# Effect of Combined Application of Foliar Sprays of Orthosilicic Acid (OSA) with Basal NPK Fertilizer on Growth and Yield of Rice (Oryza sativa L.)

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## Abstract

# Purpose

Benefits of silicon to plant growth and yield in higher plants has been explored recently. This study was conducted to assess the effects combined application of foliar application of Orthosilicic Acid (OSA) with basal NPK fertilizer on growth and yield of rice.

# Methods

The study was conducted in Ntende site at Rwagitima marshland, Gatsibo district in the Eastern province of Rwanda. The field experiment was laid in randomized complete block design with three replications across in two cropping seasons in 2019/2020. Two recommended doses of fertilizer (RDF); 100% RDF (200 $kgha^{-1}$ NPK and 100 $kgha^{-1}$ Urea) and 75% RDF (150 $kgha^{-1}$ NPK and 75 $kgha^{-1}$ Urea) were used in combination with different doses of silixol orthosilicic acid (OSA). The Si fertilizers were applied in liquid form at panicle initiation and grain filling stages.

# Results

Combined application of OSA with RDF produced better growth attributes (plant height, number of tillers, root length, flag leaf length and width) compared with using RDF only. Similarly, OSA application showed higher yield components, number of panicles, panicle weight, grain weight per panicle and 1000-grain weight. Highest yield of 5.81 t/ha which equates to 24% increase was obtained when 100% RDF + 4ml/l OSA was applied.

# Conclusion

Rice fertilization with Si helps to stimulate plant growth, yield attributes and yield. Therefore, potential of Si could further be explored among rice farmers in Rwanda.

## 1 Introduction

Silicon (Si) occupies about 27.8% – 32% of the earth's crust, and this makes Si second most abundant element in the earth's crust after oxygen (46%) [1, 2]. Si is present in the earth's crust as quartz ($SiO_2$), which is the most common mineral found in sands [3]. However, $SiO_2$ in its form cannot be utilized by plants [4]. Plants absorb Si from soil solution in form of Monosilicic acid ($H_4SiO_4$), which is often synonymously named as orthosilicic acid (OSA) [5]. Silixol is commonly applied stable formulation of OSA, and has been used as a Si fertilizer to enhance better plant growth and yield in several crops [6, 7].

The Si accumulation in plants varies greatly depending on the species and Si content in the soil and normally ranges from 0.1–10% on dry weight basis [8, 9, 10]. Graminaceous plants such as barley (*Hordeum vulgare*), sorghum (*Sorghum bicolor)* and wheat (*Triticum aestivum*) and rice (*Oryza sativa*) have been categorized as high Si accumulators [11]. Fore instance, rice was found to accumulate 4.17% of Si in its shoot [12].

Si is the only non-essential nutrient that is included in the guidelines for rice fertilization [13]. Si fertilization has been reported beneficial to rice plant growth and yield [14]. Si increases photosynthetic rate [15], plant leaf area [16] and chlorophyll content [17]. Si also has a major role in increasing rice yield attributing characters [18, 19]. Additionally, Si has been reported to play a vital role in limiting the adverse effects of abiotic and biotic stresses in rice. Si application can enhance rice resistance to brown spot [20] and blast [21]. Si can enhance tolerance of rice to radiation [22], salinity [23] and drought [24]. Application of Si was also reported to reduce accumulation of toxic arsenic [23] and cadmium [24] in rice grains.

Despite these numerous benefits of Si to the rice crop, many farmers in Rwanda have not explored the potential Si as an exogenous fertilizer for their sustainable rice production. This study was conducted to assess the effects of combined application of different doses of foliar sprays of Orthosilicic acid (OSA) with basal NPK fertilizer of the growth and yields of rice.

## 2 Materials And Methods

# 2.1 Experimental Site

This study was conducted in Gatsibo district and the field experiments were carried in Rwagitima marshland (1˚52'50" S latitude, 30˚50'20" East longitude) in the Eastern Agro-ecological zone, Eastern Province, Rwanda. The experiments were conducted in 2019–2020 in two seasons (February to June) and (September to January) (Table 1). The basic properties of the site were; clay-loam type, pH 6.20, EC 361 µS/Cm, CEC 23.4 meq/100g, organic carbon 3.04%, total nitrogen 0.17%, available nitrogen 1.9 ppm, exchangeable calcium 4.92 meq/100g, exchangeable potassium 0.31 meq/100g and exchangeable magnesium 2.07 meq/100g.

Table 1
Mean monthly temperatures and precipitation data for the two seasons in 2019 and 2020

| Year | Month | Maximum Temp (°C) | Minimum Temp (°C) | Precipitation (mm) |
|---|---|---|---|---|
| 2019 | February | 28.9 | 15.6 | 65.6 |
| | March | 28.2 | 12.1 | 80.2 |
| | April | 26.8 | 17.0 | 113.7 |
| | May | 25.8 | 17.5 | 72.5 |
| | June | 26.6 | 17.2 | 73.1 |
| | September | 28.1 | 16.8 | 85.2 |
| | October | 25.5 | 16.6 | 175.5 |
| | November | 25.8 | 16.7 | 132.1 |
| | December | 25.9 | 16.9 | 125.6 |
| 2020 | January | 26.9 | 17.1 | 121.1 |
| Source: Rwanda Meteorology Agency | | | | |

## 2.2 Treatment Structure and Experimental Design

The experiments were laid in a randomized complete block design with three replications and eight treatments. Silixol (a stabilized form of orthosilicic acid (OSA) with 0.6% concentration) was applied as a source of Si element. The treatments were: $T_1$ (recommended fertilizer dose (RDF); 200 kg $ha^{-1}$ NPK (17.17.17) and 100 kg $ha^{-1}$ Urea), $T_2$ (75% of RDF; 150 kg $ha^{-1}$ NPK and 75 kg $ha^{-1}$ Urea), $T_3$ ($T_1$ + 2 ml of silixol per litre of water), $T_4$ ($T_1$ + 3 ml of silixol per litre of water), $T_5$ ($T_1$ + 4l ml of silixol per litre of water), $T_6$ ($T_2$ + 2 ml of silixol per litre of water), $T_7$ ($T_2$ + 3 ml of silixol per litre of water) and $T_8$ ($T_2$ + 4 ml of silixol per litre of water) (Table 2). NPK (17-17-17) was applied during planting while urea was used for top-dressing at both mid-tillering and at panicle initiation stages. The silixol liquid was foliarly applied both at panicle initiation and grain filling stages using a handheld sprayer. The regular recommended crop management practices were followed for all treatments until harvesting.

Table 2
Fertilizer application at different stages of plant growth

| | Planting | Mid tillering | Panicle initiation | | Grain filling |
|---|---|---|---|---|---|
| Treatments | NPK (kg $ha^{-1}$) | Urea (kg $ha^{-1}$ | Urea (kg $ha^{-1}$ | Silixol (ml $l^{-1}$) | Silixol (ml $l^{-1}$) |
| T1 | 200 | 50.0 | 50.0 | 0 | 0 |
| T2 | 150 | 37.5 | 37.5 | 0 | 0 |
| T3 | 200 | 50.0 | 50.0 | 2 | 2 |
| T4 | 200 | 50.0 | 50.0 | 3 | 3 |
| T5 | 200 | 50.0 | 50.0 | 4 | 4 |
| T6 | 150 | 37.5 | 37.5 | 2 | 2 |
| T7 | 150 | 37.5 | 37.5 | 3 | 3 |
| T8 | 150 | 37.5 | 37.5 | 4 | 4 |

# 2.3 Growth, Yield and Yield components

Plant height, number of tillers per hill and root length data were collected from ten randomly selected hills. The plant height was measured from the bottom to the top most leaf, numbers of tillers per hill were counted and root length was recorded from the base of the plant to the tip of the longest root. For yield attributes, number of panicles, panicle weight, grain weight per panicle and 1000 grains weight were measured. Grain yield was recorded at harvesting.

# 2.4 Statistical Analysis

The data were analyzed using analysis of variance (ANOVA), GenStat data analysis software. Treatment effects were significant at $p \leq 0.05$ and means were separated by Fisher's protected least significant difference (LSD).

## 3 Results And Discussion

# 3.1 Growth Parameters

Foliar application of Si fertilizer in combined with different doses of standard fertilizer practice significantly affected growth parameters (Table 2). Plant height significantly increased when Si was applied. An increase in number of tillers was also observed among treatments that received Si fertilizer. The effect of Si was highly significant ($P < 0.01$) for root length (Table 2), flag leaf width and length (Fig. 1). Across all treatments, RDF + 4 ml/l Silixol OSA liquid ($T_5$) resulted into better rice growth attributes compared with controls (RDF only). These results are in agreement with the findings of Pati et al. [27], who reported an increase in growth attributes of rice as a result of Si addition. Plant height of wheat was also increased by application of liquid silicon [28]. Moreover plant height is an important indicator of rice grain yield potential [29]. Increase in plant height might be attributed to Si accumulation in the cell wall that leads to plant erectness [30]. Increased number of tillers as a result of Si application was previously reported by Hosseini, et al. [31] and [32]. The increased number tiller might be due enhanced tillering capacity has been associated with a high supply of silicon [33]. Our findings are similar to Hattori *et al*. [34] who reported the positive effects of Si in increasing root length. Increase in flag area due to Si application was also reported by Dorairaj et al. [35].

Table 3
Effects of foliar application of combined doses of standard fertilizer practice and Silixol on growth parameters of rice

| Treatment | Recommended dose of fertilizer (RDF) (kg/ha) | | Silixol foliar | Plant height (cm) | Number of tillers | Root length (cm) |
|---|---|---|---|---|---|---|
| | NPK | Urea | ($ml\ l^{-1}$) | | | |
| T1 | 200 | 100 | 0 | $92.63^{a}$ | $261^{abc}$ | $11.5^{abc}$ |
| T2 | 150 | 75 | 0 | $91.25^{a}$ | $216^{a}$ | $10.02^{a}$ |
| T3 | 200 | 100 | 2 | $94.33^{abc}$ | $281^{abc}$ | $12.57^{bc}$ |
| T4 | 200 | 100 | 3 | $97.65^{bc}$ | $295^{bc}$ | $13.17^{cd}$ |
| T5 | 200 | 100 | 4 | $99.02^{c}$ | $331^{c}$ | $14.97^{d}$ |
| T6 | 150 | 75 | 2 | $93.53^{ab}$ | $252^{ab}$ | $10.67^{abc}$ |
| T7 | 150 | 75 | 3 | $94.48^{abc}$ | $273^{abc}$ | $11.83^{bc}$ |
| T8 | 150 | 75 | 4 | $95.78^{abc}$ | $288^{abc}$ | $12.75^{bcd}$ |
| *P* Value | | | | < .001** | 0.003* | < .001** |
| *SED* | | | | 1.276 | 20.26 | 0.602 |
| $LSD_{0.05}$ | | | | 2.736 | 43.45 | 1.291 |
| Means with by different letters are significantly different at 0.05 probability level. | | | | | | |

# 3.2 Yield Attributes and Yield of Rice

Several yield attributes such as number of panicles, panicle weight, grain weight per panicle and 1000-grain weight were significantly affected by application Si fertilizer (Table 4). Number of panicles increased by about 21% under RDF (100%) + 4 ml/l of silixol treatment compared with control. This treatment also produced highest panicle length of 20.28cm compared to control (18.88cm), although it was not significant. Similarly, about 24% increase in panicle weight was observed with RDF (100%) + 4 ml/l silixol compared with only RDF (100%). Grain weight per panicle and 1000-grain weight were increased by about 21% and 10%, respectively when RDF (100%) + 4 ml/l OSA was applied. Grain yield was not statistically significant with supplemental Si fertilizer application. Generally, Silixol OSA liquid applied in addition to RDF resulted in increased yield attributes and yield compared to the only RDF application (Table 4). Similar results depicting positive effects of Si application on yield and yield components were previously reported in rice [18, 36]. The increase in yield attributes might be a result of Si improving plant growth, nutrient uptake and tolerance to abiotic and biotic stresses [37, 38]. Though not statistically significant, the subsequent rice yields were increased in most of the treatments that received Si, and were far greater than the average yield (4.0 t/ha) of paddy rice in Rwanda in 2019 [39].

Table 4
Effects of combination of recommended fertilizer doses with foliar application of Silixol liquid on yield and yield attributes of rice.

| Treatment | Recommended dose of fertilizer (RDF) kg/ha | | Silixol foliar (ml/l) | Number of panicles | Panicle length (cm) | Panicle weight (g) | Grain weight per panicles (g) | 1000-grain weight (g) | Yield (t/ha) |
|---|---|---|---|---|---|---|---|---|---|
| | NPK | Urea | | | | | | | |
| T1 | 200 | 100 | 0 | 230$^{abc}$ | 18.88$^{a}$ | 4.64$^{ab}$ | 4.30$^{ab}$ | 27.31$^{abc}$ | 4.69$^{a}$ |
| T2 | 150 | 75 | 0 | 204$^{a}$ | 17.88$^{a}$ | 4.27$^{a}$ | 4.06$^{a}$ | 24.52$^{a}$ | 4.35$^{a}$ |
| T3 | 200 | 100 | 2 | 245$^{abc}$ | 19.48$^{a}$ | 5.06$^{abc}$ | 4.76$^{ab}$ | 27.49$^{abc}$ | 5.08$^{a}$ |
| T4 | 200 | 100 | 3 | 277$^{bc}$ | 19.75$^{a}$ | 5.27$^{bc}$ | 5.00$^{ab}$ | 28.65$^{bc}$ | 5.69$^{a}$ |
| T5 | 200 | 100 | 4 | 279$^{c}$ | 20.28$^{a}$ | 5.74$^{c}$ | 5.20$^{b}$ | 30.11$^{c}$ | 5.81$^{a}$ |
| T6 | 150 | 75 | 2 | 221$^{ab}$ | 18.02$^{a}$ | 4.62$^{ab}$ | 4.26$^{ab}$ | 25.53$^{ab}$ | 4.53$^{a}$ |
| T7 | 150 | 75 | 3 | 241$^{abc}$ | 19.38$^{a}$ | 4.97$^{abc}$ | 4.54$^{ab}$ | 27.21$^{abc}$ | 4.62$^{a}$ |
| T8 | 150 | 75 | 4 | 260$^{abc}$ | 19.69$^{a}$ | 5.21$^{abc}$ | 4.80$^{ab}$ | 27.94$^{bc}$ | 5.25$^{a}$ |
| *P* Value | | | | 0.001** | 0.328 NS | 0.002** | 0.007** | 0.001** | 0.195 NS |
| *SED* | | | | 14.45 | 1.051 | 0.2568 | 0.2597 | 0.958 | 597.2 |
| $LSD_{0.05}$ | | | | 30.99 | 2.253 | 0.5508 | 0.557 | 2.055 | 1280.8 |
| Means with by different letters are significantly different at 0.05 probability level. | | | | | | | | | |

# 4 Conclusion

Results of this study indicate that foliar application of Si in combination with RDF resulted in positive effects agronomic and yield-related attributes of rice. Furthermore, application of 4 ml/l of OSA with RDF would improve rice growth and yield in the rice producing regions of Rwanda. Thus, Si-fertilizers have a great potential and are worth exploring for commercial rice production.

# 5 Declarations

**Ethics approval and consent to participate (Not applicable)**

### Consent for publication (Not applicable)

### Availability of data and materials

The data that support our findings within this paper are available from the corresponding author upon reasonable request.

### Competing interests

The authors declare that they have no conflict of interest with respect to research, authorship, and/or publication of this article.


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### Author contributions

**Saidi Rumanzi Mbaraka**: **Jean Claude Abayisenga:** and **Christian Nkurunziza:** Conceptualization and Experimental design (lead); Methodology (equal); Investigation (equal); and Writing original draft preparation (equal); Writing-review & editing (equal). **Francois Xavier Rucamumihigo:Sylvestre Habimana: and Loc Van Nguyen:** Data curation (equal); Formal analysis (equal);, Development of Figures and Tables (equal). **Ivan Gasangwa: Jain Neeru: Eularie Mutamuliza: Fabrice Musana Rwalinda**: Methodology (supporting); Visualization (supporting); Writing-review & editing (equal); Funding acquisition (supporting). **Pascal Rushemuka**: Project administration (lead); Funding acquisition (lead); Writing-review & editing (equal). All authors read, discussed the results, commented on the manuscript and agreed to the published version of the manuscript.


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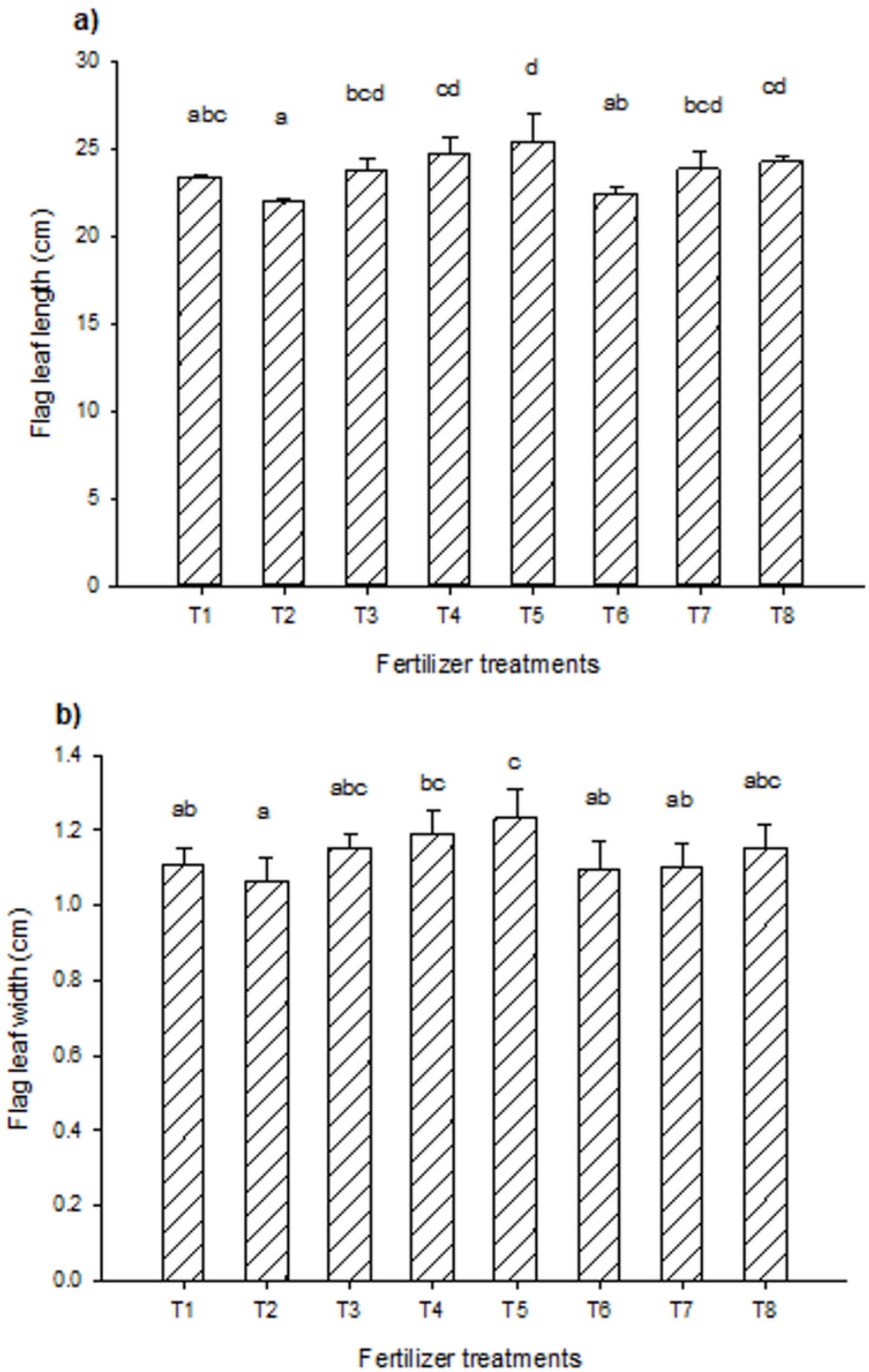
# Figures



### Figure 1

Effect of combined application of Si and NPK basal fertilizer on flag length (a) and flag width (b).