [11]. Phosphorus is Azolla's single most essential nutrient. It is earlier reported that due to slow mineralization of nitrogen in azolla after its application in the rice and provides 75% of the total fixed nitrogen in NH^{4+} form within 6 to 8 weeks (Bhattarai *et al*., 1987) [3]. Combined use of Azolla and 60 kg N ha^{-1} increased grain yield of rice by 17% over 60 kg N ha^{-1} when used alone in the field (Tuladhar, 2003) [24].

Biochar is a carbon-rich solid material produced by pyrolyzing biomass in an oxygen-limited environment. Biochar application has the potential to stimulate crop growth by improving soil quality including enhancing water storage, increasing beneficial microbial activity, improving nutrient supply and suppressing soil-borne disease. It has been reported that, biochar could be a beneficial soil amendment for crop production (Glaster *et al.,* 2014) [9]. Biochar contains some N, its application could increase total N content in the soil. However, by its direct adsorption effect and indirect microbial immobilization effect there is possibility of decrease in N availability by biochar application. According to Behera *et al*. (2007) [2], Soil application of biochar improves plant growth by improving the physical and chemical characteristics of the soil such as cation exchange capacity (CEC), bulk density, water holding capacity and permeability along with biological properties.

The current research was therefore undertaken to examine the effect of different nutrient and beneficial sources on yield of rice, nutrient content and uptake by rice crop. Consequently, the main objective of this research was to study effect of beneficial sources along with primary nutrients on the growth and production of rice crops.

Material and Methods

Pot culture experiment

The pot culture experiment was conducted at experimental farm of Department of Soil Science and Agricultural Chemistry, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth Dapoli. The experimental area is situated in the konkan region of the Maharashtra which perceives dominant area under rice crop. The rice plants were transplanted in the rectangular pot during Rabi 2020- 21 and all other cultural operations were carried out as per recommended practices.

Treatment Details

The experiment was laid out in factorial randomized block design with total fifteen treatment combination and 3 replications. Amongst the two factors first factor consisted three different sources for primary nutrients i.e. recommended dose of fertilizer (100:50:50 N:P_2O_5:K_2O kg ha^{-1}) through chemical fertilizers, 100 kg N through vermicompost and application of Konkan Anapurna Briquette (34:14:6 N:P_2O_5:K_2O) and denoted by symbols S_1, S_2 and S_3. While the second factor denoted by symbols B_0, B_1, B_2, B_3 and B_4 were beneficial sources comprising control (no any source), silica @ 150 kg ha^{-1}, azolla @ 1 ton ha^{-1}, rice husk biochar @ 5 ton ha^{-1} and potassium sulphate @ 50 kg ha^{-1}. All sources were applied at the time of transplanting of the rice.

Analysis for nutrient content

The plant samples were collected at harvest stage of the rice. The collected samples were washed in the running tap water to remove all dirt and soil particles. After air drying the samples were subjected to hot air oven to remove moisture from the plant samples. The oven dried samples then crushed and used for determination of nutrient content. The grain and straw analyzed separately to estimate nitrogen, phosphorous, potassium and silicon content.

i) Total nitrogen (%)

The plant samples were digested in H_2SO_4 and made colourless by adding 30% H_2O_2 and cooled. The digested material was transferred to a 25 ml volumetric flask and the volume was made with distilled water with repeated washing of digestion flasks and the total nitrogen content was determined by using Kjeldhal plus apparatus (Tandon, 1993) [22].

Total Phosphorus and Potassium

For determination of P and K 1.0 g of plant sample was digested in diacid; which is made by mixing nitric and perchloric acid in the ratio 9:4 and the final volume was made to 100 ml with distilled water.

ii) Total phosphorus (%)

Total phosphorus was determined by taking a known quantity of diacid extract of the plant to which HNO_3 and Vanado molybdate reagent were added. Further, phosphorus was determined colorimetrically by using Spectrophotometer at a wavelength of 420 nm (Chopra and Kanwar, 1978) [4].

iii) Total potassium (%)

Total potassium was estimated by using Flame Photometer by feeding the diluted di-acid digested solution (Piper, 1966) [17].

iv) Total silicon (%)

The plant samples were ground in to powder and 0.1 gm sample was kept in the plastic digestion tube which was suitable for the autoclave. Then 3ml 50% NaOH was added and sample was autoclaved for 20 minuets. 1 ml aliquot was transfer in to the 50 ml volumetric flask and 30 ml 20% acetic acid was added in to the flask followed by addition of 10 ml ammonium molybdate (54 gm lit^{-1}). After 5 min. 5 ml tartaric acid followed by 1 ml reducing agent (ANSA) was added for development of the colour. Wavelength was measured at 560 nm on spectrophotometer (Korndorfer *et al.,* 2001) [12].

Statistical Analysis

The data generated from present experiment was statistically analyzed by methods suggested by Panse and Sukhatme (1985) [15].

Result and Discussion

Grain and Straw Yield

Glimpses of data presented in Table 1 and depicted in Fig. 1 reported that the grain and straw yield of submerged rice was significantly influenced due to the nutrient sources and beneficial sources application.

The significantly highest grain yield (29.45 q ha^{-1}) of rice was observed due to S_1 treatment comprising application of 100:50:50 N:P_2O_5:K_2O kg ha^{-1} through chemical fertilizers. The treatment S_1 receiving 100:50:50 N:P_2O_5:K_2O kg ha^{-1} through chemical fertilizers was found significantly highest (36.27 q ha^{-1}) for straw yield of rice and it was reported at par with the S_3 treatment i.e. application of Konkan Annapurna Briquette (34:14:6 N:P_2O_5:K_2O).

Influence of beneficial sources on grain yield varied of from 20.54 to 25.76 q ha^{-1} and which was found to be non-significant. While the beneficial sources showed significant effect on the straw yield of the rice and the highest straw yield (32.61 q ha^{-1}) was recorded due to the application of treatment M_3 consisting application of rice husk biochar @ 5 ton ha^{-1}. Rice is silicon accumulator plant therefore, the application of the silicon showed strongly positive effect on the straw yield of rice. Silicon application increases the availability of the nutrients and uptake in the paddy (Pati *et al*., 2018) [16]. The application Si kept rice plant erect and increase the photosynthesis activity (Detmann *et al.* 2012) [16]. Increased dry matter production and yield attributing characters by the application of the silicon might be responsible for the increment yield of straw. The findings are tune with Malav and Ramani (2016) [13].

The data regarding interaction effect between nutrient sources and beneficial sources was found to be non-significant in respect of grain yield of rice. However, the grain yield was ranged from 11.57 to 31.76 q ha^{-1}. The significantly superior straw yield (45.88 q ha^{-1}) was noticed due to application of treatment combination S_3M_3 comprising 100:50:50 $N:P_2O_5:K_2O$ kg ha^{-1} through chemical fertilizer along with application of the rice husk biochar @ 5 ton ha^{-1}.

Effect on nutrient content of rice.

The data regarding nutrient content influenced by application of nutrient and beneficial sources in rice grain and straw is given in the table 1 and 2.

Nitrogen content

The application of S_3 treatment receiving Konkan Annapurna Briquette reported to be significantly superior nitrogen content (1.159%) in grain. Whereas, the of nutrient source application showed non-significant effect on nitrogen content in the rice straw. The solubility of the nitrogen received from urea found to be easy; in contrast, briquette releases nitrogen slowly and steadily. The sufficient nitrogen released by briquette at the time of panicle initiation and grain filling stage might be responsible for the increment in the nitrogen content in rice grain.

It was noticed that, application of beneficial source did not showed significant effect with respect to nitrogen content in the grain. The treatment B_1 consisting silica application @ 150 kg ha^{-1} and treatment B_3 consisting application of rice husk biochar @ 5 ton ha^{-1} reported similar result for nitrogen content in the straw and found to be significantly highest nitrogen (0.392%) content in straw. It was noticed from the findings that, silicon application improved nitrogen content in the grain and straw; which might be due to, it improves root activity and increase availability of nitrogen (Malav and Ramani, 2016) [13].

The treatment combination S_3B_2 consisting application of Konkan Anapurna Briquette (34:14:6 $N:P_2O_5:K_2O$) with azolla @ 1 ton ha^{-1} observed to be significantly highest (1.203%) in respect to the nitrogen content in the grain. While in case of straw, treatment S_2B_1 consisting 100 kg N ha^{-1} through vermicompost along with silica @ 150 kg ha^{-1} and treatment S_2M_3 consisting 100 kg N ha^{-1} through vermicompost along with rice husk biochar @ 5 ton ha^{-1} found significantly superior (0.420 per cent). Safriyani, 2020 confirmed that, the azolla is capable for the efficient nitrogen fixation and responsible for the improving nitrogen use efficiency in the rice. Similarly briquette application also improves the nitrogen use efficiency in rice through restricted leaching and steady nitrogen supply.

Phosphorous content

The application of S_1 treatment receiving 100:50:50 $N:P_2O_5:K_2O$ kg ha^{-1} through chemical fertilizers recorded significantly superior phosphorus content (0.320%) in grain over rest of the treatments. The phosphorus content in straw was influenced significantly superior (0.206%) because of the application of S_3 treatment consisting application of Konkan Annapurna Briquette (34:14:6 $N:P_2O_5:K_2O$).

The significantly superior phosphorus content (0.327%) in grain was observed due to application B_2 treatment receiving azolla @ 1 ton ha^{-1} over rest of the treatments. The application of B_4 treatment i.e. potassium sulphate @ 50 kg ha^{-1} noted the highest phosphorus (0.192%) content in straw and it was found to be at par with B_0 and B_1 treatment application. Gajghane *et al.* (2015) [8] reported that application of the sulphur increases the available phosphorus content in soil. The increment in phosphorus might be responsible for increase in the phosphorus content in plant.

In case of the phosphorous content in the grain the treatment S_1B_3 composed of 100:50:50 $N:P_2O_5:K_2O$ kg ha^{-1} through chemical fertilizers in combination rice husk biochar @ 5 ton ha^{-1} observed superior (0.435%) over rest of the treatments and treatment S_3B_4 comprising combination of Konkan Annapurna Briquette (34:14:6 $N:P_2O_5:K_2O$) and potassium sulphate @ 50 kg ha^{-1} application observed to be superior (0.224%) in terms of straw content. Biochar is capable of absorbing the dissolved phosphate in the soil thus increases phosphorous retention capacity of the soil (Adekiya *et al.*, 2020) [1]. Shackley *et al.*, 2011 [20] reported to biochar supply primary nutrients.

Table 1: Effect of application of nutrient sources on nutrient content in rice grain and straw.

Teatments	N content		P content		K content		Si content	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
N_1	1.103	0.358	0.320	0.176	0.502	1.498	1.326	1.747
N_2	1.058	0.375	0.262	0.173	0.481	1.448	1.167	1.668
N_3	1.159	0.370	0.249	0.196	0.394	1.547	1.221	1.787
S.E.±	0.013	0.007	0.002	0.002	0.002	0.004	0.009	0.023
C.D.@ 5%	0.039	NS	0.005	0.006	0.006	0.010	0.027	0.066

Table 2: Effect of application of beneficial source on nutrient content in rice grain and straw.

Teatments	N content		P content		K content		Si content	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
B_0	1.083	0.355	0.215	0.190	0.372	1.535	1.122	1.734
B_1	1.092	0.392	0.245	0.184	0.492	1.437	1.431	1.831
B_2	1.138	0.373	0.327	0.175	0.505	1.577	1.201	1.740
B_3	1.092	0.392	0.281	0.167	0.433	1.458	1.357	2.114
B_4	1.130	0.327	0.317	0.192	0.493	1.482	1.079	1.783
S.E.±	0.017	0.2	0.002	0.003	0.003	0.005	0.012	0.029
C.D.@ 5%	NS	0.025	0.006	0.008	0.008	0.013	0.035	0.085

Potassium content

The application of 100:50:50 $N:P_2O_5:K_2O$ kg ha^{-1} through chemical fertilizers (S_1) showed significantly superior (0.630%) effect over rest of the treatments with respect to potassium content in grain. The significantly superior potassium (1.547%) content in straw was recorded due to application of S_3 treatment consisting Konkan Annapurna Briquette (34:14:6 $N:P_2O_5:K_2O$) application.

The significantly superior phosphorus (0.327%) content in grain was observed due to application B_2 treatment receiving azolla @ 1 ton ha^{-1} over rest of the treatments. However, application of B_4 treatment i.e. potassium sulphate @ 50 kg ha^{-1} noted the highest phosphorus (0.192%) content in straw. Gajghane *et al.* (2015) [8] reported that application of the sulphur increases the available phosphorus content in soil. The increment in phosphorus might be responsible for increase in the phosphorus content in plant.

In case of the phosphorus content in the grain the treatment S_1B_3 composed of application 100:50:50 $N:P_2O_5:K_2O$ kg ha^{-1} through chemical fertilizers in combination rice husk biochar @ 5 ton ha^{-1} observed superior (0.435%) over rest of the treatments and treatment S_3B_4 comprising combination of Konkan Annapurna Briquette (34:14:6 $N:P_2O_5:K_2O$) and potassium sulphate @ 50 kg ha^{-1} application observed to be superior (0.224%) in terms of straw.

Potassium content

The application of 100:50:50 $N:P_2O_5:K_2O$ kg ha^{-1} through chemical fertilizers (S_1) showed significantly superior (0.630%) effect over rest of the treatments. The significantly superior potassium (1.547%) content in straw was recorded due to application of S_3 treatment consisting Konkan Annapurna Briquette (34:14:6 $N:P_2O_5:K_2O$) application. The highest value of potassium content in straw by briquette application might be due to steady and slow supply of the potassium from briquette.

The higher concentration of potassium (0.505%) content in grain was observed with the application of B_2 treatment receiving azolla @ 1 ton ha^{-1} and was found superior over all remaining treatments. The application of azolla @ 1 ton ha^{-1} (B_2) showed highest (1.577%) potassium in rice straw and it was found to be superior. The total potassium contain in azolla ranges from 2 to 6 per cent (Veer *et al.*, 2020) [25]. This potassium released in the soil by rapid decomposition of the azolla; the released potassium content might be withdrawn by plants, possible for increment in potassium content in grain and straw.

The potassium content in the grain was recorded significantly superior (0.630%) over rest of the treatments, due to the application of treatment S_1B_3 which consisting application of 100:50:50 $N:P_2O_5:K_2O$ kg ha^{-1} through chemical fertilizers in combination with rice husk biochar @ 5 ton ha^{-1}. In case of straw the application of Konkan Annapurna Briquette (34:14:6 $N:P_2O_5:K_2O$) in combination with azolla @ 1 ton ha^{-1} (S_3B_2) was observed to be significantly superior (1.775%). Application of the silicon through the rice husk biochar in combination with chemical fertilizers showed positive correlation with available potassium content in the soil, which increases the availability of potassium in soil, might be responsible for increment in potassium content in grain. Similar findings were reported by the Nascimento *et al.* (2019) [14] and Cuong *et al.* (2017) [5].

Silicon content

The application of S_1 treatment receiving 100:50:50 $N:P_2O_5:K_2O$ kg ha^{-1} through chemical fertilizers reported significantly superior (1.326%) over rest of the treatments in respect to the silicon content in the grain. However the treatment S_3 composed of Konkan Annapurna Briquette (34:14:6 $N:P_2O_5:K_2O$) application showed highest (1.787%) silicon concentration in straw and was found to be at par with the application of S_1 treatment.

The highest silicon (1.431%) content in grain was recorded due to the application B_1 treatment comprising silica @ 150 kg ha^{-1}. The application of rice husk biochar @ 5 ton ha^{-1} (B_3) showed the significantly superior (2.114%) result in respect to the silicon content in the rice straw over rest of the treatments. It was found to be increment in the silicon content in grain and straw might be due to external application of the silicon through biochar and silicate fertilizer respectively. The enhancing silicon content in plant due to silicon application was also reported by Cuong *et al.*, 2017 [5]; Malav and Ramani, 2016 [13].

The highest silicon content in grain (1.643%) was observed by application of S_1B_1 treatment receiving 100:50:50 $N:P_2O_5:K_2O$ kg ha^{-1} through chemical fertilizers along with silica application @ 150 kg ha^{-1} and reported significantly superior over rest of the treatments. The significantly highest (2.197%) silicon content in straw was observed by the application of 100:50:50 $N:P_2O_5:K_2O$ kg ha^{-1} through chemical fertilizers in combination with rice husk biochar @ 5 ton ha^{-1} (S_1M_3). The findings were tune with Cuong *et al.*, 2017 [5].

Effect of nutrient sources and different levels of mitigation source on nutrient uptake by rice

The data regarding uptake of nitrogen, phosphorous, potassium and silicon content by rice influenced by different nutrient and beneficial source application is given in the table 3, 4 and figure 1, 2, 3 and 4.

Nitrogen uptake

The application of S_3 treatment consisting of Konkan Annapurna briquette (34:14:6 $N:P_2O_5:K_2O$) application recorded significantly highest nitrogen uptake (33.69 kg ha^{-1}) by grain. The highest nitrogen uptake (10.04 kg ha^{-1}) by straw was observed due to the application of S_1 treatment comprising 100:50:50 $N:P_2O_5:K_2O$ kg ha^{-1} through chemical fertilizers whereas, it was showed superior effect on rest of the treatments. Total nitrogen uptake by rice ranged from 19.47 to 45.47 kg ha^{-1}.The application of S_3 treatment comprising Konkan Annapurna briquette (34:14:6 $N:P_2O_5:K_2O$) application was found to be significantly highest and which was found at par with the S_1 treatment. Jagadeeswaran *et al.*, 2005 revealed that slow release fertilizer in the form of briquette increase nitrogen use efficiency, which might be responsible for the increment in uptake.

The application of beneficial sources did not showed significant effect on nitrogen uptake by grain and it varied from 25.76 to 28.80 kg ha^{-1}. The application of treatment B_3 receiving rice husk biochar @ 5 ton ha^{-1} was found to be significantly superior in nitrogen uptake (12.58 kg ha^{-1}) by straw. The treatment B_1 consisting the application of the silica @ 150 kg ha^{-1} recorded to be significantly highest. In year 2017 Cuong and co-worker noticed that application of the silicon increase nitrogen uptake in the rice. The increased nitrogen uptake might be due to synergistic effect between applied nitrogen and silicon in the soil system which increases availability of the nitrogen in the soil.

The non-significant effect was noticed in case of interaction effect between nutrient sources and different mitigation sources application on nitrogen uptake.

Phosphorus uptake

The application of S_1 treatment comprising application of 100:50:50 $N:P_2O_5:K_2O$ kg ha^{-1} through chemical fertilizers was found to be significantly superior (9.48 kg ha^{-1}) in phosphorus uptake by grain. Whereas, the application of Konkan Annapurna Briquette (34:14:6 $N:P_2O_5:K_2O$) (S_3) was found to be significantly highest in phosphorus uptake (7.02 kg ha^{-1}) by straw and it was at showed superior effect on rest of the treatments. The significantly highest total phosphorus uptake (15.83 kg ha^{-1}) by rice was noticed due to application of S_1 treatment receiving 100:50:50 $N:P_2O_5:K_2O$ kg ha^{-1} through chemical fertilizers it was found to be superior over the S_2 and S_3 treatment.

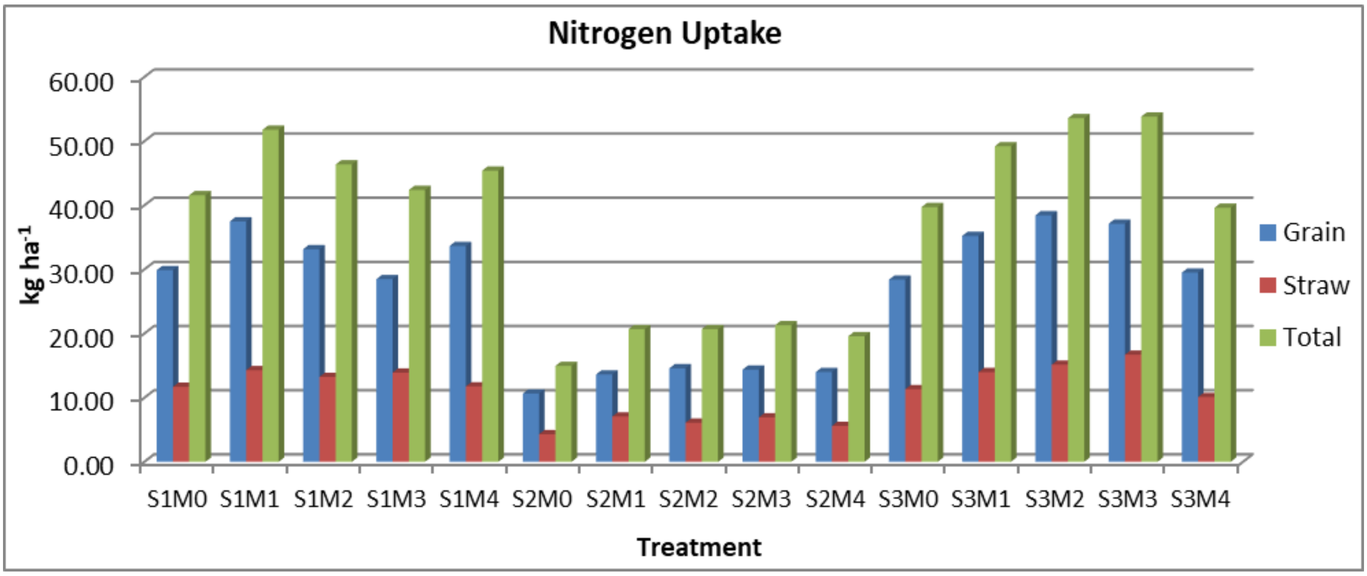

Fig 1: Interaction effect between nutrient and beneficial sources on nitrogen uptake by rice.

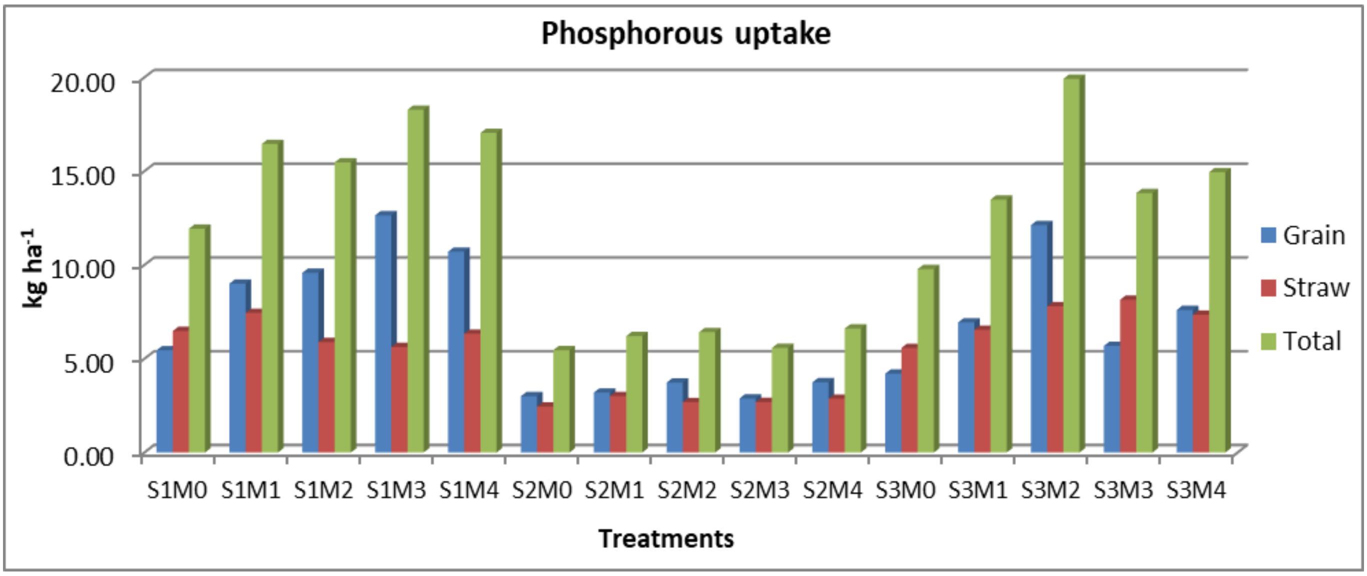

Fig 2: Interaction effect between nutrient and beneficial sources on phosphorous uptake by rice.

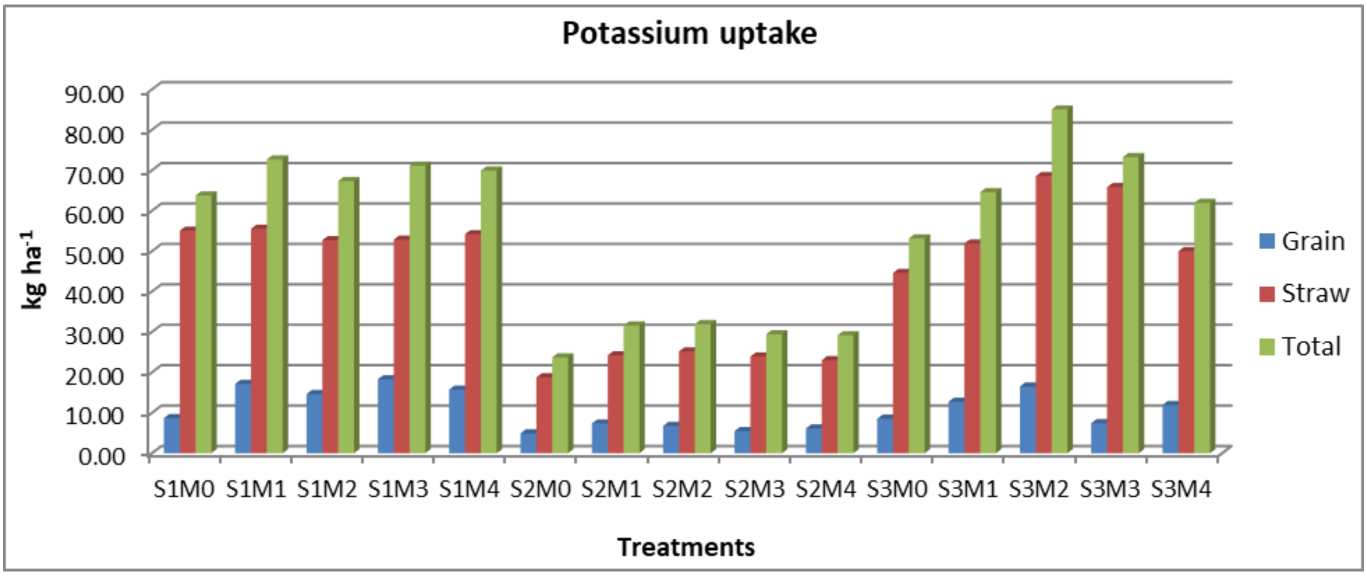

Fig 3: Interaction effect between nutrient and beneficial sources on potassium uptake by rice.

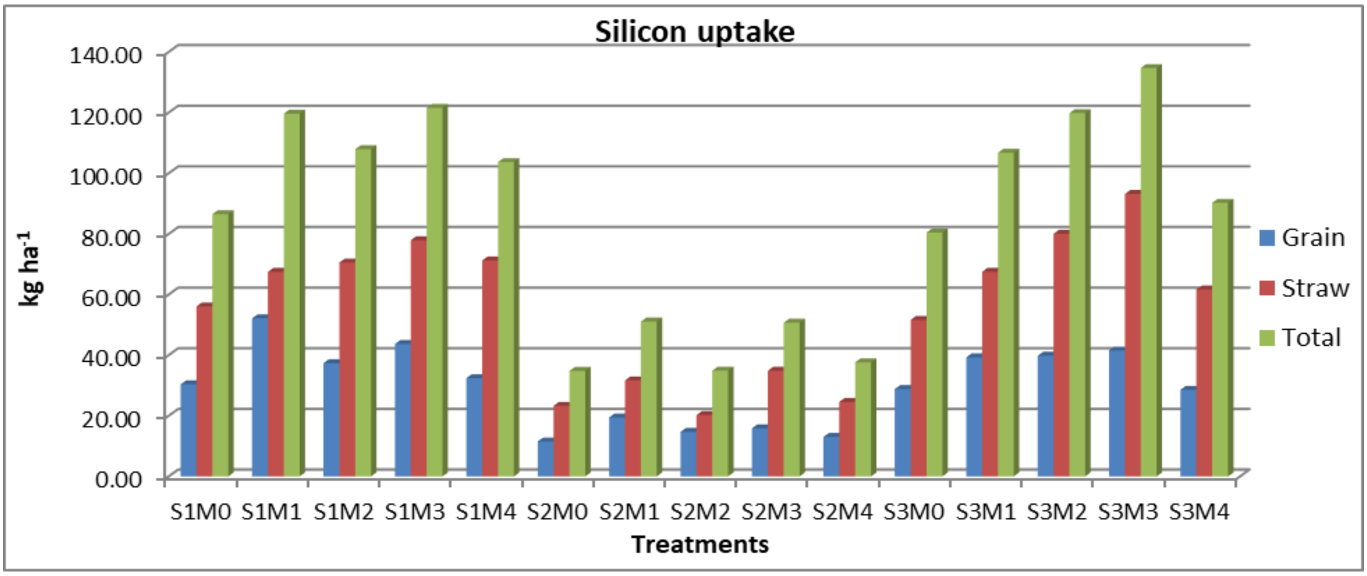

Fig 4: Interaction effect between nutrient and beneficial sources on silicon uptake by rice.

Among the different beneficial sources, the application of B_2 treatment consisting application of azolla @ 1 ton ha^{-1} observed to be significantly superior phosphorus uptake (8.47 kg ha^{-1}) by grain over all remaining treatments. The phosphorus uptake by straw did not affected significantly by various beneficial sources application and it ranged from 4.73 to 5.66 kg ha^{-1}. The significantly highest total phosphorus uptake (13.93 kg ha^{-1}) by rice was recorded due to application of B_2 treatment consisting application of the azolla @ 1 ton ha^{-1}. Decomposition of azolla release phosphorus in the soil. Increased available phosphorus might be responsible for the enhancement of the phosphorus uptake. Similar results were quoted by Singh & Singh 1990.

The application of S_1B_3 treatment consisting combine application of the 100:50:50 $N:P_2O_5:K_2O$ kg ha^{-1} through chemical fertilizers and rice husk biochar @ 5 ton ha^{-1} reported significantly highest (12.66 kg ha^{-1}) phosphorus uptake by grain and it was noticed to be at par with treatment S_3B_2. The application of the treatment S_3B_3 comprising Konkan Annapurna Briquette (34:14:6 $N:P_2O_5:K_2O$) with rice husk biochar @ 5 ton ha^{-1} recorded significantly highest value (8.15 kg ha^{-1}) for phosphorus uptake by straw. The treatment S_3B_2 receiving application of Konkan Annapurna Briquette (34:14:6 $N:P_2O_5:K_2O$) and azolla @ 1 ton ha^{-1} found to be significantly highest (19.51 kg ha^{-1}).

Potassium uptake

The application of S_1 treatment consisting 100:50:50 $N:P_2O_5:K_2O$ through chemical fertilizers showed significantly superior potassium uptake (14.91 kg ha^{-1}) by grain. The significantly highest potassium uptake (55.61kg ha^{-1}) by rice straw was recorded due to the application of S_3 treatment consisting application of Konkan Annapurna Briquette (34:14:6 $N:P_2O_5:K_2O$). The significantly highest (68.98 kg ha^{-1}) total potassium uptake by rice was found with the application of 100:50:50 $N:P_2O_5:K_2O$ through chemical fertilizers (S_1) and which was noticed to be at par with S_3 treatment.

The application of treatment B_2 receiving azolla @ 1 ton ha^{-1} was found to be significantly highest (12.63 kg ha^{-1}) in potassium uptake by grain and the application of azolla @ 1 ton ha^{-1} i.e. B_2 treatment found to be significantly highest

(48.82 kg ha^{-1}) in potassium uptake by straw. Among the different beneficial sources, application of B_2 treatment consisting application of azolla @ 1 ton ha^{-1} reported significantly highest (61.45 kg ha^{-1}) total potassium uptake. According to Veer *et al*., 2020 [25] azolla contain more than 2 per cent potassium. Decomposition of azolla added potassium content in the soil which might be responsible for the greater content and uptake by the rice grain and straw.

Table 3: Effect of application of beneficial source on the nutrient uptake by rice.

Treatments	N Uptake			P Uptake			K Uptake			Si Uptake		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
N_1	13.52	12.95	45.47	9.48	7.35	15.83	14.91	54.07	68.98	39.18	68.64	107.82
N_2	13.47	6.00	19.47	3.32	2.74	6.07	6.15	23.04	29.19	14.95	26.88	41.83
N_3	13.69	13.39	47.08	7.31	7.02	14.33	11.43	55.61	67.04	35.63	70.20	105.84
S.E.±	1.25	0.42	1.61	0.24	0.18	0.41	0.35	1.28	1.62	1.33	1.74	3.03
C.D.@ 5%	3.63	1.21	4.68	0.70	0.53	1.20	1.04	3.73	4.70	3.86	5.06	8.78

Table 2: Effect of application of beneficial source on the nutrient uptake by rice.

Treatments	N Uptake			P Uptake			K Uptake			Si Uptake		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
B_0	22.93	8.90	31.83	4.22	4.73	8.95	7.39	38.63	46.02	23.58	42.67	66.24
B_1	28.80	11.76	40.57	6.40	5.66	12.06	12.45	43.89	56.34	37.05	55.46	92.51
B_2	28.74	11.47	40.21	8.47	5.46	13.93	12.63	48.82	61.45	30.60	56.89	87.49
B_3	26.56	12.58	39.14	7.07	5.49	12.56	10.43	47.47	57.90	33.75	68.73	102.47
B_4	25.76	9.20	34.95	7.35	5.53	12.88	11.25	42.38	53.63	24.64	52.46	77.10
S.E.±	1.62	0.54	2.08	0.31	0.24	0.53	0.46	1.66	2.09	1.72	2.25	3.91
C.D.@ 5%	NS	1.57	6.04	0.91	NS	1.55	1.34	4.81	6.07	4.99	6.54	11.34

The application of treatment S_1B_3 indicating 100:50:50 $N:P_2O_5:K_2O$ kg ha^{-1} through chemical fertilizers in addition to rice husk biochar asspplication @ 5 ton ha^{-1} observed significantly highest; treatment S_3B_2 comprising application of the Konkan Annapurna Briquette (34:14:6 $N:P_2O_5:K_2O$) with the application of azolla @ 1 ton ha^{-1} found to be significantly superior over all the treatments for uptake by grain and straw respectively. The significantly superior total potassium uptake was recorded by the S_3B_2 treatment receiving Konkan Annapurna Briquette (34:14:6 $N:P_2O_5:K_2O$) and azolla @ 1 ton ha^{-1}.

Silicon uptake

The nutrient sources application showed the significant effect on silicon uptake by grain. The application of S_1 treatment consisting application of 100:50:50 $N:P_2O_5:K_2O$ kg ha^{-1} through chemical fertilizers reported highest uptake. The application of Konkan Annapurna Briquette (34:14:6 $N:P_2O_5:K_2O$) (S_3) was found to be significantly highest in respect to the silicon uptake by straw (70.20 kg ha^{-1}). The significantly highest total silicon uptake was observed in the treatment S_1 receiving application of 100:50:50 $N:P_2O_5:K_2O$ kg ha^{-1}through chemical fertilizers.

Among the different beneficial sources, the application of B_1 treatment consisting silica application @ 150 kg ha^{-1} was reported to be significantly highest silicon uptake (37.05 kg ha^{-1}) by grain. While the treatment B_3 indicating application of the rice husk biochar @ 5 ton ha^{-1} found to be significantly superior (68.73 kg ha^{-1}) over all remaining treatments in terms of straw uptake. The application of rice husk biochar @ 5 ton ha^{-1} (B_3) noticed significant highest (102.47 kg ha^{-1}) effect for the total silicon uptake by rice. It was reveals from the previous studies that application of silicon enhances the uptake of the silicon by the rice straw and grain. Increment in the silicon uptake due to silicon application was also reported by Cuong *et al*., 2017 [5] and Pati *et al*., 2018 [16]. Increment in the grain and straw yield by Si application was also important fact behind the high uptake of silicon by rice crop.

Interaction effect of the nutrient sources and beneficial sources application observed to be non-significant for grain uptake. In case of the silicon uptake by the rice straw, the interaction effect found to be significantly superior (93.38 kg ha^{-1}) due to application of the S_3B_3 treatment consisting application of Konkan Annapurna Briquette (34:14:6 $N:P_2O_5:K_2O$) with the rice husk biochar @ 5 ton ha^{-1}. The application of Konkan Annapurna Briquette (34:14:6 $N:P_2O_5:K_2O$) with rice husk biochar @ 5 ton ha^{-1} denoted by S_3B_3 noticed significantly highest total silicon uptake (135.16 kg ha^{-1}).

Conclusion

The results of the present investigation indicated that, the grain yield of the rice was significantly affected by the application of 100:50:50 $N:P_2O_5:K_2O$ kg ha^{-1} through chemical fertilizers. The application of silica @ 150 kg ha^{-1} and rice husk biochar @ 5 ton ha^{-1} significantly improved grain and straw yield, respectively. The phosphorous, potassium and silicon content was significantly influenced by application of 100:50:50 $N:P_2O_5:K_2O$ kg ha^{-1} through chemical fertilizers in rice grain, while by Konkan Annapurna Briquette in rice straw. Azolla application significantly improved phosphorous and potassium content in grain, whereas, silica application increased nitrogen content in straw and silicon content in straw. The total uptake of phosphorous, potassium and silicon enhanced by application of 100:50:50 $N:P_2O_5:K_2O$ kg ha^{-1} through chemical fertilizers; however total nitrogen uptake by briquette application. Azolla application improved total uptake of phosphorous and potassium; while total nitrogen and silicon uptake by silica and biochar application respectively.

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