

Original Research Article

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Effect of Planting Systems and Foliar Application of Iron and Silicon on Growth and Yield of Rice (*Oryza sativa* L.)

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ABSTRACT

Keywords

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A field experiment was conducted during *Kharif* season of 2019 at Department of Agronomy in Crop Research Farm, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, Uttar Pradesh, India. The objective was to study effect of planting systems and foliar application of iron and silicon on growth and yield of rice (*Oryza sativa* L.) Var. Shiats Dhan- 1 under Randomized block design comprising of 3 replications and 10 treatments (Conventional Transplanting of Rice, System of Rice Intensification, Iron at 0.5%, 1.0% and Silicon at 0.5%, 1.0% respectively). The experimental results revealed that with T₁₀ (SRI + 1.0% FA of FeSO₄ + 1.0% FA of Na₂SiO₃) recorded highest number of tillers/hill (20.07), dry weight (112.40 g), effective tillera/hill (19.20), number of grains/panicle (283.92), grain yield (6.08 t/ha), straw yield (9.31 t/ha) and harvest index (39.50%). Maximum plant height (113.87 cm) was recorded with T₃ (CTR + 1.0% FA of FeSO₄). Highest LAI (5.67) was recorded with T₈ (SRI + 1.0% FA of FeSO₄). And highest length of panicle (23.46 cm) was recorded with T₉ (SRI + 0.5% FA of FeSO₄ + 0.5% FA of Na₂SiO₃).

Introduction

Rice is a staple cereal food crop for more than half of the world's population and is generally grown by transplanting seedlings into a puddled soil in Asia. Worldwide, India stands first in rice producing area and second in production (172 million t/ha) after China of global rice production. However, the average productivity of rice in India is only 2.57 t/ha against the global average of 4.0 t/ha (FAO, 2018). Increasing productivity and production are essential to meet the food requirement of the burgeoning population. During the green

revolution era, India had achieved food security owing to introduction of high-input-responsive varieties of rice. However, it is observed that rice yields are either decelerating/ stagnating/declining in post green revolution era mainly due to imbalanced use of fertilizer, soil degradation, etc. (Prakash, 2010).

System of rice intensification (SRI) was first developed in Madagascar in 1980's. It is a combination of several practices that include slight changes in nursery management, time of transplanting and management of water,

nutrients and weeds. Through the fundamental practices remain more or less the same, SRI emphasizes certain changes in agronomic practices from conventional rice cultivation. It was noticed that, farmers adopting conventional methods could increase their production only by using expensive inputs such as chemical fertilizers, pesticides and hybrid seeds etc. (Reddy and Shenoy, 2013).

Micronutrient deficiency is considered as one of the major causes of declining productivity trends observed in rice growing countries. Foliar application of micronutrients is a simple way for making quick correction of plant nutrient status. It boosts process responsible for potential yield of crops such as nitrogen metabolism, uptake of N and protein, photosynthesis-chlorophyll synthesis carbonic anhydrase activity, resistant to abiotic and biotic stress-protection against oxidative damage (Kulhare *et al.*, 2017).

Iron plays a vital role in the formation of chlorophyll and takes part in oxidation-reduction reaction involved in RNA metabolism of chloroplast. It is a constituent of enzyme ferredoxin and cytochromes and is involved in symbiotic N fixation in the synthesis of several metalloenzymes, carbohydrate metabolism and protein synthesis (Mishra and Mishra, 2003). Fe deficiency was considered as a possible cause for the decline in rice yield (Jolley *et al.*, 1996). Soil application of inorganic Fe salts is ineffective in controlling Fe-deficiency except when application rates are large (Pal *et al.*, 2008). Although in most of the studies foliar application has an edge over soil application (Rattan *et al.*, 2008; Abadía *et al.*, 2011).

Silicon (Si) is the second most abundant element in the earth's crust. Silicon application improves the availability of applied fertilizer nutrients (namely N, P, and

K) and offers the potential to improve their agronomic performance and efficiency in terms of yield response (Rao and Susmitha, 2017). It is a principal soil component lost during weathering and the conversions of Si to secondary minerals are most important mechanisms of soil formation. Due to continuous mono-cropping and/or intensive cultivation of cereal crops like rice, the soil Si concentration is depleted which can be the main reason for declined rice yields (Mali *et al.*, 2008). A rice crop producing a yield of 5000 kg/ha removes 230-470 kg/ha. In continuous cropping with high silicon accumulator species such as sugarcane, the removal of PAS can be greater than the supply via natural processes releasing it into the soil unless fertilized with silicon (Savant *et al.*, 1997; McGinnity, 2015). The critical level of Si in soil is 40 mg/kg and the critical level of Si in rice (leaf and straw) is 5% (Rao and Susmitha, 2017). Its deficiency leads to soft and droopy leaves, reduced photosynthetic activity, reduced grain yields and number of panicles (IRRI, 2016). Reduced amounts of silicon in plants produces necrosis, disturbance in leaf photosynthetic efficiency, growth retardation and reduced grain yields in cereals especially in rice (Shashidhar *et al.*, 2008).

Materials and Methods

A field experiment was conducted during kharif season of 2019, at Crop research farm of Department of Agronomy at Sam Higginbottom University of Agriculture, Technology, and Sciences, Prayagraj which is located at 25° 24' 42" N latitude, 81° 50' 56" E longitude and 98 m altitude above the mean sea level (MSL). To assess the effect of planting systems and foliar application of iron and silicon on growth and yield of rice (*Oryza sativa L.*). The experiment was laid out in Randomized Block Design comprising of 10 treatments which are replicated thrice. Each

treatment net plot size is 3m x3m.RDF of NPK was 120:60:60in all treatments and two planting systems were taken CTR and SRI along with that iron and silicon was taken at 0.5 and 1.0%. Treatments were T₁ (CTR + Control), T₂(CTR + 0.5% FA of FeSO₄), T₃(CTR + 1.0% FA of FeSO₄), T₄ (CTR + 0.5% FA of FeSO₄ + 0.5% FA of Na₂SiO₃), T₅ (CTR + 1.0% FA of FeSO₄ + 1.0%FA of Na₂SiO₃), T₆(SRI + Control), T₇ (SRI + 0.5% FA of FeSO₄), T₈ (SRI + 1.0%FA of FeSO₄), T₉ (SRI + 0.5%FA of FeSO₄ +0.5% FA of Na₂SiO₃) and T₁₀ (SRI + 1.0% FA of FeSO₄ + 1.0% FA of Na₂SiO₃). In CTR 21 day old with spacing of 20 cm x 15 cm and 2 seedlings were transplanted. In SRI single seedling with spacing of 25 cm x 25 cm and 12 day old was transplanted. Iron was given as ferrous sulphate foliar application at 25 and 50 DAT. Whereas, Silicon as sodium silicate at 30 and 60 DAT. After harvesting, grains were separately from each net plot and were dried under sun for three days. Later winnowed, cleaned and weight of the grain per net plot value, the grain yield per ha was computed and expressed in tonnes per hectare. After complete drying under sun for 10 days straw yield from each net plot was recorded and expressed in tonnes per hectare. The data was computed and analysed by following statistical method of Gomez and Gomez (1984). The benefit: cost ratio was worked out after price value of grain with straw and total cost included in crop cultivation. After thorough field preparation initial soil samples were taken to analyse for available major nutrients. Nitrogen (N), phosphorous (P), potassium (K), Organic Carbon (OC), pH and soluble salts. The type of soil in experimental field is sandy clay. The pH of the experimental field was 7.7, EC of 0.45 dS/m, organic carbon was 0.44%. The N status of the experimental field was low (99 kg/ha), medium in available P (27 kg/ha) while available K status was in higher range (291.2 kg/ha). Growth parameters viz. plant

height (cm), No. of tillers/hill, dry matter accumulation g/hillwere recorded manually on five randomly selected representative plants from each plot of each replication separately as well as yield and yield attributing character viz. grain yield t/ha, straw yield t/ha, No. of panicles/hill, and No. of grains/panicle were recorded as per the standard method. The oxidizable organic carbon was determined by Walkley and Black (1934), pH by pH meter and ECe by electrical conductivity bridge with glass electrode in a 1:2.5 soil water suspension (Jackson 1973). Soil texture by the Bouyoucos Hydrometer Method (Gee and Baudev, 1986). Available nitrogen was determined by Subbiah and Asija (1956), Available phosphorus was determined by Olsen *et al.*, (1954) and available potash was determined by Flame photometric method, Jackson (1973).

Results and Discussion

Growth attributes

The growth attributes of rice, viz., Plant height, number of tillers/hill, dry weight, Leaf area index were significantly influenced by both planting systems; CTR, SRI and foliar application of iron and silicon.

It is evident from Table 1 that plant height measured increased with advancement in crop growth. At harvest treatment T₃ (CTR + 1.0% FeSO₄) recorded significantly higher plant height (113.87 cm) which might be due to CTR planting system i.e., with decrease in row spacing increased the plant height. Similar result was also reported by Ninad *et al.*, 2017 and Mehta *et al.*, 2019. Foliar application of micronutrients also might be reason for increase in plant height as they accelerate the enzymatic activity and auxin metabolism in plants (Sudha and Stalin, 2015).

Number of tillers per hill (20.07) and dry weight per hill (112.40 g) was recorded significantly higher with treatment T₁₀ (SRI + 1.0% FeSO₄ + 1.0% Na₂SiO₃). Increased in shoot: root ratio and production of greater number of tillers on individual hill basis with wider spacing, younger seedlings in SRI at later growth stages was the reason for increase in dry weight and number of tillers per hill was also observed by Kumar *et al.*, 2006; Rajesh and Thanunathan, 2003; Mohammed *et al.*, 2016. Iron nutrition had a positive effect on tiller production of rice as also stated by Kumar *et al.*, 2018 and dry matter production before physiological maturity of the crop by Singh and Singh, 2018. Increase in number of tillers and dry weight at physiological maturity stage, might be also due to silicon foliar application by Prakash *et al.*, 2011 and Fallah, 2012.

Higher Leaf area index (5.67) was influenced significantly with treatment T₈ (SRI + 1.0% FeSO₄). The higher leaf area index might be due to higher number of tillers putting forth more leaves resulted higher leaf area index. SRI promoted more vigorous growth leaf area index than the conventional planting was also observed by Ali and Izhar., 2017; Zheng *et al.*, 2004). (Mahajan and Khurana, 2014; Kumar *et al.*, 2015) also observed similar, result of increase in LAI with foliar application of iron when compared to control.

Yield attributes

The yield attributes of rice viz., effective tillers per hill, length of panicle, number of grains per panicle, grain yield, straw yield and harvest index were significantly influenced by both planting systems; CTR, SRI and foliar application of iron and silicon.

Number of effective tillers per hill (19.20), number of grains per panicle (283.92), grain yield (6.08 t/ha), straw yield (9.31 t/ha) and

harvest index (39.50%) were recorded significantly higher with treatment T₁₀ (SRI + 1.0% FeSO₄ + 1.0% Na₂SiO₃). Highest Length of panicle (23.46 cm) was recorded significantly with treatment T₉ (SRI + 0.5% FA of FeSO₄ + 0.5% FA of Na₂SiO₃). And there was no significant difference was found in test weight.

The maximum number of productive tillers/hill was performed with SRI while the minimum with CTR was also reported by Anwari *et al.*, 2019. The increase in number of effective tillers/hill might be due to foliar application of iron at maximum tillering stage was also observed by Sowmya *et al.*, (2017). Prakash *et al.*, (2011) and Munir *et al.*, (2003) also observed similar results with foliar spray of silicon.

The panicle length increased significantly with the combination of iron and silicon in both planting systems. Similar, finding was also reported by Viraktamath (2006). Foliar application of iron during growth period improved chlorophyll content and photosynthesis caused increase of panicle length by Gill and Walia, 2013. silicon which deposited at cellular levels makes plant parts more elongated and erect which also might be reason for increase in panicle length. Also observed by Anand *et al.*, (2018).

Increase in number of grains per panicle might be due to plant spacing with SRI considerably resulted in advantage of space, light and circulatory air which might resulted in increased nutrient uptake and better dry matter assimilation leading to a consequent increase in a greater number of grains/panicle by Saju *et al.*, (2019). And also, highest number of grains/panicle also might be also due to the foliar application of both iron and silicon. The current results were agreed with the findings of Esfahan *et al.*, (2014).

Table.1 Influence of planting system, foliar application of iron and silicon on growth characters of rice

	Treatment	Plant height (cm)	No. of tillers/hill	Dry weight (g/hill)	LAI
T ₁	CTR + Control	110.60	10.60	79.07	3.93
T ₂	CTR + 0.5% FeSO ₄	109.27	11.67	80.3	4.51
T ₃	CTR + 1.0% FeSO ₄	113.87	11.60	83.67	4.31
T ₄	CTR + 0.5% FeSO ₄ + 0.5% Na ₂ SiO ₃	111.67	11.47	82.77	4.62
T ₅	CTR + 1.0% FeSO ₄ + 1.0% Na ₂ SiO ₃	110.27	11.73	84.63	4.72
T ₆	SRI + Control	107.43	18.10	95.63	4.87
T ₇	SRI + 0.5% FeSO ₄	109.40	18.13	96.1	5.11
T ₈	SRI + 1.0% FeSO ₄	110.27	18.87	96.73	5.67
T ₉	SRI + 0.5% FeSO ₄ + 0.5% Na ₂ SiO ₃	109.40	19.40	103.3	5.26
T ₁₀	SRI + 1.0% FeSO ₄ + 1.0% Na ₂ SiO ₃	109.47	20.07	112.4	5.44
	F test	S	S	S	S
	SEm±	1.02	0.47	1.84	0.21
	CD (P=0.05)	3.04	1.38	5.48	0.62

Table.2 Influence of planting system, foliar application of iron and silicon on yield attributes and yield of rice.

	Treatment	No. of effective tillers/hill	Length of panicle (cm)	No. of grains/panicle	Test weight (g)
T ₁	CTR + Control	9.13	21.27	177.80	20.04
T ₂	CTR + 0.5% FeSO ₄	10.07	21.75	182.47	20.42
T ₃	CTR + 1.0% FeSO ₄	9.53	22.05	181.40	20.11
T ₄	CTR + 0.5% FeSO ₄ + 0.5% Na ₂ SiO ₃	10.20	22.41	263.77	20.22
T ₅	CTR + 1.0% FeSO ₄ + 1.0% Na ₂ SiO ₃	10.93	22.92	267.24	20.74
T ₆	SRI + Control	17.83	22.05	188.80	20.14
T ₇	SRI + 0.5% FeSO ₄	18.00	22.23	206.73	20.19
T ₈	SRI + 1.0% FeSO ₄	18.07	22.20	200.27	20.27
T ₉	SRI + 0.5% FeSO ₄ + 0.5% Na ₂ SiO ₃	18.47	23.46	264.33	20.52
T ₁₀	SRI + 1.0% FeSO ₄ + 1.0% Na ₂ SiO ₃	19.20	22.93	283.92	21.25
	F test	S	S	S	NS
	SEm±	0.40	0.38	7.49	0.31
	CD (P=0.05)	1.18	1.14	22.66	-

Table.3 Influence of planting system, foliar application of iron and silicon on yield of rice

	Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Harvest index (%)
T ₁	CTR + Control	5.15	8.90	36.67
T ₂	CTR + 0.5% FeSO ₄	5.23	9.02	36.69
T ₃	CTR + 1.0% FeSO ₄	5.39	8.98	37.52
T ₄	CTR + 0.5% FeSO ₄ + 0.5% Na ₂ SiO ₃	5.42	9.19	37.09
T ₅	CTR + 1.0% FeSO ₄ + 1.0% Na ₂ SiO ₃	5.83	9.16	38.88
T ₆	SRI + Control	5.30	9.01	37.05
T ₇	SRI + 0.5% FeSO ₄	5.35	9.20	36.77
T ₈	SRI + 1.0% FeSO ₄	5.46	9.17	37.30
T ₉	SRI + 0.5% FeSO ₄ + 0.5% Na ₂ SiO ₃	5.86	9.13	39.09
T ₁₀	SRI + 1.0% FeSO ₄ + 1.0% Na ₂ SiO ₃	6.08	9.31	39.50
	F test	S	S	S
	SEm±	0.09	0.05	0.39
	CD (P=0.05)	0.27	0.15	1.15

Higher grain yield with SRI had more open architecture, with tillers spreading out more widely, covering more ground area and more erect leaves that avoided mutual shedding of leaves and these plants had higher LAI due to significant increase in leaf size and erect leaves in rice which might have increased the grain yield (Kumar *et al.*, 2013). Positive effect of iron by foliar spray on grain yield might be due to increase in chlorophyll content of leaves lead to increased photosynthesis and resulted in more tillers, dry weight and LAI. Hence, more capture of solar radiation which resulted in higher grain yield (Das *et al.*, 2016). Silicon enhanced the sturdiness in plants and enhanced the photosynthetic activity, which helped in better assimilation of organic constituents (carbohydrates) which lead to increase the economic yield of rice crop (Anand *et al.*, 2018).

The highest straw yield under SRI was due to adequate supply of nutrients which might contribute towards higher dry matter accumulation and better partitioning of photosynthate resulting in higher yield traits and ultimately the straw yield (Singh *et al.*, 2015). Foliar application of iron may be attributed to increase in crop growth and photosynthates from source to sink. These results also confirm the findings of Sowmya *et al.*, 2017; Shaygany *et al.*, 2012. There was significant increase in straw yield with the silicon. This might be due to the role of silicon in improving the photosynthetic activity and accumulation in plant parts which reduced lodging and enhanced resistance against abiotic and biotic stress. All these factors might have resulted into higher straw yield. These results are in conformity with the findings of Patil *et al.*, 2017 and Singh *et al.*, 2007.

Maximum harvest index SRI promotes better aeration, more space and less competition,

which may have enabled the plants to grow vigorously. Further, better partitioning of dry matter, which leads to increase in the number of effective tillers, number of grains per panicle and grain production (Samant, 2017), ultimately resulting in enhanced harvest index. These results are in agreement with the findings of Krishna *et al.*, 2008. Simultaneously, conventional system also exhibited acceptable harvest index values which might have been due to proper availability of nutrients in all the growth stages by inorganic sources that eventually lead to higher LAI, dry matter accumulation and higher productive tillers per unit area (Nayak and Biswal, 2018). Foliar application of iron which might be due to better source to sink translocation of carbohydrates resulting in higher grain yield and less straw (Singh and Singh, 2018). Similar findings were also made by Naik and Das. (2007). Silicon which was due to increase in grain yield rather than biomass (Lavinsky *et al.*, 2016) (Table 2 and 3).

From the above results, following conclusions were observed during the research. SRI + 1.0% FeSO₄ + 1.0% Na₂SiO₃ was found to be best treatment for obtaining maximum number of tillers/hill (20.07), dry weight (112.4), effective tillers/hill (19.20), number of grains/panicle (283.92), grain yield (6.08 t/ha), straw yield (9.31 t/ha) and harvest index (39.50%).

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