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RESEARCH NOTE

Growth and yield of fennel as influenced by weed control measures and nutrient management

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ABSTRACT

A field experiment was conducted, to study the effect of by weed control measures and nutrient management on growth and yield of fennel, at Instructional Farm, College of Agriculture, Bikaner during the *Rabi* season of 2021-22. There were 16 treatment combinations with four nutrient managements: control, 75% recommended dose of fertilizers (RDF), 100% RDF and 125% RDF and four weed control measures: weed free, pre-emergence application (PE) of pendimethalin 0.75 kg/ha, post-emergence application (PoE) of oxyfluorfen 50 g/ha at 25 DAS and weedy check. A factorial randomized design with three replications was used. The reduction in weed density, biomass and increase in fennel growth and yield were significantly higher with pendimethalin 0.75 kg/ha PE than with oxyfluorfen50 g/ha PoE. Weed-free recorded the highest fennel seed yield, biological yield and net returns while pendimethalin0.75 kg/ha PE recorded the highest B: C ratio. Among nutrient levels, 100% RDF recorded the highest fennel seed yield, biological yield and net returns.

Keywords: Economics, Fennel, Nutrient management, Pendimethalin, Weed management

Fennel (*Foeniculum vulgare* Mill.) a significant seed spice crop belongs to the Umbelliferae (Apiaceae) family. The genus name "Foeniculum" originates from the Latin word *foenum*, meaning "hay," which refers to the plant's feathery foliage. Botanically, fennel is a robust, aromatic annual herb. Its seeds are nutritionally valuable, containing 9.5% protein, 10% fat, 42.3% carbohydrates, 18.5% fiber, and 13.4% mineral content (Bhunia *et al.* 2005). India is the leading country in the production, consumption and export of fennel which is commonly known as "*Saunf*" and also referred by various regional names across different parts of the country (Ashok Kumar *et al.* 2017). Major producer states of India are Gujarat, Rajasthan, Karnataka, and Andhra Pradesh. Among these, Gujarat dominates the national fennel output contributing approximately 82% of the total production. Regarding its climatic preferences, fennel is a cool-season crop. Considering the importance of fennel its average productivity is very low. The major reasons for low fennel productivity is due to inadequate availability and adoption of nutrient management and agronomic practices to control heavy weed infestation.

Fennel typically exhibits slow initial growth and takes a longer time to germinate, making it highly susceptible to weed infestation during the early stages of development (Gohil *et al.* 2015). If not managed promptly, weeds can significantly hinder crop growth and may lead to yield losses as high as 91.4% (Mali and Suwalka 1987). Furthermore, weed competition can adversely impact the quality of essential oils in fennel (Abdallah *et al.* 2021). Maintaining a weed-free fennel field typically requires 3 to 4 rounds of manual weeding to attain higher fennel productivity (Parthasarathy *et al.* 2008). Mechanical and cultural methods of weed control are often less effective and more costly, especially during labor shortages or when labor costs are high (Rao 2022). In contrast, weed control using herbicides is generally more effective, economical and reliable. Herbicides have been shown to provide substantial increases in seed yield ranging from 43.2% to 86.9% and typically offer a three to fourfold return on investment compared to other weed control practices (Patel *et al.* 2017).

Efficient and balanced fertilizer application plays a crucial role in promoting proper plant growth, development and achieving higher yields (Waskela *et al.* 2017). Since, fennel is a commercial spice crop, its yield as well as quality is important and both can be achieved only by adoption of proper nutrient management and effective and economical weed management at the critical stages of crop weed competition. Thus, this study was undertaken to

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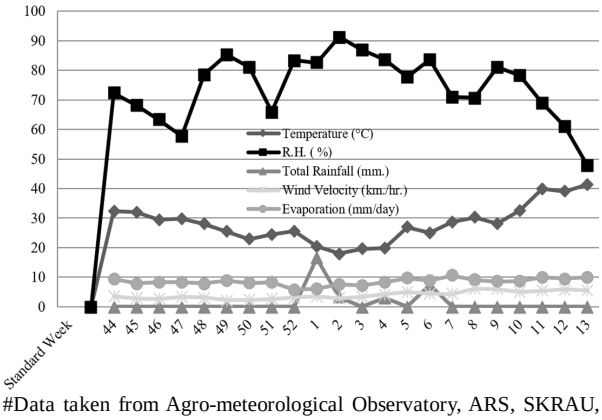
identify the most effective weed management option and optimal nutrient management practice for enhancing the productivity of fennel.

The field study was carried out during the *Rabi* season of 2021–22 at the Instructional Farm of the College of Agriculture, Swami Keshwanand Rajasthan Agricultural University, Bikaner, Rajasthan. The experimental site is located at 28.01° N latitude, 73.22° E longitude, with an elevation of 234.70 meters above mean sea level. According to the 'Agro-ecological Region Map' developed by the National Bureau of Soil Survey and Land Use Planning (NBSS&LUP) location lies in Agro-ecological Region 2 (M_9E_1) which is part of the Hot Arid Eco-region. This area is characterized by deep sandy to coarse loamy desert soils, poor water-holding capacity and a hot, arid climate that receives 350–600 mm of annual rainfall. Based on agro-climatic classifications, Bikaner falls within Zone I-C (Hyper Arid Partially Irrigated Western Plain Zone) under the National Agricultural Research Project (NARP) and Zone XIV (Western Dry Region) as per the Planning Commission of India. The soil at the site was loamy sand in texture with a pH of 8.5, organic carbon content of 0.18%, low available nitrogen (121.4 kg/ ha), medium phosphorus (19.08 kg/ha) and low potassium (191.42 kg/ha). A factorial randomized block design (FRBD) with three replications was used. There were 16 treatment combinations with four nutrient managements treatments: control (no fertilizers or FYM), 75% recommended dose of fertilizers (RDF), 100% RDF and 125% RDF and four weed control treatments: weed free, pre-emergence application (PE) of pendimethalin 0.75 kg/ ha, post-emergence application (PoE) of oxyfluorfen 50 g/ha at 25 DAS and weedy check. Weed-free plots were maintained by hand weeding thrice. The fennel cultivar '*RF 141*' was sown following the recommended package of practices. Sowing was done on 31 October 2021 using a *Deshi plough* at spacing of 50 x 20 cm with a seed rate of 8 kg/ha and a sowing depth of 2–3 cm. Fertilizers were applied as per the treatments. Recommended dose of fertilizer for fennel crop 90 N kg/ha and 40 P_2O_5 kg/ha were used. Urea and SSP were used as sources of nutrients N and P, respectively and applied as per treatment details. Half of the nitrogen dose along with the full doses of phosphorus and potassium were incorporated as basal application. The remaining nitrogen was supplied as urea in two equal splits with irrigation. Herbicide applications and hand weeding were executed according to the treatment structure. Herbicides were applied with a knapsack sprayer and manual weeding was carried out as per the treatment. Standard plant protection measures were adopted to ensure a healthy crop. At physiological maturity, the crop from the net plot area was harvested manually on 1 April 2022.

Plant population at harvest was recorded from the net plot area and converted to a per-hectare basis using the appropriate multiplication factor. For growth observations, five plants were randomly selected and permanently tagged in each plot. Plant height was measured at harvest from the base to the tip of the main shoot using a meter scale and the mean height was computed. The same tagged plants were used to record the number of branches per plant at harvest and their average values were calculated. Dry matter accumulation was assessed at 50 DAS and at harvest by sampling five randomly selected plants from each plot. After removing the root portion the samples were air-dried and then oven-dried at 70°C to constant weight the values were expressed in g/m{ ². Crop growth rate (CGR) was estimated following Radford (1967) as the increase in dry matter per unit area per unit time using periodic dry matter records. Relative growth rate (RGR) was computed according to Radford (1967) as the increase in dry matter per unit of existing biomass per unit time.

Weed density and weed dry weight (weed biomass) was measured form each plot at 50 DAS and at harvest using 1m^2 quadrat. The collected weed data were subjected to square root transformation before statistical analysis. In order to evaluate the efficacy of various weed control treatments, the weed control efficiency and weed index were calculated using standard formulae.

Biological yield was recorded as the weight of thoroughly sun-dried harvested produce from each plot prior to threshing and expressed in kg/ha. Seed yield was obtained by sun-drying, threshing and



#Data taken from Agro-meteorological Observatory, ARS, SKRAU, Beechwal, Bikaner

Figure 1. Weekly Meteorological data of Bikaner for the *Rabi* 2021-22

cleaning the produce from the net plot area after which the seed weight was measured in kg per plot and converted to kg/ha. The ratio of economic yield (seed yield) to biological yield was worked out and expressed in percentage (Singh and Stoskopf, 1971).

$$\text{Harvest index (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} \text{ X } 100$$

Economic analysis included estimation of net returns (Rs/ha) and the benefit–cost (B: C) ratio based on prevailing market prices. The data were analyzed statistically using Fisher's method of analysis of variance (ANOVA) as described by Fisher (1950).

Effect on weeds

The weed control treatments varied in their effect on weed density and biomass. Weed-free was maintained without weeds and weedy check had the highest weed density and biomass at both 50 DAS and at harvest (**Table 1**). Among the herbicides, pendimethalin 0.75 kg/ha PE and oxyfluorfen 50 g/ha PoE at 25 DAS were effective reducing weed density at 50 DAS and harvest over the weedy check. They recorded highest weed control efficiency and the lowest weed index (**Table 2**). The reduction in weed index (%) can be attributed to decreased crop-weed competition for essential resources such as light, nutrients and space which allowed the crop to more efficiently utilize available resources. This enhanced resource use efficiency ultimately contributed to improved crop growth and yield. Similar observations were reported by Kaur *et al.* (2022), Meena *et al.* (2013) and Gohil *et al.* (2015).

Effect on fennel

The weed control measure treatments differed significantly in their effect on plant population, plant height, number of branches per plant and dry matter accumulation, CGR and RGR (**Table 3**). Weed free recorded the maximum plant population, plant height, number of branches per plant, dry matter accumulation, CGR and RGR, which were 36.98, 33.32, 86.92, 32.48, 31.90 and 6.58% percent increase over weedy check, respectively at harvest. Pendimethalin 0.75 kg/ha PE was next best treatment which was equally effective in enhancing these characters of fennel. Improvement in growth attributes by pendimethalin at 0.75 kg /ha (PE) were increased by 32.06, 31.26, 67.43, 29.10, 28.48 and 5.8% over weedy check, respectively at harvest. Because there was less competition for plant growth inputs when there are lesser weeds and less weed biomass, crop plants produce more dry matter and develop to a greater height when weed control treatments were implemented as reported by Nagar *et al.* (2009) and Kumar *et al.* (2021) in fennel. Thus, sufficient availability of light, space as well as better soil and nutritional environment along with improvement in physiological and morphological characters of the plant in rhizosphere might have improved the photosynthetic efficiency, which led to more dry matter accumulation under effective treatments. In contrast, continuous growth of weeds throughout the crop season in weedy check decreased the fennel growth due to high weed-crop competition. Hand weeding done with hoeing, as in weed free, also improved the physical condition of the soil by increasing its friability, aeration and it is an effective method to prevent weeds from producing seeds that might helps in establishment and proliferation of roots and ultimately the plant growth confirming the findings of Bagri *et al. (*2014) in fenugreek.

Table 1. Effect of weed control and nutrient management treatments on weed density and biomass in fennel

Treatment	Weed density (no./m^2)		Weed biomass (g/m^2)	
	At 50 DAS	At harvest	At 50 DAS	At harvest
Nutrient management				
Control	4.64(31.7)	4.16(26.8)	7.16	48.89
75% RDF	4.89(34.7)	4.50(29.8)	8.59	53.68
100 % RDF	4.96(35.6)	4.70(32.6)	9.61	59.53
125 % RDF	5.07(37.6)	4.90(35.1)	9.95	61.58
LSD (p=0.05)	0.12	0.18	1.01	4.20
Weed control measures				
Weed free	0.71(0.0)	0.71(0.0)	0.0	0.0
Pendimethalin 0.75 kg/ha PE	4.12(16.5)	3.78(14.0)	3.61	29.57
Oxyfluorfen 50 g/ha PoE at 25 DAS	4.55(20.2)	4.03(15.9)	4.38	32.98
Weedy check	10.16(102.8)	9.73(94.5)	27.31	161.14
LSD (p=0.05)	0.12	0.18	1.01	4.20

The original weed density per m^2 is shown in parenthesis. (*A square root transformation of x + 0.5 were used)*. RDF = Recommended dose of fertilizer, NS= Non – significant, DAS= Days after sowing, PE= pre-emergence application, PoE= post-emergence application

Table 2. Effect of weed control measures on weed control efficiency and weed index in fennel

Treatment	Weed control efficiency (%)		Weed index (%)
	At 50 DAS	At harvest	
Weed free	100.00	100.00	0.00
Pendimethalin at 0.75 kg/ha PE	86.87	81.78	16.89
Oxyfluorfen at 50 g/ha PoE at 25 DAS	84.03	79.67	31.50
Weedy check	0.0	0.0	92.07
LSD (p=0.05)	-	-	-

DAS= Days after sowing, PE= pre-emergence application, PoE= post-emergence application

Weed-free throughout the crop season resulted in highest number of umbel per fennel plant, umbellate per umbel, and seeds per umbel, maximum fennel biological yield and seed yield (**Table 4**). The absence of weed competition throughout the growth period allowed the crop to fully utilize nutrients, moisture and sunlight, thereby enhancing growth and yield. Among herbicides, pendimethalin 0.75 kg/ha PE proved most effective, followed closely by oxyfluorfen 50 g/ha PoE at 25 DAS. These treatments significantly improved yield components and yields compared to the weedy check where unchecked weed growth led to excessive depletion of soil nutrients and moisture by the weeds ultimately hindering crop development Thus, season-long weed control played a crucial role in enhancing fennel productivity as reported earlier by Gohil *et al.* (2015) and Choudhary *et al.* (2021).

In the present study, maximum fennel growth parameters (plant height, number of branches/plant and dry matter accumulation) were observed with 125% RDF. Crop growth parameters improved due to fulfillment of crop nutrient requirement and created good soil environment for crop growth. Reported by Waskela *et al.* (2017) and Kalasare *et al.* (2021)

Yield attributes were significantly higher with application of 100% RDF by 31.22%, 26.84%, 44.54%, 13.90% and 38.77% increase in number of umbles/plant, umblets/umble, seeds/umble, test weight and seed yield, respectively over control. 125 % RDF also resulted in equally higher increase of the fennel yield attributes and yield. The yield attributes and yield were found to be higher due to higher nutrient availability under the recommended dose of fertilizer. The longer period of the reproductive phase due to higher nutrition (N P and K) resulted into higher seed yield per hectare. The significantly highest biological yield was also recorded with 100 % RDF and the lowest, under control, respectively. The results suggest that NPK fertilization improved both direct parameters like dry matter accumulation and indirect traits such as branching and reproductive structures confirming earlier studies of Kumawat *et al.* (2015) and Kumar *et al.* (2021).

Table 3 Effect of weed control and nutrient management treatments on fennel growth parameters

Treatment	Plants population/ ha	Plant height (cm)	No. of branches	Dry matter accumulation (g/m^2)		CGR (g/m^2/day)		RGR (mg/g/day) 50 DAS – at harvest
				At 50 DAS	At harvest	0-50 DAS	50 DAS – at harvest	
Nutrient management								
Control	78061	93.45	5.56	31.29	289.49	0.63	2.58	2.44
75% RDF	80000	107.29	6.55	37.64	341.96	0.75	3.04	2.51
100 % RDF	81654	119.40	7.21	41.92	378.05	0.84	3.36	2.56
125 % RDF	82165	121.62	7.38	42.38	382.10	0.85	3.40	2.56
LSD (p=0.05)	NS	8.12	0.52	3.00	23.95	0.06	0.24	0.03
Weed control measures								
Weed free	90129	122.17	8.15	45.49	396.52	0.91	3.51	2.58
Pendimethalin 0.75 kg/ha PE	86892	120.28	7.30	40.55	377.64	0.81	3.37	2.56
Oxyfluorfen 50 g/ha PoE at 25 DAS	79062	107.70	6.90	38.03	349.73	0.76	3.12	2.52
Weedy check	65797	91.63	4.36	29.16	267.71	0.58	2.39	2.41
LSD (p=0.05)	6097	8.12	0.52	3.00	23.95	0.06	0.24	0.03

RDF = Recommended dose of fertilizer, NS= Non – significant, DAS= Days after sowing, PE= Pre-emergence, PoE= post-emergence, the figures in the parentheses were original values

Table 4 Effect of weed control and nutrient management treatments on fennel yield attributes, yield and economics

Treatment	Biological yield (kg/ha)	Seed yield (kg/ha)	Harvest index (%)	Net returns (x10^3 Rs/ha)	B: C ratio
Nutrient management					
Control	2.86	0.81	29.64	41.95	2.19
75% RDF	3.56	1.01	28.76	58.00	2.56
100 % RDF	3.98	1.13	28.61	68.71	2.78
125 % RDF	4.12	1.17	28.64	71.66	2.82
LSD (p=0.05)	0.19	0.07	NS	6.62	0.16
Weed control measures					
Weed free	4.59	1.31	28.57	76.78	2.62
Pendimethalin 750 g/ha PE	3.89	1.12	28.85	70.33	2.97
Oxyfluorfan50 g/ha PoE at 25 DAS	3.69	1.00	28.29	60.97	2.79
Weedy check	2.34	0.69	29.95	32.24	1.98
LSD (p=0.05)	0.19	0.07	NS	6.62	0.16

RDF = Recommended dose of fertilizer, NS= Non – significant, PE= Pre-emergence, PoE= Post- emergence, DAS= Days after sowing, the figures in the parentheses were original values

Economics

Significantly highest net returns and benefit: cost ratio (2.78) were recorded with 100% RDF. All weed control treatments recorded significantly higher net returns and B:C ratios compared to the weedy check, primarily due to their higher seed yields (**Table 4**). The weed-free treatment produced the highest net returns and a B: C ratio of 2.67. Pendimethalin at 0.75 kg/ha PE recorded next highest net returns with the highest B: C ratio of 2.97, due to its lower application cost. In contrast, unrestricted weed growth in the weedy check resulted in the lowest net returns and B: C ratio (1.98) confirming earlier reports by Yadav *et al*. (2016) in coriander, Choudhary *et al*. (2021) and Mamantha *et al*. (2021) in fennel.

Conclusion

It was concluded that maximum fennel growth and yield attributes, yield, net return and the highest B: C ratio due to effective management of weeds can be attained with pendimethalin 0.75 kg/ha PE and weed-free (hand weeding thrice) in fennel crop. The season-long weed-free conditions and optimal nutrient management (100% RDF) are critical for maximizing fennel productivity and profitability. However, these results are only indicative and further experimentation is required to arrive at more consistent and definite conclusions for recommendation to the farmers.

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