# Effect of Silicon (Si) and Surface Irrigation on Rice Cropin the Ramganga Region of Western India

## Abstract

This research conducted at the College of Agriculture Sciences and Engineering, IFTM University in Moradabad, Uttar Pradesh, India, comprehensively examined the influence of various surface irrigation levels, represented by standing water depths plus silicon (Si), on rice crop performance. Among the seven treatments tested, ranging from 1.5 cm to 4.0 cm of standing water under surface irrigation combined with 2ml/l silicon (Si) spray, T6 emerged as the most successful. In T6, rice plants cultivated with an average standing water depth of 4.0 cm exhibited superior growth, yield, water use efficiency (WUE), net return, and economic viability compared to other treatments, including the control group. This finding underscores the importance of maintaining an optimal water depth of 4.0 cm under surface irrigation, complemented by silicon (Si) spray application at 2ml/l, for maximizing rice crop productivity, economic returns, and overall agricultural sustainability. The benefit-cost ratio (BCR) further supported the economic feasibility of this approach, highlighting its potential for enhancing both agricultural yield and economic gains for farmers in similar agro-climatic regions.The study demonstrated that maintaining a standing water depth of 4.0 cm, coupled with silicon (Si) spray at a concentration of 2ml/l, led to superior outcomes in terms of plant growth, yield, water use efficiency (WUE), net return, and overall economic viability at treatment T6, and compared control treatment T7. The outcomes emphasize the importance of this particular water depth and the application of silicon (Si) in enhancing rice crop productivity.

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**Keywords:**Surface Irrigation, Silicon, Rice, Net Income, Benefit-cost ratio

## 1. Introduction

Rice is the seed of the grass species *Oryza sativa* (Asian rice) or *Oryza glaberrima*(African rice). As a cereal grain, it is the most widely consumed staple food for a large part of the world's human population, especially in Asia. It is the agricultural commodity with the third-highest worldwide production of rice (741.5 million tonnes in 2014) after sugarcane (1.9 billion tonnes) and maize (1.0 billion tonnes).

Rice is the staple food for more than half of the world's population, and more than 90% of the world's rice is produced in Asia **(FAO, 2009).** According to some scenarios **(Timmer *et al.*, 2010),** a general decline in rice demand may occur by 2050, especially in Asia and the Middle East; while an increase is expected in the African countries **(Ma and Takahashi, 2002)**. There is, however, a high degree of uncertainty relating to these projections, since future rice consumption will depend on different factors such as the population growth, the income growth and its distribution, and the urbanization of the population **(Rao, *et al.*, 2017).**

Rice is the staple food crop of India where it is grown in an area of 43.9 ha with a total production of 106.5 million tonnes and with an average productivity of 24.24 q/ha**(Anonymous, 2014)**. Uttar Pradesh ranks second after West Bengal where the total production is 14.41 million tonnes with a share of 13.80% to total rice production in the country **(Anonymous, 2013)**. India has to produce 170 to 180 million tonnes of rice (115-120 million tonnes of milled rice) by 2020 with an average productivity of 4.03 t/ha to maintain present level of self-sufficiency **(Mishra *et al.*, 2006)**.

Nitrogen also plays a role in grain filling, improving the photo-synthetic capacity, and promoting carbohydrate accumulation in culms and leaf sheaths **(Mae, 1997)**.This is especially the case in the northwest Indo-Gangetic plains (IGP) of India, where the production of irrigated rice and wheat is critical for food security of the country **(Humphreys *et al.*,2010).** The steady decline of ground water has led to general acceptance of the need to find ways to reduce irrigation water input while maintaining yield **(Yadav *et al.*,2011).** One way to reduce water input to rice is by improved irrigation management such as reduction in ponded water depth **(Kukal and Aggarwal, 2002; kumar and Singh, 2022),** Rice is regarded as the major staple food in many countries as well as primary source of energy and protein **(Zhang, *et al.*, 2008)**. Effects of silicon (Si) on0 yield are related to the deposition of the element under the leaf epidermis which results a physical mechanism of defense, reduces lodging, increases photosynthesis capacity and decreases transpiration losses **(Korndorfer, *et al.*, 2004)**.In Asia, rice is grown on 143 Mha, out of which 44 Mha are grown in India, contributing about 106.7 million tons of grain production, out of which dry-season (rabi) rice adds 15.2 million tons while the remaining 91.5 million tons come from wet-season (kharif) rice **(GOI, 2016a).**

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Silicon (Si) is considered as a beneficial element for crop growth, especially for crops under Poaceae family. Rice is a typical silicon (Si) accumulating plant and it benefits from silicon (Si) nutrition. Si is absorbed in the form of monosilicic acid and its transportation is governed by three genes *i.e.* LSi1, LSi2 and LSi6**(Cui *et al.*, 2010)**. Silicon (Si) is deposited beneath the cuticle as cuticle-silicon (Si) double layer in the form of silicic acid. Highly weathered soils are low in available silicon (Si) mainly due to leaching loss. Its supply is essential for healthy growth and economic yield of the rice crop**(Li *et al.*, 2011).** Silicon (Si) interacts favorably with other applied nutrients and improves their agronomic performance and efficiency in terms of yield response. Also it improves the tolerance of rice plants to abiotic and biotic stresses. Hence, silicon (Si) management is essential for increasing and sustaining rice productivity **(Rao, *et al.*, 2017).** In Asia, rice production is limited due to water shortage **(Arora *et al.*, 2006; Mahajan *et al.*, 2010),** thus, irrigation patterns directly influence rice production. Alternating wetting and drying could regulate rice yield **(Zhang *et al.*,2012; Ceylan, 1995).**

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Water is essential for growing crops, but it is important to use it efficiently because water can be scarce**(Kassam *et al.*, 2019)**. The rice cropping system is important for food security and livelihoods in many regions. To make the most of the water available, it is important to understand how much water is needed at different stages of rice growth**(Singh *et al.*, 2019)**. The water production function of a rice cropping system quantifies this relationship, providing valuable information on how changes in water availability affect crop performance**(Cui and Zornberg, 2009)**. This information can be used to develop optimal water management practices, which can help farmers, agronomists, and policymakers make informed decisions about irrigation scheduling, water allocation, and resource management.

## 2. Material and Methods

### 2.1 Experimental Site

The experiment was carried out in an area College of Agriculture Sciences and Engineering, IFTM University, Moradabad (Uttar Pradesh) at coordinates 28.83°N latitude, 78.78°E longitude and it had an elevation of approximately 205.67 meters above mean sea level (MSL) of Ram Ganga River shown in Fig. 1.The experimental plots have flat topography with homogenous fertility and soil characteristics typical to suit Paddy crop cultivation. The fields were fairly leveled and had good drainage having assured irrigation facility.The soil samples were collected randomly from different spots on the experimental site at the depth of 0-15 cm before conduct of experiment and a composite soil sample was prepared after proper during, mixing and sieving **(Kumar *et al.*, 2022)**. The composite soil sample were analyzed for different physical-chemical properties of the soil. The soil of the experimental site was sandy loam in texture, having pH is 7.8 with 0.43 per cent of organic carbon.

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## 2.2 Weather and climate

Meteorological conditions such as distributions of rainfall, maximum and minimum temperature, wind speed, average relative humidity recorded during the crop season of year 2019 were collected from the website (www.accuweather.com). The minimum and maximum temperature were revealed during crop (29.77 to 12.71°C) and (34.01 to 28.1°C), respectively. The maximum rainfall of 26.4 mm and relative humidity was highest 96.71% of the year 2019 graphically depicted in Fig.2.

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## 2.3 Layout and treatment details

The total no of plot 21, one plot size 3×3 m and total area of experimental field 202.4 $m^2$ including irrigation channel, using a randomized block design, seven distinct treatments were replicated three times. The chosen rice variety was Selection *IMR-001*, and the transplantation method (TPR) was employed for sowing in all treatments. Plant-to-plant (20 cm) and row-to-row (15 cm) and surface irrigation was uniformly applied. Details of the field experiment treatments are provided in Table 1.

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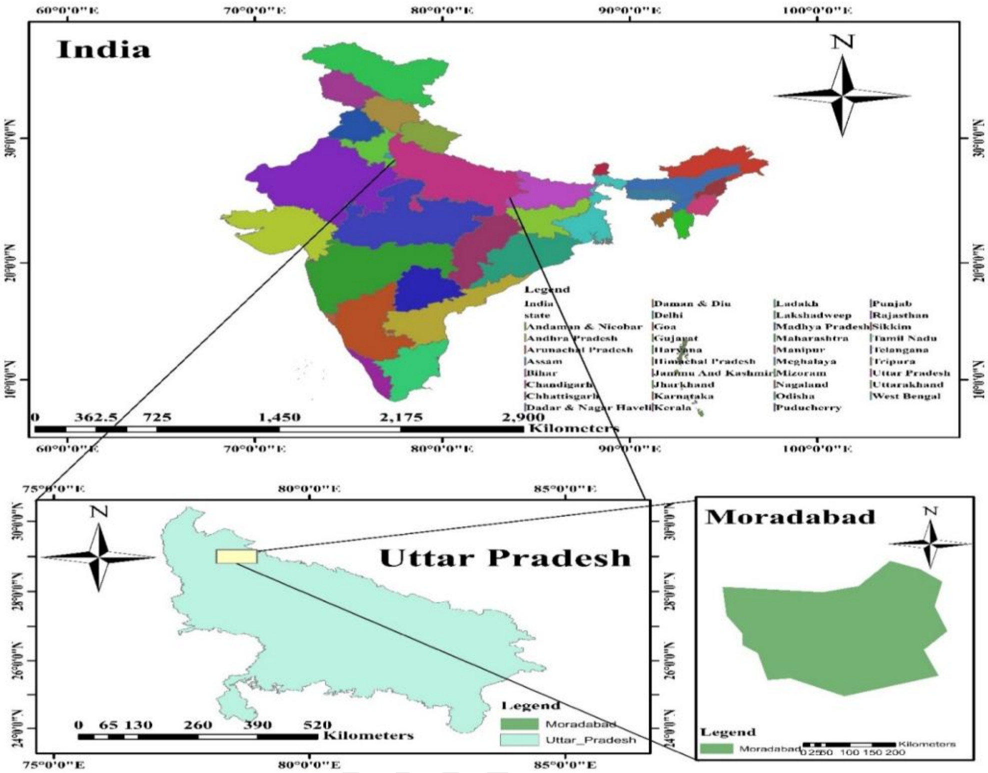

Fig. 1 Study area map

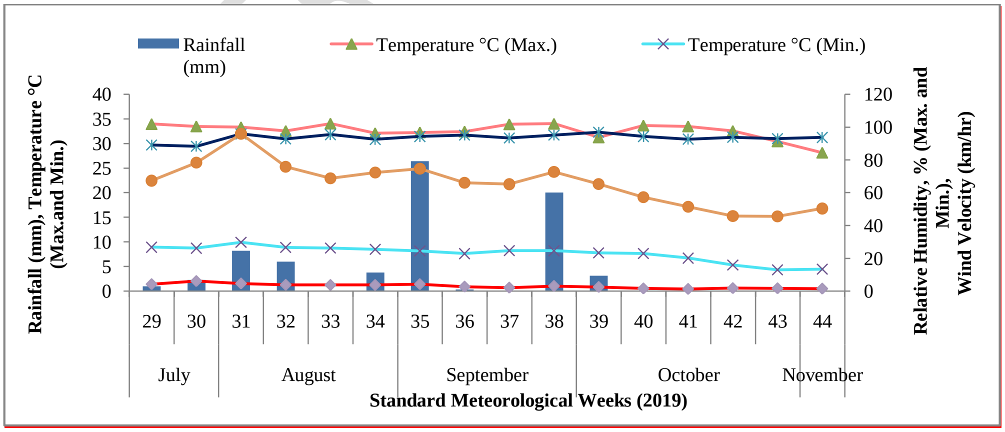

Fig. 2 Weekly meteorological data during crop season

**Table 1 Treatments combination of rice crop**

| Irrigation treatments | Treatment details |
|---|---|
| T1 | Transplanted rice with average 1.5 cm depth of standing water under surface irrigation + Silicon (Si) s pray @ 2m/lit water (at 25 & 45 DAT) |
| T2 | Transplanted rice with average 2.0 cm depth of standing water under surface irrigation + Silicon (Si)  s pray @ 3m/lit water (at 25 & 45 DAT) |
| T3 | Transplanted rice with average 2.5 cm depth of standing water under surface irrigation + Silicon (Si)  s pray @ 2m/lit water (at 25 & 45 DAT) |
| T4 | Transplanted rice with average 3.0 cm depth of standing water under surface irrigation++ Silicon (Si)  s pray @ 2m/lit water (at 25 & 45 DAT) |
| T5 | Transplanted rice with average 3.5 cm depth of standing water under surface irrigation + Silicon (Si)  s pray @ 2m/lit water (at 25 & 45 DAT) |
| T6 | Transplanted rice with average 4.0 cm depth of standing water under surface irrigation + Silicon (Si)  s pray @ 2m/lit water (at 25 & 45 DAT) |
| T7 | Transplanted rice with average control |

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### 2.4 Plant growth character

The plant height, was measured at 30, 60, 90 and 120 DAT and at harvest by selecting three tagged plants. The height of the three tagged sample plants were measured in centimeter with the help of meter scale and their mean values were worked out. Height of the main shoot of the sample plant was measured from the base of the plant to tip of the longest leaf while, after panicle emergence it was measured from base of the plant to tip of the panicle.

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The number of tillers-per plant was measured at 30, 60, 90, and 120 DAT and by selecting three plant randomly in each plot were counted plant$^{-1}$ of tillers and averaged to get the no. of tillers. Dry weight was recorded randomly at 45, 90  DAT  from each individual plots within a quadrate, plant enclosed within quadrate were cut down carefully closed to ground

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surface and then dried in room temperature (7 days). After drying these samples collected in paper bags by cutting in small pieces and was put in oven at 61°C for (48hr.) drying to obtain the constant dry weight and weighed by using electronic balance. The average dry matter value was calculated from the observation recorded in gm.

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$$\text{Harvest index (\%)} = \frac{Economical\ \ yield}{Biological\ \ yield} \times 100 \qquad \ldots (1)$$

### 2.5 Water Use Efficiency

Water use efficiency (WUE) is a measure of how well crops use water. It is calculated by dividing the crop yield by the amount of irrigation water applied. In the study you mentioned, the researchers calculated WUE for different treatments by dividing the fruit yield per hectare by the amount of water used per hectare.

$$\text{WUE} = \frac{\text{Yield (q ha}^{-1}\text{)}}{\text{Amount of water applied (mm)}} \qquad \ldots (2)$$

### 2.6 Economics analysis

Costs of cultivation for different treatments were worked out by adding variable cost of various treatments to common cost of cultivation.Gross income was out by multiplying grain and straw yield separately under various treatment combinations with their added together in order in order in archives gross income ($ha^{1}$) Gross income = Total income from grain yield and straw yield**.** Net return was calculated by subtracting the cost of cultivation from the gross return of individual treatment combination.Net return (Rs $ha^{-1}$) = Gross return (Rs $ha^{-1}$) - cost of cultivation (Rs $ha^{-1}$)**.** The cost of cultivation was worked out by considering all the expenses gross return was worked out by multiplying grain and straw yield by its price prevailing in the market on per hectare basis under various treatments. The money value of grain and straw yields was added together. Net returns were calculated by subtracting the cost of cultivation from the gross return of the treatment.

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$$\text{BCR} = \frac{\text{Net return (Rs.ha}^{-1}\text{)}}{\text{Total cost of cultivation (Rs.ha}^{-1}\text{)}} \qquad \ldots (3)$$

### 2.7Statistical analysis

All statistical analyses were performed using the software package. All data were tested of the variance analysisto ensure that the data met the requirements of the variance analysis. A two-way ANOVA wasused to analyze differences in growth, yield, WUE and economics, with treatment type as independent factors.

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## 3. Results and Discussion

### 3.1 Growth parameters

Plant height in all treatments increased continuously from 30 days after transplanting (DAT) to 60 DAT and 90 DAT, except for 120 DAT. Plant height was significantly different among all treatments at all growth stages. At 30 DAT, the highest plant height was observed in treatment T6 (85.22 cm), while the lowest plant height was observed in treatment T7 (76.56 cm). At 60 days after transplanting (DAT), plants in treatment T6 was the tallest (130.78 cm), while plants in treatment T7 was the shortest (127.56 cm). At 90 (DAT), plants in treatment T6 was the maximum height (139.33 cm), while plants in treatment T7 was the minimum height (129.11 cm). Similarly, highest plant height was found in T6 (137.50 cm) compared in T7 (126.50 cm) as shown in Fig. 3. There was also a significant difference in plant height between silicon (Si) levels and surface water at all growth stages. In other words, silicon (Si) levels and surface water had a significant effect on plant height at all growth stages. Plants that received higher levels of silicon (Si) or surface water grew taller than plants that did not receive these treatments. Treatment T4 had the highest plant height at 30, 60, 90 and 120 DAT, while treatment T7 had the lowest plant height at 30, 60, 90 and120 DAT. This suggests that treatment T4 was more effective at promoting plant growth than treatment T7.

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The data regarding number of tillers per plantof rice as influenced by silicon (Si) (foliar spray) with surface irrigation water levels recorded at different crop growth stages, analyzed statistically and the results have been presented in Fig. 4. The maximum number of tillers per plant was recorded in T6 (8.2) while minimum number of tillers per plant was obtained in T7 (6.2) at 30 DAT. Treatment T6 receded the number of tillers per plantat 30, 60, 90 and 120 DAT, while treatment T7 obtained the lowest number of tillers per plantat 30, 60, 90 and 120 DAT. Same finding were also reported by (**Mandal *et al.*, 1992; Rupp and Hubner, 1995**). The

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Silicon (Si) promotes growth and it also strengthens culms of rice plant, increases resistance and photosynthesis (**Lewin and Reimann, 1969; Bhaskaran, 2014)**.

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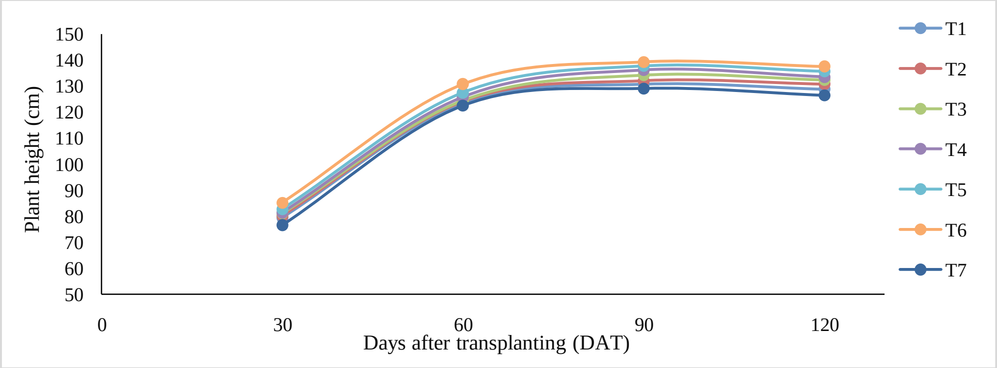

**Fig. 3Effect of silicon (Si) and different levels of surface irrigation water on plant height of rice crop under surface irrigation**

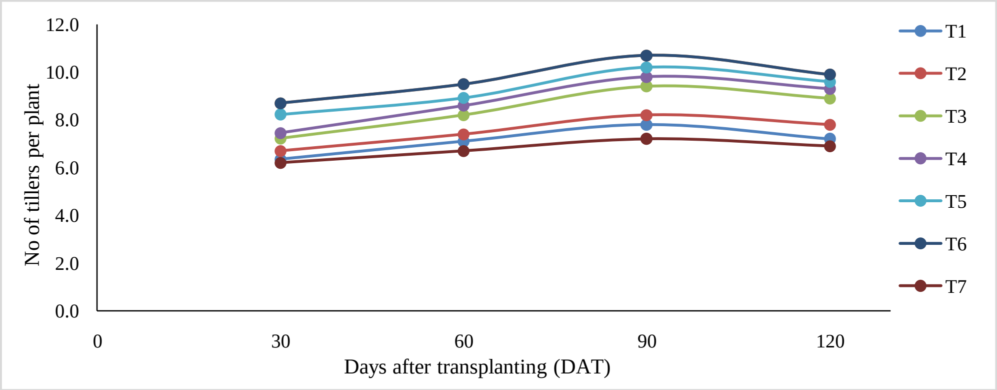

**Fig. 4Effect of silicon (Si) and different levels of surface irrigation water on number of tillers per plant on rice crop under surface irrigation**

### 3.2 Yield Parameters

The results show in Fig. 5, that treatment T6 had the highest grain yield (65.30 t/ha), followed by treatments T5(63.25 q/ha), T4 (61.93 q/ha), T3 (60.25 q/ha), T2 (59.80 q/ha), T1 (56.85 q/ha) and T7 (53.99 q/ha), respectively. Treatment T4 had the lowest grain yield (53.99 q/ha). The maximum straw yield was receded in treatment T6 (105.57 t/ha), in terms of followed by treatments T5 (102.77 q/ha), T4 (100.51 q/ha), T3 (98.38 q/ha), T2 (95.78 q/ha), T1 (90.18 q/ha) and T7 (87.27 q/ha), respectively, respectively. Treatment T4 had the lowest grain yield (53.99 q/ha). Similarly also significantly highest biological yield was found in T6 (170.87 q/ha) compared among treatment had lowest biological yield recorded in T7 (141.26 q/ha) as shown in Fig. 5. The maximum harvest index was obtained among the treatment of T1 (4.67%), while minimum in T7 (4.22%). Silicon (Si) and surface irrigation is a plant nutrient that can help rice plants to grow better and produce more grain. Applying small amounts of silicon (Si) to rice fields can increase in the grain and straw, which can lead to higher yields. This is supported by research from **(Hwang *et al.*, 2008; Mishra *et al.*, (2015).**

### 3.3 Water Use Efficiency (WUE)

From Fig. 6, shows that the amount of water required to produce a kilogram of rice varied among the different treatments. Among treatment T2, which involved transplanting rice (TPR) with a shallow water depth of 2.0 cm, had the highest water use efficiency (WUE) of 4.67 kg/ha-mm. Treatment T7 had the second highest WUE of 4.22 kg/ha-mm.

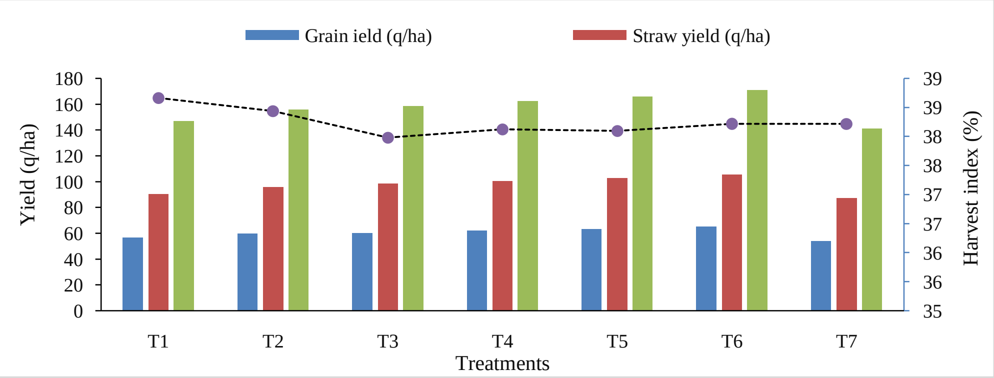

**Fig. 5Effect of silicon (Si) and different levels of surface irrigation water on grain, straw, biological yield and harvest index under silicon (Si) and surface irrigation method**

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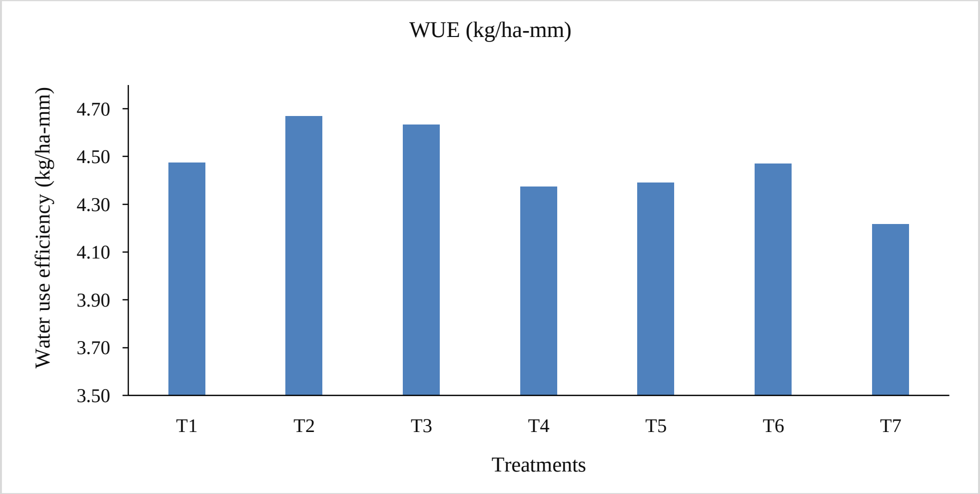

**Fig. 6 Effect of silicon (Si) and different levels of surface irrigation water on Water use efficiency**

### 3.4 Economics analysis

The cost of cultivation, gross return, net return and benefit cost ratio varies with different levels of silicon (Si) and surfaceirrigation. The data presented in Table 2, reveal that cost of cultivation (Rs/ha) differs significantly from remaining treatments after the harvesting. The maximum cost of cultivation was recorded after the harvest from T6(37898 Rs/ha) followed by the minimum cost of cultivation was recorded from $T_7$. The maximum gross income was recorded after the harvest from T6 (126689 Rs/ha) compared minimum gross income was recorded from T7 (103214 Rs/ha). Similarly, from Table 2 revealedhighest net return was recorded after the harvest from T6 (88689 Rs/ha) followed by T7 (76196 Rs/ha). The maximum benefit cost ratio (BCR) was recorded after the harvest from T6 (2.34), in terms followed T7 (1.96). The benefit cost ratio ha-1 varies with different levels of NPK and Silicon (Si) and nitrogen combinations. The data shown in table no.4.12 reveal that benefit cost ratio ha-1 different significantly from remaining treatments after the harvesting.

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**Table 2 Effect of silicon (Si) and different levels of surface irrigation water on cost of cultivation, gross return, net return and benefit cost ratio**

| Treatment details | Cost of cultivation (Rs/ha) | Gross income (Rs/ha) | Net return(Rs/ha) | Benefit cost ratio |
|---|---|---|---|---|
| **$T_1$** | 35339 | 111535 | 76196 | 2.16 |
| **$T_2$** | 35373 | 1z14566 | 79192 | 2.24 |
| **$T_3$** | 35602 | 115276 | 79674 | 2.24 |
| **$T_4$** | 36559 | 118369 | 81810 | 2.24 |
| **$T_5$** | 36583 | 119297 | 82715 | 2.26 |
| **$T_6$** | 37898 | 126587 | 88689 | 2.34 |
| **$T_7$** | 34812 | 103215 | 68403 | 1.96 |

## Conclusions

The study demonstrated that maintaining a standing water depth of 4.0 cm, coupled with silicon (Si) spray at a concentration of 2ml/l, led to superior outcomes in terms of plant growth, yield, water use efficiency (WUE), net return, and overall economic viability at treatment T6, and compared control treatment T7. The outcomes emphasize the importance of this particular water depth and the application of silicon (Si) in enhancing rice crop productivity. Furthermore, the economic analysis showcased a robust benefit-cost ratio (BCR), highlighting the economic feasibility of this method.In conclusion, the research suggests that adopting a 4.0 cm standing water depth along with silicon (Si) supplementation at 2ml/l is a promising strategy to maximize rice crop yield, ensure higher financial returns, and promote agricultural sustainability. These findings have significant implications for farmers, especially in similar agro-climatic regions, providing a viable pathway for enhancing agricultural productivity and profitability.

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