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Quality and soil fertility as infuenced by different row spacing and intercropping systems in *Rabi* fennel (*Foeniculum vulgare* Mill.)

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ABSTRACT : A field experiment was conducted on loamy sand soil of Agronomy Instructional Farm, Department of Agronomy, Chimanbhai Patel College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar during the *Rabi* seasons of 2012-13 and 2013-14 to study *Rabi* fennel (*Foeniculum vulgare* Mill.) based intercropping systems under different row spacing. The soil of the experimental plot was low in organic carbon and available nitrogen, medium in available phosphorus and potash. The experiment was laid out in split plot design with three replications. Twenty four treatment combinations comprised of four row spacing *viz.*, S_1 : (45 cm), S_2 : (60 cm), S_3 : (75 cm) and S_4 : (90 cm) and six intercropping systems treatment *viz.*, IC_1 : Fennel sole, IC_2 : Fennel + carrot (1:1), IC_3 : Fennel + cabbage (1:1), IC_4 : Fennel + cauliflower (1:1), IC_5 : Fennel + radish (1:1) and IC_6 : Fennel + vegetable fenugreek (1:1) were evaluated. The highest seed and straw yields were recorded when the crop was sown at 60 cm row spacing while the lowest seed yield was obtained with the narrow row spacing *i.e.*, 45 cm and straw yield was found with wider row spacing *i.e.*, 90 cm. However, volatile oil and protein yields differed significantly. Significantly higher volatile oil and protein yields were recorded under 60 cm row spacing. Seed and straw yields were recorded significantly the highest with fennel sole as compared to intercropping systems. However, volatile oil and protein yields were recorded significantly the highest with sole fennel. Available nitrogen and phosphorus secured significantly higher values with fennel + vegetable fenugreek (1:1).

KEY **W**ORDS : Row spacing, Intercropping systems, Fennel

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Fennel (*Foeniculum vulgare* Mill.) commonly known as variyali or saunf is native of Mediterranean countries and belonging to the family of Apiaceae. It is cold weather loving crop and comes up well under dry and mild climate. It is mainly grown as transplanted and drill crop during *Kharif* and *Rabi* season, respectively. Area under *Rabi* drilled fennel is increasing due to ever increasing demand of fennel

seed at national and international market and being a more profitable crop as compared to other *Rabi* crops like cumin, mustard, wheat, gram etc.

Fennel seeds have a faragrant odour and a pleasant aromatic taste. They are widely used in various food preparation, candies soups, sauces, pastries, pickles, liquors, bakery items etc. The leaves and seeds are digestive, appetizing, stimulant and carminative used for cough, flatulence, colic, thirst, constipation, dysentery and diarrhoea (Randhawa *et al*., 1978). Fennel seeds contain 1.4 to 4.0 per cent essential volatile oil, pale yellow in colour. The main constituents of fennel oil are anethole and fenchone. The residue left after the distillation of essential oil from the seed is used as feed for cattle as it contains about 20 per cent crude fibre (Lal and Sen, 1972 and Nichita *et al*., 1981). Volatile oil of fennel possesses pharmacological properties such as nematicidal, antimicrobial and detoxifying enzyme inducing activities.

Spacing and plant population per unit area plays an important role for growth and development of the crop. Optimum plant spacing is one of the important factors in increasing the yield per hectare of fennel crop. The main principles involved in selecting intercrops are that they should not be competitive with the main crop for soil moisture, nutrients and sunlight. Very little work has been done in selection of suitable crops like carrot, cabbage, cauliflower, radish and fenugreek for intercropping in fennel. Shortages of vegetables in the country have focused the attention on intercropping systems which have capacity to improve the physical, biological and chemical properties of soil.

RESEARCH PROCEDURE

A field experiment was conducted at Agronomy Instructional Farm, Chimanbhai Patel College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar (Gujarat) during *Rabi* seasons of 2012-13 and 2013-14.

The experiment was laid out in split plot design with three replications. In all, twenty four treatment combinations comprised of four row spacing *viz*., S_1: (45 cm), S_2 : (60 cm), S_3 : (75 cm) and S_4 : (90 cm) and six intercropping systems treatment *viz*., IC_1 : Fennel sole, IC_2 : Fennel + carrot (1:1), IC_3 : Fennel + cabbage (1:1), IC_4 : Fennel + cauliflower (1:1), IC_5 : Fennel + radish (1:1) and IC_6 : Fennel + vegetable fenugreek (1:1) were evaluated in present study.

The result of soil analysis indicated that the soil of the experimental plot was loamy sand in texture, low in organic carbon and available nitrogen, medium in available phosphorus and medium in available potash. Electrical conductivity was very low showing that the soil was free from salinity hazard.

Protein content (%) :

Seed samples were digested in micro - Kjeldhal's for nitrogen estimation. Protein content of the seeds was estimated by multiplying the nitrogen values by 6.25.

Volatile oil content (%) :

Volatile oil content of the seed was estimated as per steam distillation method (AOAC, 1970).

Protein yield (kg/ha) :

Protein yield was calculated by using the following formula.

$$\text{Protein yield (kg/ha)} = \frac{\text{Protein content in seed (\%) x Seed yield (kg / ha)}}{100}$$

Volatile oil yield (kg/ha) :

Volatile oil yield was calculated by using the following formula.

$$\text{Volatile oil yield (kg/ha)} = \frac{\text{Volatile oil content in seed (\%) x Seed yield (kg/ha)}}{100}$$

NPK status of soil initial and after harvest of crop :

Prior to sowing, composite soil sample was taken and analyzed for the nutrient status. After harvest of the crop the soil samples were taken from each plot and

Table A : Chemical properties of the experimental soil

Chemical properties		Soil depth (cm)		Methods employed
		0-15	15-30	
1.	Available N (kg/ha)	159	148	Alkaline permanganate method (Jackson, 1973)
2.	Available P_2O_5 (kg/ha)	39	36	Olsen's method (Olsen *et al.*, 1954)
3.	Available K_2O (kg/ha)	275	271	Flame photometer method (Jackson, 1973)

analyzed for N, P and K status as per the prescribed procedure given in Table A.

RESEARCH ANALYSIS AND REASONING

The findings of the present study as well as relevant discussion have been presented under following heads :

Effect of row spacing on fennel :

Seed yield of *Rabi* fennel was significantly influenced by different row spacing (Table 1). Row spacing treatment S_2 : (60 cm) produced significantly higher seed yield of *Rabi* fennel (2154 kg/ha). Increased seed yield of *Rabi* fennel by row spacing treatment S_2 : (60 cm) was higher by 5.2, 32.1 and 37.7 per cent over S_3 : (75 cm), S_4 : (90 cm) and S_1 : (45 cm), respectively on pooled basis. The increased seed yield with 60 cm row spacing might be due to higher values of growth and yield attributes. These are the important growth and yield components, which showed significant and positive correlation with seed yield. The lower values of growth and yield components under narrow spacing have evidently resulted in lesser seed yield. The main reason was dense plant population, which accelerate the competition within crop plant for space, light, nutrients and moisture. Thus, sowing of crop at 60 cm row spacing apart emerged to be the best spacing for obtaining higher seed yield. These findings are in conformity with those of Randhawa and Gill (1985); Ammen *et al*. (1988); Patel (2000); Yadav *et al*. (2000); Singh *et al*. (2001); Yadav *et al*. (2002); Amin *et al*. (2005); Mehta *et al*. (2011); Dewangan *et al*. (2012); Bhardwaj *et al*. (2013) and Mehta *et al*. (2013).

Protein content per cent was not differed remarkably due to different row spacing. Protein yield of *Rabi* fennel was significantly influenced by different row spacing (Table 1). Row spacing treatment S_2 : (60 cm) produced significantly higher protein yield of *Rabi* fennel (336.7 kg/ha). The increased protein yield of *Rabi* fennel by row spacing S_2 : (60 cm) was higher by 4.7, 31.2 and 38.2 per cent over S_3 : (75 cm), S_4 : (90 cm) and S_1 : (45 cm), respectively on pooled basis. This is due to higher fennel seed yield obtained with 60 cm row spacing.

Volatile oil content per cent was not significantly influenced due to different row spacing. Volatile oil yield of *Rabi* fennel was significantly influenced by different

Table 1 : Effect of row spacing and intercropping systems on seed yield, quality and soil nutrient status after harvest of *Rabi* fennel (pooled of 2012-13 to 2013-14)

Treatments	Seed yield (kg/ha)	Protein content (%)	Volatile oil content (%)	Protein yield (kg/ha)	Volatile oil yield (kg/ha)	Available N (kg/ha)	Available P_2O_5 (kg/ha)	Available K_2O (kg/ha)
Row spacing								
S_1 : (45 cm row spacing)	1564	15.56	1.82	243.6	28.6	172.7	41.2	282.0
S_2 : (60 cm row spacing)	2154	15.63	1.85	336.7	39.9	174.3	41.4	283.8
S_3 : (75 cm row spacing)	2048	15.68	1.87	321.5	38.4	176.2	41.8	286.2
S_4 : (90 cm row spacing)	1631	15.72	1.89	256.6	30.9	177.5	42.4	287.8
S.E. $\pm$	38	0.11	0.02	6.80	0.80	1.63	0.31	2.48
C. D. (P=0.05)	116	NS	NS	20.96	2.46	NS	NS	NS
Intercropping systems								
IC_1 : Fennel sole	2287	15.75	1.89	360.2	43.1	173.2	41.7	284.9
IC_2 : Fennel + carrot (1:1)	1493	15.55	1.83	232.1	27.4	171.5	40.9	283.1
IC_3 : Fennel + cabbage (1:1)	1819	15.67	1.87	285.2	34.1	177.2	42.1	285.1
IC_4 : Fennel + cauliflower (1:1)	1685	15.63	1.84	263.4	31.1	179.2	42.0	286.2
IC_5 : Fennel + radish (1:1)	1635	15.52	1.81	253.5	29.6	169.6	40.8	282.9
IC_6 : Fennel + vegetable fenugreek (1:1)	2177	15.77	1.90	343.4	41.4	180.4	42.7	287.7
S.E. $\pm$	35	0.10	0.02	5.72	0.70	1.14	0.25	1.82
C. D. (P=0.05)	99	NS	NS	16.11	1.97	3.21	0.70	NS
Interaction								
S x IC	NS	NS	NS	NS	NS	NS	NS	NS

NS= Non-significant

row spacing (Table 1). Row spacing treatment S_2 : (60 cm) produced significantly higher volatile oil yield of *Rabi* fennel (39.9 kg/ha). The increased volatile oil yield of *Rabi* fennel by row spacing S_2 : (60 cm) was higher by 3.9, 29.1 and 39.5 per cent over S_3 : (75 cm), S_4 : (90 cm) and S_1 : (45 cm), respectively on pooled basis. These findings are in close conformity with those of Falzari *et al*. (2005) and Selim *et al.* (2013).

Effect of intercropping systems on fennel :

Seed yield of *Rabi* fennel was significantly influenced by different intercropping systems (Table 1). Intercropping treatment of (IC_1) : fennel sole produced significantly higher seed yield of *Rabi* fennel (2287 kg/ha). The increased seed yield of *Rabi* fennel by intercropping systems IC_1 : fennel sole was higher by 5.1, 25.7, 35.7, 39.9 and 53.2 per cent over IC_6 : fennel + vegetable fenugreek (1:1), IC_3 : fennel + cabbage (1:1), IC_4 : fennel + cauliflower (1:1), IC_5 : fennel + radish (1:1) and IC_2 : fennel + carrot (1:1), respectively, on pooled basis. The higher yield attributes and yield of sole fennel might be due to lesser competition for space, sunlight, water and nutrients between fennel and component crops which gave higher growth parameters resulting in higher translocation of photosynthates from source to sink resulting in higher yield and yield attributes of fennel. These findings are in close agreement with those of Nandekar *et al*. (1995); Tiwari *et al*. (2002) and Mehta *et al*. (2010).

Protein content per cent was not differed remarkably due to different intercropping systems. Protein yield of *Rabi* fennel was significantly influenced by different intercropping systems (Table 1). Intercropping treatment of IC_1: fennel sole produced significantly higher protein yield of *Rabi* fennel (360.2 kg/ha). The increased protein yield of *Rabi* fennel by intercropping systems treatment of IC_1 : fennel sole was higher by 4.9, 26.3, 36.8, 42.1 and 55.2 per cent over IC_6 : fennel + vegetable fenugreek (1:1), IC_3 : fennel + cabbage (1:1), IC_4 : fennel + cauliflower (1:1), IC_5 : fennel + radish (1:1) and IC_2 : fennel + carrot (1:1), respectively, on pooled basis. The higher protein yield with fennel sole might be due to higher yield produced in this treatment.

Volatile oil content per cent was not differed remarkably due to different intercropping systems. Volatile oil yield of *Rabi* fennel was significantly influenced by different intercropping systems (Table 1). Intercropping treatment IC_1 : fennel sole produced significantly higher volatile oil yield of *Rabi* fennel 43.1 kg/ha. The increased volatile oil yield of *Rabi* fennel by intercropping systems treatment of IC_1 : fennel sole was higher by 4.1, 26.4, 38.6, 45.6 and 57.3 per cent over IC_6 : fennel + vegetable fenugreek (1:1), IC_3 : fennel + cabbage (1:1), IC_4 : fennel + cauliflower (1:1), IC_5 : fennel + radish (1:1) and IC_2 : fennel + carrot (1:1), respectively, on pooled basis. The higher volatile oil yield with fennel sole might be due to higher yield produced in this treatment.

Soil status after harvest of crops :

Effect of row spacing :

The data on available nitrogen, available phosphorus and available potassium were found to be non - significant in different row spacing, on pooled basis (Table 1).

Effect of intercropping systems :

From the data (Table 1), it seems that available nitrogen and phosphorus in soil were observed significantly affected due to intercropping systems on pooled basis and potassium was found non - significant. Significantly higher available nitrogen content was found with IC_6 : fennel + vegetable fenugreek (1:1) which was 180.4 kg/ha on pooled basis, than rest of intercropping systems and fennel sole. Significantly higher available phosphorus content was found with IC_6 : fennel + vegetable fenugreek (1:1) which was 42.7 kg/ha on pooled basis, than rest of intercropping systems and fennel sole. This might be attributed to the supplementation of nitrogen synthesized in the root zone of fenugreek by the process of symbiotic nitrogen fixation and added soil organic matter in fennel + fenugreek. Thereby, resulted in the additive enrichment and enhanced soil fertility.

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