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# Growth, lodging and yield of transplanted rice (*Oryza sativa* L.) under Kashmir conditions as influenced by nitrogen and silicon applications

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## Abstract

The field experiment entitled "Growth, lodging and yield of transplanted rice (*Oryza sativa* L.) under Kashmir conditions as influenced by nitrogen and silicon applications was conducted at Agronomy Research Farm of Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir during Kharif season 2014 and 2015. The soil of the experiment was silty clay loam in texture, neutral in reaction with medium available nitrogen (442.88kg ha$^{-1}$), phosphorus (9.3kg ha$^{-1}$), potassium (221.60kg ha$^{-1}$) and low available silicon (280.23kg ha$^{-1}$). The experiment was laid out in Factorial Randomized Completely Block Design assigning combinations of nitrogen levels and silicon applications with four replications. The results revealed that the growth character *viz*. dry matter accumulation was significantly highest with 180kgN ha$^{-1}$ from 30-45DAT. But from 60DAT upto at harvest, dry matter accumulation was significantly highest with 120kgN ha$^{-1}$ during 2014 and 2015. Culm thickness was significantly highest with 120kgN ha$^{-1}$ at all growth stages during both the years. Internodal length (except mid tillering) were significantly superior with 180kgN ha$^{-1}$ at all growth stages during both the years. The lodging parameters *viz*. breaking resistance and bending moment were significantly highest with 120kgN ha$^{-1}$ while lodging index decreased with the same treatment during both the years. Significantly highest grain yield (75.61q ha$^{-1}$and 76.39q ha$^{-1}$) and straw yield (93.38 q ha$^{-1}$ and 94.56q ha$^{-1}$) were recorded with 120kgN ha$^{-1}$ during both the years respectively. So far as application of silicon is concerned, 15%Si caused significant improvement in crop growth parameters *viz*. dry matter accumulation, culm thickness and internode length during 2014 and 2015. Similar trend was also observed for grain yield (76.41q ha$^{-1}$ and 77.11q ha$^{-1}$) and straw yield (94.36q ha$^{-1}$ and 95.09q ha$^{-1}$) during both the years. The lodging parameters *viz*. breaking resistance and bending moment were significantly highest with 15%Si while lodging index decreased with the same treatment during both the years.

**Keywords:** B:C ratio, growth, lodging, nitrogen, rice, silicon, yield

## Introduction

Nitrogen fertilizer is an important practice for increasing rice yield. It is essential to the rice plant, with about 75 per cent of leaf nitrogen associated with chloroplasts, which are physiologically important in dry matter production (Dalling, 1995) [2]. The presence of nitrogen in excess promotes development of the above ground organs with abundant dark green (high chlorophyll) tissues of soft consistency and relatively poor root growth. This increases the risk of lodging and reduces the plant resistance to harsh climatic condition and foliar diseases (Mohammadin *et al.* 2011) [14].

Silicon is usually considered as one of the most important beneficial elements for rice production as rice requires large amounts of silica for its growth. The silicon content of soils can vary dramatically from <1 to 45 per cent by dry weight basis (Sommer *et al.* 2006) [21] and its uptake by plants takesplace in the form of silicic acid [$Si(OH)_4$]. It is estimated that nearly 20 kg of silica is removed from the soil by rice plants for production of 100 kg brown rice (Dobermann and Fairhurst, 1997) [3].

Lodging may occur in vigorously growing rice plants after heading stage. It constitutes a major constraint to rice production, especially in high yielding environments. It causes direct loss in grain yield and quality (Fallah, 2000) [4]. Silicon helps plants to overcome multiple stresses including biotic stresses such as insect-pests and diseases like blast, brown spot and sheath blight and also abiotic stresses such as metal toxicity, salinity, drought and temperature (Ma, 2004 and Liang *et al.* 2007) [13, 10]. Keeping in view the above facts, the present study entitled" Growth, lodging and yield of transplanted rice (*Oryza sativa* L.) under Kashmir conditions as influenced by nitrogen and silicon applications was designed with following objectives:

To study the impact of silicon and nitrogen on growth and yield of rice

To study the effect of nitrogen and silicon on lodging

## Material and Methods

Field experiment was conducted at Research Farm of Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar during Kharif season, 2014 and 2015. The factorial experiment (two factors) based on randomised complete block design with four replications was laid out. The factors included three N levels ($N_1$: 120, $N_2$: 150, $N_3$: 180 kg/ha) and four Si applications ($Si_0$: Control, $Si_1$: 5%, $Si_2$: 10% and $Si_3$:15%) and the treatment combinations were $N_1Si_0$, $N_1Si_1$, $N_1Si_2$, $N_1Si_3$, $N_2Si_0$, $N_2Si_1$, $N_2Si_2$, $N_2Si_3$, $N_3Si_0$, $N_3Si_1$, $N_3Si_2$ and $N_3Si_3$.The various growth, lodging, yield parameters and relative economics were recorded. Culm thickness was recorded at 15 days interval after transplanting till harvest using veirneir clipper. Breaking resistance can be measured with a bending hardness tester. Bending moment (g.cm) using the formula,

$BMN_3$ = Length from the lowest node of $N_3$ to the top of panicle × $(W_1+W_2)$

Where $w_1$ is the fresh weight of whole plant and $w_2$ is the fresh weight of third internode with leaf sheath. Lodging index (%) = Bending moment/Breaking resistance×100.

## Result and Discussion

Data from table 1 showed an increase in dry matter accumulation with the advancement of crop. Application of180kgN ha$^{-1}$ recorded significantly highest crop dry matter accumulation from 30DAT to 45DAT during 2014 and 2015. There are many reports on the increased of total dry matter due to increased nitrogen fertilizer application (Prasad, 1981 and Park, 1987) [18, 15]. But from 60 DAT upto at harvest, 120kgN ha$^{-1}$ recorded significantly highest crop dry matter accumulation followed by 150kgN ha$^{-1}$ during both the consecutive years. It is because of increased number of tillers thereby increased dry matter production. Similar results were also reported by Stalin *et al.* (1999) [22], Rao *et al.* (2004) [19] and Prasad *et al.* (2011) [17].

With regards to the effect of silicon applications, 15%Si recorded significantly highest dry matter accumulation followed by 10% Si which remained statistically at par with 5%Si. It might be the maintenance of photosynthetic activity due to silicon fertilization could be one of the reason for the increased dry matter production (Agurie *et al.* 1992) [1]. Culm thickness is important character to express the lodging index of the plant, which ultimately influences the economic yield. Data pertaining to culm thickness in table 2 indicated that significantly highest culm thickness was recorded with 120kgN ha$^{-1}$ followed by 150kgN ha$^{-1}$ from 30DAT upto at harvest during both the years. Reason is being that optimum nitrogen level *viz*. 120kgN ha$^{-1}$ helps in stem strength and higher nitrogen fertilizer levels primarily induced significant reduction of dry weight which resulted in lower breaking resistance and consequently, reduced stem physical strength which caused a reduction in culm thickness thereby, resulted in poor lodging resistance of rice plants. Similar findings were reported by Wei *et al.* 2008; Yang *et al.* 2009; Wang *et al.* 2012 and Zhang *et al.* 2013 [28, 25, 26,29].

The data further revealed that among silicon applications, 15%Si recorded significantly higher culm thickness followed by 10%Si remained at par with 5%Si from 45DAT upto at harvest during both the consecutive years. It might be due to silicon improved epidermal cell wall thickness and size of vascular bundles which resulted in increases culm thickness. Fallah (2012) [5] were also studied the same results. Data presented in table 3 indicated that internode length was significantly highest with 180kgN ha$^{-1}$ followed by 150kgN ha$^{-1}$ at all growth stages. It might be due to higher plant height.

Among silicon applications, 15%Si observed significantly highest internode length followed by 10%Si being remained at par with 5%Si at all growth stages except mid tillering during both the years. Data presented in table 4 indicated that breaking resistance and bending moment were significantly highest with 120kgN ha$^{-1}$ followed by 150kgN ha$^{-1}$ during both the years. It may be due to lower plant height and internode length. Guo *et al.* 2003 [6] were reported the similar results. It was further observed that among different silicon applications, 15%Si recorded highest breaking resistance and bending moment followed by 10%Si which was statistically at par with 5%Si during both the consecutive years. It may be due to the thickening of cell wall of the sclerenchyma tissue in the culm and/or shortening and thickening of internodes or increase in silicon content of lower internodes provides mechanical strength to enable plant to resist lodging and also this study showed that breaking resistance and bending moment increased with increasing silicon concentration. Lee (1990) [9]; Liang (1994) [11] and Takahashi (1995) [23] were also noticed an increase in resistance to lodging due to application of silicon fertilizer to rice.

Out of the three nitrogen levels presented in table 4, application of 120kgN ha$^{-1}$ proved significantly efficient in controlling lodging followed by 150kgN ha$^{-1}$ during both the years. This is in accordance to the study of Hui *et al.* (2013) [7] where high nitrogen input increased basal internode length, breaking resistance and lodging index.

Among silicon applications, 15%Si proved significantly better measure for recording lodging index as compared to 10%Si and 5%Si during both the years. It could be ascribed to the fact that increased silicon content plant has been reported to increase mechanical strength of plant tissue, which resulted in reduced lodging index (Takahashi *et al.* 1990 and Liang 1994) [24, 11]. Shimoyama (1958) [20] has mentioned that thickness of culm walls and vascular bundles becomes larger when silicon is applied. Silica deposited in these plant sections also contributes to an increase in the mechanical strength of culms. Therefore, sufficient supply of silicon has an effect on the stability of culms and serves to decrease the risk of lodging. From the table 5 indicated that 120kgN ha$^{-1}$ recorded significantly higher grain yield followed by 150kgN ha$^{-1}$ during both the years. It is because of highest yield attributing characters which ultimately caused the increase of rice grain yield. Similar results were reported by Huang *et al.* 2011 [8]. Also, the increment of grain yield by the application of nitrogen upto a certain level was reported by Zhaowen *et al.* 2013 [30] Among different silicon applications, 15%Si recorded the highest grain yield followed by 10%Si being at par with 5%Si during both the years.

It is because of silicon is responsible to control stomatal activity, photosynthesis, water use efficiency which ultimately results in better vegetative growth results in higher grain yield. Data presented in table 5 indicated that 120kgN ha$^{-1}$ provided significantly higher straw yield.It might be due to the more number of dry matter accumulation which ultimately confirmed the greater yield of straw. Similar trend of the effect of nitrogen levels on straw yield were also reported by Pramanik and Bera (2013) [16]. Among different silicon applications, 15%Si produced significantly highest straw yield during both the years. It may be attributed to leaf erectness which facilitated better penetration of sunlight leading to higher photosynthetic activity of plant and higher production of carbohydrates. Similar results were also noticed by Ma *et al*. (1989) [12].

**Table 1:** Impact of nitrogen and silicon on dry matter accumulation (q ha$^{-1}$) of transplanted rice

| **Years** | **2014** | **2015** | **2014** | **2015** | **2014** | **2015** | **2014** | **2015** | **2014** | **2015** |
|---|---|---|---|---|---|---|---|---|---|---|
| **Treatments** | **15D AT** | | **30 DAT** | | **45 DAT** | | **60 DAT** | | **75 DAT** | |
| **Nitrogen levels (kg ha$^{-1}$)** | | | | | | | | | | |
| 120 ($N_1$) | 3.91 | 4.05 | 12.98 | 13.84 | 35.28 | 37.16 | 60.86 | 63.05 | 96.97 | 98.63 |
| 150 ($N_2$) | 4.06 | 4.20 | 13.26 | 14.23 | 35.64 | 37.97 | 58.92 | 61.36 | 94.55 | 96.26 |
| 180 ($N_3$) | 4.06 | 4.30 | 13.53 | 14.62 | 36.00 | 38.52 | 57.24 | 58.83 | 92.39 | 94.01 |
| SEm± | 0.12 | 0.13 | 0.08 | 0.11 | 0.09 | 0.12 | 0.52 | 0.53 | 0.65 | 0.75 |
| CD($p \leq 0.05$) | NS | NS | 0.24 | 0.34 | 0.28 | 0.37 | 1.53 | 1.57 | 1.92 | 2.21 |
| **Silicon applications (%)** | | | | | | | | | | |
| Control ($Si_0$) | 3.79 | 3.96 | 13.11 | 14.05 | 34.20 | 37.01 | 55.27 | 56.70 | 91.39 | 92.42 |
| 5 ($Si_1$) | 3.97 | 4.14 | 13.20 | 14.17 | 35.93 | 37.91 | 58.48 | 61.03 | 94.09 | 95.65 |
| 10 ($Si_2$) | 4.10 | 4.27 | 13.31 | 14.27 | 36.03 | 38.06 | 59.83 | 62.38 | 95.38 | 97.04 |
| 15 ($Si_3$) | 4.18 | 4.35 | 13.41 | 14.43 | 36.40 | 38.55 | 62.44 | 64.20 | 97.69 | 100.09 |
| SEm± | 0.14 | 0.15 | 0.09 | 0.13 | 0.11 | 0.14 | 0.60 | 0.61 | 0.76 | 0.87 |
| CD($p \leq 0.05$) | 0.42 | NS | NS | NS | 0.32 | 0.42 | 1.76 | 1.81 | 2.23 | 2.55 |

**Table 1:** Contd.

| **Years** | **2014** | **2015** | **2014** | **2015** | **2014** | **2015** | **2014** | **2015** |
|---|---|---|---|---|---|---|---|---|
| **Treatments** | **90 DAT** | | **105 DAT** | | **120 DAT** | | **At harvest** | |
| **Nitrogen levels (kg ha$^{-1}$)** | | | | | | | | |
| 120 ($N_1$) | 149.50 | 152.45 | 159.81 | 162.62 | 164.60 | 167.13 | 168.37 | 170.65 |
| 150 ($N_2$) | 147.04 | 149.84 | 157.06 | 159.82 | 161.68 | 164.00 | 164.40 | 166.29 |
| 180 ($N_3$) | 144.86 | 145.60 | 150.55 | 153.48 | 153.94 | 156.54 | 156.60 | 157.97 |
| SEm± | 0.71 | 0.74 | 0.93 | 0.95 | 0.97 | 0.99 | 1.19 | 1.06 |
| CD($p \leq 0.05$) | 2.08 | 2.17 | 2.72 | 2.79 | 2.86 | 2.92 | 3.49 | 3.13 |
| **Silicon applications (%)** | | | | | | | | |
| Control ($Si_0$) | 140.32 | 142.27 | 148.41 | 151.15 | 150.76 | 153.44 | 151.27 | 154.05 |
| 5 ($Si_1$) | 147.39 | 149.61 | 155.18 | 158.81 | 160.89 | 162.45 | 164.06 | 165.41 |
| 10 ($Si_2$) | 148.93 | 151.05 | 157.54 | 160.23 | 162.25 | 164.90 | 166.43 | 168.11 |
| 15 ($Si_3$) | 151.90 | 154.25 | 162.10 | 164.38 | 166.39 | 169.44 | 170.74 | 172.32 |
| SEm± | 0.82 | 0.85 | 1.07 | 1.09 | 1.12 | 1.15 | 1.37 | 1.23 |
| CD($p \leq 0.05$) | 2.41 | 2.51 | 3.15 | 3.22 | 3.30 | 3.38 | 4.04 | 3.61 |

**Table 2:** Impact of nitrogen and silicon on culm thickness (mm) of transplanted rice

| **Years** | **2014** | **2015** | **2014** | **2015** | **2014** | **2015** | **2014** | **2015** | **2014** | **2015** |
|---|---|---|---|---|---|---|---|---|---|---|
| **Treatments** | **15DAT** | | **30DAT** | | **45DAT** | | **60DAT** | | **75DAT** | |
| **Nitrogen levels (kg ha$^{-1}$)** | | | | | | | | | | |
| 120 ($N_1$) | 0.35 | 0.37 | 1.74 | 1.80 | 10.61 | 11.86 | 17.19 | 18.35 | 19.80 | 20.91 |
| 150 ($N_2$) | 0.35 | 0.35 | 1.61 | 1.66 | 10.24 | 11.48 | 17.00 | 18.15 | 19.52 | 20.64 |
| 180 ($N_3$) | 0.33 | 0.35 | 1.45 | 1.52 | 9.88 | 11.06 | 16.72 | 17.85 | 19.17 | 20.27 |
| SEm± | 0.01 | 0.02 | 0.04 | 0.05 | 0.09 | 0.10 | 0.05 | 0.06 | 0.08 | 0.08 |
| CD($p \leq 0.05$) | NS | NS | 0.13 | 0.14 | 0.26 | 0.30 | 0.17 | 0.19 | 0.24 | 0.26 |
| **Silicon applications (%)** | | | | | | | | | | |
| Control ($Si_0$) | 0.31 | 0.32 | 1.56 | 1.54 | 9.41 | 10.57 | 16.43 | 17.54 | 18.72 | 19.82 |
| 5 ($Si_1$) | 0.33 | 0.35 | 1.57 | 1.65 | 10.15 | 11.42 | 16.92 | 18.09 | 19.44 | 20.56 |
| 10 ($Si_2$) | 0.35 | 0.36 | 1.62 | 1.70 | 10.39 | 11.62 | 17.03 | 18.23 | 19.63 | 20.75 |
| 15 ($Si_3$) | 0.37 | 0.39 | 1.65 | 1.74 | 11.02 | 12.26 | 17.49 | 18.61 | 20.19 | 21.31 |
| SEm± | 0.02 | 0.02 | 0.05 | 0.05 | 0.10 | 0.11 | 0.06 | 0.07 | 0.09 | 0.10 |
| CD($p \leq 0.05$) | NS | NS | NS | NS | 0.30 | 0.34 | 0.19 | 0.22 | 0.28 | 0.30 |

**Table 2:** Contd.

| **Years** | **2014** | **2015** | **2014** | **2015** | **2014** | **2015** | **2014** | **2015** |
|---|---|---|---|---|---|---|---|---|
| **Treatments** | **90DAT** | | **105DAT** | | **120DAT** | | **At harvest** | |
| **Nitrogen levels (kg ha$^{-1}$)** | | | | | | | | |
| 120 ($N_1$) | 20.85 | 21.64 | 21.78 | 22.89 | 21.90 | 23.13 | 22.14 | 23.23 |
| 150 ($N_2$) | 20.48 | 21.24 | 21.30 | 22.48 | 21.43 | 22.63 | 21.68 | 22.79 |
| 180 ($N_3$) | 20.01 | 20.77 | 20.90 | 22.01 | 21.02 | 22.15 | 21.13 | 22.23 |
| SEm± | 0.12 | 0.13 | 0.13 | 0.14 | 0.14 | 0.16 | 0.15 | 0.14 |
| CD($p \leq 0.05$) | 0.37 | 0.39 | 0.39 | 0.41 | 0.41 | 0.48 | 0.44 | 0.42 |
| **Silicon applications (%)** | | | | | | | | |
| Control ($Si_0$) | 19.36 | 20.12 | 20.26 | 21.38 | 20.37 | 21.52 | 20.44 | 21.52 |
| 5 ($Si_1$) | 20.44 | 21.21 | 21.38 | 22.53 | 21.50 | 22.72 | 21.80 | 22.88 |
| 10 ($Si_2$) | 20.68 | 21.44 | 21.53 | 22.66 | 21.65 | 22.84 | 21.92 | 23.00 |
| 15 ($Si_3$) | 21.30 | 22.09 | 22.15 | 23.29 | 22.27 | 23.46 | 22.45 | 23.59 |
| SEm± | 0.14 | 0.15 | 0.15 | 0.16 | 0.16 | 0.19 | 0.17 | 0.18 |
| CD($p \leq 0.05$) | 0.43 | 0.45 | 0.46 | 0.48 | 0.48 | 0.58 | 0.51 | 0.54 |

**Table 3:** Impact of nitrogen and silicon on internode length (cm) of transplanted rice

| **Years** | **2014** | **2015** | **2014** | **2015** | **2014** | **2015** | **2014** | **2015** |
|---|---|---|---|---|---|---|---|---|
| **Treatments** | **Mid tillering** | | **Panicle initiation** | | **Anthesis** | | **Maturity** | |
| **Nitrogen levels (kg ha$^{-1}$)** | | | | | | | | |
| 120 ($N_1$) | 1.74 | 1.75 | 13.95 | 15.02 | 24.78 | 25.58 | 26.35 | 26.85 |
| 150 ($N_2$) | 1.76 | 1.78 | 14.56 | 15.62 | 25.80 | 27.19 | 27.39 | 28.66 |
| 180 ($N_3$) | 1.79 | 1.82 | 14.78 | 15.84 | 26.75 | 28.20 | 28.45 | 29.74 |
| SEm± | 0.008 | 0.01 | 0.04 | 0.06 | 0.30 | 0.33 | 0.32 | 0.35 |
| CD($p \leq 0.05$) | 0.02 | 0.03 | 0.13 | 0.18 | 0.89 | 0.97 | 0.94 | 1.03 |
| **Silicon applications (%)** | | | | | | | | |
| Control ($Si_0$) | 1.74 | 1.76 | 14.04 | 15.02 | 24.01 | 24.88 | 25.17 | 26.19 |
| 5 ($Si_1$) | 1.77 | 1.78 | 14.48 | 15.51 | 25.74 | 27.18 | 27.59 | 28.63 |
| 10 ($Si_2$) | 1.77 | 1.79 | 14.51 | 15.60 | 26.12 | 27.37 | 27.85 | 28.81 |
| 15 ($Si_3$) | 1.78 | 1.79 | 14.70 | 15.83 | 27.23 | 28.53 | 28.98 | 30.04 |
| SEm± | 0.009 | 0.01 | 0.05 | 0.07 | 0.35 | 0.38 | 0.37 | 0.40 |
| CD($p \leq 0.05$) | NS | NS | 0.15 | 0.21 | 1.03 | 1.12 | 1.08 | 1.19 |

**Table 4:** Impact of nitrogen and silicon on lodging parameters of transplanted rice

| **Years** | **2014** | **2015** | **2014** | **2015** | **2014** | **2015** |
|---|---|---|---|---|---|---|
| **Treatments** | **Breaking resistance (g. cm)** | | **Bending moment (g.cm)** | | **Lodging index (%)** | |
| **Nitrogen levels (kg ha$^{-1}$)** | | | | | | |
| 120 ($N_1$) | 1659.93 | 1718.92 | 1589.98 | 1658.08 | 94.86 | 95.09 |
| 150 ($N_2$) | 1574.46 | 1644.83 | 1511.87 | 1586.34 | 95.89 | 96.06 |
| 180 ($N_3$) | 1485.84 | 1569.48 | 1438.26 | 1514.35 | 96.93 | 97.05 |
| SEm± | 24.17 | 24.97 | 22.43 | 23.65 | 0.33 | 0.32 |
| CD($p \leq 0.05$) | 70.92 | 73.23 | 65.80 | 69.38 | 1.01 | 0.97 |
| **Silicon applications (%)** | | | | | | |
| Control ($Si_0$) | 1459.04 | 1531.27 | 1406.83 | 1476.71 | 97.80 | 97.92 |
| 5 ($Si_1$) | 1544.55 | 1624.75 | 1490.16 | 1561.83 | 96.63 | 96.83 |
| 10 ($Si_2$) | 1600.19 | 1668.03 | 1536.50 | 1611.32 | 96.28 | 96.62 |
| 15 ($Si_3$) | 1689.87 | 1753.60 | 1619.99 | 1695.17 | 95.13 | 95.46 |
| SEm± | 27.92 | 28.83 | 25.90 | 27.31 | 0.37 | 0.35 |
| CD($p \leq 0.05$) | 81.90 | 84.56 | 75.98 | 80.11 | 1.13 | 1.07 |

**Table 5:** Impact of nitrogen and silicon on grain yield and straw yield of transplanted rice

| **Years** | **2014** | | **2015** | **2014** | **2015** |
|---|---|---|---|---|---|
| **Treatments** | | **Grain yield (q ha$^{-1}$)** | | **Straw yield (q ha$^{-1}$)** | |
| | **Nitrogen levels (kg ha$^{-1}$)** | | | | |
| 120 ($N_1$) | 75.61 | | 76.39 | 93.38 | 94.56 |
| 150 ($N_2$) | 73.55 | | 74.52 | 91.23 | 92.09 |
| 180 ($N_3$) | 68.45 | | 69.21 | 87.69 | 88.70 |
| SEm± | 0.48 | | 0.54 | 0.53 | 0.55 |
| CD($p \leq 0.05$) | 1.42 | | 1.62 | 1.57 | 1.62 |
| | **Silicon applications (%)** | | | | |
| Control ($Si_0$) | 66.87 | | 67.67 | 84.55 | 86.49 |
| 5 ($Si_1$) | 72.75 | | 73.67 | 91.63 | 92.30 |
| 10 ($Si_2$) | 74.12 | | 75.04 | 92.52 | 93.26 |
| 15 ($Si_3$) | 76.41 | | 77.11 | 94.36 | 95.09 |
| SEm± | 0.56 | | 0.59 | 0.62 | 0.64 |
| CD($p \leq 0.05$) | 1.65 | | 1.77 | 1.82 | 1.87 |

## Conclusion

The two year study revealed that silicon applications can significantly regulate plant growth, lodging and yield if applied at proper time with feasible concentration. As far as fertilization of rice crop is concerned-application of nitrogen fertilizer is an important practice for increasing rice yield. However, nitrogen applied in excess may limit yield due to lodging which promoted shading and susceptibility to insects and diseases. These effects could be minimized by the use of silicon. Considering the influence of nitrogen levels and silicon applications, it can be suggested that for realising economically higher grain yield of rice and reducing lodging with 120kg ha$^{-1}$ with 15%Si based nutrient management during 2014 and 2015 respectively.

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