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Effect of different sources and methods of silicon application on direct sown rice

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Abstract
A field experiment was carried out to study the effect of different sources and methods of silicon application on direct sown rice during the *kharif* season in 2019-20 at Agricultural college farm, Bapatla, A.P, India. Experimental plot was laid out in randomized complete block design having nine treatments with three replications. Among different treatments imposed application of calcium silicate @ 200 kg ha^{-1} along with 100% RDF significantly increased the growth attributes like plant height, average number of tillers per hill and dry matter production as well as yield of direct sown rice.

Keywords: Calcium silicate, silicon, growth, yield, direct sown rice

Introduction
Silicon is second most abundant element in the earth's crust. The only plant available silicon is monosilicic acid (H_4SiO_4) it ranges from 14 to 20 mg L^{-1}(Devanur, 2015) [4]. Silicon concentration in plant shoots varies from 0.1% to 10% Si on dry weight basis (Babu Rao and susmitha, 2017) [2]. Due to continuous mono-cropping and intensive cultivation of highly silicon accumulating crops like rice leads to silicon deficiency. Highly weathered soils of tropics and subtropical soils are low in plant available silicon mainly through leaching of available silicon. Silicon fertilization is the only viable option to reduce silicon deficiency because silicon application significantly increases the growth attributing characters through its deposition on leaf surfaces. Whenever silicon is uptake by the rice plant through transpiration stream it is deposited on leaf surfaces causes erectness of the leaves, these erected leaves having ability to increased photosynthesizing capacity (Jawahar *et al.*, 2018) [8] as well as enhanced the yields of rice (Pati *et al.*, 2016) [12]. Silicon is also considered as an eco -friendly element to be used on soils as a fertilizer and for plant nutrition purposes as well (Jawahar *et al.*, 2019) [6,7]. Direct sown rice is the only viable option to reduce cost of cultivation and increased rice yields reported by Deelstra *et al*., 2017 [3]. So far the application of different silicon sources through soil and foliar methods to puddled and upland rice crops have been studied But, the information regarding effect of different silicon sources on growth and yield of direct sown rice is very limited. Thus, present study was undertaken with the premier objective to provide some additional information on how far exogenously applied silicon sources influences the growth attributes and yield of direct sown rice.

Materials and Methods
A field experiment conducted at Agricultural college farm, Bapatla in Guntur district of A.P state in India during *kharif* season 2019 to 20. The experiment was laid out in complete Randomized Block Design (RBD) with nine treatments and three replications. The treatments comprises of T_1: 100% RDF, T_2: 100% RDF + soil application of 100 kg ha^{-1} calcium silicate, T_3: 100% RDF + soil application of 200 kg ha^{-1} calcium silicate, T_4: 100% RDF + soil application of 20 kg ha^{-1} silixol granules, T_5: 100% RDF + soil application of 40 kg ha^{-1} silixol granules, T_6: 100% RDF + foliar application of stabilized silicic acid @ 0.4% at 30 and 60 DAS, T_7: 100% RDF + foliar application of stabilized silicic acid @ 0.4% at 30, 60 and 90 DAS, T_8: 100% RDF + foliar application of potassium silicate @ 0.8% at 30 and 90 DAS, T_9: 100% RDF + foliar application of 0.8% potassium silicate at 30, 60 & 90 DAS. For recording biometric observations five representative hills from each net plot were selected randomly. Those selected hills were labelled with proper notations. Plant height and average number of tiller per hill are measured in labelled hills at tillering, panicle initiation and harvest stage. Dry matter production was estimated randomly selected hills are taken from above ground portion at tillering, panicle initiation and harvest stage, those samples are oven dried and weights were taken. Finally, grain and straw yield data taken per plot that converted in to kg ha^{-1}.

The data generated from the present experiment is statistically analyzed as per the methods suggested by Panse and Sukhatme (1985).

Table 1: Initial characteristics of the experimental soil

Particulars	Value
A. Physical characteristics	
Sand (%)	50.2
Silt (%)	10.0
Clay (%)	39.8
Textural class	Sandy clay
Bulk Density (Mg m^{-3})	1.41
Water Holding Capacity (%)	21.0
B. Physico - chemical characteristics	
pH (1: 2.5 soil water suspension)	7.93
EC (dS m^{-1} at 25 ^0C) (1: 2.5 soil water extract)	0.27
Organic carbon (%)	0.41
C. Available nutrient status	
Available N (kg ha^{-1})	275
Available P_2O_5 (kg ha^{-1})	51.52
Available K_2O (kg ha^{-1})	572
Available Sulphur (ppm)	8.1
Available Silicon (ppm)	115.5
Available Zn (mg kg^{-1})	1.69
Available Fe (mg kg^{-1})	8.38
Available Mn (mg kg^{-1})	8.12
Available Cu (mg kg^{-1})	2.30

Results and Discussion
On growth attributes
i. Plant height (cm)
Data pertaining to table 2 and figure 1 represented that effect of different sources and methods of silicon application significantly increased the plant height in direct sown rice.
The maximum plant height was observed (72.4, 85.9 and 111.5 cm at tillering, panicle initiation and harvest stages respectively) in T_3 treatment it was on par with T_7, T_9 and T_5. Minimum plant height was observed (54.6, 68.6 and 76.8 cm at tillering, panicle initiation and harvest stages respectively) in control (T_1) treatment.
The graded application of silicon significantly increased the plant height also reported by Jawahar and Vaiyapuri (2010) [5], Nagula *et al*., 2015 [10], Pati *et al*., 2016 [12], Patil *et al*., 2018a [15]. Silicon application significantly increased the plant height might be due to deposition of silicon in leaf tissues and maintained leaf in erected position (Jawahar *et al*., 2019b) [9].

Table 2: Effect of different sources and methods of silicon application on plant height (cm) in direct sown rice

Treatments	Plant height(cm)		
	Tillering	Panicle initiation	Harvest
T_1: 100% RDF	54.6	68.6	76.8
T_2: T_1+ Soil application of 100 kg ha^{-1}CS	60.6	76.4	99.4
T_3: T_1 + Soil application of 200 kg ha^{-1}CS	72.4	85.9	111.5
T_4: T_1 + Soil application of 20 kg ha^{-1} SG CS	58.1	73.8	98.4
T_5: T_1 + Soil application of 40 kg ha^{-1} SG	65.5	79.4	107.4
T_6: T_1 + Foliar application of 0.4% SS at 30 & 60 DAS	60.0	75.6	99.2
T_7: T_1+ Foliar application of 0.4% SS at 30, 60 & 90 DAS	69.1	83.0	110.0
T_8: T_1 + Foliar application of 0.8% PS at 30 & 60 DAS	58.9	74.9	98.8
T_9: T_1+ Foliar application of 0.8% PS at 30, 60 & 90 DAS	66.5	80.6	108.9
S.Em(±)	2.58	5.23	7.88
CD (P=0.05 %)	7.75	9.49	23.63
C.V (%)	7.13	7.07	13.50

RDF: Recommended Dose of Fertilizer, CS: Calcium Silicate, SG: Silixol Granules, SS: Stabilized Silicic acid, PS: Potassium Silicate, DAS: Days after Sowing

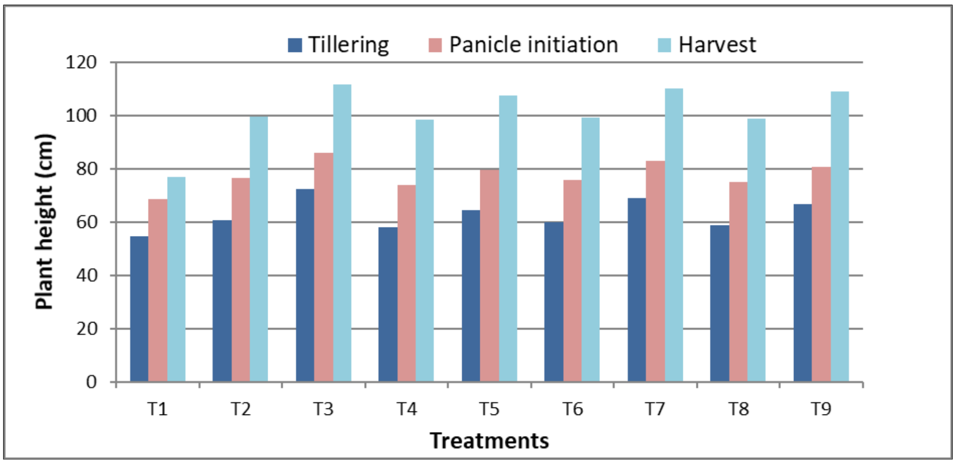

Fig 1: Effect of different sources and methods of silicon application on plant height (cm) in direct sown rice

ii. Average number of tiller per hill
The data presented in table 3 and depicted in figure 2 revealed that there was a significant difference observed with average number of tillers per hill of direct sown rice by application of different silicon sources and methods.
Among different treatments, the highest average number of tillers per hill was observed (16.33, 20.53 and 20.03 at tillering, panicle initiation and harvest stages respectively) in treatment T_3 and it was on par with T_7, T_9, T_5 whereas the lowest average number of tiller per hill was observed (12.20, 15.37 and 15.07 at tillering, panicle initiation and harvest stages respectively) in control treatment (T_1).
Jawahar and Vaiyapuri (2010) [5], Prakash *et al*., 2011 [16], Ahmad *et al*., 2013 [1], Patil *et al*., 2018b [14], reported similar results. Tillering is the production of expanding auxiliary buds which is clearly depends upon the nutritional condition of mother culm because tillers receive nutrients from mother culm at early growth stages so that silicon improves the nutritional condition of mother culm automatically mother culm produces more number of tillers per hill (Singh *et al*., 2006a) [17].

Table 3: Effect of different sources and methods of silicon application on average number in tillers per hill of direct sown rice

Treatments	Average number of tillers per hill		
	Tillering	Panicle initiation	Harvest
T_1: 100% RDF	12.20	15.37	15.07
T_2: T_1+ Soil application of 100 kg ha^{-1}CS	14.27	17.90	17.43
T_3: T_1 + Soil application of 200 kg ha^{-1}CS	16.33	20.53	20.03
T_4: T_1 + Soil application of 20 kg ha^{-1} SG CS	13.37	16.67	16.43
T_5: T_1 + Soil application of 40 kg ha^{-1} SG	14.70	19.00	18.10
T_6: T_1 + Foliar application of 0.4% SS at 30 & 60 DAS	13.90	17.77	17.10
T_7: T_1+ Foliar application of 0.4% SS at 30, 60 & 90 DAS	15.07	19.77	18.87
T_8: T_1 + Foliar application of 0.8% PS at 30 & 60 DAS	13.73	17.53	17.07
T_9: T_1+ Foliar application of 0.8% PS at 30, 60 & 90 DAS	14.93	19.23	18.30
S.Em(±)	0.72	0.90	0.82
CD (P=0.05 %)	2.17	2.70	2.45
C.V (%)	8.79	8.58	8.05

RDF: Recommended Dose of Fertilizer, CS: Calcium Silicate, SG: Silixol Granules, SS: Stabilized Silicic acid, PS: Potassium Silicate, DAS: Days after Sowing

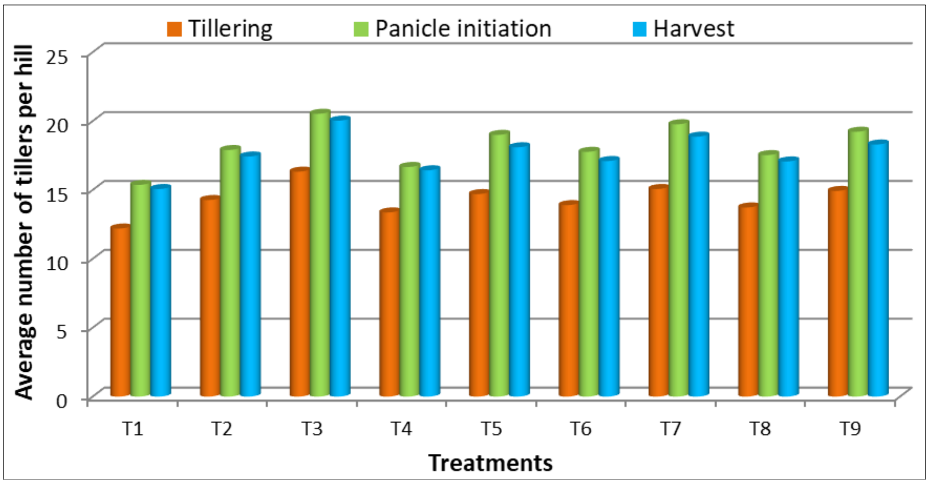

Fig 2: Effect of different sources and methods of silicon application on average number in tillers per hill of direct sown rice

On dry matter production

Data pertaining to table 4 and figure 3 represented that dry matter accumulation in direct sown rice was significantly increased by application of different silicon sources and methods. Dry matter accumulation increased from tillering to harvest stage of rice crop. The highest dry matter accumulation (2849, 5994 and 10673 kg ha^{-1}) was observed in T_3 treatment it was on par with (2893, 5875 and 10396 kg ha^{-1}) T_7, (2757, 5763 and 10240 kg ha^{-1}) T_9 and (2588, 5589 and 9989 kg ha^{-1}) T_5 at tillering, panicle initiation and harvest stage, respectively.

Maximum percent increase of dry matter accumulation was observed (38.9%, 24.3% and 19% at tillering, panicle initiation and harvest stages, respectively) in T_3 treatment.

Above results were in agreement with Singh *et al.* (2006a) [17], Jawahar and Vaipuri (2010) [5], Patil *et al.* (2018a) [15]. The beneficial effect of silicon on dry matter production (DMP) was mainly due to the leaf erectness, better penetration of solar energy leading to higher photosynthetic activity and reduction in the incidence of insects and pests (Sudhakar *et al.*, 2006) [18].

Table 4: Effect of different sources and methods of silicon application on dry matter production (Kg ha^{-1}) in direct sown rice

Treatments	Dry matter production (Kg ha^{-1})		
	Tillering	Panicle initiation	Harvest
T_1: 100% RDF	2147	4821	8976
T_2: T_1+ Soil application of 100 kg ha^{-1}CS	2468	5427	9831
T_3: T_1 + Soil application of 200 kg ha^{-1}CS	2982	5994	10673
T_4: T_1 + Soil application of 20 kg ha^{-1} SG CS	2317	5137	9324
T_5: T_1 + Soil application of 40 kg ha^{-1} SG	2588	5589	9989
T_6: T_1 + Foliar application of 0.4% SS at 30 & 60 DAS	2436	5394	9794
T_7: T_1+ Foliar application of 0.4% SS at 30, 60 & 90 DAS	2893	5875	10396
T_8: T_1 + Foliar application of 0.8% PS at 30 & 60 DAS	2355	5316	9765
T_9: T_1+ Foliar application of 0.8% PS at 30, 60 & 90 DAS	2757	5763	10240
S.Em(±)	132.38	229.28	316.75
CD (P=0.05 %)	396.87	687.39	949.63
C.V (%)	8.99	7.25	5.55

RDF: Recommended Dose of Fertilizer, CS: Calcium Silicate, SG: Silixol Granules, SS: Stabilized Silicic acid, PS: Potassium Silicate, DAS: Days after Sowing.

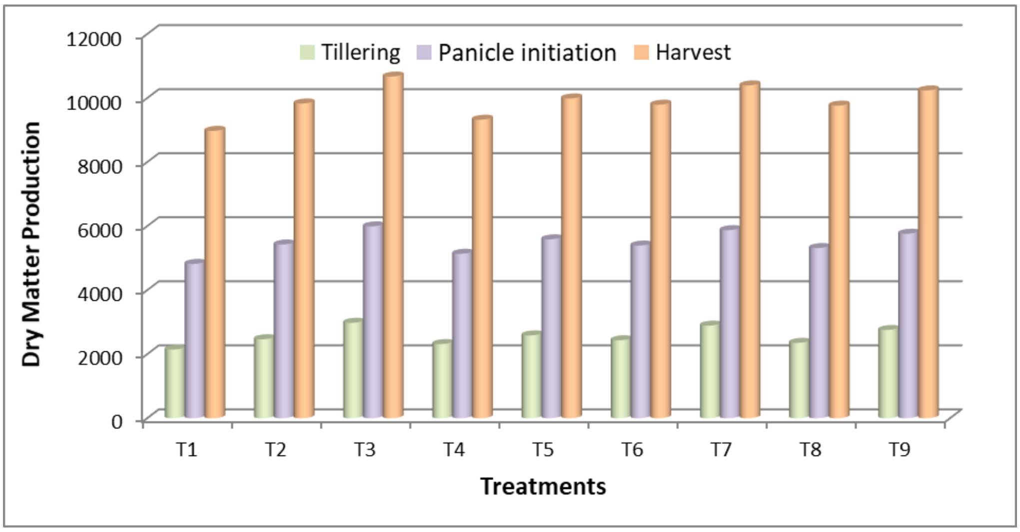

Fig 3: Effect of different sources and methods of silicon application on dry matter production (Kg ha^{-1}) in direct sown rice

Grain and Straw Yield (Kg ha^{-1})

Data on grain and straw yield of direct sown rice was presented in table 5 and depicted in figure 4. The results indicated that significant differences among treatments on grain yield and straw yield of direct sown rice by application of various silicon sources and methods.

The highest grain yield (5149 kg ha^{-1}) was obtained with T_3 (100% RDF + soil application of 200 kg ha^{-1} calcium silicate) treatment and it was on par with T_7 (4883 kg ha^{-1}), T_9 (4573 kg ha^{-1}) and T_5 (4424 kg ha^{-1}) whereas the lowest grain yield (3556 kg ha^{-1}) obtained with T_1 (100% RDF) treatment.

The highest straw yield 7276 kg ha^{-1} was noticed in T_3 (100% RDF + soil application of 200 kg ha^{-1} calcium silicate) treatment it was on par with T_7 (6934 kg ha^{-1}), T_9 (6512 kg ha^{-1}) and T_5 (6386 kg ha^{-1}) whereas lowest straw yield 5152 kg ha^{-1} was noticed in T_1 (100% RDF).

Above results were in agreement with Sudhakar *et al.*, 2006 [18], Patil *et al.*, 2018a [15], Jawahar *et al.*, 2019 [6, 7]. Silicon application in upland paddy increases the sturdiness of plant and helps to grow erect without any lodging. These erected leaves receive more sunlight, which leads to more photosynthetic activity and assimilation of organic constituents. They promote the growth and development of crop as well as reduce the incidence of pest and disease. Ultimately the crop grows vigorously and utilized the nutrients, moisture from soil which in turn increases the yield of upland paddy reported by Patil *et al.*, 2017 [13]

Table 5: Effect of different sources and methods of silicon application on grain yield (kg ha^{-1}) and straw yield (kg ha^{-1}) of direct sown rice

Treatments	At Harvest	
	Grain yield (kg ha^{-1})	**Straw yield (kg ha^{-1})**
T_1: 100% RDF	3556	5152
T_2: T_1+ Soil application of 100 kg ha^{-1}CS	4269	6057
T_3: T_1 + Soil application of 200 kg ha^{-1}CS	5149	7276
T_4: T_1 + Soil application of 20 kg ha^{-1} SG CS	3960	5549
T_5: T_1 + Soil application of 40 kg ha^{-1} SG	4424	6386
T_6: T_1 + Foliar application of 0.4% SS at 30 & 60 DAS	4198	5998
T_7: T_1+ Foliar application of 0.4% SS at 30, 60 & 90 DAS	4883	6934
T_8: T_1 + Foliar application of 0.8% PS at 30 & 60 DAS	4032	5718
T_9: T_1+ Foliar application of 0.8% PS at 30, 60 & 90 DAS	4573	6512
S.Em(±)	259.14	307.67
CD (P=0.05 %)	776.89	922.40
C.V (%)	10.35	8.66

RDF: Recommended Dose of Fertilizer, CS: Calcium Silicate, SG: Silixol Granules, SS: Stabilized Silicic acid, PS: Potassium Silicate, DAS: Days after Sowing

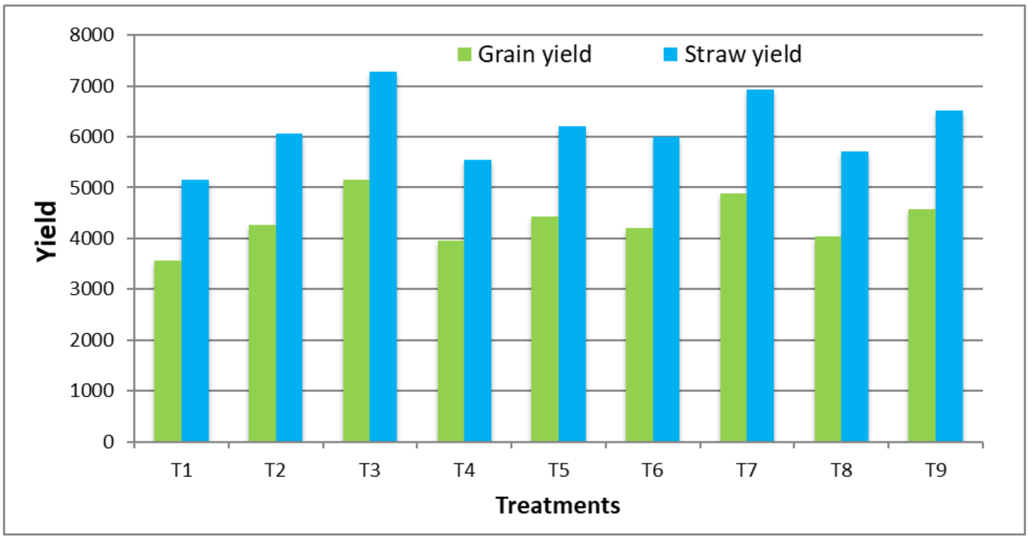

Fig 4: Effect of different sources and methods of silicon application on grain yield (kg ha^{-1}) and straw yield (kg ha^{-1}) of direct sown rice

Conclusion

Soil application of 200 kg ha^{-1} calcium silicate along with 100% RDF (T_3) significantly recorded the maximum plant height, average number of tiller per hill, dry matter production and yield of direct sown rice variety BPT-5204. T_3 treatment was on par with T_7 (100% RDF + Foliar application of 0.4% SS at 30, 60 & 90 DAS), T_9 (100% RDF + Foliar application of 0.8% PS at 30, 60 & 90 DAS) and T_5 (100% RDF + Soil application of 40 kg ha^{-1} SG).

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