

Original Research Article

Correlation and regression studies of organic maize grown under different doses of active silica

ABSTRACT

A field experiment was conducted during the *Kharif* season of 2018 and 2019 at the Organic Unit of Instructional Farm, Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur (Rajasthan). The experiment was laid out in split plot design with three replications consisting of 36 treatment combinations of six soil application in main plots (0, 50, 75, 100, 125 and 150 kg/ha) and six foliar application of active silica in sub plots (No spray, water spray, 0.25, 0.50, 0.75 and 1.0%). The analysis showed that dry matter accumulation at 60, 75 DAS and harvest increase with plant height at 60, 75 DAS and harvest, respectively, grains/cob and test weight showed positive correlation with grain yield. Stover yield also increased with increasing plant height and dry matter accumulation. The analysis revealed that total N, P and K uptake increased with increasing biological yield; and protein content in grain increased with increasing N content, Si uptake increased with increasing Si content at 60, 75 DAS and harvest.

Keywords: Active silica; correlation; maize; organic farming; regression.

1. INTRODUCTION

Maize (*Zea mays* L.) is the world's leading crop and is widely cultivated as cereal grain. It is one of the most versatile emerging crops having wider adaptability. Globally, maize is known as queen of cereals because of its highest genetic yield potential. It is the only food cereal crop that can be grown in diverse seasons, ecologies and uses. Organic food production is gradually gaining momentum worldwide. Organic growers utilize a wide range of cultural practices and natural inputs to manage crops in a manner they consider safe for the environment and the consumer. In organic production, natural sources of silicon (Si) can be used to increase the growth and yields of crops. Si is second most abundant elements found in the earth's crust, but it

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is mostly inert and only slightly soluble [1]. Si has a key role in improving crop abilities to withstand biotic and abiotic stresses [2]. Si benefits in maize have been related to its effect on the improving of effective leaf area, photosynthetic efficiency and quality as well as the delay of leaf senescence [3, 4]. Photosynthesis is a determinant factor for crop growth and development as maximum photosynthesis contributes toward more yield and production, and it is the most basic and critical physiological process directly related to maize yield, especially at late developmental stages [5]. In oilseed rape, the improvement of plants resistance to winter conditions and formation of larger seeds were observed [6]. Dry matter accumulation increases with plant height is also influenced by photosynthesis [7]. Si application increases the growth attributes viz., plant height, stem diameter, number of leaves, cob length [8], yield attributes viz., a number of grains/cob, pods/plant, kernel/spike, seeds per pod and test weight [8, 9, 10] and grain and biological yield [8] in different crops. Si fertilization in the form of monosilicic acid in soil and foliar application significantly increased grain yield and improvement of grain quality of maize [11]. The highest positive influence of Si application was observed with the use of Si at 30 DAS and tasseling stages at 1.0% foliar application of active silica which provided plant height, dry matter accumulation, biological yield and nutrient uptake in maize under organic production system [12].

2. MATERIALS AND METHODS

A field experiment was conducted during the *Kharif* season of 2018 and 2019 at the Organic Unit of Instructional Farm, Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur (Rajasthan). The experiment was laid out in split plot design with six soil application in main plots viz., 0, 50, 75, 100, 125 (S₅) and 150 kg/ha; and six foliar application of active silica in sub plots viz., No spray, water spray, 0.25, 0.50, 0.75 and 1.0% and replicated thrice. The crop was sown in row 60 cm apart and plant to plant distances of 25 cm by using 20 kg/ha seed rate. Diatomaceous earth was used as source of active silica. It was procured from Seema Minerals and Metal Ltd. at Udaipur. It has 80.69% SiO₂. Soil application of active silica was applied before sowing and foliar spray of active silica was done at 30 DAS and initiation of tasseling stage. Plant height, dry matter accumulation, grain, stover and biological yield were observed by standard method. The protein content was estimated by multiplying N content of seed with a factor 6.25 [13]. Si content was estimated in plant using method suggested by Ma and Takahashi [14]. The N, P and K content of grain and straw were

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estimated by colorimetric method using spectronic 20 after development of colour with Nessler's reagent [15], Vanadomolybdo phosphoric acid yellow colour method [16] and Flame photometer method [16], respectively. The uptake of Si (at 60, 75 DAS and harvest), N, P and K (at harvest) were determined by multiplying nutrient content with their respective dry matter.

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To investigate the relationship between fodder yield and various growth, yield, physiological and nutrition factors a correlation matrix was created. Correlation between various parameters viz., growth attributes, yield components, yield, nutrient content and uptake were determined at probability 1 and 5% using method given by Panse and Sukhatme [17]. Simple linear regression equations for various growth, yield and nutrition characteristics were worked out [17].

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3. RESULTS AND DISCUSSION

3.1 Soil application

Soil application of active silica showed the significant and positive relationship among various growth, yield attributes, yield, nutrient content and uptake (Table 1). The relationship between plant height and dry matter accumulation revealed that dry matter accumulation at 60 ($r = 0.953^{**}$), 75 DAS ($r = 0.967^{**}$) and harvest ($r = 0.971^{**}$) increased with increasing plant height at 60, 75 DAS and harvest, respectively, and were positively correlated with each other. Increased dry matter accumulation resulted in a considerable increase in plant height due to an increase in doses of active silica. This might be owing to deposition of Si at cellular parts such as cell wall, cell lumens and intercellular space and its deposition below and above of cuticle layer lead to enhanced cell division and cell elongation, caused erectness of leaves and stem which ultimately lead to enhanced plant height and also increase in chlorophyll content resulted into better leaf area index, light interception and photosynthesis activity which enhanced higher dry matter accumulation. These findings are closely associated with Singh et al. [18] and Mukherjee and Sen [19]. Grains/cob ($r = 0.993^{**}$) and test weight ($r = 0.997^{**}$) shows positive correlation with grain yield. Stover yield also increases with increasing plant height ($r = 0.940^{**}$) and dry matter accumulation ($r = 0.923^{**}$). Indicating that grain and stover yield are dependent on these yield parameters like plant height, dry matter accumulation grains/cob test weight. Since growth is assessed in terms of rate of dry matter production and plant height, and partitioning into distinct plant sections, which ultimately reflects on grain and stover yield, because it is a result of

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multiple physiological and biological processes. In this manner, the grains serve as a source of dry matter production and the vegetative plant parts as a sink for dry matter accumulation. In maize, vegetative part is the source and sinks in the view of photosynthetic area and assimilation in the grain as it forms the economical part. This might be owing to increasing dose of active silica which increases biomass of grains owing to accumulation of carbohydrate and ultimately increased the test weight. These findings supported the results of Singh et al. [18], Singh et al. [20] and Jawahar and Vaiyapuri [21]. Correlation studies shows that total N uptake ($r = -0.991^{**}$), P uptake ($r = 0.993^{**}$) and K uptake ($r = -0.996^{**}$) were positively correlated with biological yield; and protein content in grain ($r = 1.000^{**}$) positively correlated and increased with increasing N content and also Si uptake increased with increasing Si content at 60 ($r = -0.986^{**}$), 75 DAS ($r = 0.996^{**}$) and harvest ($r = 0.997^{**}$). N, P and K content increase in grain and stover owing to availability of N, P and K increased in soil, because of N has synergetic effect with Si. Si increased retention capacity of soil and increased solubility of P which leading to increased nutrients efficiency of phosphatic fertilizer and positive response of higher silica with K, might be linked to cell wall [22]. Increased N, P, and K uptake with the increasing doses of active silica could be attributed to the better availability of N, P, and K and their transport to the plant from the soil. The higher nutrient uptake was mainly due to higher biological yield [23, 24, 25]. Significantly higher dry matter accumulation at different growth stage due to increased photosynthetic activity and minimized biotic and abiotic stress by soil application of active silica at 150 kg/ha which is synchronized supply according to crop needs.

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3.2 Foliar application

The relationship between various growth, yield attributes, yield, nutrient content and uptake were found significant and positive due to foliar application of active silica (Table 2). Dry matter accumulation was significantly and positively correlated with plant height at 60 ($r = 0.999^{**}$), 75 DAS ($r = 0.996^{**}$) and harvest ($r = 0.993^{**}$). Such relation between plant height and dry matter accumulation might be due to foliar application of active silica at 30 DAS and initiation of tasseling stage. It enhances the deposition of Si at cellular level which resulted into increased chlorophyll content, leaf area index, photosynthesis capacity and better light interception which ultimately lead to better vegetative growth, plant height as well as dry matter accumulation. These findings are closely associated with [18]. Grains/cob ($r = 0.983^{**}$) and test weight (r

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=0.974**) showed positive relationship with grain yield. Stover yield also showed significantly positive correlation and increased with increasing plant height ($r = 0.988^{**}$) and dry matter accumulation ($r = 0.986^{**}$). This might be owing to active silica applied particularly during reproductive stage which enhanced the plant to more exposure in sunlight resulted assimilation of carbohydrates, and growth and development of crop vigorously resulted better nutrients and moisture is taken from the soil which turned into higher grain and stover yield. This might be the reason for increasing the grain and stover yield by foliar application of active silica. Similar results were also observed by Ahmad et al. [26], Patil et al. [27] and Sarma and Shankhdhar [28]. Correlation analysis showed that total N ($r = 0.996^{**}$), P ($r = 0.999^{**}$) and K uptake ($r = 0.999^{**}$) were significantly positive correlated and increased with increasing biological yield, and protein content in grain ($r = 1.000^{**}$) increased with increasing N content, and also Si uptake increased with increasing Si content at 60 ($r = 0.995^{**}$), 75 DAS ($r = 0.999^{**}$) and harvest ($r = 1.000^{**}$). Jawahar and Vaiyapuri [21] also reported similar results.

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4. CONCLUSION

Based on the present experiment, results indicated that various growth, yield attributes, yield, protein, nutrient content and uptake were significantly and positively correlated with each other under soil application of active silica. Meanwhile, the positive and highly significant relationship between various attributes viz., growth, yield attributes, yield, protein, nutrient content and uptake were also noticed in case of foliar spray of active silica. Overall, it can be concluded that various phenology, nutritional and yield characters of maize in organic production system were significantly and positively related under both soil and foliar application of active silica.

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COMPETING INTERESTS DISCLAIMER:

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of

knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

REFERENCES

1. Savant NK, Korndörfer GH, Datnoff LE, Snyder GH. Silicon nutrition and sugarcane production. *Journal of Plant Nutrition*, 1999; 22(12): 1853–1903.
2. Xie Z, Song F, Xu H, Shao H, Song RI. Effects of silicon on photosynthetic characteristics of maize (*Zea mays* L.) on alluvial soil. *The Scientific World Journal*, 2014; 6: 1–6.
3. Gao XP, Zou CQ, Wang LJ. Silicon improves water use efficiency in maize plants. *Journal of Plant Nutrition*, 2004; 27(8): 457–1470.
4. Zou CQ, Gao XP, Zhang FS. Effects of silicon application on growth and transpiration rate of maize. *Chinese Journal of Eco-Agriculture*, 2007; 15(3): 55–57.
5. Ahmad A, Tahir, M, Ullah E, Naem M, Ayub M, Rehman HU. Effect of silicon and boron foliar application on yield and quality of rice. *Pakistan Journal of Life and Social Sciences*, 2012; 10(2): 161–165.
6. Gugała M, Sikorska A, Zarzecka K, Kapela K, Mystkowska I. The effect of sowing method and biostimulators on autumn development and overwintering of winter rape. *Scientiarum Polonorum Agricultura*, 2017; 16: 111–120.
7. Naik PK, Swain BK, Chakurkar EB, Singh NP. Effect of seed rate on yield and proximate constituents of different parts of hydroponics maize fodder. *Indian Journal of Animal Sciences*, 2017; 87(1): 109–112.
8. Amin M, Ahmad R, Ali A, Hussain I, Mahmood R, Aslam M, Lee DJ. Influence of silicon fertilization on maize performance under limited water supply. *Silicon*, 2016; 10: 177–183.
9. Kalandyk A, Waligorski P, Dubert F. Use of biostimulators in mitigating the effects of drought and other environmental stresses in soybean (*Glycine max* L. Merr.). *Epistem. Czas. Nauk.–Kult.*, 2014; 22: 267–274.

10. White B, Tubana BS, Babu T, Mascagni HJR, Agostinho F, Datnoff LE, Harrison S. Effect of silicate slag application on wheat grown under two nitrogen rates. *Plants*, 2017; 6: 47.
11. Jawahar S, Kalaiyaran C, Sriramachandrasekharan MV, Neeru J, Naveen Kumar M. Effect of orthosilicic acid formulations on growth and field of maize in different soils. In proceedings of the 7th International conference on silicon in agriculture, Bengaluru, India, 24–28 October 2017, p. 132.
12. Prajapat BS, Kaushik MK, Sharma SK, Chaudhary R, Yadav SK, Meena SN, Meena RL, Siddhartha Naik BSS. Effect of active silica on performance of maize (*Zea mays*) under organic farming. *Indian Journal of Agricultural Sciences*, 2021; 91(10): 1519–1523.
13. A.O.A.C. Official Methods of Analysis of A.O.A.C. International 17th edition (ed. Gaithersburg, Maryland). Associated of official analysis chemical, International, Virginia, 1960; USA.
14. Ma, JF, Takahashi E. Soil, Fertilizer and Plant silicon Research in Japan. Elsevier Science, 2002; pp. 1–294.
15. Snell PD, Snell GT. Colorimetric Method of Analysis, 3rd Ed. Vol. II–D, Van Nostrand CO. Inc. 1949; New York.
16. Jackson ML. Soil Chemical Analysis. Prentice Hall of India (P) Ltd., New Delhi. 1973; pp. 183–192.
17. Panse, V. G. and Sukhatme, P. V. Statistical Methods for Agricultural Workers. ICAR, 1985; New Delhi.
18. Singh K, Singh R, Singh KK, Singh Y. Effect of silicon carriers and time of application on rice productivity in a rice–wheat cropping sequence. *International Rice Research Newsletter*, 2007; 32(1): 30–31.
19. Mukherjee D, Sen A. Influence of rice husk and fertility levels on the growth and yield of wetland paddy (*Oryza sativa* L.). *Agricultural Science Digest*, 2005; 23(4): 284–286.
20. Singh AK, Singh R, Singh K. 2005 Growth, yield and economics of rice (*Oryza sativa*) as influenced by level and time of silicon application. *Indian Journal of Agronomy*, 2005; 50(3): 190–193.
21. Jawahar S, Vaiyapuri V. Effect of sulphur and silicon fertilization on growth and yield of rice. *International Journal Current Research*, 2010; 9: 36–38.

22. Pati S, Pal B, Badole S, Hazra GC, Mandal B. Effect of silicon fertilization on growth, yield, and nutrient uptake of rice. *Communications in Soil Science and Plant Analysis*, 2016; 47(3): 284–290.
23. Sudhakar PC, Singh JP, Yogeshwar S, Raghavendra S. Effect of graded fertility levels and silicon sources on crop yield, uptake and nutrient–use efficiency in rice (*Oryza sativa*). *Indian Journal of Agronomy*, 2006; 51(3): 186–188.
24. Gong HJ, Chen KM, Chen GC, Wang SM, Zhang CL. Effect of silicon on growth of wheat under drought. *Journal of Plant Nutrition*, 2011; 26: 1055–1063.
25. Meshram MR, Dwivedi SK, Ransing DM, Pandey P. Response of customized fertilizer on productivity, nutrient uptake and energy use of rice (*Oryza sativa* L.). *The Ecoscan*, 2015; 9: 373–376.
26. Ahmad A, Afzal M, Ahmad AUH, Tahir M. Effect of foliar application of silicon on yield and quality of rice (*Oryza sativa* L.). *Cercetari Agronomice in Moldova*, 2013; 46(3): 21–28.
27. Patil AA, Durgude AG, Pharande AL, Kadlag AD, Nimbalkar CA. Effect of calcium silicate as a silicon source on growth and yield of rice plants. *International Journal of Chemical Studies*, 2017; 5(6): 545–549.
28. Sarma RS, Shankhdhar D. Ameliorative effects of silicon solublizers on grain qualities in different rice genotypes (*Oryza sativa* L.). *International Journal of Current Microbiology and Applied Sciences*, 2017; 6(11): 4164–4175.

Table 1. Correlation coefficient and regression equation showing relationship between 'X' and 'Y' variable of soil application of active silica

| S.No. | Dependent variable (Y) | Independent variable (X) | Correlation coefficient (r) | Regression equation (Y=a+bX) |
|-------|------------------------------|------------------------------|-----------------------------|------------------------------|
| 1. | Plant height (cm) at 60 DAS | DMA (g/plant) at 60 DAS | 0.953** | Y = 29.588 +1.575X |
| 2. | Plant height (cm) at 75 DAS | DMA (g/plant) at 75 DAS | 0.967** | Y =78.266+0.764X |
| 3. | Plant height (cm) at harvest | DMA (g/plant) at harvest | 0.971** | Y= 99.796+0.548X |
| 4. | Grain yield (kg/ha) | Grains/cob | 0.993** | Y = -583.166+14.328X |
| 5. | Grain yield (kg/ha) | Test weight (g) | 0.997** | Y = -6884.738+46.029X |
| 6. | Stover yield (kg/ha) | Plant height (cm) at harvest | 0.940** | Y = -5091.239+54.525X |
| 7. | Stover yield (kg/ha) | DMA (g/plant) at harvest | 0.923** | Y = 410.481+29.359X |
| 8. | Biological yield (kg/ha) | N uptake (kg/ha) by crop | 0.991** | Y = 2201.451+64.174X |
| 9. | Biological yield (kg/ha) | P uptake (kg/ha) by crop | 0.993** | Y = 1675.767+365.810X |
| 10. | Biological yield (kg/ha) | K uptake (kg/ha) by crop | 0.996** | Y = 2322.805+66.084X |
| 11. | Protein in grain (%) | N content (%) in grain | 1.000** | Y = 0.000+6.250X |
| 12. | Si content (%) at 60 DAS | Si uptake (kg/ha) at 60 DAS | 0.986** | Y = 0.240+0.017X |
| 13. | Si content (%) at 75 DAS | Si uptake (kg/ha) at 75 DAS | 0.996** | Y = 0.615+0.244X |
| 14. | Si content (%) at harvest | Si uptake (kg/ha) at harvest | 0.997** | Y = 0.402+0.011X |

Table 2. Correlation coefficient and regression equation showing relationship between ‘X’ and ‘Y’ variable of foliar application of active silica

| S.No. | Dependent variable (Y) | Independent variable (X) | Correlation coefficient (r) | Regression equation (Y=a+bX) |
|-------|------------------------------|------------------------------|-----------------------------|------------------------------|
| 1. | Plant height (cm) at 60 DAS | DMA (g/plant) at 60 DAS | 0.999** | Y = 52.684+1.243X |
| 2. | Plant height (cm) at 75 DAS | DMA (g/plant) at 75 DAS | 0.996** | Y = -3.781+1.548X |
| 3. | Plant height (cm) at harvest | DMA (g/plant) at harvest | 0.993** | Y = 3.942+1.330X |
| 4. | Grain yield (kg/ha) | Grains/cob | 0.983** | Y = 4.257+11.688X |
| 5. | Grain yield (kg/ha) | Test weight (g) | 0.974** | Y = -4224.148+33.054X |
| 6. | Stover yield (kg/ha) | Plant height (cm) at harvest | 0.988** | Y = -8733.919+76.060X |
| 7. | Stover yield (kg/ha) | DMA (g/plant) at harvest | 0.986** | Y = -8518.398+101.850X |
| 8. | Biological yield (kg/ha) | N uptake (kg/ha) by crop | 0.996** | Y = 1442.706+75.308X |
| 9. | Biological yield (kg/ha) | P uptake (kg/ha) by crop | 0.999** | Y = 942.637+420.299X |
| 10. | Biological yield (kg/ha) | K uptake (kg/ha) by crop | 0.999** | Y = 892.610+88.270X |
| 11. | Protein in grain (%) | N content (%) in grain | 1.000** | Y = 0.000+6.250X |
| 12. | Si content (%) at 60 DAS | Si uptake (kg/ha) at 60 DAS | 0.995** | Y = 0.184+0.018X |
| 13. | Si content (%) at 75 DAS | Si uptake (kg/ha) at 75 DAS | 0.999** | Y = 0.137+0.014X |
| 14. | Si content (%) at harvest | Si uptake (kg/ha) at harvest | 1.000** | Y = 0.059+0.013X |