Madras Agric. J., 2018; doi:10.29321/MAJ 2018.000198

RESEARCH ARTICLE

Effect of Silicon Fertilization on Growth and Yield of Hybrid Maize Under Irrigated and Rainfed Conditions

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Received : 30th July, 2018
Revised : 24th August, 2018
Accepted : 24th August, 2018

ABSTRACT

A field experiment was conducted to study the effect of silicon fertilization on growth and yield of hybrid maize under irrigated and rainfed conditions during *Rabi*, 2017-18 at Eastern Block farm of Tamil Nadu Agricultural University, Coimbatore. The treatments comprised of two factors. Factor one consistsed of three irrigation strategies *viz*., M_1 – adequate irrigation (at regular intervals), M_2 – limited irrigation (at critical stages) and M_3 – no irrigation (rainfed) and factor two consistsed of silicon sources *viz.,* S_1 - seed priming with 1.5 mM of sodium meta silicate for 12 hrs, S_2 – foliar application of silicic acid @ 0.2 % at knee high and tassel initiation stages, S_3 – seed priming with 1.5 mM sodium meta silicate and foliar application of silicic acid @ 0.2 % twice at knee high and tassel initiation stages, S_4 – water spray and S_5 – control. The results of the study indicated that adequate irrigation strategy registered significantly higher growth and yield parameters, grain and stover yield of maize. Higher grain yield 6679 kg/ha was recorded under adequate irrigation (M_1) condition. Silicon application as seed priming with 1.5 mM of sodium meta silicate and foliar application of silicic acid @ 0.2 % at knee high and tassel initiation stages was recorded higher grain yield of 6130 kg/ha. It was comparable with foliar application of silicic acid @ 0.2 % at knee high and tassel initiation stages alone in registering higher growth and yield of maize.

Keywords: *Maize, Irrigation strategies, Silicon sources, Yield*

Maize (*Zea mays* L.) is an important cereal and fodder crop occupying 27% of the world acreage and accounts for about 34% of the world grain production. It is world's third most important cereal crop next to rice and wheat. In India, maize is grown in about 9.3 m ha with a production of 24.19 m t and average productivity of 2.60 t/ha (MOA, 2016). In Tamil Nadu, it is grown in an area of 3.8 lakh ha with a production of 2.24 m t and productivity of 5902 kg/ha (Season and Crop Report, 2016). Drought is the second important constraint of maize production in the developing countries. Drought affects the organ growth and leads to reduction in leaf and silk elongation thus decreasing light interception and increasing the anthesis-silking interval, finally affecting corn production (Boyer, 1970; Saab and Sharp, 1989). Many of the world's poorest people do their farming in areas with inadequate rainfall. The major global research focus to overcome the moisture stress is a real challenge for the scientists as it leads to extensive yield losses. The role of various macro and micro nutrients in enhancing the yield has been understood very well. However, the present focus is to examine the beneficial role of any nutrient in alleviating moisture stress in crops besides maximising their yield. The potentiality of silicon (Si) towards its drought tolerance mechanism was evaluated in various crops through several researches conducted elsewhere. The role of Si on drought tolerance examined by Hattori *et al.* (2005) in *Sorghum bicolor*, clearly indicated that Si applied sorghum could extract a large amount of water from drier soils and can maintain a higher stomatal conductance. Similar results were obtained by Ma *et al.* (2004) in cucumber; they concluded that Si enhances the net photosynthetic rate of cucumber under drought stress. Si has also been found to reduce the oxidative membrane damage and improves the water use efficiency up to 35% in maize (Gao *et al.,* 2004). Kaya *et al.* (2006) reported an enhancement in relative water content indicating the retention of water in cells increasing the moisture stress tolerance in maize. Pei *et al.* (2010) reported that Si application stimulates antioxidant defense mechanism in wheat, when grown under water stress conditions. The present investigation was undertaken with the objective to study the effect of silicon

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application on growth and yield of hybrid maize under the three irrigation strategies *viz.,* adequate irrigation, limited irrigation and no irrigation conditions.

Material and Methods

The field experiment was carried out at Eastern block farm, Department of Farm Management, Tamil Nadu Agricultural University, Coimbatore during *Rabi,* 2017-18. The farm is geographically situated in Western Agro Climatic Zone of Tamil Nadu with coordinates of 11°N latitude, 77°E longitude and an altitude of 426.7 m above Mean Sea Level (MSL). During the cropping period (October 2017 to February 2018), a total rainfall of 217.7 mm was received in 12 rainy days. The soil of the experimental site was clay loam texture and was slightly alkaline in pH (8.59), non-saline in EC (0.36 dS/m), medium in available N (238.0 kg/ ha), medium in available P (14.0 kg/ ha), high in available K (452.0 kg/ ha). The organic carbon status in the experimental soil was 0.72 % with available silicon content of 72.0 kg/ha. TNAU maize hybrid Co 6 was used for the field experiment. The experiment was laid out in split plot design with three replications. The treatment details comprised of two factors. Factor one consists of three irrigation strategies *viz.,* M_1 –adequate irrigation (at regular intervals), M_2 –limited irrigation (at critical stages) and M_3 – no irrigation (rainfed) and factor two consists of silicon sources *viz.,* S_1 - seed priming with 1.5 mM of sodium meta silicate for 12 hrs, S_2 - foliar application of silicic acid @ 0.2 % at knee high and tassel initiation stages, S_3 – seed priming with 1.5 mM sodium meta silicate and foliar application of silicic acid @ 0.2 % twice at knee high and tassel initiation stages, S_4 – water spray and S_5 – control. The recommended cultural practices were carried out as per the Crop Production Guide (CPG, 2012). The recommended dose of NPK (250: 75: 75 kg/ha) was applied to the crop in three splits (as basal and two top dressings). Irrigation was given as per the treatments plots. For adequate irrigation M_1 (*i.e.,* irrigation at regular intervals), nine irrigations were given throughout the crop growth period at an interval of 8 - 12 days, whereas five irrigations were given to M_2 treatment (limited irrigation at critical stages) at seedling, knee high, tasseling, silking and maturity stages. The M_3 treatment was maintained completely under rainfed condition. Biometric observations on growth parameters *viz.,* plant height and dry matter production were recorded at different growth stages. Similarly, the yield parameters (cob length, cob girth, cob weight, number of grains/cob and test weight) with grain yield and stover yield were recorded at the time of harvest. The data collected were subjected to statistical analysis following the standard procedure (Gomez and Gomez, 2010) and presented.

Results and Discussion

Different irrigation strategies and silicon sources showed significant influence on the growth parameters (plant height and dry matter production) yield parameters (cob length, cob girth, cob weight, No. of grains/cob and test weight) and grain and stover yields of maize crop. The data are furnished in Tables 1 and 2.

Table 1. Effect of irrigation strategies and silicon sources on plant height (cm) and DMP (kg/ha) of maize at different growth stages

Treatment	Plant height (cm)			DMP (kg ha^{-1})		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
Main plots						
M_1	36.3	179.5	240.8	3678	9375	17538
M_2	37.0	171.3	229.9	3627	7083	17158
M_3	37.3	151.9	202.9	3599	5710	15643
SEd	0.5	1.4	2.9	63	167.0	275.8
CD (P = 0.05)	NS	4.0	6.5	NS	363.8	565.8
Sub plots						
S_1	37.7	169.1	227.5	3618	7450	16781
S_2	36.7	168.5	239.6	3626	7679	17525
S_3	38.2	173.7	237.4	3676	7795	17651
S_4	36.2	164.6	213.2	3640	7125	16043
S_5	35.7	161.5	205.0	3615	6898	15899
SEd	0.9	3.2	4.9	77	110.9	364.1
CD (P = 0.05)	NS	6.7	10.1	NS	228.9	751.5

Treatment Details

Main plot

M_1: Adequate irrigation (irrigation with regular intervals)

M_2: Limited irrigation (irrigation at critical stages)
M_3: No irrigation
Sub plot
S_1: Seed priming with 1.5 mM of sodium meta silicate for 12 hrs.
S_2: Foliar application of silicic acid @ 0.2 % at knee high stage (25 DAS) & tassel initiation stage (45 DAS)
S_3: S_1 + S_2
S_4: Water spray
S_5: Control

Growth parameters

Plant height is a direct index to assess the growth and vigour of the plant. Though plant height is basically a genetically controlled parameter, it can be modified through certain agronomic manipulations. Among the three irrigation strategies studied, no significant influence was observed for this parameter at 30 DAS. However, as the crop growth advanced, significantly taller plants were recorded under the supply of adequate irrigation at regular intervals with the plant height of 179.5 and 240.8 cm at 60 and 90 DAS, respectively. It revealed that supply of adequate irrigation (at regular intervals) had produced higher plant height when compared to limited and no irrigation conditions. Frequent and steady supply of irrigation water to the crop helped in translocation of assimilates without any stress and that lead to substantial growth and development of plant, which was visually reflected in higher plant height. The results are in conformity with the findings of Hussaini *et al*. (2008). With regard to silicon sources also, no significant influence was observed for plant height of the crop at 30 DAS. Seed priming with sodium meta silicate and foliar application of silicic acid twice at knee high and tassel initiation stages had registered taller plants of 173.7 cm at 60 DAS. At 90 DAS, foliar spray of silicic acid twice at knee high and tassel initiation stages had produced taller plant height of 239.6 cm. As silicon is less mobile in the soil pool, exogenous application of silicon along with native silicon might have improved the photosynthetic capacity of maize with effective light interception, leading to increased plant height. Elawad *et al.* (1982) reported that plant height was quadratically related to the rate of Si application.

Table 2. Effect of irri gation strategies and silicon sources on yield parameters, grain yield and stover yield of maize

Treatment	Cob length (cm)	Cob girth (cm)	Cob weight (g)	No. of grains/cob	Test weight (g)	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})
Main plots							
M_1	19.3	14.5	275.9	470	40.2	6679	11119
M_2	18.9	14.5	263.8	452	39.7	5851	9483
M_3	16.3	13.5	235.8	437	37.9	4980	8498
SEd	0.3	0.2	6.1	3.5	0.6	136	266
CD (P = 0.05)	0.7	0.5	12.3	7.2	1.3	298	538
Sub plots							
S_1	18.4	14.3	259.1	452	39.9	5847	9631
S_2	18.7	14.2	262.7	468	39.9	6033	10005
S_3	18.8	14.4	269.7	483	39.4	6130	9699
S_4	17.5	14.1	251.1	438	38.6	5668	9666
S_5	17.5	13.8	249.9	425	38.7	5505	9499
SEd	0.3	0.2	4.3	5.0	0.7	148	213
CD (P = 0.05)	0.7	NS	8.9	10.3	NS	306	NS

Treatment Details
Main plot
M_1: Adequate irrigation (irrigation with regular intervals
M_2: Limited irrigation (irrigation at critical stages)
M_3: No irrigation
Sub plot
S_1: Seed priming with 1.5 mM of sodium meta silicate for 12 hrs.
S_2: Foliar application of silicic acid @ 0.2 % at knee high stage (25 DAS) & tassel initiation stage (45 DAS)
S_3: S_1 + S_2
S_4: Water spray
S_5: Control

Dry matter production (DMP) has direct relationship with crop productivity. With regard to the three irrigation strategies tested, no significant effect was observed at 30 DAS. At 60 DAS and 90 DAS, significantly higher DMP was registered under adequate irrigation with the values of 9375 kg/ha and 17538 kg/ha, respectively. The higher dry matter production with adequate irrigation condition might be due to the increased plant height, in turn resulting in more photosynthates accumulation. These above results are in agreement with the findings of Singh *et al.* (2005). Among the silicon sources, significant difference between the treatments towards DMP was observed at 60 and 90 DAS. Seed priming with sodium meta silicate and foliar application of silicic acid at knee high and tassel initiation stages did produce higher DMP of 7795 kg/ha and 17651 kg/ha at 60 and 90 DAS, respectively. Silicon application helped to improve the biomass production as a consequence of improved light interception and better photosynthetic activity. Similar findings were reported by Gong and Chen (2012).

Yield parameters

Irrigation strategies and silicon sources had significantly affected the yield attributes of hybrid maize. Among the three irrigation strategies experimented, higher cob length (19.3 cm), higher cob girth (14.5 cm), higher cob weight (275.9 g), maximum number of grains per cob (470 Nos.) and increased hundred grain weight (40.2 g) was registered under adequate irrigation condition, supplied at regular intervals. This might be due to increased plant growth characters up to significant level by increased availability of water and nutrients to plants under stress free moisture availability. The excellent utilization of water and nutrients in required amount on account of better availability through adequate irrigation and transfer of photosynthates from source to sink during grain filling stage might have caused superiority in aforesaid yield attributing characters as compared to the other two irrigation strategies *viz*., limited and no irrigation conditions. Similar findings were reported by Khan *et al.* (1996) and El-Tantawy *et al.* (2007). With regard to the silicon sources, higher cob length (18.8 cm), higher cob weight (269.7 g) and higher number of grains/cob (483) was recorded with seed priming with sodium meta silicate and foliar application of silicic acid @ 0.2% twice at knee high stage and tassel initiation stage. The reason might be due to exogenous silicon nutrition which might have helped in maintaining photosynthetic activity along with increased water influx from the soil solution and limited transpiration loss which favoured in improved growth, yield parameters and ultimately, the yield. Mukhtar and Goyal (2012) revealed that silicon nutrition has significant effect on crop growth, physiological attributes and yield parameters at Rawalpindi (Pakistan) location in wheat crop.

Grain and stover yield

Significantly higher grain yield of 6679 kg/ha was recorded under adequate irrigation, supplied at regular intervals, when compared to the other two irrigation strategies adopted. This strategy might have resulted in a favourable soil environment and better solubilization, uptake and assimilation of soil and applied nutrients. Seed priming with sodium meta silicate and foliar application of silicic acid at knee high and tassel initiation stages resulted in higher grain yield of 6130 kg/ha than other treatments. However, the treatment was statistically on par with foliar application of silicic acid at knee high and tassel initiation stages. Exogenous supply of silicon could have improved the photosynthetic activity, enabling the maize plant to accumulate sufficient photosynthates and there by higher DMP and these together with efficient translocation resulted in higher grain yield. Similar results were noticed in rice by Narayanan *et al.* (2008). Stover yield also showed similar trend as that of grain yield. Crop raised under adequate irrigation condition did produce significantly higher stover yield of 11119 kg/ha than with the limited irrigation and no irrigation conditions. The increased stover yield might be due to better vegetative growth and higher dry matter production.

Conclusion

It is concluded that application of silicon sources as seed priming with 1.5 mM of sodium meta silicate and foliar application of silicic acid @ 0.2 % at knee and high tasseling stages had influenced higher growth and yield of maize even under the strategy of no irrigation as compared with adequate and limited irrigation strategies. Therefore, application of silicon through seed priming or foliar spray could be a suitable management strategy for sustainable production of TNAU maize hybrid CO 6 under irrigated and rainfed conditions.

References

Boyer, J. S. 1970. Leaf enlargement and metabolic rates in corn, bean and sunflower at various leaf water potential. *Plant Physiol.* **46:**233- 235.

CPG. 2012. Crop production guide. Published by Directorate of Agri., Chennai and Tamil Nadu Agricultural University, Coimbatore, India. pp. 93 - 100.

Elawad, S, Gascho, G, and Street, J. 1982. Response of Sugarcane to Silicate Source and Rate. I. Growth and Yield. *J. Agronomy., 74***(3):** 481-484.

El-Tantawy, M, Ouda, S, and F. Khalil 2007. Irrigation scheduling for maize crop grown under middle Egypt conditions. *Research Journal of Agriculture and Biological Science, **3***, 456-462.

Gao, X, Zou C, Wang L and F. Zhang. 2004. Silicon improves water use efficiency in maize plants. J. Plant Nutr. **8(27):**1457-1470.

Gomez, K.A. and A.A. Gomez. (2010). Statistical Procedures for Agricultural Research (3-Ed.). John Wiley and Sons, New York, U.S.A.

Gong, H, and K. Chen. 2012. The regulatory role of silicon on water relations, photosynthetic gas exchange, and carboxylation activities of wheat leaves in field drought conditions. *Acta Physiologiae Plantarum, **34*(4):** 1589-1594.

Gunes, A, Kadioglu, Y. K, Pilbeam, D. J, Inal, A, Coban, S, and A. Aksu. 2008. Influence of Silicon on Sunflower Cultivars under Drought Stress, II: Essential and Nonessential Element Uptake determined by Polarized Energy Dispersive X-ray Fluorescence. *Community of Soil Science and Plant, **39:*** 1904-1927.

Hattori, T, Inanaga, S, Araki, H, An, P, Morita, S, Luxová, M, and A . Lux. 2005. Application of silicon on enhanced drought tolerance in *Sorghum bicolor*. *Physiol. Plant*. **123(4)**: 459- 466.

Hussaini, M. A, Ogunlela, V. B, Ramalan, A. A, and A. M. Falaki (2008). Mineral composition of dry season maize (Zea mays L.) in response to varying levels of nitrogen, phosphorus and irrigation at Kadawa, Nigeria. *World Journal of Agricultural Sciences*, *4*(6), 775-780.

Kaya, C, Tuna, L, and D. Higgs. 200. Effect of silicon on plant growth and mineral nutrition of maize grown under water stress conditions. *J. Plant Nutr.* **29:** 1469-1480.

Khan, G.D, Shah, G, Bali, M.A, and K. Singh. 1996. Response of intercropping system involving maize (*Zea mays*) to irrigation level in Kashmir valley. *Indian J. Agric.l Sci., **66*(5):** 272-275.

Ma, C, Li, Q, Gao, Y, and T. Xin. 2004. Effect of silicon application on drought resistance of cucumber plants. *Soil Sci. and Plant Nutr.* **50**:623-632.

MOA. 2016. Ministry of Agriculture. Annual report 2015-16. Retrived from http://agricoop.nic.in.

Mukhtar, A and A. M. Goyal. 2012. A Silicon the non-essential bene cial plant nutrient to enhanced drought tolerance in wheat crop plant. Retrived from *http://www.intechopen.com/books/crop-plant/silicon-the-non-essential-bene cial-plant nutrient to-enhanced-drought-tolerance-in-wheat*.

Narayanan, S, Sandy, A, Shu, D, Sprung, M, Preissner, C, and J. Sullivan. 2008. Design and performance of an ultra-high-vacuum-compatible artificial channel-cut monochromator. *Journal of synchrotron radiation, **15*(1):** 12-18.

Pei, Z. F, Ming, D. F, Liu, D, Wan, G. L, Geng, X. X, Gong, H. J, and W. J. Zhou. 2010. Silicon improves the tolerance of water deficit stress induced by polyethylene glycol in wheat (*Triticum aestivum* L.) seedlings. *J. Plant Growth Regul.,* **29:**106-115.

Saab, I.N, and R.E. Sharp. 1989. Non-hydraulic signals from maize roots in drying soil: inhibition of leaf elongation but not stomatal conductance. *Planta,* **179:**466-474.

Season and Crop Report. 2016. Department of Economics and Statistics, Chennai.

Singh, K.K, Singh, K, Singh, R.S, Singh, R, and R. S. Chandel. 2005. Silicon nutrition in rice-a review. Agricultural Reviews-Agricultural Research Communications Centre, India. ***26*(3):** 223.