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# Role of biochar and foliar applied silicon on the nutrient content and uptake by fenugreek (*Trigonella foenum-graecum* L.) under organic farming

**Akshita Bhatt, MK Kaushik, Roshan Choudhary, Gajanand Jat and SK Sharma**

**Abstract**
To study the effects of biochar and foliar applied silicon, individually as well as their combine interactions on the nutrient content and uptake in fenugreek *cv.* PRM-45, a field experiment was conducted at organic farm, Rajasthan College of Agriculture, Udaipur in *rabi* season of 2020-21. Four levels of biochar (control, 2, 3 and 4 t ha$^{-1}$) and four levels of foliar applied silicon (water spray, 1.5, 2.0 and 2.5%) were allocated in the field in factorial randomized block design (FRBD) which were replicated three times. The maximum increase in the nitrogen content (3.03%) and phosphorus content (0.43%) in seed and nitrogen content (1.18%), phosphorus content (0.23%) in haulm were found with 4 t ha$^{-1}$ biochar while no significant increase observed with silicon levels. Si content and uptake in seed as well as in haulm were recorded highest with the foliar application of 2.5% silicon. Maximum Si uptake by seed (14.50%) were reported in the plots treated with the combined application of 2 t ha$^{-1}$ biochar and 2.5% silicon.

**Keywords:** Biochar, silicon, nutrient content, uptake, fenugreek, organic

## Introduction

India has always been the land of spices since the time of civilization and domestication. Fenugreek (*Trigonella foenum-graecum* L.) is one of the spice crop in India which is not only known for its importance in culinary purposes but also holds same position in medicinal purposes. Belonging to the fabaceae family, it is a versatile annual *rabi* season crop having multi purposes. It is used in various pharmaceutical as well as cosmetic industries because of the beneficial effects on diabetes, obesity, inflammation, pain relief, hormonal imbalance. The seeds of the crop are rich in protein, vitamins, iron, manganese, magnesium and essential oils but taste bitter because of the presence of alkaloid '*trigonelline*'. Besides this, it is also used by several food industries for coloring, flavoring and changing the texture of the products. India leads the fenugreek production among the world with an area of 2.29 lakh ha, production 288.48 thousand tonnes and average productivity of 1012 kg ha$^{-1}$ as per the advance estimate of 2019-20 (Spice Board of India, 2020) [13]. In the fiscal year 2020, volume of fenugreek production in India accounted for over 285 thousand tonnes (Statista Research Department, 2020) [14]. In the present study, the effects of the two factors namely, biochar and foliar applied silicon has been taken into account on the nutrient content and uptake in fenugreek.

Biochar is a carbonaceous product of the pyrolysis of solid biomass formed after heating at the temperature of 300-600 $^0$C in the absence of oxygen. It is a dark colored powdery product with several unique properties like high porosity, high cation exchange site which provides favorable conditions for living microbiota in the soil and increase the soil carbon pool. It is predominantly known to optimize the bulk density of the soil. Crop residue biochars contained, on an average, 1.23% nitrogen, 0.32% phosphorus, 0.56% sulphur, 2.73% potassium and carbon 50-70%, the content may vary according to the type of biomass and pyrolysis conditions (Li *et al.* 2019) [7]. So biochar application improves the overall properties of soil and act as a soil amendment to enhance soil fertility. Silicon on the other hand is considered as a beneficial element and helps in enhacing several physiological processes in plants which leads to better crop yield. So, integrated management of silicon with the other essential nutrients is desirable for sustaining the productivity of an agricultural ecosystem.

## Materials and Methods

The field experiment was carried out during *rabi* 2020-21 at the organic unit, MPUAT, Udaipur (Rajasthan). The soil of the site was clay loam in nature, with slightly alkaline reaction (pH 7.8), medium organic carbon content (0.70%), medium nitrogen content (283.44 kg $ha^{-1}$), medium phosphorus content (22.2 kg $ha^{-1}$) and medium potassium content (279.3 kg $ha^{-1}$). The treatments consisting of four biochar levels (control, 2, 3 and 4 t $ha^{-1}$) and four levels of foliar applied silicon (water spray, 1.5, 2.0 and 2.5%) laid out in factorial randomized block design (FRBD) and replicated three times. Recommended dose of nutrients in organic cultivation of fenugreek were 20 kg N $ha^{-1}$ and 40 kg $ha^{-1}$ $P_2O_5$ applied as basal through organic sources like vermicompost, NADEP and neem cake. Biochar was applied before the sowing and incorporated well in the soil. The source of foliar applied silicon was diatomaceous earth (80% Si) sprayed twice at 45 DAS and 90 DAS. The crop variety Pratap Rajasthan Methi-45 (PRM-45) was sown using 25 kg seed $ha^{-1}$ with row X plant spacing of 30 X 10 $cm^2$. Manual harvesting was done after 137 days and plant samples 5 from each plot were collected for nutrient analysis. The chemical analysis of plants for the nutrient content was done after harvesting when plant samples were subjected to oven drying ($65^0$ C). Plant analysis for the determination of nutrient content in seed and haulm were done with the standard procedures *viz*., nitrogen by nessler's reagent colorimetric method (Snell and Snell, 1959) [12], phosphorus by vanado-molybdo phosphoric yellow colour method (Richards, 1968) [11], potassium by flame photometer (Jackson, 1973) and silicon by colorimetric method (Korndorfer *et al.* 2001) [6]. The uptake of nitrogen, phosphorus, potassium and silicon were done by the following formula:

$$\text{Nutrient uptake (kg ha}^{-1}\text{) by seed or haulm} = \frac{\text{Nutrient content (\%) in seed or haulm X Seed or haulm yield (kg ha}^{-1}\text{)}}{100}$$

## Results and Discussion

### Effect of biochar levels

The data on the nutrient analysis in seed and haulm of fenugreek after the harvest of the crop has been presented in Table 1. Results showed that significantly maximum nitrogen content (3.03%) and phosphorus content (0.43%) in seed was observed with the biochar application of 4 t $ha^{-1}$ over control. Further, nitrogen (1.18%) and phosphorus (0.23%) content in haulm found maximum with 4 t $ha^{-1}$ biochar in the soil over control. While different levels of biochar had no significant impact on the potassium content in seed as well as haulm of fenugreek. The nutrient uptake by seed and haulm is given in Table 2. The following results revealed that all biochar levels in soil had significantly influenced the nutrient uptake by seed and haulm of fenugreek from soil. Application of 4 t $ha^{-1}$ biochar had highest nitrogen (60.39 kg $ha^{-1}$), phosphorus (8.48 kg $ha^{-1}$), and potassium (21.48 kg $ha^{-1}$) uptake by seed. Similarly, highest nitrogen (56.98 kg $ha^{-1}$), phosphorus (10.92 kg $ha^{-1}$) and potassium (60.78 kg $ha^{-1}$) uptake by haulm were found maximum with soil application of 4 t $ha^{-1}$ biochar. Moreover, biochar application significantly influenced Si uptake by seed (10.41%) and haulm (15.68 kg $ha^{-1}$) while it failed to show any significant variations in Si content in seed as well as haulm of fenugreek (Table 3).

The increase in nutrient content and the uptake of the nutrients after the addition of biochar especially nitrogen and phosphorus may be because of the mobilization of nutrients, modification in cation exchange sites, pH and also by improving biological environment of the soil. The increase in the nitrogen uptake by the roots may be attributed as the improvement in the soil micro biota that increases the biological nitrogen fixation as well as organic forms of nitrogen in soil like amines, amino acids, and amino sugars in comparatively smaller amount which become bioavailable to the plants (Younis *et al.*, 2014) [15]. Due to the increased availability of nitrogen and phosphorus content in soil, its content and uptake by the plant also get enhanced which was found similar with the findings of Liu *et al.* (2017) [8], (Inal *et al*. 2015) [4] and Arif *et al.* (2021) [1].

### Effect of silicon levels

The varying levels of foliar applied silicon had no significant effect on the nutrient (N, P and K) content (Table 1) in fenugreek but showed positive effect on the nutrient uptake by seed and haulm of the crop. Foliar application of 2.5% silicon recorded significantly maximum nitrogen uptake by seed (57.35 kg $ha^{-1}$) and haulm (53.82 kg $ha^{-1}$). The significant maximum uptake of phosphorus (7.97 kg $ha^{-1}$) and potassium (19.86 kg $ha^{-1}$) by seed were recorded in the plots treated with 2.5% foliar application of silicon over control. The maximum uptake of phosphorus (10.33 kg $ha^{-1}$) and potassium (61.35 kg $ha^{-1}$) by haulm were found under 2.5% foliar application of silicon. Further, the results showed that foliar applied silicon increased the Si content and uptake by seed and haulm of fenugreek. The Si content in seed (0.64%) was maximum with 2.5% foliar application of silicon and minimum under control (0.40%). Maximum Si content in haulm (0.35%) was reported with 2.5% foliage applied silicon and minimum under control (0.29%). The increase in Si uptake by seed (12.38 kg $ha^{-1}$) and by haulm (16.90 kg $ha^{-1}$) was observed in the plots which were treated with the foliar application of 2.5% silicon over control and the rest plots.

The increase in nitrogen, phosphorus and potassium uptake could be due to one of the promoting effect of silicon to increase the transcellular and apoplastic uptake, photosynthetic machinery and stomatal activities as confirmed by the results of Mehrabanjoubani *et al.* (2015) [9] and Hafez *et al.* (2021) [3] in wheat, cotton and canola. The similar results were also found by Pati *et al.* (2016) [10] on the increase of N, P, K and Si content and uptake by the straw and grain of paddy with application of silicon (Diatomaceous Earth). The increased N, P, K and Si uptake due to foliar application of active silicon is resembling with the results of Crusciol *et al.* (2013) [2].

### Interaction effect

Biochar and foliar applied silicon had shown positive interaction effect on Si uptake (Table 4) by seed of fenugreek. Si uptake by seed (14.50 kg $ha^{-1}$) was found significantly maximum with the treatment combination of 2 t $ha^{-1}$ biochar and 2.5% foliar applied silicon over control (4.94 kg $ha^{-1}$) and other treatment combinations. This could be due to positive interaction of both the factors on the seed yield of fenugreek which was reflected in the nutrient uptake by seed of the crop.

Biochar increases the nutrient retention and bioavailability in the soil while active silicon plays important role in the nutrient movement within the plants.

**Table 1:** Effect of biochar and foliar applied silicon on nutrient content (%) in seed and haulm

| Treatments | Nutrient content (%) | | | | | |
|---|---|---|---|---|---|---|
| | Seed | | | Haulm | | |
| | N | P | K | N | P | K |
| **Biochar levels(t ha$^{-1}$)** | | | | | | |
| Control | 2.85 | 0.39 | 0.99 | 1.07 | 0.20 | 1.22 |
| 2 | 2.92 | 0.41 | 1.02 | 1.06 | 0.21 | 1.23 |
| 3 | 2.93 | 0.42 | 1.05 | 1.11 | 0.21 | 1.26 |
| 4 | 3.03 | 0.43 | 1.08 | 1.18 | 0.23 | 1.26 |
| S.Em ± | 0.04 | 0.01 | 0.03 | 0.03 | 0.003 | 0.02 |
| CD (P=0.05) | 0.12 | 0.02 | NS | 0.08 | 0.01 | NS |
| Silicon levels (%) | | | | | | |
| Water spray | 2.94 | 0.40 | 0.98 | 1.06 | 0.21 | 1.22 |
| 1.5 | 2.89 | 0.41 | 1.06 | 1.10 | 0.21 | 1.23 |
| 2.0 | 2.90 | 0.42 | 1.05 | 1.14 | 0.21 | 1.25 |
| 2.5 | 2.99 | 0.42 | 1.03 | 1.12 | 0.22 | 1.28 |
| S.Em ± | 0.04 | 0.01 | 0.03 | 0.03 | 0.003 | 0.02 |
| CD (P=0.05) | NS | NS | NS | NS | NS | NS |
| BXS | | | | | | |
| S.Em ± | 0.08 | 0.01 | 0.05 | 0.05 | 0.01 | 0.04 |
| CD (P=0.05) | NS | NS | NS | NS | NS | NS |

**Table 2:** Effect of biochar and foliar applied silicon on the nutrient uptake (kg ha$^{-1}$) by seed and haulm

| Treatments | Nutrient uptake (kg ha$^{-1}$) | | | | | |
|---|---|---|---|---|---|---|
| | Seed | | | Haulm | | |
| | N | P | K | N | P | K |
| **Biochar levels(t ha$^{-1}$)** | | | | | | |
| Control | 37.88 | 5.22 | 13.21 | 42.27 | 7.86 | 48.19 |
| 2 | 56.46 | 7.94 | 19.59 | 48.52 | 9.69 | 56.18 |
| 3 | 57.61 | 8.34 | 20.66 | 52.24 | 10.03 | 59.23 |
| 4 | 60.39 | 8.48 | 21.48 | 56.98 | 10.92 | 60.78 |
| S.Em ± | 1.08 | 0.14 | 0.53 | 1.60 | 0.21 | 1.21 |
| CD (P=0.05) | 3.11 | 0.41 | 1.53 | 4.61 | 0.60 | 3.44 |
| Silicon levels (%) | | | | | | |
| Water spray | 50.57 | 6.95 | 16.92 | 46.14 | 9.14 | 52.95 |
| 1.5 | 50.88 | 7.30 | 18.74 | 48.42 | 9.29 | 53.77 |
| 2.0 | 53.34 | 7.75 | 19.43 | 51.62 | 9.74 | 56.29 |
| 2.5 | 57.35 | 7.97 | 19.86 | 53.82 | 10.33 | 61.35 |
| S.Em ± | 1.08 | 0.14 | 0.53 | 1.60 | 0.21 | 1.21 |
| CD (P=0.05) | 3.11 | 0.42 | 1.53 | 4.61 | 0.60 | 3.44 |
| BXS | | | | | | |
| S.Em ± | 2.15 | 0.29 | 1.06 | 3.19 | 0.41 | 2.42 |
| CD (P=0.05) | NS | NS | NS | NS | NS | NS |

**Table 3:** Effect of biochar and foliar applied silicon on Si content (%) and uptake (kg ha$^{-1}$) by seed and haulm

| Treatments | Si Content (%) | | Si Uptake (kg ha$^{-1}$) | |
|---|---|---|---|---|
| | Seed | Haulm | Seed | Haulm |
| **Biochar levels (t ha$^{-1}$)** | | | | |
| Control | 0.50 | 0.31 | 6.63 | 12.46 |
| 2 | 0.51 | 0.32 | 9.97 | 14.70 |
| 3 | 0.52 | 0.32 | 10.38 | 15.04 |
| 4 | 0.52 | 0.33 | 10.41 | 15.68 |
| S.Em ± | 0.01 | 0.01 | 0.18 | 0.34 |
| CD (P=0.05) | NS | NS | 0.52 | 0.97 |
| Silicon levels (%) | | | | |
| Water spray | 0.40 | 0.29 | 6.82 | 12.59 |
| 1.5 | 0.48 | 0.31 | 8.44 | 13.63 |
| 2.0 | 0.53 | 0.33 | 9.75 | 14.76 |
| 2.5 | 0.64 | 0.35 | 12.38 | 16.90 |
| S.Em ± | 0.01 | 0.01 | 0.18 | 0.34 |
| CD (P=0.05) | 0.02 | 0.02 | 0.52 | 0.89 |
| BXS | | | | |
| S.Em ± | 0.02 | 0.01 | 0.36 | 0.67 |
| CD (P=0.05) | NS | NS | 1.04 | NS |

**Table 4:** Interaction effect of biochar and foliar applied silicon on Si uptake (kg ha$^{-1}$) by seed

| Biochar levels (t ha$^{-1}$) | Silicon levels (%) | | | |
|---|---|---|---|---|
| | Water spray | 1.5 | 2.0 | 2.5 |
| Control | 4.94 | 6.03 | 7.18 | 8.36 |
| 2 | 7.25 | 8.54 | 9.60 | 14.50 |
| 3 | 7.45 | 9.61 | 11.27 | 13.17 |
| 4 | 7.64 | 9.56 | 10.94 | 13.50 |
| S.Em ± | 0.36 | | | |
| CD (P=0.05) | 1.04 | | | |

## Conclusion

With the view of above mentioned results due to the effect of biochar and foliar applied silicon on the nutrient content and uptake in fenugreek, it is opined that 2 t ha$^{-1}$ biochar and 2.5% foliar applied silicon showed maximum uptake of nitrogen, phosphorus and silicon by seed while their interaction effect was not visible on nutrient content in seed and haulm in the prevailing agro-climatic conditions.

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