Effect of Fertility and Silicon Levels on Grain Quality of Maize (*Zea mays* L.)

Abstract

A field experiment was conducted to study the 'effect of fertility and silicon levels on the nutritional quality of maize' during *Kharif* 2022 and 2023 at Rajasthan College of Agriculture (RCA), MPUAT, Udaipur, Rajasthan, India. The main plot treatments consist of fourlevels of fertilizer (F_0: Control, F_{50}: 50% RDF, F_{75}:75% RDF and F_{100}: 100% RDF) and the sub-plot treatments consist of fourlevels of soil application of DiatomaceousEarth (Si_0, Si_{100}, Si_{200} and Si_{300}). Pratap Makka-9 of maize variety was used for research purpose.The protein content, protein yield, carbohydrate and energy in maize grain were recorded higher under 100% RDF than other levels of fertilizer. Application of 300 kg Diatomaceous Earth per hectare recorded higher protein content, protein yield, carbohydrate and energy in maize grain over the rest of silicon levels. The crude fat in maize grain was recorded lower in the application of 100% RDF. Application of 300 kg Diatomaceous Earth per hectare recorded lower crude fat in maize grain. Significantly higher protein yield was recorded under the combined application of 100% RDF and 300 kg diatomaceous earth per hectare. However, protein yield was at par in the application of 75% RDF with 300 kg Diatomaceous Earth per hectare and 100% RDF with 200 kg Diatomaceous Earth per hectare. The significantly lowest crude fat was recorded under the combined application of 100% RDF and 300 kg Diatomaceous Earth per hectare over the rest of treatment combinations.

Keywords: Fertilizer, Silicon, Protein, Crude fate, Diatomaceous Earth

Introduction

Maize (Zea mays L.) is the most efficient, productive and cereal crop and also have industrial importance. That ranks first in global production. Maize is a staple food in many parts of the world, with total maize production exceeding that of wheat or rice production. It is a good source of carbohydrates, protein, iron, vitamin B, and minerals. Approximately 70% of maize is used for animal feed, with the remainder going into industrial products (Rajoo, 1998). Maize is an exhausting crop, thus the nutrient requirements cannot be meet only by soil nutrient reserves; additional nutrients can be addressed through fertilizer application. Maize yields in Rajasthan are low because of an uneven nutrient application. Scientists face a challenge when recommended fertilizer doses since they must meet both the crop's nutritional need and the production system's sustainability(Shankar and Umesh, 2008).

Silic8on is the most plentiful element (in the earth's crust) after oxygen, with soils containing roughly 28% silicon by weight (Lindsay, 1979). Because of its abundance in the biosphere, silicon's importance as a micronutrient for higher plants is difficult to demonstrate. Agricultural activities tend to extract a substantial amount of silicon from soil. Even highly filtered water contains approximately 20 nM Si (Werner and Roth, 1983), while the leaves of silicon accumulator plants that were not exposed to silicon treatment typically contain between 0.5 and 1.9 mg Si g^{-1} leaf dry weight.Although silicon is considered a necessary component for many Poaceae species, direct evidence that it is a component of a molecule that is a necessary plant constituent or metabolite is still lacking, making it impossible to prove that silicon is necessary for all higher plants (Epstein, 1999).

Material and Method

Location

The experiment was conducted during *kharif* season of 2022 and 2023 at Instructional Farm, RCA, MPUAT(Udaipur). The geographical co-ordinates of the experimental site is 24^{o}.35' N latitude and 73^{o}.42' E longitude at an altitude of 582.2 m above mean sea level. RCA, MPUAT, Udaipur comes under the IVaZone of Rajasthan. The soil of the experimental site was clay loam soil (TypisHaplustepts).

Experimental details

The treatments were laid out in a split plot design with four levels of fertilizer as control, 50% RDF, 75% RDF and 100% RDF (F_0, F_{50}, F_{75} and F_{100}, respectively) with four levels of silicon @ control, 100, 200 and 300 kg DE ha^{-1} (Si_0, Si_{100}, Si_{200} and Si_{300}, respectively). Levels of fertilizer were included as a main plot and silicon levels as sub plot. Recommended dose of fertilizer (RDF) @ 90: 40: 30 N: P_2O_5: K_2O kg ha^{-1} was used and were calculated as per treatments based on gross plot size. The variety of maize Pratap Makka-9 was used for sowing. Sowing were under taken on 15^{th} July and 8^{th} July during 2022 and 2023, respectively. The nutrients *viz*., nitrogen, phosphorous and potassium were applied in the form of urea, di-ammonium phosphate (DAP) and muriate of potash (MOP), respectively.The silicon levels were applied in the form of diatomaceous earth (DE).

Analysis of nutritional quality of maize

Protein content

The protein content was calculated by measuring the nitrogen content of the sample using the Kjeldahl method (Snell and Snell (1949). The protein content of the products was calculated by multiplying the nitrogen content of the material by a factor of 6.25 ((A.O.A.C., 1960).

$$\text{Protein content (\%)} = \text{Percent Nitrogen} * 6.25$$

Protein yield

Protein yield was computed by using following formula;

$$\text{Protein yield (kg ha}^{-1}\text{)} = \frac{\text{Seed yield } (\text{kg ha}^{-1})\text{x protein content (\%)}}{100}$$

Crude fat

The fat content of the maize samples was estimated as crude ether extract of moisture free samples using the Soxhlet's Extraction Method on Socs Plus System. A thimble was filled with a weighed amount of moisture- free sample (5 g) and placed in the thimble holder, which was placed in an already weighed beaker, and 80 ml petroleum ether (60-80 □) was poured into the beaker. The system was loaded with beakers and the temperature was set to 100 □. After 120 minutes of operation, which was twice the initial boiling temperature. Rinsing was thus performed twice to collect any remaining fat in the sample. Beakers were removed and placed in a hot air oven. The beakers were weighed after the thimble holders were removed. The fat co8ntent of the sample was determined using the following formula:

$$\text{Crude fat (\%)} = \frac{\text{Weight of ether extract fat (B}-\text{A)}}{\text{Weight of sample (g)}} \text{ x } 100$$

Where,

A= Weight of empty flask (g)

B= Weight of flask + fat (g)

B-A= Weight of fat (g)

Carbohydrate content

The phenolsulphuric acid method as described by Roberts *et al*., 2011 was used to estimate carbohydrate contents in selected maize accessions. The powder of each accession (0.1g) was mixed in 5 mL of 2.5 *N*HCL and heated in a water bath for 3 to 4 hours. It was then neutralized by adding sodium carbonate (Na_2CO_3) and volume increase up to 100 to 150 mL.

Glucose with good strength was used as a standard for carbohydrate estimation. Each experimental sample was mixed with 1 mL of 5% phenol solution and 5 mL of 96% sulphuric acid (H_2SO_4) solution and kept at 30 □ for 20 min. After that absorbance was taken at 490 nm of wavelength of spectrophotometer obtained from standard curve was used to estimate carbohydrate content in selected maize cob grain accessions.

$$X = \frac{Y-0.2981}{0.0337} \times 100$$

Energy

The sample's energy value were calculated using physiological energy values of 4 Kcal per gram for potein, 9 Kcal per gram for fat and 4 Kcal per gram for carbohydrate.

Energy (Kcal/100g)= [(% protein x 4) + (% carbohydrates x 4) + (% fat x9)]

Result and Discussion

Effect of fertility levels

Protein content

The data (Table 1)show it clear that rising fertility levels considerably improve the protein content of maize grainup to 75% RDF (F_{75}). When 75% RDF was applied, the protein content increased by 15.9 and 6.1% in the pooled mean, compared to the control (F_0) and F_{50} level of fertility.In terms of statistics, the protein content between 75% RDF and 100% RDF remained at par. The addition of NPK fertilizers is an important practices for increasing protein content in maize. Nitrogen is directly involved in protein synthesis, phosphorus supplies energy for metabolic processes, and potassium promotes enzyme performance and nutrient transport. Together, these nutrients insure that maize plants develop healthily, efficiently use nutrients, and yield grains with higher protein content. A similar study was given by Ashoka *et al.* 2009.

Protein yield

Protein yield of maize is presented in Table 1. The maximum value 528.3 kg ha^{-1} for protein yield was observed in application of 100% RDF. The significant improvement in protein yield with the application of fertility levels seems to be due to enhancing production of protein content and higher grain yield.

Carbohydrate content

The data clearly shows that rising fertilizer levels improved the carbohydrate content in maize grain, however, the increase was only statistically significant up to 75% RDF (Table 2). The carbohydrate content in maize grain is statistically at par under 75 and 100% RDF. Increased fertilizer levels may improve carbohydrate content in maize grain, resulting in better growth, higher yields and superior nutritional value. A similar study was observed by Kour and Singh (2020).

Crude fat

The crude fat content of maize grain decreased dramatically as fertilizer levels increased (Table 2). Lower crude fat in maize grain was recorded with the application of 100% RDF. Fertilizers promote healthier plants, improve growth and metabolism, and result in decreased crude fat content. The same findings were also reported by Shinde *et al*., 2014.

Energy

The maximum energy (364.74 kcal/100gm)was obtained from maize grain under the application of 100% RDF which at par with the 75% RDF (Table 2). Fertiliser application to maize crops is critical for increasing grain energy content, which leads to higher yields, better quality, and improved plant health.

Effect of silicon levels

Protein content

The data in Table 1 show that increasing fertility levels significantly improves protein content in maize grain.The highest protein content recorded under the application of 300 kg DE ha^{-1}(Si_{300}). However, protein content remained statistically at parwith200 (Si_{200}) and 300 (Si_{300}) silicon levels.The 200 kg DE ha^{-1} (Si_{200}) reported an increase of 9.3 and 4.6 per cent inthe pooled analysisover the control (Si_{0}) and 100 kg DE ha^{-1} (Si_{100}), respectively. These results are in conformity with the findings of Ahmed *et al.* (2011), Bakhat (2012) and El-Temsah (2017).

Protein yield

The data shown in Table 1 shows that increasing silicon levels significantly increases the protein yield in maize. The highest protein yield was recorded under 300 kg DE ha^{-1}(Si) application.Silicon applications can help plants grow healthier and produce more protein by reducing stress and boosting physiological functioning.

Carbohydrate content

The carbohydrate content increased significantly with the successive increase in the levels of silicon up to 200 kg DE ha^{-1} (Table 2). The carbohydrate content remained statistically at par under 200 (Si_{200}) and 300 (Si_{300}) kg DE ha^{-1}. The silicon application results in healthier, more resilient plants with higher carbohydrate output. Similar studies were reported by Iqbal *et al.*, 2011.

Crude fat

The data clearly shows in Table 2 that increasing the levels of silicon caused a significant decreasein crude fat in maize grain. The lowest crude fat content in maize grain was observed under the 300 kg DE ha^{-1}application.The application of silicon makes plants healthier, and more resilient, optimizes their growth and resource utilization, resulted in reducing crude fat content. These results conform to the findings of Artyszak, 2018.

Energy

The data (Table 2) shows that significantly enhanced energy in maize grain with increasing levels of silicon up to 200 kg DE ha^{-1}(Si_{200}). The energy in maize grain remained statistically at par under 200 (Si_{200}) and 300 (Si_{300}) kg DE ha^{-1}. The use of silicon significantly increases maize growth, stress tolerance as well as improves the energy content in the grain.

Combined effect of fertilizer and silicon

Protein yield

Application of 100% RDF with 300 kg DE ha^{-1} ($F_{100}Si_{300}$) was recorded highest protein yield which was significantly increased over the rest of the treatment combinations but found at par with the application of 75% RDF with 300 kg DE ha^{-1} ($F_{75}Si_{300}$) and 100% RDF with 200 kg DE ha^{-1} ($F_{100}Si_{200}$) (Table 3).

Crude fat

Application of 100% RDF with 300 kg DE ha^{-1} ($F_{100}Si_{300}$) was recorded lowest crude fat which was significantly increased over the rest of the treatment combinations (Table 3).

Conclusion

The use of fertilizers and silicon can considerably improve the nutritional value of maize grain. Fertilizers give nutrients required for growth and development, whereas silicon promotes plant health and stress tolerance. These togethermeasures improve grain energy content, protein content, carbohydrate content, protein yield and crude fat. Application of 100% RDF with 300 kg DE ha^{-1} ($F_{100}Si_{300}$) was best treatment for the nutritional quality of maize grain.

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Table 1 Effect of fertilizer and silicon on protein content and protein yield in maize grain

Treatments	**Protein content (%)**			**Protein yield (kg ha^{-1})**		
	2022	**2023**	**Pooled**	**2022**	**2023**	**Pooled**
Fertility levels						
Control	9.13	9.32	9.23	310.2	327.6	318.9
50% RDF	10.06	10.10	10.08	437.8	452.9	445.3
75% RDF	10.63	10.75	10.69	521.7	536.3	529.0
100% RDF	10.73	10.91	10.82	551.9	564.7	558.3
S.Em.±	0.11	0.14	0.09	7.55	9.04	5.89
C.D. (P=0.05)	0.37	0.49	0.27	26.13	31.27	18.14
Silicon levels						
Control	9.56	9.70	9.63	377.8	389.2	383.5
100 kg DE ha^{-1}	9.99	10.13	10.06	433.8	447.8	440.8
200 kg DE ha^{-1}	10.48	10.57	10.53	489.5	502.2	495.9
300 kg DE ha^{-1}	10.52	10.67	10.60	520.4	542.2	531.3

S.Em.±	0.10	0.10	0.07	9.79	8.94	6.63
C.D. (P=0.05)	0.30	0.29	0.20	28.57	26.08	18.84

Table 2 Effect of fertilizer and silicon on carbohydrate content, crude fat and energy in maize grain

Treatments	Carbohydrate content (%)			Crude fat (%)			Energy (kcal/100g)		
	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled
Fertility levels									
Control	72.20	72.58	72.39	1.18	1.20	1.19	335.92	338.37	337.15
50% RDF	74.32	74.76	74.54	1.11	1.15	1.13	347.54	349.80	348.67
75% RDF	76.98	77.38	77.18	1.01	1.05	1.03	359.49	361.99	360.74
100% RDF	77.72	78.71	78.22	0.92	0.99	0.95	362.10	367.38	364.74
SEm±	1.03	1.07	0.74	0.02	0.01	0.01	3.95	4.31	2.92
CD(P=0.05)	3.58	3.69	2.29	0.05	0.05	0.03	13.67	14.92	9.01
Silicon levels									
Control	72.23	72.59	72.41	1.14	1.18	1.16	337.45	339.82	338.64
100 kg DE ha^{-1}	73.56	74.36	73.96	1.11	1.15	1.13	344.21	348.31	346.26
200 kg DE ha^{-1}	76.59	77.59	77.09	1.02	1.06	1.04	357.45	362.20	359.83
300 kg DE ha^{-1}	78.85	78.89	78.87	0.94	0.99	0.97	365.93	367.21	366.57
SEm±	1.02	1.00	0.71	0.01	0.01	0.01	4.15	4.09	2.91
CD(P=0.05)	2.96	2.92	2.03	0.04	0.04	0.03	12.12	11.94	8.29

Table 3 Combined effect of fertilizer and silicon on protein yield and crude fat in maize grain

F x Si	Protein yield				Crude fat			
	Si_0	Si_{100}	Si_{200}	Si_{300}	Si_0	Si_{100}	Si_{200}	Si_{300}
F_0	247.96	319.15	353.43	355.09	1.32	1.23	1.17	1.03

F_{50}	401.12	426.84	474.78	478.52	1.17	1.15	1.14	1.08
F_{75}	425.32	508.99	540.48	641.03	1.10	1.09	0.99	0.94
F_{100}	459.54	508.29	614.80	650.55	1.06	1.07	0.87	0.81
SEm±	13.25				0.020			
CD (P=0.05)	37.69				0.057			