

Research Article

Enhancement of agronomic traits and yield of rice var. ADT 43 grown in typical ustifluent soil through silicon fertilization

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Abstract

Rice is a rich accumulator of silicon and its supply is essential for the growth and economic yield of rice. Hence, a field experiment was conducted in sandy clay loam soil belonging to Padugai series (Typic ustifluent) at farmers holding in Kuttalam block, Mayiladuthurai district, Tamil Nadu to assess the role of silicon in improving agronomic characters and yield of rice ADT 43, *Oryza sativa*. The treatments included T₁ - Recommended dose of fertilizer (RDF), T₂ - RDF + Potassium silicate (FS) - 0.25%, T₃ - RDF + FS - 0.50%, T₄ - RDF + FS - 1.00%, T₅ - RDF + FS - 0.25%, T₆ - RDF + FS - 0.50%, T₇ - RDF + FS - 1.00%, T₈ - RDF + SA - 50 kg ha⁻¹, T₉ - RDF + SA - 100 kg ha⁻¹ and T₁₀ - RDF + SA - 150 kg ha⁻¹. From T₂ to T₄, the foliar spray was done at tillering stage and from T₅ to T₇, the foliar spray was done at tillering and panicle initiation stage. The silicon was applied through FS with the rice crop. The soil application of silicon relatively recorded higher growth and yield compared to foliar application. Besides improving different agronomic characters of the rice, the soil application of 50 kg Si ha⁻¹ registered the highest grain yield (6183.3 kg ha⁻¹) and straw yield (6740 kg ha⁻¹) and was comparable with a single foliar spray of 1% Si. Growth and rice yield increased with Si concentration of 0.25% to 1%. Thus, the soil application of silicon @50 kg ha⁻¹ through potassium silicate is advocated to realize maximum rice yield.

Keywords: Growth, Rice, Silicon, Yield

INTRODUCTION

Rice is a staple food for about 800 million people in India. Rice holds a pivotal role in the food and livelihood security of people as it is a major food for more than sixty-five percent of the Indian population by bestowing approximately forty percent of total food grain. The area, production and productivity of rice in India is 43 Mha, 112 million tons (Mt) of milled rice and 2.6 t ha⁻¹, respectively (Pathak *et al.*, 2020). An effective soil nutrient management is an essential component of crop production, responsible for increasing and sustaining crop yields at high levels (Gerami *et al.*, 2012). 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 and Aery, 2008). Silicon is indexed as a beneficial plant nutrient since the effect of its application on plant growth and yield is mostly conducted on silicon accumulator plants like rice and sugarcane (Ma and Takahashi 2002; Haynes, 2014). Silicon (Si) is ranked as the second-most abundant element (after oxygen) in the earth's crust, with nearly 29% mean content (Sommer *et al.*, 2006). Silicon is absorbed as PAS (monosilicic acid) by rice plants in far larger quantities than the macronutrients. The potential of Si in improving crop yield has been demonstrated in many studies, especially under abiotic and biotic stress con-

ditions (drought, heavy metals, salinity and pathogens (Farooq and Dietz, 2015). Silicon is beneficial to many crops when added to some soils as a fertilizer. Method of fertilizer application, including soil incorporation, top-dressing and foliar application, is crucial as it affects nutrient accessibility. Silicon plays an important role in the plant growth and development and yield of rice (Patil *et al.*, 2017; Singh *et al.*, 2020; Chaiwong *et al.*, 2021). Silicon exerts positive interaction with other applied nutrients and results in better agronomic performance and efficiency in yield response. Also, silicon spares no effort in providing tolerance to rice plants against abiotic and biotic stresses. Hence, silicon management is essential for increasing and sustaining rice productivity (Rao *et al.*, 2017; Ramirez-Olvera *et al.*, 2021). Therefore, a field trial was conducted to assess the impact of silicon applied through potassium silicate on rice grown in typical ustifluent soil of Kuttalam block, Mayiladuthurai district Tamil Nadu.

MATERIALS AND METHODS

The field experiment was conducted in sandy clay loam soil belonging to Padugai series (Typic Ustifluent) at farmers holding in Kuttalam block, Mayiladuthurai district, Tamil Nadu. The experimental soil had pH-7.25, EC-0.15 dSm⁻¹, soil organic carbon-3.5 g kg⁻¹, KMnO₄-N- 265 kg ha⁻¹ (low), Olsen P- 18.4 kg ha⁻¹(medium), NH₄OAc-K- 228 kg ha⁻¹(medium) and available silicon-25 mg kg⁻¹. The treatment structure furnished is given in Table 1.

From T₂ to T₄, foliar spray was done at tillering stage and from T₅ to T₇, the foliar spray was done at tillering and panicle initiation stage. The recommended dose of 150:50:50 N, P₂O₅ and K₂O ha⁻¹ through urea, superphosphate and muriate of potash was added uniformly to all the plots. The potassium silicate contains 22 per cent Si and 11 per cent K₂O. Foliar and soil application of silicon was applied as per the treatment schedule and the amount of potassium silicate-based on treatment was calculated. The amount of potassium supplied through potassium silicate was taken out while applying the recommended potassium dose to all the plots. A short-duration rice var ADT 43 was the test crop. The experiment was conducted in randomized block design (RBD) design with three replications. Randomly tagged five rice plants in each plot was used to measure plant height (Plant height was recorded by measuring the height of the plant from the surface of the soil to the tip of the top most leaf and expressed in centimetres), tiller count, LAI (leaf area index)(Williams, 1946), chlorophyll (Arnon 1949), yield characters (The number of panicles m⁻² was counted by placing gradient at four different places in each plot, The well filled grains from representative panicles were differentiated into chaffs and grains and counted separately

and recorded, one thousand grains were counted from the produce from each plot and weighed and expressed in grams and the ear head samples were collected from the tagged hill at harvest and the panicle length was measured and expressed in cm. . At the time of harvest, grain and straw yield was recorded separately from each plot and expressed as kg/ha.

RESULTS AND DISCUSSION

Growth characters

On close perusal of the data furnished in Table 2 clearly showed significant (P< 0.05) effect of foliar and soil application of potassium silicate on the rice plant height, productive tillers, LAI, chlorophyll content, crop growth rate (CGR), relative growth rate (RGR) and net assimilation rate (NAR) over control. Soil application of silicon relatively recorded higher growth characters compared to foliar application. Among the treatments, the tallest plant (86.5 cm), maximum productive tillers hill⁻¹(12.2), LAI (4.07), chlorophyll content(3.31 mg/g), CGR (8.51 g m⁻² d⁻¹), RGR(26.1 mg g⁻¹ d⁻¹) and NAR (2.63 g m⁻² d⁻¹) was realised with soil application of 50 kg /ha Si through potassium silicate and was comparable with foliar spray of 1% Si sprayed at the tillering stage but superior to rest of the treatments. All growth characters declined when soil application of silicon increased from 50 to 150 kg ha⁻¹. Similarly, all the growth characters increased with foliar application of 0.25 to 1.0% silicon. However, when foliar spray was done twice, growth characters increased at 0.25 and 0.5% Si. But when sprayed at 1% silicon, it declined. Plant height is one of the most important traits in determining the vigour and potential of any crop. The stature of the plant leads to structure and capacity to capture sunlight to assimilate photosynthesis by virtue of more leaves. Improved plant height due to silicon is associated with improved cell division, elongation and expansion. This was in harmony with the outcome of Yavarzadeh *et al.*

Table 1. Treatment structure of the present study.

| | |
|-----------------|---|
| T ₁ | RDF + No silicon |
| T ₂ | RDF + PS (FS) - 0.25% @ TS |
| T ₃ | RDF + PS (FS) - 0.50% @ TS |
| T ₄ | RDF + PS (FS) - 1% @ TS |
| T ₅ | RDF + PS (FS) - 0.25% @ TS & PI |
| T ₆ | RDF + PS (FS) - 0.50% @ TS & PI |
| T ₇ | RDF + PS (FS) - 1% @ TS & PI |
| T ₈ | RDF + PS (SA) - 50 kg ha ⁻¹ |
| T ₉ | RDF + PS (SA) - 100 kg ha ⁻¹ |
| T ₁₀ | RDF + PS (SA) - 150 kg ha ⁻¹ |

RDF-Recommended dose of fertilizer; PS- Potassium silicate, FS- Foliar spray, SA- soil application, TS – Tillering stage, PI- Panicle initiation

(2008) who revealed that enhanced plant height is ascribed to deposition of silicon on the rice plant tissue leading to erectness of the leaves and stem. In the present study, number of tillers per hill was significantly increased with the application of Si fertilizer, since tillering is the outcome of expanding axillary bud, and it is the result of the nutritional condition of the mother clump. Jawahar *et al.* (2015) also reported the beneficial role of Si fertilizer in increasing number of tillers per hill. A higher leaf area index could be due to the erectness of leaves. Silicon improves high interception of light by keeping leaves erect, thereby stimulating canopy photosynthesis in rice (Singh *et al.*, 2005). Chlorophyll plays a role not only in the capacity but also in the efficiency of plant photosynthesis. Improvement in chlorophyll content due to silicon is due to reinforcement of the cell wall due to the deposit of silicon in the form of amorphous silica. Further erectness of the leaves and synthesis of chloroplast results in a higher chlorophyll concentration per unit area of leaf tissue (Cao *et al.*, 2013). Foliar application of potassium silicate stimulated antioxidant superoxide dismutase activity and increased photosynthesis capacity and chlorophyll content in bent grass especially under a high fertilizer regime (Schmidt *et al.*, 1999). Doaa *et al.* (2012) reported an increase in chlorophyll content in rice on the spraying of 5% potassium silicate. The crop growth rate is a unit increase in dry matter of crop on a daily basis, relative growth rate measures the increase in dry matter with a given amount of assimilating material at a given

point of time and net assimilation rate measures the mean photosynthetic efficiency of leaves in a crop community. Ahmad *et al.* (2013) reported increased CGR, RGR and NAR on silicon addition. Anand Lokadal and Sreekanth (2018) also echoed a similar effect of silicon on rice var BPT 5204 growth cultivated in sandy soils of Bapatla, Andhra Pradesh.

Yield attributes

The various yield contributing characters were statistically significant at 5% level due to soil and foliar administration of silicon through potassium silicate over control (Table 3). The highest number of panicles m^{-2} (360), the highest number of grains panicle $^{-1}$ (131), the highest number of filled grains panicle $^{-1}$ (112), the lengthiest panicle (16.7 cm) and maximum 1000 grain weight (17 g) was noticed with of 50 kg Si ha^{-1} followed by foliar spray of 1% silicon applied at tillering stage. But superior to rest of the treatments. Foliar application of silicon twice recorded higher yield attributes compared to single spray. Soil application of 50 kg Si ha^{-1} and single foliar spray of silicon at 1% caused 11 and 9.8% (number of panicles m^{-2}), 9.2 and 7.5% (number of grains panicle $^{-1}$), 11 and 8.9% (number of filled grains panicle $^{-1}$), 5.7 and 3.8% (panicle length) and 7.6 and 6.9% (1000 grain weight). Availability of plant-available silicon and a steady supply of silicon in the form of silicic acid for a longer period to crop and promotional effect of silicon with other nutrients resulted in better photosynthetic activity by the crop and led to

Table 2. Effect of potassium silicate on growth components of rice var ADT 43

| Treatments | Plant Height (cm) at harvest | Productive tillers hill $^{-1}$ | LAI at P.I Stage | Chlorophyll (mg/g) at P.I stage | CGR (g $m^{-2} d^{-1}$) at 30-60 DAT | RGR (mg $g^{-1} d^{-1}$) at 30-60 DAT | NAR (g $m^{-2} d^{-1}$) at 30-60 DAT |
|--|------------------------------|---------------------------------|------------------|---------------------------------|---------------------------------------|--|---------------------------------------|
| T ₁ – RDF (Control) | 83.8 | 11.2 | 3.18 | 3.01 | 7.15 | 23.7 | 2.22 |
| T ₂ – RDF + PS (FS) - 0.25% @ TS | 84.2 | 11.7 | 3.65 | 3.15 | 7.38 | 24.2 | 2.33 |
| T ₃ – RDF + PS (FS) - 0.50% @ TS | 85.1 | 12.0 | 3.72 | 3.20 | 7.67 | 24.6 | 2.35 |
| T ₄ – RDF + PS (FS) - 1% | 85.9 | 12.2 | 3.87 | 3.29 | 8.21 | 25.1 | 2.46 |
| T ₅ – RDF + PS (FS) - 0.25% @ TS & PI | 85.4 | 11.9 | 3.78 | 3.20 | 7.55 | 24.8 | 2.41 |
| T ₆ – RDF + PS (FS) - 0.5% @ TS & PI | 86.0 | 12.1 | 3.80 | 3.24 | 7.92 | 25.0 | 2.45 |
| T ₇ – RDF + PS (FS) - 1% @ TS & PI | 85.5 | 12.0 | 3.81 | 3.27 | 7.71 | 24.9 | 2.46 |
| T ₈ – RDF + PS (SA) - 50 | 86.5 | 12.2 | 4.07 | 3.31 | 8.51 | 26.1 | 2.63 |
| T ₉ – RDF + PS (SA) - | 86.0 | 12.0 | 4.03 | 3.29 | 8.44 | 25.8 | 2.60 |
| T ₁₀ – RDF + PS (SA) - 150 kg ha^{-1} | 85.7 | 11.9 | 3.99 | 3.28 | 8.21 | 25.7 | 2.56 |
| SE _d | 0.47 | 0.43 | 0.06 | 0.05 | 0.05 | 0.14 | 0.03 |
| CD @ 5% | 1.00 | 0.90 | 0.13 | 0.11 | 0.12 | 0.30 | 0.08 |

higher yield attributes. Panicle formation is directly related to the number of productive tillers, resulting in a higher number of panicles per unit area. It was confirmed by a positive correlation between productive tillers with a number of panicles m^{-2} ($r=0.835^{**}$) and a number of grains panicle $^{-1}$ ($r=0.924^{**}$). Increased filled grains were due to better assimilates of carbohydrates in a panicle. An increase in the number of spikelet's panicle $^{-1}$ of rice due to silicon addition was reported by Deivaseeno *et al.* (2020) and Mohammad *et al.* (2012). Higher test weight is attributed to better availability and translocation of nutrients as well as photosynthates from source to sink. Silicon has been reported to reduce the shattering of seeds in rice and increase the number and weight of filled grains (Seebold *et al.*, 2000). An increase in 1000 grain weight could also be due to greater deposition of silicon in paleae and lemma (Balastra *et al.*, 1989). Singh *et al.* (2006) and Ahmad *et al.* (2013) reported an increase in yield attributes through the foliar spray of 1% silicon, which they attribute due to better silicon nutrition of rice plant.

Rice yield

On close examination of data furnished in Table 4 showed significant ($P < 0.05$) impact of graded dose of foliar and soil application of silicon through potassium silicate on grain and straw yield over control. The grain yield ranged from 5283 to 6183 $kg\ ha^{-1}$ and straw yield ranged from 5653 to 6740 $kg\ ha^{-1}$. Soil application of 50 $kg\ Si\ ha^{-1}$ recorded the highest grain yield (6183 $kg\ ha^{-1}$) and straw yield (6740 $kg\ ha^{-1}$). Foliar spray of silicon increased the grain yield from 5530 to 6133 $kg\ ha^{-1}$ over control (5283 $kg\ ha^{-1}$) and straw yield from 6028 to 6747 $kg\ ha^{-1}$ over control (5653 $kg\ ha^{-1}$). Twice foliar spray of silicon recorded higher rice yield compared to single spray except for foliar spray @ 1%. Among the foliar spray, application @ 0.5 and 0.25% twice recorded higher rice yield compared to their single spray. But when 1.0% Si foliar spray was applied twice, it reduced the yield. Sol application of 50 $kg\ Si\ ha^{-1}$ was comparable with foliar spray of Si @ 1% applied at tillering stage. Per cent increase in grain yield ranged from 4.7 to 17 and straw yield ranged from 6.6 to 19.4 due to

Table 3. Effect of potassium silicate on yield attributes of rice var. ADT 43

| Treatments | Number of panicles m^{-2} | Number of grains panicle $^{-1}$ | Panicle length (m) | 1000 grain weight (g) | Number of filled grains panicle $^{-1}$ |
|---|-----------------------------|----------------------------------|--------------------|-----------------------|---|
| T ₁ – RDF (Control) | 325 | 120 | 15.8 | 15.8 | 101 |
| T ₂ – RDF + PS (FS) - 0.25% @ TS | 329 | 123 | 16.0 | 16.0 | 103 |
| T ₃ – RDF + PS (FS) - 0.50% @ TS | 341 | 125 | 16.1 | 16.7 | 105 |
| T ₄ – RDF + PS (FS) - 1% @ TS | 357 | 129 | 16.4 | 16.9 | 110 |
| T ₅ – RDF + PS (FS) - 0.25% @ TS & PI | 335 | 125 | 16.2 | 16.3 | 105 |
| T ₆ – RDF + PS (FS) - 0.50% @ TS & PI | 348 | 127 | 16.4 | 16.5 | 107 |
| T ₇ – RDF + PS (FS) - 1% @ TS & PI | 352 | 127 | 16.2 | 16.7 | 108 |
| T ₈ – RDF + PS (SA) - 50 $kg\ ha^{-1}$ | 360 | 131 | 16.7 | 17.0 | 112 |
| T ₉ – RDF + PS (SA) - 100 $kg\ ha^{-1}$ | 355 | 126 | 16.4 | 16.8 | 110 |
| T ₁₀ – RDF + PS (SA) - 150 $kg\ ha^{-1}$ | 352 | 125 | 16.3 | 16.7 | 107 |
| SE _d | 1.83 | 2.53 | 0.36 | 0.27 | 3.57 |
| CD @ 5% | 5.44 | 5.33 | 0.77 | 0.56 | 7.50 |

Table 4. Effect of potassium silicate on grain and straw yield of rice var. ADT 43

| Treatments | Grain yield ($kg\ ha^{-1}$) | Straw yield ($kg\ ha^{-1}$) | Per cent increase over control (Grain) | Per cent increase over control (Straw) |
|---|-------------------------------|-------------------------------|--|--|
| T ₁ – RDF (Control) | 5283 | 5653 | - | - |
| T ₂ – RDF + PS (FS) - 0.25% @ TS | 5530 | 6028 | 4.7 | 6.6 |
| T ₃ – RDF + PS (FS) - 0.50% @ TS | 6067 | 6522 | 14.8 | 15.3 |
| T ₄ – RDF + PS (FS) - 1% @ TS | 6133 | 6747 | 16.1 | 19.4 |
| T ₅ – RDF + PS (FS) - 0.25% @ TS & PI | 5750 | 6210 | 8.8 | 9.9 |
| T ₆ – RDF + PS (FS) - 0.50% @ TS & PI | 5983 | 6613 | 13.2 | 16.9 |
| T ₇ – RDF + PS (FS) - 1% @ TS & PI | 5633 | 6197 | 6.6 | 9.6 |
| T ₈ – RDF + PS (SA) - 50 $kg\ ha^{-1}$ | 6183 | 6740 | 17.0 | 19.2 |
| T ₉ – RDF + PS (SA) - 100 $kg\ ha^{-1}$ | 5733 | 6192 | 8.5 | 9.5 |
| T ₁₀ – RDF + PS (SA) - 150 $kg\ ha^{-1}$ | 5567 | 6123 | 5.4 | 8.3 |
| SE _d | 50.0 | 98 | | |
| CD @ 5% | 149 | 205 | | |

various treatment and the highest per cent increase in grain yield was noticed with soil application of 50 kg Si ha⁻¹ (17.0) followed by single spray @ 1% Si applied at tillering stage (16.1). The lowest response was noticed with foliar spray of Si @ 0.25 per cent applied at tillering stage. Silicon effects on yield are related to the deposition of the element under the leaf epidermis, which results in physical mechanism of defense, production of phenols which stimulate phytoalexin production, reducing lodging, decreases transpiration losses and increases photosynthetic capacity of rice plant as reported by Ahmad *et al.*, (2013).

The enhanced grain yield could be due to increased large leaf area and high chlorophyll content, which might have accumulated more photosynthates and produced higher biological yield. In the present study, soil application of 50 kg Si/ha registered maximum LAI and chlorophyll. Higher rice yield due to silicon inclusion is associated with increased spikelet's panicle-1, 1000 grain weight, and panicle length. The silicon application improved significantly yield attributes. This was corroborated by the equation of quadratic relationship found between rice yields with various attributes viz., number of panicles/m², number of grains/panicle, number of

filled grains/panicle, panicle length and 1000 grain weight (Fig. 1). The equation found that all of them positively contributed to higher yield. But it was number of grains panicle-1 that contributed much to grain yield (70.8%) followed by 1000 grain weight (57.1%), panicle length (56.2), number of filled grains (49.0%) and number of panicles m⁻² (43.4%). Gerami *et al.* (2012), Yogendra *et al.* (2014), Singh *et al.* (2020) and Siregar *et al.* (2021) reported enhanced rice grain yield due to Si fertilization in silicon deficient soil and they attributed to an increase in DMP and yield attributes. The present study also witnessed higher DMP and yield attributes due to silicon fertilization and eventually it had contributed to higher yield as witnessed by earlier workers

Conclusion

The field experiment conducted on the response of rice var ADT 43 to soil and foliar application of silicon through potassium silicate indicated that the rice responded well to silicon fertilization administered either through soil or foliar techniques. From the present study, it can be concluded that soil application of 50 kg Si/ha or foliar spray of Si@ 1% sprayed at tillering

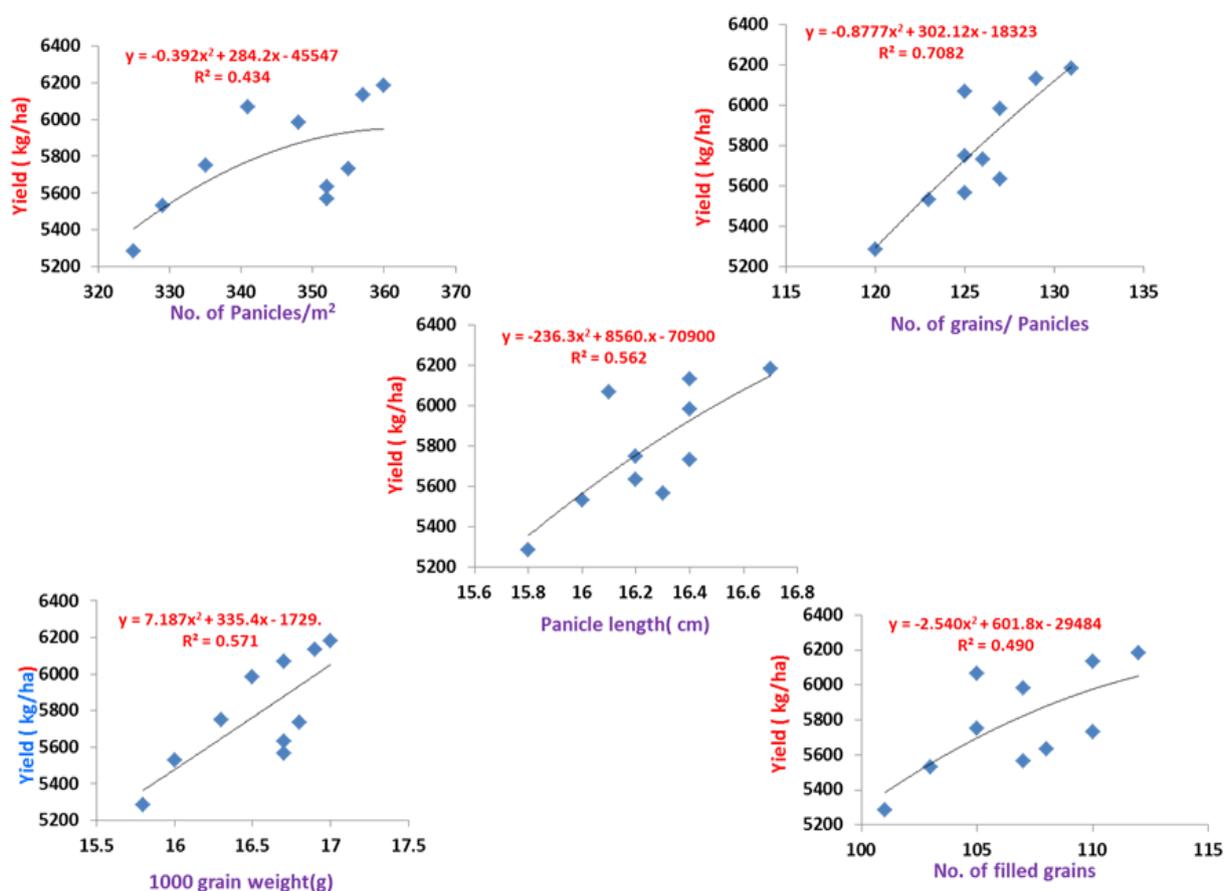


Fig.1. Showing quadratic relationship between grain yields and the yield attributes of rice var. ADT 43

stage through potassium silicate enhanced the growth and yield of rice grown in Kuttalam block, Mayiladuthurai district, Tamil Nadu. The experiment has to be conducted in other rice-growing soils also to validate the result emanated from the present study before it is passed on to farmers for adoption.

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Conflict of interest

The authors declare that they have no conflict of interest.

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