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EFFECT OF SILICON ADDITION TO DIFFERENT FERTILIZER ON THE YIELD, CU AND ZN CONTENT OF RICE PLANTS (*ORYZA SATIVA* L.)

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Abstract

Two pot experiments were conducted during two successive seasons to study the effect of silicon addition to different fertilizer on the yield, Cu and Zn content and uptake of rice plants. The important results can be summarized in the following:

- Dry matter of roots, shoots and grain yield significantly increased by Si addition to all the used fertilizers.
- The highest values of dry matter of roots, shoots and grains were obtained by using the NPK + Si treatment followed by NP + Si, NK + Si and N + Si in decreasing order.
- Silicon addition to the different fertilizer treatments significantly increased the content of Cu and Zn in the roots, while they significantly decreased in the shoots and grains of rice plant.
- Cu and Zn uptake by all the parts of rice plant (roots, shoots and grains) significantly increased by Si addition as they compared with those without Si addition.
- Generally, data show that the highest of Zn and Cu uptake by the different parts of rice were obtained by using NPK + Si treatment followed by NP + Si, NK + Si and N + Si in decreasing order.
- Either Zn and Cu had the same trend when Si was added to the different fertilizer treatments.

Keywords: Rice, Zn, Cu, NPK, Yield, Si, Uptake.

Introduction

Rice (*Oryza sativa* L.) is an important staple food crop for more than two third of the population of South East Asia and plays a vital role in national food security and a means of livelihood for millions of people in India, Adequate nutrient management is essential to enhance its productivity to satisfy the rising global food demand without adverse impact on environment, besides the essential nutrients, silicon (Si) imparts some role in improving the biomass yield of rice (Elmer and Datnoff, 2014).

HMs are one of the most important abiotic stresses that inhibit the growth and development in living organisms, lead to an early senescence of them (Jan and Parray, 2016).

In the environment, heavy elements exist in both essential and non-essential forms. At optimum level essential heavy elements such as Cu, Fe, Mn, Zn, Co, Mo, Pb, V and Ni play a beneficial role in plant growth and development. These ions readily influence role of various enzymes and proteins, arrest metabolism, and reveal phyto-toxicity (Arif *et al.*, 2016 & Saco *et al.*, 2013).

Some of the HMs, such as Ni(nickel) Cu(Copper), Zn(zinc), Fe(iron), Mn(manganese), and Mo(Molybdenum) depend on their concentration, could act as nutrient that are essential for some enzyme activities as cofactor and very beneficial for growing organisms in the plant (Chibuike and Obiora 2014).

Heavy metals enter the food chain through the soil and become hazardous contaminants of food, entering the human body as a cumulative poison (Benavides *et al.*, 2005). HMs are known as biotic stress and hazardous chemical that could after human health by influencing the food chain and aquifers. They are also, known as one of the reasons to inhibition of plant growth (Wuana and Okieimen, 2011).

Among heavy metals, cadmium (Cd) and copper (Cu) have been known to hinder the growth of crop plants, especially rice plants (Takahashi *et al.*, 2011).

Cu, bioaccumulation in side plant tissues tends to disturb the enzymatic activities required for chlorophyll biosynthesis. In addition, Cu influences leaf elongation, cell wall elasticity, potassium levels, and sugar accumulation (Patra *et al.*, 2004).

Zinc is commonly both a defiant and phytotoxic element in soils (Chaney, 2010). It is an essential micronutrient for plant health growth and development. However, an excess of Zn presence in soil can be extremely toxic to plant cells by interfering with the uptake transport and homeostasis of essential ions, and the disruption metabolism presses. The greater mobility of Zn in the soils also contributes to the increasing concern of Zn phytotoxicity.

Although silicon (Si) has not been considered as an essential nutrient for plant, Si is beneficial for rice growth, development and resistance against abiotic (metal toxicity, salt and drought stress, nutrient imbalance) and biotic stress (plant diseases and insect pests). Many studies confirmed that the application of Si fertilizer or Si-enriched materials can alleviate the toxicity of heavy metals to rice plants and other plants. Overall, S and Si amendments appeared to be potentially useful remediation methods for heavy metal-contaminated paddy soils (Ning *et al.*, 2016 & Limmer *et al.*, 2018).

Silicon also modifies the translocation of nutrients within the plant and water use efficiency by reducing transpiration (Saud *et al.*, 2014).

The aim of this study was to assess the effect of silicate application to different fertilizer on yield and Cu, Zn concentration and uptake of rice plants.

Materials and Methods

Two pot experiments were conducted during two successive seasons to study the effect of silicon addition on the yield and Cu and Zn content and uptake by different rice parts. Soil samples at a depth from (0-30 cm) from the surface layer of clay loam soil has a 26.7% sand, 39.6% silt and 33.7% clay pots, contain air dried soil were arranged in a complete randomize design.

The experiment included of four fertilizer treatments: a) Nitrogen alone (0.8 gm/pot (Urea), b) Nitrogen + Phosphorus (0.8 gm/Pot Urea + 0.8 gm/pot superphosphate), c) Nitrogen + Potassium (0.8 gm/pot Urea + 0.8 gm/pot Potassium Sulphate) and d) Nitrogen + Phosphorus + Potassium (0.8 gm/pot Urea + 0.8 gm/pot Supperphosphate + 0.8 gm/pot Potassium Sulphate).

Silicon was added to four pots at a rate of 1.87 gm Si/pot in the form of sodium meta silicate ($Na2\ SiO3.5H2O$) with irrigation water. The plants of the four other pots of each treatment were not supplied with silicon. Throughout the growth period which lasted 140 days, the pots received sufficient distilled water for flooding.

Roots shoots and grains of the rice plants were dried in an aerated oven at 70°C for 24 hours in order to obtain the oven dried weight. The plant materials were the ground and stored.

Chemically analyzed for Cu and Zn, determination was carried out as described by Jackson (1982) and Cottenie (1982) in the different parts of the rice plant (roots, shoots, and grains).

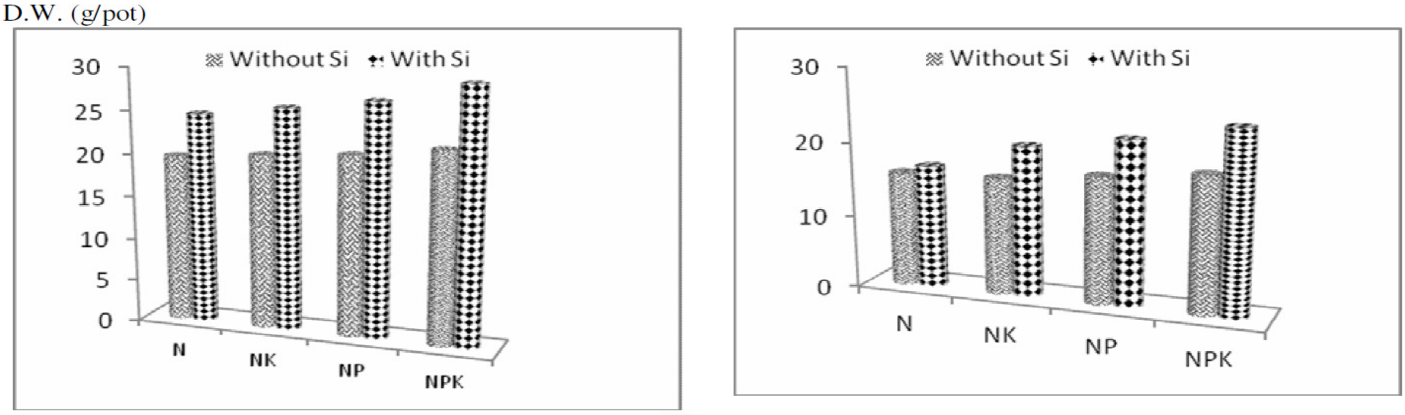
Statistical Analysis: Performed analysis were performed using the least significant difference (L.S.D.) method at 1% and 5% according to Stell and Torrie (1980).

Results and Discussion

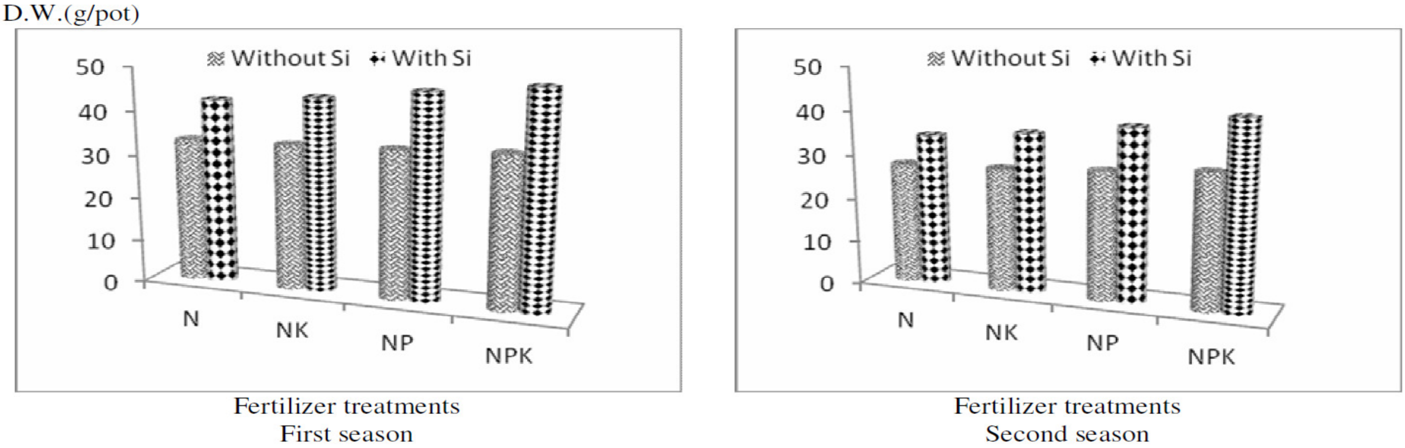
Dry Weight

As illustrated by Fig. (1) the effect of silicon addition to different fertilizer on dry weight production of different parts of rice plant (root, shoot and grain) the results showed that Si application affected significantly increased the studied root, straw and grain yield of rice plant Fig. (1) attributes as compared with the control plants (non-Si) under submerged soil

Roots



Shoots



Grain Yield

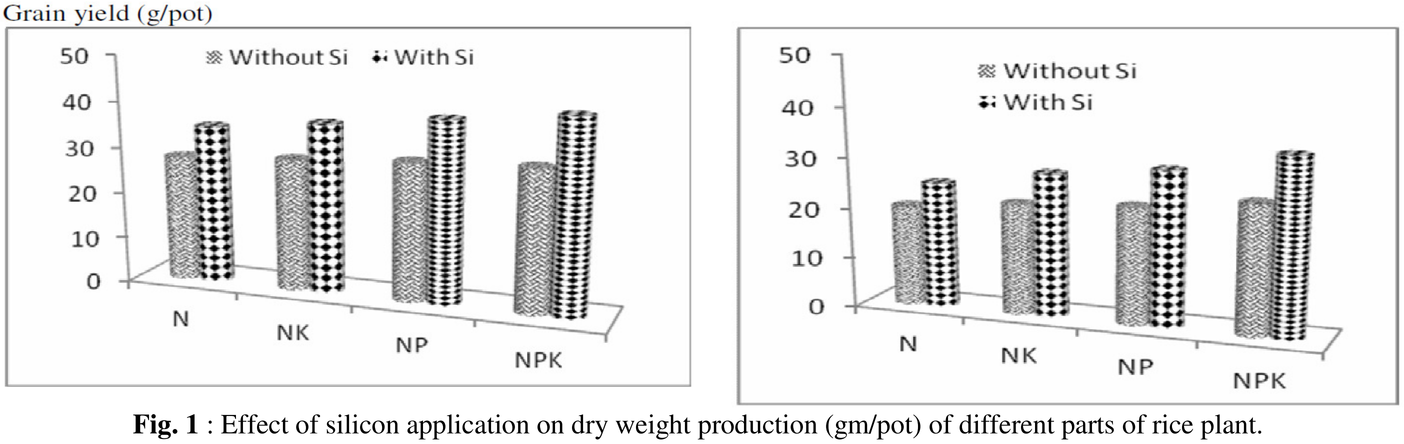


Fig. 1 : Effect of silicon application on dry weight production (gm/pot) of different parts of rice plant.

The positive effect of Si increasing yield of rice plant, this effect may be due to the benefits of using silicon indirect effects such as increased capacity and efficiency of photosynthesis and transpiration (Romero *et al.*, 2006). These results are agreement with by (Zhihong *et al.*, 2019) how studied that the addition of Si significantly ($P < 0.0001$) increased rice biomass and yield, also (Yoon-Ha Kim *et al.*, 2014) added that Si application various physiological parameters, such as shoot and root length, biomass, and chlorophyll content were significantly higher in the Si-treated plants compared to the control plants under heavy metal stress. Data reveal that the highest mean values of dry weight of grain (41.61, 34.75gm) and shoots (48.86, 42.47gm) and roots (29.48, 24.35gm) at the first and second seasons, respectively were obtained by using the NPK + Si treatments, on the other hand, the lowest mean values were observed under control (non –Si).

In this concern, numerous studied have revealed that Si is a beneficial element to higher plants, particularly grasses and various cultivated crops like rice, wheat tomato, and cucumber (Liang and Ding 2002 & Kim *et al.*, 2011).

Effect of Silicon application on Cu and Zn content and uptake of rice plants:

Copper:

Data in Table (1) and Fig. (2) show that addition of sodium meta silicate to the different fertilizer treatments increased Cu content in the roots of rice plant Grown for two seasons. These increases may be due to the silicon influenced Mn and Cu distribution in root. (Sandra *et al.*, 2018). These increases were significant for all the fertilizer treatments at the second season, while, and only significant for the N and KPK treatments at the first one. On the other hand, data reveal that Cu content in shoots and grains were significantly decreased by Si addition in the second seasons, these results confirmed by (Zhihong *et al.*, 2019) how added that the silicon treatment decreased Cu concentration in rice straw, these results attributed to the possible mechanisms for Si inhibition or metal transport in plants may be due

To the thickening of the casparian strips in the endodermis and cell wall of the xylem causing the eposition of lignin and Si in the cell walls of the dermal regions (Da Cunha & DoNascimento 2009). In this concern, data show that in Table (1) and Fig (2), Cu content was lower in plants shoot and grains grown under NPK + Si addition (12.00 and 11 ppm) at the first season and (12.50 and 12.28 ppm) at the first second season, respectively than those grain without Si addition to NPK fertilizer (22.98 and 12.00 ppm) and (14.95 and 14.23 ppm), respectively in both season. In this concern, results show that in the first season, Si addition did not affect Cu content in grains but significantly decreased Cu content in shoots for the N, NK and NPK treatments. These results are in good agreement with those obtained by Zhihong *et al.* (2019) and Holah (1989) who revealed that the addition of Si to the nutrient solutions decreased accumulation of Cu in the plant tissues. Furthermore, a recent report (Matichenkov and Bocharnikova, 2010) demonstrated that the leaching of heavymetals (Cu, Pb, Cr, Ni, and Co) was reduced significantly by over 50% with the addition of a Si fertilizer (diatomaceous earth), this reduction in leaching of heavy metals may be explained by the interaction between the heavy metals and Si-rich substances, such as diatomaceous earth, they added that Si ameliorated Cu and Zn toxicity by decreasing the accumulation of these nutrients in the plant organs (Keller *et al.*, 2015). How added that these results attributed to the major effects of Si on the reduction of metal is reducing the metal content and transport in plants, it was reported by many researchers that Si application would enhance tolerance to heavy metals in many plant species by reducing the uptake and translocation of metals. Si-mediated decrease in Cu uptake and translocation was observed in wheat. Also, decrease in metal translocation from roots to shoot and grains might be due to structural alteration in shoots and roots an/or co-precipitation and chelation of metals in plants (Adrees *et al.*, 2015). Furthermore, Savvas *et al.* (2002) how reported that Si is recognized as a beneficial element for plants growing under biotic and abiotic stresses, for example heavy metals drought, salinity and pathogens.

Data presented in Table (1) and illustrated in Fig. (2) show that Si application significantly increased Cu uptake by roots, shoots and grains of rice plant, these results were true for all the fertilizer treatments for the two growing seasons, data showed that the highest mean values of Cu uptake by roots (1.47 and 1.29), (0.59 and 0.53) and (0.46 and 0.43) mg/pot for first and second growing seasons, respectively. Generally, data demonstrate that the highest Cu content and uptake by roots, shoots and grains of rice plant were found by using NPK + Si treatment followed by NP + Si, NK +Si, and N + Si in decreasing order.

Zinc:

Data in Table (2) and Fig. (3) show that a highly significant and remarkable increases in Zn content in the roots of rice plants by Si addition in the two seasons. On the other hand, data show that Zn content in shoots and grains significantly decreased by Si addition. Zn content was highest in plant root grown under NPK + Si addition (101 ppm) in the first season and (134 ppm) in the second season respectively, while data in table (2) show that the Zn content was lower in plants shoot and grain grown under NPK + Si addition, these values were (49 and 54 ppm) in the first season and (53 and 60 ppm) at in the second season respectively, these results attributed to that Si application inhibited Zn transfer from stems + sheaths to leaf blades and silicate addition changed the Zn distribution among different tissues of seedlings to some degree, where less Zn accumulated in leaf blade (Hai-Hong *et al.*, 2012). Furthermore, this suggested that silicate addition changed the compartment distribution of Zn and increased the cell-wall-bound fraction in the whole seedling plant and a recent research reported that Si could alleviate Zn toxicity to rice by the Si-mediated antioxidant defense capacity and membrane integrate (Song *et al.*, 2011). These results were true for all the fertilizer treatments, except in the shoots of in N treatment in the first season. These results are in good agreement with those obtained by Holah (1989) Lux *et al.* (2003) and Sajal *et al.* (2018) how added that silicon had significant negative correlation with Zn and also that Si application had an antagonistic effect on Zn nutrition of rice, in this concern (Bohn *et al.* 2008) stated the antagonistic relationship of Si with Zn and Fe may be due to better internal metabolism of P results in more phytic acid production which disrupts Zn and Fe bioavailability in rice and (Xu *et al.*, 2015) added that the better internal homeostatic effect of Si fertilization on Zn and Fe metabolism affecting shoot to grain ratio.

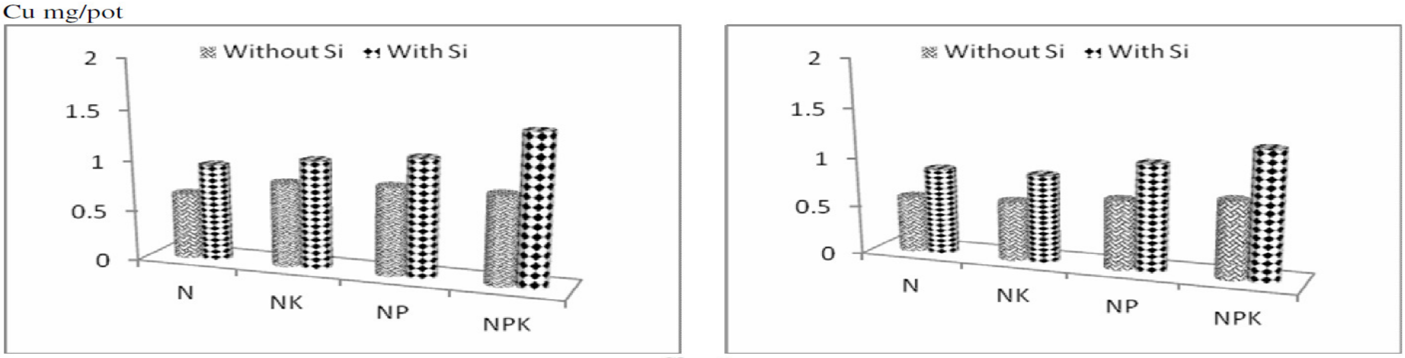
Also, data in Table (2) and in Fig. (3) show that Si addition to all the fertilizer treatments in the two growing seasons significantly increased Zn uptake by roots, shoots, and grains of rice plants, except in shoots of N treatment in the first season which did not reach the significance level of 5%.

Table 1: Effect of silicon application on Cu content and uptake by different parts of rice plants grown for two seasons.

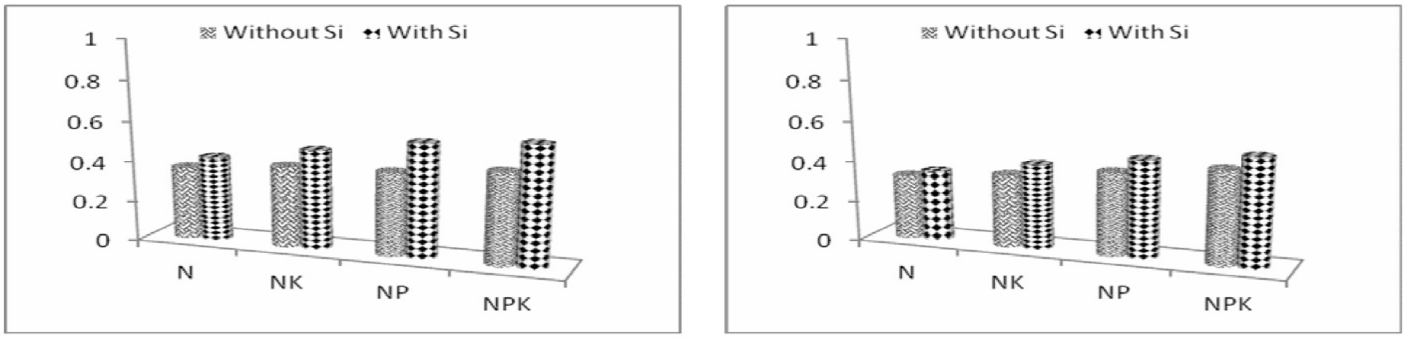
Fertilizer treatments	**1st Season**						**2nd Season**					
	Roots		**Shoots**		**Grains**		**Roots**		**Shoots**		**Grains**	
	-Si	**+Si**	**-Si**	**+Si**	**-Si**	**+Si**	**-Si**	**+Si**	**-Si**	**+Si**	**-Si**	**+Si**
	Cu content (ppm)											
N	33.00	39.00	11.00	10.00	10.00	9.55	37.00	45.00	11.72	10.18	10.50	9.50
NK	41.00	41.25	12.00	11.00	11.00	10.00	38.00	44.00	13.00	11.45	12.72	11.45
NP	41.25	42.75	12.05	12.00	11.00	11.00	41.00	49.00	14.10	12.37	13.97	11.63
NPK	39.00	50.00	12.98	12.00	12.00	11.00	43.00	53.00	14.95	12.50	14.23	12.28
L.S.D. At Level of : 5%	4.59		0.75		1.52		5.40		0.79		0.59	
Level of : 1%	6.25		1.02		2.07		7.35		1.08		0.80	
	Cu uptake (mg / pot)											
N	0.65	0.96	0.36	0.42	0.28	0.33	0.57	0.88	0.32	0.35	0.21	0.24
NK	0.83	1.07	0.40	0.49	0.32	0.37	0.60	0.89	0.36	0.42	0.28	0.32
NP	0.87	1.16	0.41	0.56	0.33	0.43	0.70	1.08	0.41	0.48	0.32	0.35
NPK	0.87	1.47	0.45	0.59	0.37	0.46	0.78	1.29	0.46	0.53	0.36	0.43
L.S.D. At Level of : 5%	0.13		0.04		0.05		0.10		0.03		0.02	
Level of : 1%	0.18		0.06		0.08		0.14		0.04		0.03	

- Si Without silicon addition. + Si With silicon addition.

Roots



Shoots



Grains

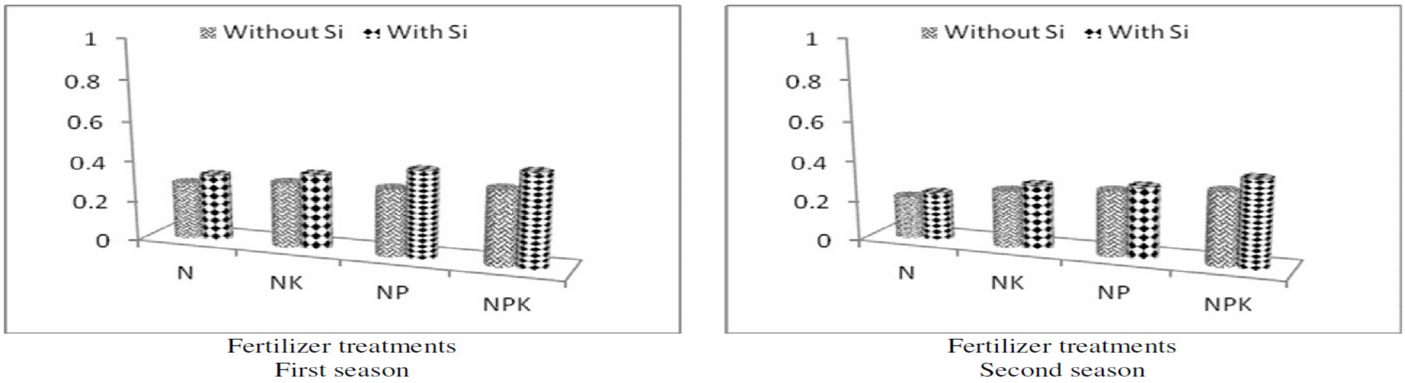


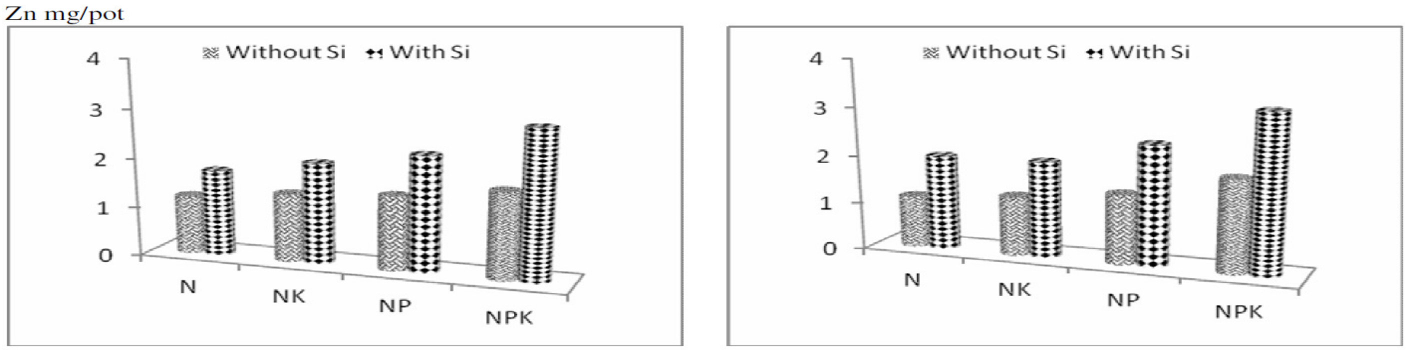
Fig. 2 : Effect of silicon application on Cu uptake (mg/pot) by different parts of rice plant

Table 2 : Effect of silicon application on Zn content and uptake by different parts of rice plants grown for two seasons.

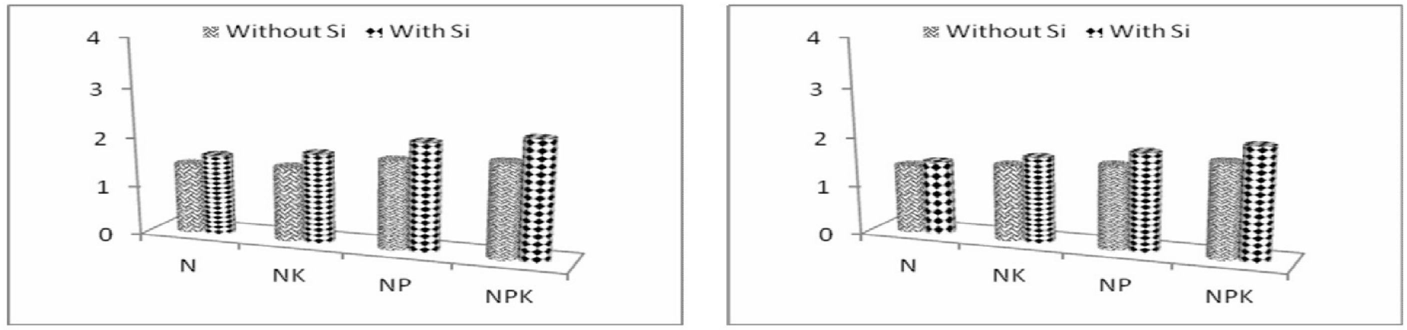
	1st Season						2nd Season					
	Roots		**Shoots**		**Grains**		**Roots**		**Shoots**		**Grains**	
	-Si	**+Si**	**-Si**	**+Si**	**-Si**	**+Si**	**-Si**	**+Si**	**-Si**	**+Si**	**-Si**	**+Si**
	Zn content (ppm)											
N	61.00	71.00	43.00	38.75	45.00	40.60	70.00	101.00	50.75	45.00	55.00	49.00
NK	68.00	79.00	46.50	41.00	52.00	46.00	79.00	99.00	55.00	48.00	59.25	54.00
NP	74.00	i,6.00	53.00	46.75	56.12	52.00	85.00	113.00	58.00	50.75	62.00	55.75
NPK	78.00	101.00	55.00	49.00	58.12	54.00	105.00	134.00	62.00	53.00	65.00	60.00
L.S.D. At												
Level												
of : 5%	4.70		5.47		4.11		7.58		3.03		2.10	
Level												
of : 1%	6.39		7.44		5.60		10.32		4.12		2.86	
	Zn uptake (mg / pot)											
N	1.19	1.75	1.42	1.64	1.24	1.41	1.09	1.98	1.39	1.55	1.10	1.23
NK	1.38	2.04	1.55	1.81	1.49	1.69	1.24	2.00	1.54	1.74	1.30	1.53
NP	1.55	2.33	1.79	2.18	1.68	2.04	1.45	2.49	1.69	1.98	1.43	1.70
NPK	1.74	2.98	1.90	2.39	1.79	2.25	1.92	3.26	1.90	2.25	1.66	2.09
L.S.p. At												
Level												
of : 5%	0.15		0.25		0.17		0.16		0.11		0.08	
Level												
of : 1%	0.20		0.34		0.24		0.21		0.14		0.11	

- Si Without silicon addition. + Si With silicon addition.

Roots



Shoots



Grains

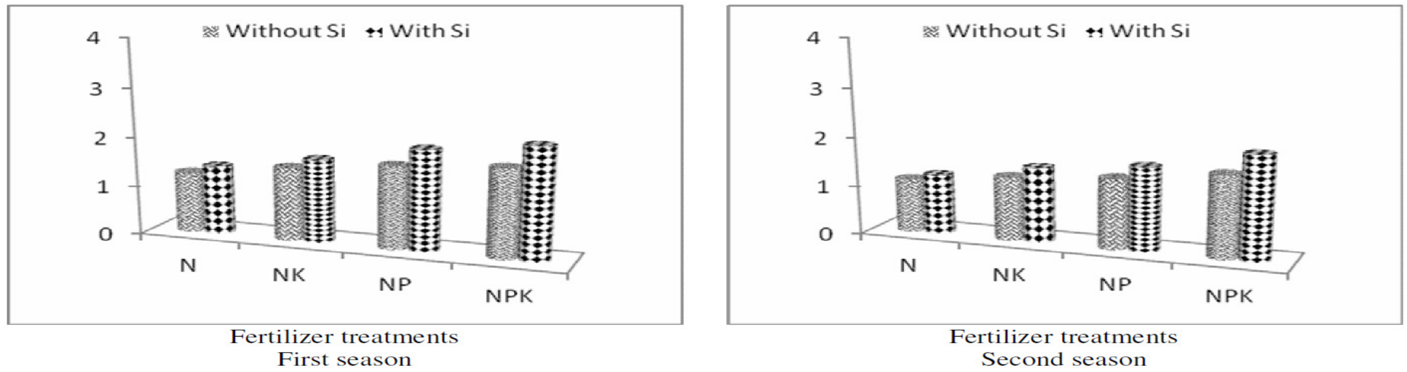


Fig. 3 : Effect of silicon application on Zn uptake (mg/pot) by different parts of rice plant

Application of 1.87 gm Si/pot to NPK fertilizer increased the Zn uptake in root shoot and grain yield of rice, these values were (2.98, 2.39 and 2.25 mg/pot) for root, shoot and grain, respectively at the first season if compared with those without Si addition fertilizer, these values were 1.74, 1.90 and 1.79 mg/pot for root, shoot and grain, respectively at the first season when addition of NPK alone.

These results may be due to the effect of Si on HMs changes according to cultivars and tissue (Wu *et al*., 2013) that can attribute to different Si uptake by the roots (Ma *et al*., 2006) and the major role of Si, when encounters with abiotic stress, is the elevation of the plant resistant by increasing the antioxidant enzyme activity (Nascimento *et al*., 2016) in this concern, (Wu *et al*., 2016) indicated that the Si-medium in cells deceases the toxic concentration caused by HMs, symplast, apoplast, and incensemet Si-absorbed in cell walls, and limits the root to shoot HMs translocations.

Generally, data show that the highest levels of Zn uptake by the different parts of rice were obtained by using NPK + Si treatment followed by NP + Si, NK + Si and N + Si in decreasing order.

These results attributed to the beneficial effects of silicon on uptake and in plant mobility have been reported for both nutrient (e.g., K, Mn, Fe) and non-nutrient minerals (e.g., Na, Al heavy metals). Furthermore, Si has been reported to mitigate both nutriet deficiencies and toxicities of nutrients and non-nutrient elements (Zhu and Gong 2014).

Furthermore, it was observed that Zn-silicate is a transient stoage compound for the metal and undergoes a slow degree of degradation to SiO_2, Zn is then translocate into the vacuoles and accumulated in an unknown form, it was suggested that the formation of Zn-silicate is part of the mechanism of heavy metal tolerance and may be responsible for the alleviation of Zn toxicity in cardaminopsis. (Benavides *et al*., 2005).

Finally, either Zn and Cu had the same trend when Si was added to the different fertilizer treatments.

Conclusion

From the foregoing results, it can be concluded that: All the studied silicate applications had a significant positive effect on yield and chemical composition of rice plants.

Generally silicon addition to the different fertilizer treatment significantly increase the content of Cu and Zn in the roots, while they significantly decreased in the shoots and grains of rice plant, so Si decreased the translocation of Cu and Zn from rice roots to shoots and grains.

Also Cu and Zn uptake by all the parts of rice plant (roots, shoots and grains) significantly increased by Si addition as they compared with those without Si addition, the highest values of Si content and uptake by the different parts of rice plant were obtained when the NPK + Si treatment was used.

Generally use of Sodium meta Silicate achieved positive effect on yield and chemical composition of rice plants.

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