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PK Boori
SKN College of Agriculture (SKN Agriculture University) Jobner, Rajasthan, India

AC Shivran
SKN College of Agriculture (SKN Agriculture University) Jobner, Rajasthan, India

GK Giana
SKN College of Agriculture (SKN Agriculture University) Jobner, Rajasthan, India

ML Jat
SKN College of Agriculture (SKN Agriculture University) Jobner, Rajasthan, India

Gopali Yadav
SKN College of Agriculture (SKN Agriculture University) Jobner, Rajasthan, India

Sangita Meena
SKN College of Agriculture (SKN Agriculture University) Jobner, Rajasthan, India

Correspondence
PK Boori
SKN College of Agriculture (SKN Agriculture University) Jobner, Rajasthan, India

Growth and production potential of fenugreek as influenced by intercropping systems and Sulphur levels

PK Boori, AC Shivran, GK Giana, ML Jat, Gopali Yadav and Sangita Meena

Abstract
The present study was carried out at Jobner, Rajasthan during *rabi* season of 2013-14 to evaluate effect of intercropping and Sulphur in different row ratios on fenugreek. The field experiment was laid out in three times replicated randomized complete block design with three intercropping systems (sole fenugreek, fennel + fenugreek in 1:1 and 1:2 row ratios) and four Sulphur levels (0, 20, 40 and 60 kg S/ha). The results of experiment revealed that planting of fenugreek in 1:1 row ratio recorded significantly maximum plant height of fenugreek at 40, 80 DAS and at harvest, however, in case of dry matter accumulation at all growth stages, number of pods/plant and number of seeds/pod were significantly lowest as compared to 1:2 row ratio and sole crop of fenugreek. The fennel planting in 1:2 row ratios could not bring significant variation in growth parameters, yield attributes of fenugreek as compared to sole fenugreek. The planting of fenugreek in 1:1 row ratio gave significantly minimum seed (7.18 q/ha), straw (17.68 q/ha) and biological yields (24.86 q/ha) than 1:2 row ratio and sole fenugreek. The intercropping in 1:2 row ratio also recorded significantly lower seed (9.13 q/ha), straw (21.53 q/ha) and biological yields (30.65 q/ha) over sole fenugreek. The seed yield was reduced by 21.35 and 52.03% with intercropping of fenugreek in 1:1 row ratio as compared 1:2 row ratio and sole fenugreek, respectively. The intercropping of fenugreek in 1:2 row ratios also reduced seed yield significantly by 39.01% over sole fenugreek. However, when system productivity was compared in terms of LER, intercropping in 1:1 row ratio registered significantly highest land equivalent ratio (1.45) in comparison to intercropping in 1:2 row ratio as well as sole fenugreek. Application of Sulphur upto 40 kg/ha significantly increased plant height and dry matter accumulation at different growth stage, number of pods/plant and number of seeds/pod, seed (11.32 q/ha), straw (26.73 q/ha) and biological yields (38.05 q/ha) of fenugreek. Application of 40 kg S/ha in fenugreek intercropping system was found suitable as it recorded 31.78 and 9.79% higher seed yield over control and application of 20 kg S/ha, respectively. Similarly, Sulphur application at 40 kg/ha obtained significantly maximum LER (1.20) over control.

Keywords: Intercropping, fenugreek, Sulphur, yield, LER

Introduction
India is the world's largest producers, consumers and exporter of seed spices. Among all the states of India, Gujarat and Rajasthan together contribute more than 80 per cent of the total seed spices production in the country and thus, both the states together are known as "seed spices bowl" of India. Fenugreek is considered as spice as well as legume crop. It is annual herbaceous and autogamous crop belonging to family fabaceae and sub family papillionaceae. Fenugreek (*Trigonella foenum-graecum* L.*)* popularly known by its vernacular name '*methi'* is an important vegetable and condiment crop grown in Northern India during *rabi* season for leaves, shoots and seeds. Fenugreek is a multipurpose crop, every part of which is consumed in one or the other form. Its fresh tender leaves and pods are eaten as fried vegetables being rich in iron, calcium, protein and vitamins. Its chopped leaves are mixed in flour to prepare "*parantha*". Its grains are used to form a concentrate feed for animals. Besides this, it has immense medicinal utility. Fenugreek seeds have high nutritive values containing protein (9.5%), fat (10%), crude fiber (18.5%), carbohydrate (42.3%) and many other minor nutrients and vitamins. It also contain good percentage of gums (23.06%), mucilage (28%), trigonelline (0.13-30%), saponine (1.7%) and calorific values (370 calories per 100 gm seed). Rajasthan produces the lion's share of India's production, accounting for over 80% of the nation's total fenugreek output. It is a cash crop occupying prime place amongst the seed spices grown in Rajasthan. Its high market price attracts the farmers to include this crop in their cropping system. In Rajasthan, it occupies 65.51 thousand hectare area with the production of 71.52 thousand tonnes and average productivity of 1092 kg/ha. In Rajasthan, fenugreek is mainly cultivated in the districts of Bikaner, Sikar, Churu, Pratapgardh and Jhalawar (Anonymous, 2012-13). However, its productivity has been reported to be stagnate in India and Rajasthan from many years.

The legumes crops are attaining more attention of farmers as compared to other crop, as they serves dual purpose of both grain and fodder and also gives better yield under low water scare condition due to their ability to fix atmospheric nitrogen. The system of intercropping not only improves the yield and returns but also reduces the risk of complete crop failure as compared to the sole cropping system. Plant population and spatial arrangement in intercropping have important effects on the balance of competition between crops and their productivity. Sulphur is being considered as the fourth major nutrient whose deficiency has especially been observed in soils of Rajasthan and in these soils each unit of Sulphur applied can augment the supply of edible oil by 3-3.5 units (Tandon, 1986) [15]. Crop removal is the major cause of Sulphur depletion in soil. This suggests that maximum economical crop production cannot be expected from the use of NPK fertilizers alone, but that Sulphur must be included in the fertilization programmed. Keeping this in view, present investigation was undertaken to find out the optimum row ratio and level of Sulphur for fennel-fenugreek intercropping system.

Materials and Methods

The field experiment was carried out at Agronomy Farm of S.K.N. College of Agriculture, Jobner, Jaipur during *rabi* season of 2013-14. The experimental farm is located at a distance of approximately 45 km West of Jaipur (26^0,05' North latitute, 75^0,28' East longitude and at an altitude of 427 metres above mean sea level). The soil was loamy sand in texture, alkaline in reaction (pH 8.2), poor in organic carbon (0.16%) with low available nitrogen (134.1 kg N/ha) and Sulphur (8.34 ppm SO_4^{-2}/ha) and medium in phosphorus (17.1 kg P_2O_5/ha) and potassium content (170.1 kg K_2O/ha). The experiment was laid out in complete randomized block design consisting of a combination of three intercropping systems *viz.*, sole fenugreek, fennel + fenugreek (1:1), and fennel + fenugreek (1:2) row proportions and four Sulphur levels (0, 20, 40 and 60 kg S/ha) through gypsum with three replications. The crop variety RMt-305 sown on November 18, 2013 using 25 kg/ha seed in plots of 4.5 x 4 m size and harvested on April 15, 2014. The sowing of fenugreek was done at 30 cm row to row spacing in sole crops. One row of fenugreek was added in fennel rows planted at 50 cm row spacing in 1:1 row ratio, whereas, two rows of fenugreek were added in fennel rows planted at 100 cm row spacing in 1:2 row ratio. A uniform basal dose of 40 kg N + 45 kg P_2O_5/ha through urea and DAP was drilled prior to sowing and Sulphur through gypsum ($CaSO_4.2H_2O$) was incorporated in the soil before sowing as per treatments. Five plants were selected randomly from net plot and tagged for recording growth and yield attribute observations. Height of each tagged plant was measured periodically at 40, 80 DAS and at harvest from base of the plant to the tip of the main shoot by metre scale and average of five plant was computed as mean plant height. Dry matter production was recorded at 40, 80 DAS and at harvest. For this, plants from one metre row length were uprooted randomly from sample rows of each plot. After removal of root portion, the samples were first air dried for some days and finally dried in an electric oven at 70 ^{0}C till constant weight. The weight was recorded and expressed as average dry matter per meter row length. The pods of five tagged plants at harvest were counted and their average was workout to record pods per plant. At the time of threshing, ten pods were randomly selected from five tagged plants in each plot and their total seeds were counted to record the average number of seeds per pod. At maturity, the net plots were harvested, sun-dried and total biological yield was recorded. After threshing, cleaning and drying, the seed yield was recorded. Straw yield was obtained by subtracting seed yield from the total biological yield. Harvest index was calculated by dividing the seed yield with biological yield (Singh and Stoskopf, 1971) [13]. The yield of fenugreek was further used for computation of land equivalent ratio (LER) as suggested by Willey (1979) [17]. Data were statically analyzed by the procedure as described by Panse and Sukhatme (1978).

Results and Discussion

Intercropping

Results showed that all the growth and yield attributing parameters of fenugreek were influenced significantly by different intercropping systems (Table 1). The planting of fenugreek in 1:1 row ratio recorded significantly highest plant height at 40 DAS by 7.84 & 10.00% and at 80 DAS by 8.09 & 14.98% as compared to 1:2 row ratio and sole fenugreek, respectively. Whereas at harvest, intercropping in 1:1 row ratio, being at par with 1:2 row ratio, produced significantly higher plant height which was 13.99% over sole fenugreek. This increase in plant height might be primarily due to increased competition between plants for sunlight and nutrients in 1:1 row planting of fenugreek and secondly due to shading effect of fennel on fenugreek which compelled the fenugreek plants to grow more vertically rather than horizontally for light and ultimately increased the plant height. Similar result has also been reported by Ahlawat *et al.* (2005) [1]. The main crop (fennel) had significant effect on growth parameters (dry matter accumulation) and yield attributes (pods/plant and seeds/pod) of fenugreek. The intercropping in 1:1 row ratio significantly reduced the dry matter production by 13.44 and 16.87% at 40 DAS, 21.17 and 20.00% at 80 DAS and 24.27 and 21.87% at harvest, pods/plant by 25.00 and 22.00% and seeds/pod by 18.52 and 18.00% as compared to 1:2 row ratio and sole planting of fenugreek, respectively. However, the fenugreek planting in 1:2 row ratio remained at par with sole fenugreek for producing growth and yield attributing characters of fenugreek. The reduction in the growth and yield parameters under planting in 1:1 row ratio (additive series) might be due to competition between the component crops for nutrients, light and water which might have adversely affected the growth of fenugreek as compared to intercropping of fenugreek in 1:2 row ratios and sole fenugreek. It might be due to less space available in 1:1 row ratio, whereas, proper space was available in sole crop and intercropping in 1:2 row ratios (replacement series) which resulted into extensive root development and better utilization of nutrients and sunlight as evidenced by increase in growth and yield attributes of sole fenugreek during the experiment. Similar results of increasing growth parameters and yield attributes under sole crops were also reported by Kumar *et al.* (2013) [7] and Wasaya *et al.* (2013) [16].

Further examination of experimental data revealed that intercropping of fennel with fenugreek in 1:1 row ratio significantly reduced fenugreek yield where it recorded lowest seed (7.18 q/ha), straw (17.68 q/ha) and biological yields (24.86 q/ha) as compared to 1:2 row ratio (9.13, 21.53 and 30.65 q/ha) and sole fenugreek (14.97, 35.67, 50.64 q/ha) (Table 2). The decrease in seed, straw and biological yields of fenugreek in 1:1 row ratio was 21.35, 17.88 and 18.89% over its planting in 1:2 row ratio and 52.03, 50.43 and 50.90% as

compared to sole fenugreek, respectively. The intercropping in 1:2 row ratios also decreased seed, straw and biological yields significantly by 39.01, 39.64 and 39.47% over sole fenugreek. Reduction in yield of intercrop (fenugreek) in intercropping systems might also be due to significant reduction in yield attributes (pods/plant and seeds/pod) as a consequence of poor growth and development in these intercropping systems. The seed, straw and biological yields being the function of growth and yield attributes, reduced with the reduction in these parameters under influence of intercropping. These results are in close conformity with those of Kumar *et al.* (2013) [7] who reported significant reduction in yield attributes and yield of chickpea when intercropped with mustard. Awasthi *et al.* (2011) [3] also reported reduction in seed yield of chickpea in intercropping with fennel as compared to their sole stands.

Intercropping systems brought about significant differences in the land equivalent ratio (Table 2). The highest LER (1.45) were also found under 1:1 row ratio over sole crops and was comparable with 1:2 row ratio. The 1:1 row ratio recorded 16.93 and 45% more land equivalent ratio over 1:2 row ratio and sole cropping of fenugreek. Mehta *et al*. (2010) [9], while studying the coriander based intercropping system at Ajmer, also reported that the higher LER were obtained under 1:1 row ratio than pure stands and other intercropping systems. The highest LER under intercropping might be due to biological efficiency of system in terms of yield per unit area. Similar results were also reported by Awasthi *et al.* (2011) [3].

Sulphur

Application of Sulphur significantly increased all growth parameters in fenugreek *viz*. plant height and dry matter production upto 40 kg S/ha (Table 1). Application of 40 kg S/ha increased the plant height at 40, 80 and harvest by 23.42, 23.47 and 29.49% and dry matter production by 21.50, 23.51 and 26.68% over control, respectively. The improvement in crop growth with the application of Sulphur could be ascribed to its pivotal role in regulating the physiological and metabolic system in plant. Singh and Meena (2004) [12] opined that overall improvement in growth characters of plant owing to Sulphur application may be due to Sulphur enhanced cell multiplication, elongation and expansion resulting in greater amounts of dry matter in comparison to Sulphur deficient plant. Jat *et al*. (2012) [5] and Jat *et al*. (2013) [6] also noted similar findings of increased plant growth and development with Sulphur application.

It is explicit from the result that application of Sulphur upto 40 kg S/ha significantly improved yield attributed and yield of fenugreek (Table 1 & 2). The increase in pods/plant and seeds/pod caused by 40 kg S/ha were 31.14 & 22.07% over control and 9.58 & 7.12% over 20 kg S/ha, respectively. Application of 60 kg S/ha, being par with 20 and 40 kg S/ha, recorded significantly higher test weight of fenugreek which was superior over control by 6.22%. It is obvious fact that application of Sulphur improved overall nutritional environment of the rhizosphere as well as in the plant system which in turn enhanced plant metabolism and photosynthetic activity resulting into better growth and development of plants and ultimately the yield attributes. Similar results were also reported by Kumawat *et al*. (2011) [8] and Bochalia *et al*. (2011) [4]. Crop productivity estimates *viz*. seed, straw and biological yield increased significantly with increasing rate of Sulphur upto 40 kg/ha. The extent of increase in seed (11.32 q/ha), straw (26.73 q/ha) and biological yields (38.05 q/ha) with 40 kg S/ha was 31.78, 24.44, 26.53% over control and 9.79, 8.30 and 8.37% over 20 kg S/ha, respectively. Thus cumulative influence of Sulphur application seems to have maintained balance between source and sink through improving both the events of crop development (vegetative and reproductive), which ultimately resulted in increased seed yield. Singh and Singh (2005) [1, 14] reported that increase in seed yield was mainly due to enhanced rate of photosynthesis and carbohydrate metabolism as influenced by Sulphur application.

Significantly more land equivalent ratio (1.20) was also obtained with application of Sulphur at 40 kg/ha over control (Table 2). This indicates that Sulphur application resulted in improving system productivity per unit area. These results also corroborate the findings of prajapat *et al*. (2011) [11].

Table 1: Effect of intercropping systems and Sulphur on growth and yield attributes of fenugreek

Treatment	Plant height (cm)			Dry matter /m row length (g)			Pods/plant	Seeds/pod	Test weight (g)
	40 DAS	80 DAS	At harvest	40 DAS	80 DAS	At harvest			
Intercropping system									
Fenugreek sole	11.99	35.76	54.82	7.05	50.90	127.90	37.00	14.00	13.17
Fennel + fenugreek (1:1)	13.19	41.12	62.49	5.86	40.72	99.92	28.86	11.48	12.56
Fennel + fenugreek (1:2)	12.23	38.04	59.20	6.77	51.91	131.95	38.48	14.09	12.84
SEm ±	0.22	0.70	1.30	0.11	0.90	2.52	0.82	0.23	0.21
CD (P=0.05)	0.65	2.08	3.81	0.35	2.64	7.41	2.43	0.69	NS
Sulphur (kg S/ha)									
0	10.76	33.01	48.96	5.72	41.21	101.34	28.67	11.46	12.37
20	12.30	37.91	58.08	6.50	47.34	118.42	34.31	13.06	12.84
40	13.28	40.76	63.40	6.95	50.90	128.38	37.60	13.99	13.07

60	13.53	41.57	64.92	7.08	51.92	131.55	38.54	14.25	13.14
SEm ±	0.25	0.81	1.50	0.13	1.03	2.91	0.95	0.27	0.25
CD (P=0.05)	0.75	2.40	4.42	0.40	3.05	8.55	2.80	0.79	0.74

Table 2: Yields and land equivalent ratio (LER) of fenugreek as influenced by different intercropping systems and Sulphur levels

Treatment	Yield (q/ha)			Harvest index (%)	LER
	Seed	Straw	Biological		
Intercropping system					
Fenugreek sole	14.97	35.67	50.64	29.54	1.00
Fennel + fenugreek (1:1)	7.18	17.68	24.86	28.76	1.45
Fennel + fenugreek (1:2)	9.13	21.53	30.65	29.72	1.24
SEm ±	0.24	0.56	0.81	0.69	0.02
CD (P=0.05)	0.71	1.62	2.40	NS	0.07
Sulphur (kg S/ha)					
0	8.59	21.48	30.07	28.43	1.12
20	10.31	24.68	34.99	29.39	1.17
40	11.32	26.73	38.05	29.70	1.20
60	11.49	26.94	38.43	29.83	1.20
SEm ±	0.27	0.65	0.94	0.80	0.02
CD (P=0.05)	0.82	1.91	2.77	NS	0.07

Conclusion

Based on the study of present experiment**,** the results inferred that intercropping of fennel with fenugreek in 1:1 row ratio (addition) along with sulphur application at 40 kg/ha could be recommended for realizing higher growth and system productivity.

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