Pak. J. Bot., 41(3): 1385-1390, 2009.

EFFECTS OF SILICON LEVELS ON GROWTH AND YIELD OF WHEAT IN SILTY LOAM SOIL

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Abstract

Silicon is the abundant mineral in soil, present exclusively in the form of silicic acid (H_4SiO_4). It is absorbed by plants in the form of silicic acid. The different levels of silicic acid were tested in a pot experiment to assess their effects on improvement of growth and yield in wheat. In a complete randomized block design the seeds of three varieties viz., Mehran, Abadgar and Kiran-95 were sown in pots filled with 2 kg of silty loam soil. The silicic acid was added to soil in a concentration of no silicic acid (T1), 0.25% silicic acid (T2), 0.50% silicic acid (T3) and 0.75% silicic acid (T4). The silicic acid concentrations affected crop positively as well as negatively as all the varieties produced highest plant growth and yield at 0.25% and 0.50% silicic acid application while the lowest plant growth and yield was found under 0.75% silicic acid. The highest plant growth and yield was observed in Abadgar followed by Mehran wheat variety.

Introduction

Silicon (Si) is the most abundant in soil next to oxygen and comprises 31% of its weight, 3-17% in soil solution (Epstein 1999). It is most commonly found in soils in the form of solution as Silicic Acid (H_4SiO_4) (Chen *et al*., 2000) and is taken up directly as silicic acid (Ma *et al*., 2001). Mitani *et al*., (2005) found that Si is translocated in the form of monosilicic acid through the xylem in rice. It primarily accumulates in leaves because it is distributed with the transpiration stream (Aston & Jones, 1976). In dried plant parts the silica bodies are located in silica cells below the epidermis and in epidermal appendices (Dagmar *et al*., 2003). Being a dominant component of soil minerals the silicon has many important functions in environment. Although the silicon is not considered as an essential plant nutrient because most plants can be grown from seed to seed with out its presence (Marschner, 1995), however, many plants can accumulate silicon concentrations higher than essential macronutrients (Epstein, 1999). Many studies have suggested the positive growth effects of silicon, including increased dry mass and yield, enhanced pollination (Korndörfer & Lepsch, 2001) and most commonly increased disease resistance (Bowen *et al*., 1992; Gilman *et al*., 2003; Rodrigues, 2004). It reduces micronutrient and metal toxicity (Horst & Marschner, 1978; Horiguchi & Morita, 1987; Cocker *et al*., 1998a; Britez *et al*., 2002) even if not taken up in appreciable amounts (Voogt & Sonnenfeld, 2001.). Silicon can also alleviate imbalances between zinc and phosphorus supply. Recently a number of workers have shown that silicon (Si) can decrease the toxic effects of Al in hydroponics culture in several species (Ma *et al*., 1997; Cocker *et al*., 1998b; Zsoldos *et al*., 2000). Gypsum is known to improve the productivity of dispersive soils and Sodium silicate has shown to maintain root activity under waterlogged conditions (Ma *et al*., 1989). Sundahri *et al*., (2001) found positive effects of gypsum and sodium silicate on the wheat grown under waterlogged and dispersed soils at anthesis especially in increasing plant height leaf and

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shoot dry mass, though there were no significant effects on yield at final harvest. Although the effect of silicon is positive on many crops but its efficacy as fertilizer has not been determined. Therefore, this study is planed to evaluate the efficacy of silicon in the agriculture determining its effects on crop growth and yield.

Materials and Methods

Germination: The aim of this study was to assess the effects of different levels of Silicic acid on germination of wheat seeds. The seeds of three varieties viz., Mehran, Abadgar and Kiran-95 were obtained from wheat Research institute Sakrand, Sindh. The selected healthy seeds, before sowing, were surface sterilized with 10% Sodium hypochlorite and were washed thoroughly with deionized distilled water. The experiment was laid out in 90 mm glass oven sterilized Petri dishes lined with two layers of Whattman filter paper and one layer of toilet roll. The filter paper and toilet rolls were irrigated with respective solutions at their saturation point and excess solution was discarded. Ten seeds per variety per Petri dish were sown in total 48 Petri dishes which were set in a complete randomized block design. The lid covered Petri dishes were placed in a germinator (Philip-Harris UK) under constant darkness at a temperature of 20^{o}C and 30-40% relative humidity. The solution treatments were applied as T1= control (water only), T2= 0.25% Silicic acid T3= 0.5%, Silicic acid and T4= 0.75% Silicic acid. After 7 days of sowing number of total seeds germinated of all varieties under all treatments were counted.

The rate of germination was calculated by the formula:

$$\text{Germination rate} = \frac{\text{Total no. of plants germinated}}{\text{Total no. of seeds sown}} \text{ X } 100$$

Growth & yield: A pot experiment was conducted in a green house of Department of Botany, Shah Abdul Latif University, Khairpur during the fall season of 2005-2006. In earthen pots of 8” mouth and 4” base diameter the three Kg of silty loam soil (65% silt, 25% clay and 10% fine sand) with pH 8.2, ECe 0.76 dSm^{-1} and 2.5% organic matter was filled. The soil was prepared separately for each treatment dividing it into several parts and mixing silicic acid thoroughly. The silicic acid was added @ 2.5 g, 5.0 g and 7.5 g per Kg soil in three treatments respectively along with one control in which soil contained no silicic acid. The total 48 pots were placed in complete randomized design with each treatment replicated 4 times. The seeds of three varieties viz., Mehran, Abadgar and Kiran- 95 were sown at the seed rate of 10 seeds per pot at the depth of 6 inches. The data for plant height, spike length, spikeletes per spike, seeds per spike and seed weight per plant was recorded and statistically analyzed for ANOVA and LSD @ 0.05% probability, using Minitab V. 11 statistical program.

Results

Germination: The final germination of all varieties was not significantly affected under first three treatments, however, the significant reduction in final germination percentage was recorded in treatment 4 (7.2g silicic acid Kg^{-1}), this shows that increased levels of silicic acid reduces the germination rate (Table 1). Though non-significant, but overall mean shows that under treatment 2 the varieties attended highest germination percentage of 99.20. Similarly, the response of different wheat varieties was found non-significant under first three treatments while under 4th treatment Abadgar was found highest responsive variety with reference to germinating.

Table 1. Mean % germination of wheat varieties under different Silicic acid treatments (after 5 days).

	Control	0.25%	0.5%	0.75%	Mean
Mehran	92.25	100.00	97.50	62.50	88.10
Abadgar	95.00	100.00	97.50	85.00	94.40
Kiran-95	90.00	97.50	97.50	60.00	86.30
Mean	**92.50**	**99.20**	**97.50**	**69.16**	

LSD (0.05) Treatments = 0.58
LSD (0.05) Varieties = 0.58
Interaction T x V = **

Table 2. Mean plant height (cm) per plant of wheat varieties under different treatments of Silicic acid.

	Control	0.5%	1.0%	1.5%	Mean
Mehran	63.33	89.45	79.90	57.25	72.48
Abadgar	73.10	103.75	90.05	75.00	85.48
Kiran-95	63.00	90.10	77.80	80.05	77.74
Mean	**66.48**	**94.43**	**82.58**	**70.77**	

Table 3. Mean spike length (cm) per plant of wheat varieties under different Silicic acid treatment.

	Control	5 g	10 g	15 g	Mean
Mehran	9.18	40.73	14.38	9.60	18.47
Abadgar	10.58	18.30	14.08	12.23	13.79
Kiran-95	9.33	16.08	14.30	10.08	12.44
Mean	**9.69**	**25.03**	**14.25**	**10.63**	

Growth & yield: The plant height (cm) increased significantly under treatment 2 & 3 while a slight decreased ratio has been observed under treatment 4 (0.75% Silicic acid) (Table 2). The highest plant height was produced by Abadgar. The LSD (0.05) showed significant differences among varieties as well as treatments. The varieties and treatment interaction was also found highly significant (Table 2).

A positive response of all varieties was observed for spike length under low and moderate silicic acid concentrations while it significantly decreased as the levels of Silicic acid increased (Table 3). The significant differences were found among varieties as well as treatments (Table 3) with the highest results produced by treatment 2 and variety Mehran while lowest in treatment 4 and Kiran -95 (Table 3).

The number of fertile Spiklets per spike was significantly higher under treatment 2 and lowest under treatment 4 followed by treatment 1. The highest number of spikelets was produced by Abadgar followed by Mehran (Table 4).

The number of seeds per plant increased with the moderate and low levels of silicic acid. The highest increase was observed under the treatment 2 followed by treatment 3 while treatment 4 followed by treatment 1 produced lowest results (Table 5).

The seed weight (g) per plant was significantly different under treatments as well as varieties. The highest seed weight was observed under treatment 2 of variety Abadgar while lowest seed weight was observed of variety Kiran-95 under treatment 4 followed by treatment 1 (Table 6).

Table 4. Mean Spiklets per spike of wheat varieties under different silicon treatments.

	Control	5 g	10g	15g	Mean
Mehran	11.85	16.40	13.80	11.90	13.49
Abadgar	11.75	18.90	16.10	11.65	14.60
Kiran-95	11.40	14.10	12.10	10.05	11.91
Mean	**11.67**	**16.47**	**14.00**	**11.20**	

LSD (0.05) for treat = 1.03
LSD (0.05) for Varieties = 0.86
Interaction T x V = **

Table 5. Mean seeds per plant of wheat varieties under different Silicon treatments.

	Control	5 g	10g	15g	Mean
Mehran	32.90	46.45	38.15	32.60	37.53
Abadgar	32.65	54.55	46.10	32.75	41.51
Kiran-95	31.30	40.05	33.50	26.95	32.95
Mean	**32.28**	**47.02**	**39.25**	**30.77**	

LSD (0.05) for treat = 2.79
LSD (0.05) for Varieties = 2.34
Interaction T x V = **

Table 6. Mean Seed weight (g) per plant of wheat varieties under different silicon treatments.

	Control	5 g	10g	15g	MEAN
Mehran	4.15	5.83	4.58	4.18	4.68
Abadgar	4.23	6.66	5.47	4.13	5.12
Kiran-95	4.05	4.95	4.08	3.45	4.13
Mean	**4.14**	**5.81**	**4.71**	**3.92**	

LSD (0.05) for treat = 0.36
LSD (0.05) for Varieties = 0.31
Interaction T x V = **

Discussion

It has been found by various workers that silicon has many positive effects on the growth and yield as well physiology and metabolism of different crops. Gong *et al*., (2003) observed that silicon increased plant height, leaf area and dry mass of wheat even under drought. Similarly, Singh *et al*., (2006) suggested that the increased dry matter and yield in rice. The indirect effects of silicon also cause increase in growth and yield in cereals, Ma & Takahashi (1990) concluded that there is a high phosphate uptake in rice with silicon application which directly correlates the increased growth and yield. Mukkram *et al*., (2006) also found that silicon increased growth and yield due to decreased Na^+ uptake in wheat under salt stress. Since germination remains un-affected even under usual stress conditions because the seed itself has enough nutrients to germinate. However, it has been found that the initial vigor produced in seeds lasts to the later stages of plant growth thus a remarkable increase in the yield of crop is evident (Rashid *et al*., 2000).

The findings of this study showed that when Silicic acid was applied at 0.25-050% level as fertilizer, the rate of germination was increased. While if its levels exceeded the limits it was found harmful resultantly reduced the germination rate and also affected the total crop stand as well as yield.

The effects of different levels of Silicon in the form of Silicic acid have been investigated by many investigators. Singh *et al*., (2006) found that the 180 kg ha^{-1} of Silicon increased nitrogen and phosphate levels in the grain and straw of rice. This suggests that silicon in lesser amounts can be beneficial in increasing grain yield and growth of cereal crops. In the present study the Silicon levels of 0.25 & 0.50% have been found positive effects while overdose not only found un-advantageous but also reduced growth and yield in wheat crop.

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(Received for publication 29 September 2008)