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Effect of irrigation and crop geometry on growth, yield, quality and profitability of transplanted fennel (*Foeniculum vulgare* Mill.)

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Abstract

Field experiments were conducted in two adjoining farmer's field in a tribal area of district Sirohi (Rajasthan) during two successive seasons from July to March, 2011 and 2012 to study the impact of varied crop geometry and irrigation methods on production, quality and profitability of fennel. The trench method of irrigation exhibited significantly higher plant height, number of branches, number of roots plant^{-1}, root length, fresh weight of shoot and roots plant^{-1}, maximum number of umbels plant^{-1}, umbellate umbel^{-1}, number of seed umbel^{-1}, highest seed yield (26.52 q ha^{-1}) with maximum gross return (Rs. 305,714.15), net return (Rs. 266,314.15) and benefit:cost ratio (6.75). Comparatively less time (26.25 h) was required for one hectare irrigation in the same treatment in both the years. The crop planted in paired row (210 cm/120 cm × 25 cm) significantly influenced crop growth, yield and profitability of fennel. In this treatment, highest plant height, number of branches plant^{-1}, number of roots plant^{-1}, root length, fresh weight of shoot and root, maximum number of umbel plant^{-1}, umbellate umbel^{-1}, number of seed umbel^{-1}, highest seed yield (28.55 q ha^{-1}) with maximum gross return (Rs. 336,940.80), net return (Rs. 294,670.80) and benefit: cost ratio (6.97) was observed in both the years. Lower growth, yield and profitability were found in border strip method of irrigation and single row (90 cm × 45 cm) method of planting.

Keywords: crop geometry, irrigation, pair row planting, umbel, umbellate

Introduction

Fennel (*Foeniculum vulgare* Mill.) which belongs to the family *Apiacae* is one of the widely cultivated seed spices in temperate and sub tropical regions of the world. It is a biennial herb mainly grown in the *rabi* season by direct sowing but in some parts of south west Rajasthan like Sirohi it is also grown in *kharif* by transplanting. The total area under fennel cultivation in Rajasthan is 7500 ha and production is 6249 tonnes out of which 60.37% area (4528 ha) and 69.59% production (4349

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tonnes) is in district Sirohi (Anonymous 2009). Because fennel transplanting is recently introduced, there is an urgent need to find out suitable agro-techniques for higher production and income. Optimum crop geometry is one of the important factors for higher production. Proper crop geometry significantly increased yield, quality of seed, profitability and productivity of dill (Mehta *et al.* 2012). Appropriate irrigation method not only increases the productivity and quality of seeds but also helps in uniform growth and development of plant and reduces weed and disease infestation. Very less work has been done with regards to irrigation methods and crop geometry for production of transplanted fennel. Keeping in view the above facts, an experiment was conducted to find out the suitable irrigation method and optimum crop geometry for maximizing economic returns in transplanted fennel.

Materials and methods

The field experiments were conducted on two adjoining sites at Kacholi village in district Sirohi (Rajasthan) during two consecutive *kharif* seasons of year 2011 and 2012. The soil texture of experimental plot was sandy loam with pH 7.5, having organic carbon 0.55% and 0.52%, available P 27.5 and 22.5 kg ha^{-1} and K 375.0 and 372.0 kg ha^{-1} during both years of experimentation, respectively. Both the experiments were conducted in completely randomized design. The first experiment comprised of four types of irrigation methods (I_1-border strip method, I_2-check basin method, I_3-trench method and I_4-drip method) and the second experiment comprised of four types of crop geometry (R_1- 90 cm × 45 cm, R_2-120 cm × 35 cm, R_3-150 cm × 30 cm and R_4-paired row planting with 210 cm/120 cm × 25 cm spacing) with five replications (Fig. 1 & 2). In a well prepared field, 40-45 days old seedlings of fennel local cultivar '*Abu saunf*' were transplanted at 90 cm × 45 cm (24,691 plants ha^{-1}), 120 cm × 35 cm (23,809 plants ha^{-1}), 150 cm × 30 cm (22,222 plants ha^{-1}) and pair row planting at 210 cm/ 120 cm × 25 cm (24,271 plants ha^{-1}) during first week of August. Light irrigation was applied immediately after transplanting. In another experiment the transplanted crop was irrigated by border strip, check basin, trench and drip methods of irrigation. Randomly selected five plants were used for observations on plant growth, yield attributes and yield from each plot. Plant height (at 90 DAT and at harvesting) was measured from soil surface to the highest shoot tip by straightening all branches. Stem girth was measured from one cm above the base of the stem using vernier calliper. Observations on number of branches, number of nodes on main shoots at harvest, first flower initiation, last flower initiation, number of umbel $plant^{-1}$, number of umbellate $umbel^{-1}$, number of seeds $umbel^{-1}$ were recorded by standard counting method. Number of roots and root length was measured by destructive sampling. Stem and root were weighed to record the fresh weight. Test weight was measured by weighing 1000 seeds and expressed in gram. The total yield was calculated by weighing total seed produced and is presented on hectare basis. Market rate of fennel seeds was taken from local and Unjha mandi (Gujarat) at the time of experimentation in both the years. Further, the net return was calculated by subtracting cost of each treatment from gross return. The gross return was calculated from yield multiplied by average market rate during the period of investigation. The benefit cost ratio was calculated by dividing net return to total cost. Disease incidence and quality of seed was measured by visual inspection. The time required for irrigation was calculated as per actual time required for irrigation of specified area by different methods of irrigation. Also, horizontal expansion of technology was observed by technical survey of cropping area of district with the help of village level workers. The significance of variance in the pooled data was done by the standard procedure described by Panse & Sukhatme (1985). Significance of difference among the treatments effect was tested by 'F' test and critical difference (CD) was calculated.

Results and discussion

Effect of irrigation methods

Irrigation methods significantly influenced growth attributes at all the stages (Table 1 & Fig. 1). The crop irrigated by trench method

Table 1. Effect of irrigation methods on growth, yield and yield attributes of fennel

Parameters	Irrigation methods (pooled)				S.Em ±	CD (P<0.05)
	Border strip (I_1)	Check basin method (I_2)	Trench method (I_3)	Drip method (I_4)		
Plant height at 90 DAT (cm)	56.19	59.66	68.46	65.21	0.907	3.561
Plant height at harvest (cm)	120.65	132.91	180.4	150.91	2.390	9.381
Number of primary branches plant^{-1}	7.38	8.33	12.51	9.91	0.134	0.528
Number of secondary branches plant^{-1}	13.89	15.97	28.93	23.26	0.590	2.317
Number of nodes on main shoot at harvest	6.62	8.33	13.28	11.53	0.271	1.067
Stem girth (mm)	8.06	8.79	11.50	9.81	0.193	0.760
Number of roots plant^{-1}	15.50	16.16	24.06	19.79	0.272	1.068
Root length (cm)	22.30	25.29	32.51	20.13	0.530	2.081
Fresh weight of shoot (g)	616.47	630.07	835.14	749.96	7.361	5.199
Fresh weight of root (g)	129.49	129.12	156.32	141.03	1.559	6.120
Root/shoot ratio	0.205	0.205	0.187	0.188	0.002	0.011
First flower initiation (DAT)	90.43	88.49	80.04	85.40	1.368	5.370
Last flower initiation (DAT)	181.95	186.77	217.14	203.07	2.011	7.897
Number of umbels plant^{-1}	14.34	15.22	21.52	18.18	0.343	1.348
Number of umbellate umbel^{-1}	12.64	14.21	22.39	18.10	0.343	1.348
Number of seeds umbel^{-1}	375.48	382.20	460.31	402.22	4.214	16.544
Test weight (g)	9.91	9.94	10.84	10.34	0.343	NS
Seed yield (q ha^{-1})	13.17	14.27	26.52	18.67	0.459	1.804
Disease incidence*	3.85	3.70	1.50	2.25	0.019	0.077
Quality of seed**	3.26	3.45	4.20	3.76	0.051	0.203
Gross return (Rs. ha^{-1})	116255.80	133706.10	305714.15	189999.12	1073.46	4213.64
Net return (Rs. ha^{-1})	85755.80	101406.10	266314.15	158099.12	1073.46	4213.64
Benefit: Cost ratio	2.81	3.13	6.75	4.95	0.027	0.107
Average time required for irrigation ha^{-1} (hour) ***	46.25	40.50	26.25	18.50	2.059	8.082
	(0.00%)	(12.43%)	(43.25%)	(60.0%)	-	-
Horizontal expansion of technology (%)	-30	-10	35	5	-	-

*On basis of visual symptoms of disease (1=no symptoms; 2=slight infestation; 3=normal infestation; 4=high infestation; 5=severe infestation); ** Marking on the basis of quality of seed (1=very poor quality; 2=poor quality; 3=average quality; 4=good quality; 5=excellent quality); *** Per cent saving of water in irrigation as per time required for irrigation ha^{-11}

(I_3) resulted in higher plant height of 68.46 cm (90 DAT), 180.40 cm (at harvesting), number of primary branches plant^{-1} (12.51), secondary branches plant^{-1} (28.93), number of nodes on main shoot (13.25), stem girth (11.50 mm), maximum number of roots plant^{-1} (24.06), highest root length (32.51 cm), fresh weight of shoot (835.14 g), fresh weight of root (156.32 g), least root/shoot ratio (0.187), minimum days required for first flower initiation (80.04 DAT) and maximum extended flowering duration (137.10 days). Maximum number of umbels

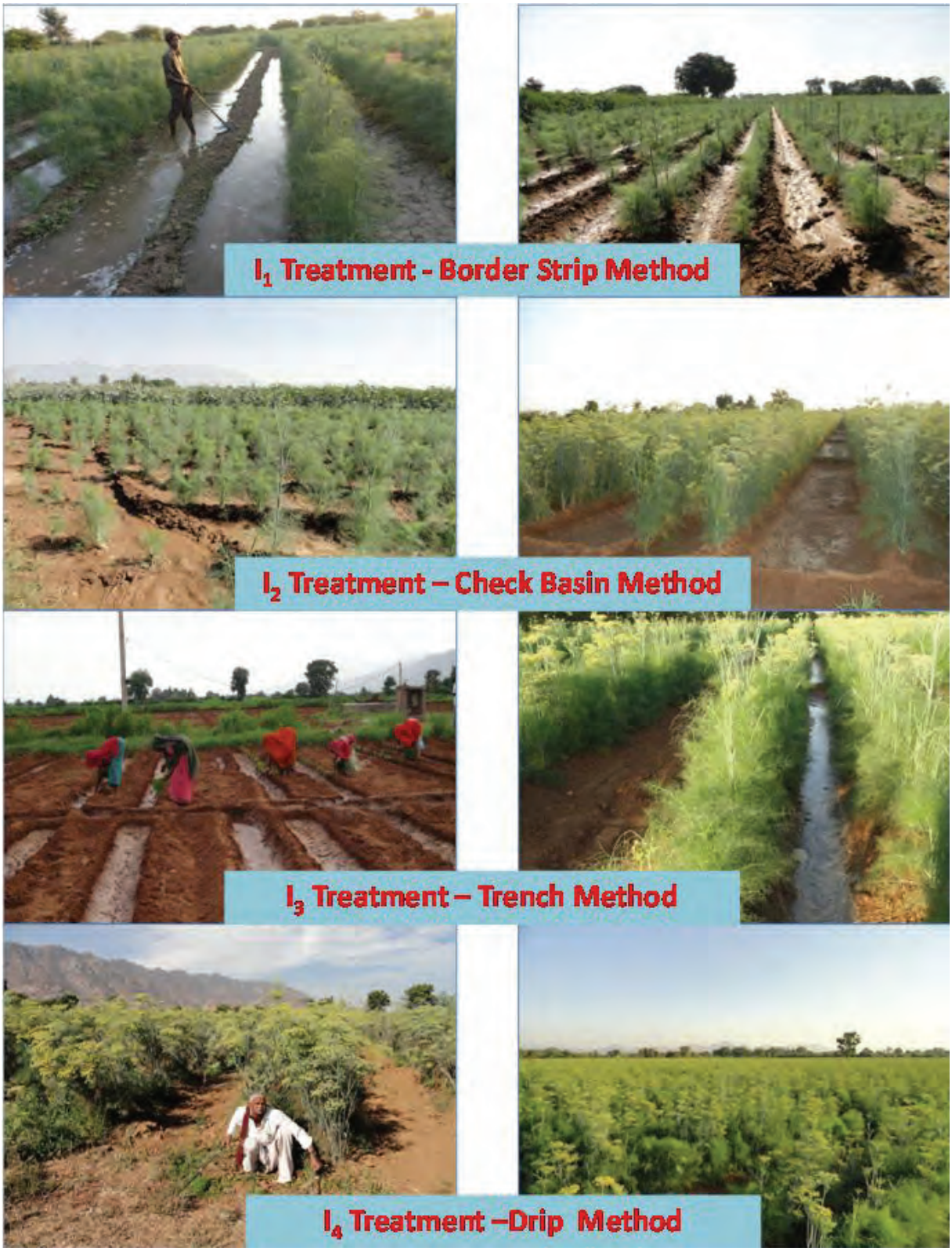

Fig. 1. Different method of irrigation in fennel

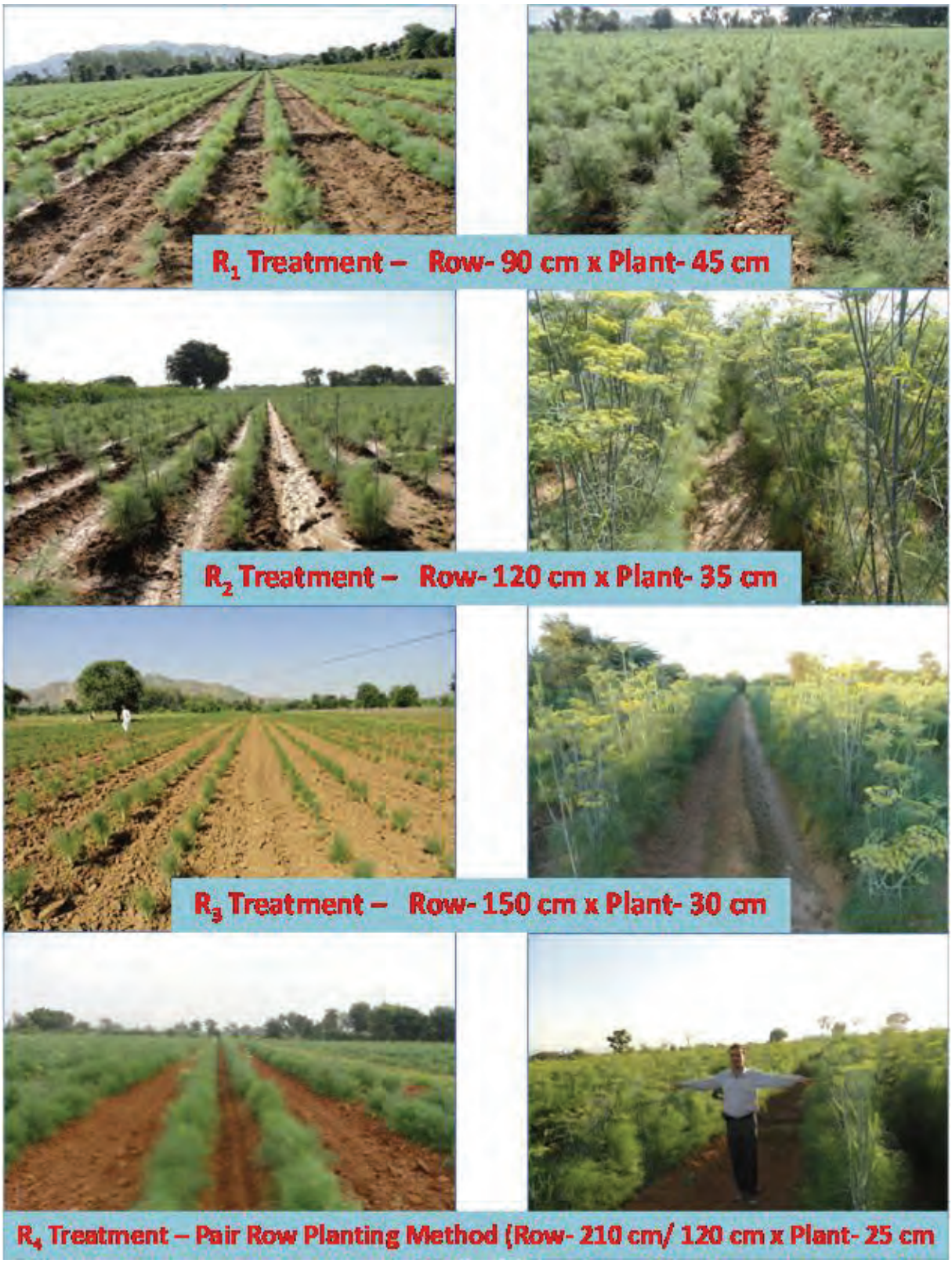

Fig. 2. Different crop geometry of fennel

plant^{-1} (21.52), number of umbellates umbel^{-1} (22.39), maximum number of seeds umbel^{-1} (460.31), highest test weight (10.84 g) and seed yield (26.52 q ha^{-1}) were produced with trench method of irrigation (Table 1). The higher available moisture status in soil favourably influenced the uptake of nutrients leading to favourable growth and development of plant. Bhardwaj *et al.* (2013) strongly supported the finding that fresh biomass and yield of fennel was increased when crop was irrigated by trench method, which may be due to better development of root system of the crop. Irrigation methods also significantly influenced the gross return, net return and benefit cost ratio in fennel (Table 1). The highest gross return (Rs. 305,714.15), net return (Rs. 266,314.15) and maximum benefit cost ratio (6.75) was also obtained in trench method. All the growth and yield attributes were least in border strip method (I_1). In trench method, the availability of water and nutrients to plant for growth and development led to higher yield attributes. Similar results were reported by Bhardwaj (2011a) and Bhardwaj *et al.* (2013) in fennel. In trench method, the crop logging was reduced at time of flowering and harvesting of umbel, disease incidence was significantly reduced (1.50), quality of seed was improved (4.20) and irrigation time was saved (26.25 hour ha^{-1}) (Table 1). This is due to the fact that in the trench method, minimum area (37.5%) was irrigated and remaining area was dry during the cropping period which significantly reduced additional moisture level in the soil which in turn reduced disease infestation as well as improved quality of produce. Similar response to irrigation methods in different crops was reported by Thavaprakaash *et al.* (2005), Bhardwaj (2011b) and Sarolia & Bhardwaj (2012). This irrigation technology has by and large resulted in an average horizontal expansion of 35% during the last two years in fennel growing areas of district Sirohi (Rajasthan).

Effect of crop geometry

Crop geometry had significant influence on growth characters of transplanted fennel during both the years (Table 2 & Fig. 1). Fennel raised by pair row (210 cm/120 cm × 25 cm) planting method produced taller plants (51.66 cm at 90 DAT and 150.91 cm at harvesting), more number of primary branches (12.62) and secondary branches (37.26), highest number of nodes on main shoot (15.53), more stem girth (14.46 mm), maximum number of roots plant^{-1} (23.39), root length (32.11 cm), more fresh weight of shoot (669.45 g), maximum fresh weight of root (182.52 g), higher root/shoot ratio (0.272), longer flowering duration (124.80 days) than other crop geometry. Wider space availability between the rows and closer intra-rows might have increased the root spread which eventually utilized the resources such as water, nutrients, space and light very effectively. Similar results were reported by Metha *et al.* (2012) in dill. Yield attributes such as number of umbels plant^{-1}, number of umbellates umbel^{-1}, number of seeds umbel^{-1} and test weight differed significantly due to altered crop geometry (Table 2). Pair row (210 cm/ 120cm × 25 cm) planting had stimulatory effect on the yield attributes of fennel.

Maximum number of umbels plant^{-1} (23.40), number of umbellates umbel^{-1} (23.70), highest number of seeds umbel^{-1} (452.26), more test weight (11.10 g) and maximum seed yield (28.55 q ha^{-1}) were recorded during both years of experimentation with crop geometry of 150 cm × 30 cm (Table 2). The enhanced yield components might be due to the fact that in pair row planting more sun light penetrates within the crop canopy leading to increased photosynthetic area (leaf and green stem), higher photosynthetic rate and accumulation of more assimilates which in turn increased the seed yield and quality of fennel. Higher yield attributes of maize under paired row planting due to better availability of resources was also observed by Jiotode *et al.* (2002). The highest gross return (Rs. 336,940.80), net return (Rs. 294,670.80) and maximum benefit cost ratio (6.97) was observed in R_4 treatment (210 cm/120 cm × 25 cm). Minimum disease incidence (2.18), highest score (4.36) of seed quality and least

Table 2. Effect of crop geometry on growth, yield and yield attributes of fennel

Parameters	Crop geometry of fennel (pooled)				S.Em ±	CD (P<0.05)
	90cm × 45cm (R_1)	120cm × 35cm (R_2)	150cm × 30cm (R_3)	210/120cm × 25cm (R_4)		
Plant height at 90 DAT (cm)	43.19	47.68	49.21	51.66	0.907	3.561
Plant height at harvest (cm)	110.43	122.55	133.45	150.91	2.389	9.381
Number of primary branches plant^{-1}	5.51	7.96	9.30	12.62	0.134	0.527
Number of secondary branches plant^{-1}	17.98	22.93	30.60	37.26	0.590	2.317
Number of nodes on main shoot at harvest	9.49	10.31	12.39	15.53	0.271	1.067
Stem girth (mm)	8.39	9.44	11.18	14.46	0.193	0.760
Number of roots plant^{-1}	13.19	15.18	18.89	23.39	0.272	1.068
Root length (cm)	22.30	24.52	26.41	32.11	0.530	2.081
Fresh weight of shoot (g)	623.94	635.75	657.83	669.45	2.751	10.798
Fresh weight of root (g)	119.95	128.94	150.06	182.52	2.632	10.331
Root/shoot ratio	0.192	0.203	0.228	0.272	0.002	0.011
First flower initiation (DAT)	85.65	89.70	90.32	93.34	1.368	5.370
Last flower initiation (DAT)	175.16	182.14	189.84	218.14	2.011	7.897
Number of umbels plant^{-1}	12.49	14.24	19.25	23.40	0.343	1.348
Number of umbellate umbel^{-1}	12.30	14.51	19.40	23.70	0.343	1.348
Number of seeds umbel^{-1}	375.10	380.95	410.31	452.26	4.214	16.544
Test weight (g)	10.10	10.24	10.79	11.10	0.343	NS
Seed yield (q ha^{-1})	11.68	13.22	18.93	28.55	0.459	1.804
Disease incidence*	3.71	3.68	2.58	2.18	0.117	0.462
Quality of seed**	3.13	3.36	3.51	4.36	0.051	0.203
Gross return (Rs. ha^{-1})	98.959.28	120281.10	179836.60	336940.80	1073.46	4213.64
Net return (Rs. ha^{-1})	66459.28	87781.10	147336.60	294670.80	1073.46	4213.64
Benefit: Cost ratio	2.04	2.70	4.53	6.97	0.027	0.107
Average time required for irrigation ha^{-1} (hour)***	46.25	40.50	32.45	26.25		
	(0.00%)	(12.43%)	(29.84%)	(43.25%)	0.632	2.482
Horizontal expansion of technology (%)	-30	-10	2	38	-	-

*On basis of visual symptoms of disease (1=no symptoms; 2=slight infestation; 3=normal infestation; 4=high infestation; 5=severe infestation); **Marking on the basis of quality of seed (1=very poor quality; 2=poor quality; 3=average quality; 4=good quality; 5=excellent quality); ***Per cent saving of water in irrigation as per time required for irrigation ha^{-1}

time (26.25 hours) required for irrigation in pair row planting method was observed in both the years of experimentation. Bhardwaj *et al.* (2013) also observed higher seed yield and minimum infestation of disease when the crop was planted in paired row (210 cm/120 cm × 25 cm) Similar results were reported by Thavaprakaash *et al.* (2005) in maize, Bhardwaj *et al.* (2011) in fennel and Metha *et al.* (2012) in dill. Better crop production with least water requirement in pair row (210 cm/120 cm × 25 cm) planting technology has become popular among the farmers. So horizontal expansion of this technology was observed to be 38% in fennel growing areas of district Sirohi. It is concluded that in transplanted fennel, trench method of irrigation and planting in paired row (210 cm/ 120 cm × 25 cm) are optimum conditions for attaining higher yield, quality seed production and profitability.

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