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Effects of silicon and irrigation levels on nutrient content and uptake of fenugreek (*Trigonella foenum-graecum* L.)

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Abstract
A field experiment entitled "Performance of Fenugreek (*Trigonella foenum-graecum* L.) under Varying Levels of Silicon under Restricted Irrigation Conditions" was conducted at Instructional Farm of Agronomy, Department of Agronomy, Rajasthan College of Agriculture, MPUAT, Udaipur during the *rabi* season of 2020-21 to study the effect of silicon levels under varying soil moisture regimes, selection of suitable irrigation level and arrive at most economically viable treatment. The soil of experimental field was clay loam in texture, slightly alkaline in reaction (pH 8.5), medium in available nitrogen (278.42 kg ha^{-1}) and phosphorus (18.07 kg ha^{-1}) while high in available potassium status (312.45 kg ha^{-1}). The experimental design split plot design was used comprises main factor irrigation having four levels *viz*., control, one, two and three irrigations sub plot factor silicon which also having four levels *viz*., control, 50, 100 and 150 kg ha^{-1} combined having 16 treatment combinations, which were replicated three time. Fenugreek crop variety PRM-45 was used as test crop. The results revealed that application of three irrigations at 20, 40 and 60 DAS in fenugreek crop produced significantly increased nutrient content and uptake. Among irrigation levels, application of three irrigations at 20, 40 and 60 DAS proved most effective in elevating nutrient status of seed and haulm as compared to two one and no irrigation. The fenugreek crop irrigated thrice at 20, 40 and 60 DAS accumulated highest quantum of nutrients in seed and haulm, thereby total accumulation. The magnitude of increase in total N, P and K uptake by crop was 14.83, 15.23, 11.5 per cent over two, 37.61, 38.13, 23.66 per cent over one and 78.32, 57.14, 83-37 per cent over no irrigation, respectively. Crops fertilized with 150 kg silicon ha^{-1} accumulated highest quantum of nutrients in seed and haulm, thereby total accumulation closely followed by application of 100 kg ha^{-1}. The magnitude of increase in total N, P and K uptake due to application of 150 kg silicon ha^{-1} was14.58, 14.77, 7.73 and 29.75, 29.48, 18.89 per cent over application of 50 kg silicon ha^{-1} and control, respectively. The corresponding increases in total uptake due to application 100 kg silicon ha^{-1} was and 10.85, 13.8, 5.55 and 25.52, 27.32, 16.47 per cent, respectively.

Keywords: Performance, fenugreek, silicon, restricted irrigation

Introduction

Fenugreek (*Trigonella foenum-graecum* L.) popularly known by its vernacular name "methi" has been in culinary and medicinal uses due to its restorative and nutraceutical properties for more than 2500 years. The seed contain an alkaloid *Trigonallin* (0.12-0.38%) is thought to reduce glycosuria in diabetes. The sapogenin, is an estrogen precursor and helps in managing menopause. The concentration of diosgenin varies from 0.86 to 2.2% in seed (Bochalia *et al*., 2011) [3]. Fenugreek leaves and seed have been used extensively to prepare extracts and powders for medicinal uses. Fenugreek is reported to have anti-diabetic, anti-fertility, anticancer, anti-microbial, anti-parasitic and hypocholesterolaemic effects (Al-Habori and Raman 2002) [2].

Botanical name of Fenugreek is *Trigonella foenum-graecum* L. the genus, Trigonella, is old Greek word meaning "three angled'', the form of its corolla. Fenugreek belongs to family Fabaceae. It is an important winter seasons legume spice mainly grown in arid and semi-arid regions of India. It is grown on 1.2 lakh ha with 188.48 thousand tonnes production at an average productivity status of 1007 kg ha^{-1} (Spice Board of India, 2020). In India, major fenugreek growing states are Rajasthan, Gujarat, Madhya Pradesh, Tamil Nadu, Uttar Pradesh and Punjab. More than 77 per cent area and production of the country contributed by Rajasthan alone. The major districts growing fenugreek in Rajasthan are Sikar, Chittorgarh, Jaipur, Pali, Nagour, Jhalawar and Alwar with area of 1.5 lakh ha, total production of 160 thousand tonnes and average productivity of 1066 kg ha^{-1}in 2016-17 (Sachan *et al.*, 2020) [21]. Fenugreek (*Trigonella foenum-graecum* L.) is mostly grown as an irrigated crop during *rabi* (winter) North India and *kharif* (rainy) seasons in South India (Ravindran *et al*., 2001) [20].

The agronomic package of practices needs to be developed for enhancing fenugreek productivity on sustainable lines in different agro-climatic zones of India. Among agro-inputs, water is profound value for enhancing the productivity of different crops including legume and fenugreek. Kalpana and Selvi (2008) [10] conveyed that water management is most important for augmenting crop productivity especially of legume crops due to their high susceptibility to both water stress and water logging at various stages of crop growth. Thus, development and adoption of irrigation schedule which just ensure a favorable soil moisture regime is necessary, so that yield levels are maximized by virtue of enhanced crop growth and yield promoting factors. In the present day of water scarcity, optimum irrigation plays a vital role in economizing water use through augmenting the water use efficiency.

Nutrient for the growth and development of plants. It is the second most common abundant elements turns in soil after oxygen. In conventional cropping system silicon recognised as functional nutrient for cereal crops and play vital role in growth and development of crop plants. It promotes upright growth (stronger and thicker stem, shorter internodes), prevent lodging, enhanced disease and insect resistance and reduced water consumption results of research on silicon on crops shows that uptake of silicon is greater than the uptake of nitrogen and potassium because of synergistic effect (Savant *et al*., 1997). Evidence put toward that application of silicon increased plants tolerance several biotic and abiotic stresses (Liang *et al*., 2007) [15], drought, toxic metal stress (Kaya *et al*., 2006) [12]. Also reduced a storage of diverse processes in plants including stomatal conductivity, photosynthesis, nutrient uptake and transport, membrane permeability, relative water content and plant growth rate (Tahir *et al*., 2006) [24]. It is absorbed in the form of H_4SiO_4.

Keeping in view the above facts, an investigation entitled "Performance of Fenugreek (*Trigonella foenum-graecum* L.) under Varying Levels of Silicon and Restricted Irrigation Conditions" was conducted at RCA, MPUAT, Udaipur.

Material and Methods

The experiment was laid out at the Instructional Farm, Rajasthan College of Agriculture, Udaipur which is situated at 24° 35' North latitude and 74° 42' East longitude at an altitude of 579.5 meter above mean sea level. It falls under agro climatic zone IVa "Sub-Humid Southern Plain and Aravali Hills" of Rajasthan. The soil of experimental field was clay loam in texture, slightly alkaline in reaction (pH 8.5), medium in available nitrogen (278.42 kg ha^{-1}) and phosphorus (18.07 kg ha^{-1}) while high in available potassium status (312.45 kg ha^{-1}). The experimental design split plot design was used comprises main factor irrigation having four levels *viz*., control, one, two and three irrigations sub plot factor silicon which also having four levels *viz*., control, 50, 100 and 150 kg ha^{-1} combined having 16 treatment combinations, which were replicated three time. Fenugreek crop variety PRM-45 was used as test crop.

Field Preparation: The experimental field was ploughed with a tractor drawn mould board plough and two cross harrowing followed by planking to obtain well pulverized soil tilth. The field was then demarcated into different plots each of 5.0 m x 3.0 m as per details gives in with provisions for irrigation channels and a path. Furthermore, each plot was levelled with a rake to facilitate uniform distribution of irrigation water.

Fertilizers application: As per recommendation, 40 kg nitrogen + 20 kg P_2O_5 ha^{-1} was applied. Urea and DAP were used as a source of nitrogen and phosphorus, respectively.

Treatment application

Irrigation: A common (60 mm) irrigation through a slow stream was given immediately after sowing the seeds. Thereafter irrigations were applied as the treatment details. Irrigation water was measured with 7.5 cm parshall flume installed in the irrigation channel to give 60 mm water for each irrigation.

Silicon: The whole quantity of silicon as per treatment allocation were applied at the time of sowing with recommended dose of nitrogen and phosphorus.

Sowing- The fenugreek seed of variety PRM-45 was sown on 13th November, 2020. The uniform seed rate of 25 kg ha^{-1} was used and seeds were treated with *Rhizobium meliloti* culture before sowing. Fenugreek seeds were drilled in furrows opened at the depth of 5 cm at 30 cm row to row spacing

Weed management: In order to minimize weed competition, herbicide Imazethapyr @ 55 g ha^{-1} was applied through knapsack sprayer fitted with flat fan nozzle using spray volume of 500 litre ha^{-1} at 25 DAS. One hand weeding was also done at 40 DAS follow by hoeing to keep weeds under control.

Harvesting: The crop was harvested from the individual plot when plants were fully dried. The plant of border rows were harvested first and removed from each plot. Thereafter the crop from net plot areas were harvested and produce was tied in bundles separately and tagged. The harvesting was carried out on 10th march, 2021. The tagged bundles were kept for sun drying.

Threshing and winnowing: Dried bundles of individual plot was weighed separately to record biological yield, then threshed with power operated thresher and the produce was winnowed, cleaned and weighed separately to record seed yield per plot. This in turn used to compute yield ha^{-1}. The composite seed and haulms samples were collected for laboratory studies from each plot.

Results and Discussion

Effect of Irrigation and Silicon on Nutrient Content

Nitrogen

Irrigation levels: An examination of data (Table 1.1) reveals that increasing level of irrigation significantly improved N status of seed and haulm. Thus when compared to control, application of one, two and three irrigation significantly elevated nitrogen status of seed by 5.82, 11.12, 13.98 per cent and haulm by 10.37, 23.14, 38.63 per cent, respectively. Among irrigation levels, application of three irrigation produced seed and haulm having highest nitrogen content which was significantly higher by2.52, 7.70 and 2.52, 26.16, 12.58 per cent, respectively over application of two and one irrigations.

Silicon levels: Data (Table 1) further reflects that increasing level of silicon application up to 100 kg ha^{-1} significantly improved nitrogen status of seed by 2.46, 7.64 per cent and haulm by 11.14 and 25.55 per cent as compared to application of silicon 50 kg ha^{-1} and control, respectively. Further increase in silicon level from 100 to 150 kg ha^{-1}through increased N status of seed and haulm but failed to attain statistical significance.

Phosphorus

Irrigation levels: It can be inferred from the data (Table 1) that irrigation level had significant effect on phosphorus content of seed and haulm. Thus when compared to no irrigation, application of one, two and three irrigation significantly improved phosphorus status of seed by 6.07, 9.26, 15.40 per cent and haulm by 8.14, 23.13, 35.78 per cent, respectively. The highest phosphorus status of seed and haulm was estimated when crop was given three irrigations at 20, 40 and 60 DAS which was significantly higher by 5.62, 8.62 and 10.27, 25.55per cent, respectively over application of two and one irrigations.

Silicon levels: It is evident from data (Table 1) that amongst of silicon levels, significantly higher phosphorus content in seed and haulm were estimated under application of silicon 150 kg ha^{-1} which was found at par with the application of silicon 100 kg ha^{-1}. Thus when compared to application of 50 kg silicon ha^{-1} and control, application of 100 kg silicon ha^{-1} significantly increased phosphorus content in seed by 2.61,4.86 and haulm by 14.49, 29.53 per cent, respectively.

Potassium

Irrigation levels: A perusal of data (Table 1) reveal that potassium content in seed and haulm was significantly influenced due to varying irrigation levels. Thus compared to control, application of one, two and three irrigation significantly improved potassium status of seed by 7.0, 13.92, 25.83 per cent and haulm by 7.11, 11.14,15.74per cent, respectively. The highest potassium status of seed and haulm was recorded when crop was given three irrigations which was significantly higher by 10.46, 17.60 and 4.14, 8.06 per cent, respectively over application of two and one irrigations.

Silicon levels: Data (Table 1) show that increasing level of silicon up to 100 kg ha^{-1} significantly increased potassium content of seed by 3.98, 6.71 and haulm by 2.85, 8.97 per cent as compared to application of silicon 50 kg ha^{-1} and control, respectively. Further increase in silicon level from 100 to 150 kg ha^{-1} though increased potassium content but failed to attain statistical significance.

Effects of Irrigation on Nutrient Content Uptake

The plant analysis revealed that successive increase in irrigation levels from one to three brought about significant improvement in N, P and K content in seed and haulm over application of two, one irrigation and control. Further crop irrigated three times accumulated highest quantum of N, P and K in seed, haulm, there by total uptake over application of one, two irrigation and control (Table 2).

The marked improvement in N, P and K content of both plant parts with higher irrigation levels seems to be increased moisture supply to the root systems. Secondarily it can be attributed to the efficient extraction/translocation due to increase in root ramification/activities as irrigation plays vital role in maintaining physico-chemical and biological properties of soil. Since protein content is dependent on nitrogen content of seed increase in protein content with successive increase in frequency of irrigations was expected. It is believed that in the plants extracted nutrient are used for maintaining their critical concentration that can be used for plant growth as evident from higher accumulation of dry matter under the influence of three irrigations further reveals that there was adequate supply of photosynthates from shoot to root. This might have promoted growth of roots as well as their functional activity leading to higher extraction of nutrients from soil to plant root. Thus at higher irrigation level adequate moisture supply might have increased availability of these nutrients for their absorption by the roots and translocation to the plants by virtue of increased transpiration ultimately enhancing status of these nutrients in plant parts. The results are in close agreement with the findings of Yougendra (2005), Bhunia *et al.* (2006) and Lakpale *et al.* (2007).

It is well established fact that uptake of nutrient by the crop is primarily governed by total biomass production and secondarily on nutrient status at cellular level. Thus improvement in both these under higher irrigation level results in higher uptake of added nutrients. It is also evident from significant positive correlation between biological yield and total uptake of nitrogen ($r=0.963^{**}$), phosphorus ($r=0.959^{**}$) and potassium ($r=0.991^{**}$).

Effects of Silicon on Nutrient Content Uptake

Application of increasing rate of silicon up to 100 kg ha^{-1} significantly improved N, P and K status of seed and haulm over application of 50 kg silicon ha^{-1} and control. Similarly the uptake of nutrients by these plant parts and total uptake by crop showed increasing trend up to highest level of silicon fertilization but significant response was observed only up to 100 kg silicon ha^{-1} (Table 2).

The positive influence of silicon application on nutrient status of plant parts seems to be due to their increased availability in the root zone. Moreover increase in shoot growth as evident from higher accumulation of dry matter under the influence of 100 kg silicon ha^{-1}, further reveals that there was adequate supply of photosynthates from shoot to root. This might have promoted growth of roots as well as their functional activity leading to higher extraction of nutrients from soil to plant parts. In this direction Michael and Baringer (1980) ascribed that expanded root promotes, shoot growth which enhance root metabolism. Since most of nutrients (N, P, K) in seed is relocated from their reserves in vegetative parts, better nutritional conditions of seed with silicon application seems to be on account of their higher concentration in plants. The results are in close agreement with findings of several researchers (Meena *et al.*, 2016; Patil *et al.*, 2018; Kapoor, 2019) [17]. They also ascribed marked improvement in nutritional status of plant under silicon application due to their increase availability in the root zone and higher extraction due to better growth of roots.

It is well established fact that uptake of nutrients by the crop is primarily governed by total biomass production and secondarily on nutrient status at cellular level. Thus, improvement in both these due to silicon application resulted in higher uptake of these nutrients. The regression studies also substantiate dependence of nutrient uptake on biological yield. The results confirm the findings of Patel *et al.* (2019) and Pooja *et al.* (2019) [19].

The significant improvement in protein content with increasing rate of silicon application seems to be due to higher concentration of N in seed. These findings are in close conformity with the findings of Yougendra (2005) and Dhaker *et al.* (2017) [5].

Table 1: Effect of irrigation and silicon levels on nutrient content of fenugreek

Treatments	Nutrient content (%)					
	Nitrogen		Phosphorus		Potassium	
	Seed	Haulm	Seed	Haulm	Seed	Haulm
Control	2.68	0.97	0.428	0.161	0.445	1.066
One	2.83	1.07	0.454	0.188	0.477	1.142
Two	2.97	1.20	0.467	0.214	0.507	1.185
Three	3.05	1.35	0.493	0.236	0.561	1.234
S.Em.±	0.02	0.03	0.003	0.004	0.004	0.010
C.D.(P=0.05)	0.08	0.09	0.011	0.013	0.012	0.034
Silicon levels (kg ha^{-1})						
0	2.74	0.98	0.446	0.167	0.478	1.090
50	2.88	1.11	0.458	0.187	0.491	1.155
100	2.95	1.23	0.468	0.221	0.510	1.188
150	2.97	1.26	0.470	0.225	0.511	1.194
S.Em.±	0.02	0.03	0.003	0.003	0.003	0.011
C.D.(P=0.05)	0.06	0.08	0.008	0.009	0.008	0.031

Table 2: Effect of irrigation and silicon levels on nutrient uptake by fenugreek

Treatments	Nutrient uptake (kg ha^{-1})								
	Nitrogen			Phosphorus			Potassium		
	Seed	Haulm	Total	Seed	Haulm	Total	Seed	Haulm	Total
Irrigation levels									
Control	31.16	34.16	65.32	5.20	37.34	42.53	4.99	5.71	10.70
One	40.74	43.91	84.64	6.84	46.73	53.58	6.51	7.72	14.24
Two	50.17	51.25	101.43	8.56	50.86	59.42	7.87	9.19	17.07
Three	54.97	61.51	116.48	10.11	56.15	66.26	8.89	10.77	19.67
S.Em.±	0.70	1.42	1.62	0.10	0.64	0.66	0.10	0.22	0.27
C.D.(P=0.05)	2.44	4.91	5.61	0.34	2.20	2.30	0.33	0.77	0.95
Silicon levels (kg ha^{-1})									
0	39.55	38.97	78.52	6.95	42.81	49.76	6.46	6.68	13.14
50	43.17	45.74	88.91	7.42	47.49	54.91	6.89	7.80	14.70
100	46.74	51.82	98.56	8.14	49.82	57.96	7.43	9.30	16.73
150	47.58	54.30	101.88	8.20	50.96	59.16	7.48	9.62	17.10
S.Em..±	0.46	1.19	1.28	0.08	0.49	0.48	0.08	0.14	0.16
C.D.(P=0.05)	1.36	3.48	3.73	0.23	1.44	1.39	0.22	0.40	0.47

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