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RESEARCH ARTICLE Agricultural Science Digest

Role of Planting Patterns and Weed Control Methods on Growth and Development of Fennel (*Foeniculum vulgare* Mill.)

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10.18805/ag.D-6224

ABSTRACT

Background: The field experiment was conducted at the Research Farm of Lovely Professional University, Phagwara, Punjab, India during *Rabi* season 2023-24 to find out the role of planting patterns and weed control methods on growth and development of Fennel (*Foeniculum vulgare* Mill.).

Methods: The experiment was laid out in split plot design with three replications. In main plots, four planting patterns *i.e.* two rows per bed (90 cm), ridge sowing (45 cm), flat sowing (45 cm) *f.b.* earthing up, flat sowing (45 cm) and in sub plots, four weed control treatments, *i.e.* black plastic mulch, white plastic mulch, hand weeding *f.b.* straw mulch (5 t ha^{-1}) and unweeded (control) were kept.

Result: The results of the study revealed that weed count and weed dry matter in flat sowing (45 cm) *f.b.* earthing up was significantly less than flat sowing (45 cm) and among weed control treatments, black plastic mulch recorded significantly less weed count and weed dry matter than other treatments. Plant height, dry matter per plant, seed yield and biological yield were found significantly higher in flat sowing (45 cm) *f.b.* earthing up as compared to flat sowing (45 cm). Black plastic mulch and white plastic mulch recorded significantly higher growth and yield parameters than unweeded (control). The seed yield in flat sowing (45 cm) *f.b.* earthing up was 33.5% higher than flat sowing (45 cm). Black plastic mulch recorded 85.28% higher seed yield over control, which was significantly more as compared to all other treatments. It was concluded that the combination of flat sowing (45 cm) *f.b.* earthing up and black plastic mulch gave better results as compared to all other treatments.

Key words: Bed sowing, Black plastic mulch, Earthing up, Straw mulch, Weed, White plastic mulch.

INTRODUCTION

Fennel (*Foeniculum vulgare* Mill.) is a robust, fragrant annual herb native to Southern Europe and the Mediterranean region and is an essential seed spice that is locally known as “Saunf” (Abd El-Wahab and Mehasen, 2009). Major fennel-producing states in India include Gujarat, Rajasthan and Uttar Pradesh, while many other states, including Bihar, Madhya Pradesh, Punjab and Haryana, cultivate it on a smaller scale (Anonymous, 2018). Fennel is currently grown on 82.0 thousand hectares in India, producing 137 thousand tonnes and overall productivity is about 16 q ha^{-1} (Verma and Saxena, 2024).

Fennel usually takes longer to germinate and grows slowly at first, which frequently encourages a severe weed infestation. These weeds negatively influence growth and result in significant yield losses if not controlled during initial growth stages. Therefore, one of the most important variables in achieving optimal yield of fennel is weed management. Despite referring to the seed production, Patel *et al.* (2021) revealed that fennel is extremely sensitive to weed competition. Fennel grows slowly during initial growth stages, which frequently results in intense agricultural weed competition (Patel *et al.,* 2019). It reduces the seed output by 50% if weeds are not kept under control in weedy check (Gohil *et al.,* 2015). The application of plastic mulch has become a routine practice for most vegetable growers, which results in decreased evaporation, better weed control, reduced fertilizer leaching and reduced soil compaction, as well as increased soil temperatures that encourage early plant maturity. According to Farag *et al.* (2020), mulching with the right materials enhanced soil temperature, preserved soil moisture and reduced weeds, pests and diseases.

Among various factors which can increase the yield, sowing date and planting patterns are the most important. Different planting geometry/sowing methods significantly affected the branches per plant and number of umbels per plant in fennel crop. Ridge sowing produced maximum number of branches per plant which might be attributed to proper plant spacing and better agronomic practices in this method which resulted in better use of soil and environmental factors towards growth and development as compared to other sowing methods (Mahmood, 2013). In comparison to flat sowing, bed sowing and ridge sowing

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How to cite this article: Chaudhary, M., Walia, U.S. and Singh, R. (2025). Role of Planting Patterns and Weed Control Methods on Growth and Development of Fennel (*Foeniculum vulgare* Mill.). Agricultural Science Digest. 1-5. doi: 10.18805/ag.D-6224.

Submitted: 14-10-2024 **Accepted:** 11-02-2025 **Online:** 08-05-2025

methods substantially decrease irrigation time. In comparison to flat sowing, bed and ridge sowing has a greater germination count (plants m^{-2}). According to Asif *et al.* (2019), bed sowing produced a grain yield that was 16.36% greater than flat sowing. Maximum weed control efficiency was found in raised bed planting method. There was significant reduction in dry weight of weeds in bed sowing as compared to conventional planting method (Yadav *et al.,* 2019). To evaluate the effect of planting patterns and weed control treatments, the following experiment was conducted.

MATERIALS AND METHODS

The field experiment was carried out at Research Farm of Lovely Professional University, Phagwara, Punjab, India during *Rabi* season 2023-24. The location comes under Trans Gangetic Plains. The experiment was laid out in Split Plot Design with three replications. In main plots, different planting patterns i.e. two rows per bed (90 cm), ridge sowing (45 cm), flat sowing (45 cm) *f.b.* earthing up, flat sowing (45 cm) and in sub plots, four weed control treatments *i.e.* black plastic mulch, white plastic mulch, hand weeding *f.b.* straw mulch (5 t ha^{-1}) and unweeded (control) were kept. Uniform plant population was maintained in all the planting patterns. The sowing of the seeds was done with dibbling method on 29th of October 2023. Fennel seeds of variety, Ajmer fennel-2 were used with seed rate of 10 kg ha^{-1} with row to row spacing of 45 cm and plant to plant 20 cm. Fertilizers were applied uniformly in all the treatments. N was applied @ 50 kg ha^{-1} in four equal splits and P was applied @ 25 kg ha^{-1} as the basal dose. Earthing up, hand weeding and straw mulching was done according to treatments at 45 days after sowing. Data was collected at subsequent intervals and harvesting was done with a sickle when the seeds started turning yellow. After harvesting the seeds were dried in shade for 2-3 days and then threshing was done.

RESULTS AND DISCUSSION

Weed count (m^{-2}) and weed dry matter (q ha^{-1})

The data presented in Table 1 indicates the effect of planting patterns and weed control treatments on weed count and weed dry matter of the crop at harvest. The weed count was significantly less in flat sowing (45 cm) *f.b.* earthing up than ridge sowing and flat sowing. The weed count in two rows per bed (90 cm) was at par with flat sowing (45 cm) *f.b.* earthing up. However, significantly higher number of weeds were found in flat sowing (45 cm). Generally, weeds emerge in flat or damp environments, so raised bed structures or earthing up practice may help in the suppression of weed growth because there is less competition for water and nutrients. Therefore, fennel plants can grow more robustly in raised bed or earthing up (Singh *et al.,* 2019). Among sub plots, black plastic mulch recorded significantly lower number of weeds as compared to unweeded (control). Mulches have a weed suppressing effect which can result from limited penetration of light reaching the soil surface and as a result reduce the germination and growth of weeds. The unweeded check recorded the highest dry biomass of weeds due to uncontrolled condition which resulted in luxurious growth of weeds (Patel *et al.,* 2018). By mulching the soil and covering it with polyethylene sheet to capture solar radiation, it weakens the infestation of weeds (Kumar *et al*., 2024).

Weed dry matter in flat sowing (45 cm) *f.b.* earthing up was significantly less as compared to all other planting patterns and significantly more weed dry matter was found in flat sowing (45 cm) than other planting patterns (Table 1).

Table 1: Effect of planting patterns and weed control treatments on weed count (m^{-2}) and weed dry matter (q ha^{-1}) at harvest.

Treatment details	Weed count (m^{-2})	Weed dry matter (q ha^{-1})
Main plots (Planting patterns)		
Two rows per bed (90 cm)	5.3(42.1)	5.3(35.2)
Ridge sowing (45 cm)	6.7(59.7)	5.7(40.3)
Flat sowing (45 cm) *f.b.* earthing up	5.3(37.0)	4.9(29.3)
Flat sowing (45 cm)	7.6(71.4)	6.4(52.9)
SEm±	0.06	0.07
C.D. at 5%	0.22	0.24
Sub-plots (Weed control treatments)		
Black plastic mulch	3.4(12.0)	3.5(11.8)
White plastic mulch	4.0(15.9)	3.9(14.4)
Hand weeding *f.b.* straw mulch (5t ha^{-1})	4.9(23.6)	4.1(15.9)
Unweeded (control)	12.6(158.8)	10.7(115.6)
SEm±	0.10	0.11
C.D. at 5%	0.30	0.32
Interaction (A*B) C.D. at 5%	NS	NS

Note: Values without parenthesis are transformed values; values within parenthesis are original values.

The effective control of weeds in earthing up may be due to better utilization of water and nutrients and crop-weed competition is less as compared to flat sowing (Singh *et al.,* 2019). Among sub plots, black plastic mulch and white plastic mulch recorded significantly less weed dry matter as compared to unweeded (control) treatment, which showed higher values of weed dry matter. These treatments kept the crop almost weed free at initial stages which resulted in significant reduction in competition for resources like nutrients and water by weeds because of which reduction in dry matter and nutrient depletion by weeds occurred (Patel *et al.,* 2016). The weed biomass and density were found significantly lower in the treatment of mulching in comparison to hand weeding and control treatments (Singh and Walia, 2024).

Plant height (cm) and plant dry matter per plant (g)

The data shown in Table 2 represents the effect of planting patterns and weed control treatments on plant height and dry matter per plant at harvest. The results showed that, plant height in flat sowing (45 cm) *f.b.* earthing up was significantly higher than in flat sowing (45 cm). However, the treatment of two rows per bed (90 cm) remained at par with flat sowing (45 cm) *f.b.* earthing up. There was increase in growth attributes in earthing up and bed sowing as it leads to better soil physical conditions, optimizing photosynthesis and light interception (Ayub *et al.,* 2008). In sub plots, black plastic mulch and white plastic mulch recorded significantly higher plant height as compared to hand weeding *f.b.* straw mulch. Unweeded (control), recorded significantly less plant height than all other treatments. Reduced competition of crop and weed under black plastic mulch saved the amount of water nutrients for crop growth that led to increased crop growth by utilizing moisture and nutrients from deeper layers of soil.

Similarly, the plant dry matter was found to be significantly higher in flat sowing (45 cm) *f.b.* earthing up

Table 2: Effect of planting patterns and weed control treatments on plant height (cm) and plant dry matter per plant (g) at harvest.

Treatment details	Plant height (cm)	Plant dry matter per plant (g)
Main plots (Planting patterns)		
Two rows per bed (90 cm)	158.4	171.2
Ridge sowing (45 cm)	156.0	135.6
Flat sowing (45 cm) *f.b.* earthing up	163.6	188.7
Flat sowing (45 cm)	150.4	111.4
SEm±	2.28	6.50
C.D. at 5%	8.04	22.94
Sub-plots (Weed control treatments)		
Black plastic mulch	175.2	243.5
White plastic mulch	172.2	178.3
Hand weeding *f.b.* straw mulch (5 t ha^{-1})	157.4	132.1
Unweeded (control)	123.7	52.9
SEm±	2.08	6.87
C.D. at 5%	6.11	20.18
Interaction (A*B) C.D. at 5%	NS	NS

Table 3: Effect of planting patterns and weed control treatments on seed yield (q ha^{-1}) and biological yield (q ha^{-1}) at harvest.

Treatment details	Seed yield (q ha^{-1})	Biological yield (q ha^{-1})
Main plots (Planting patterns)		
Two rows per bed (90 cm)	11.9	85.7
Ridge sowing (45 cm)	9.4	76.1
Flat sowing (45 cm) *f.b.* earthing up	12.4	88.2
Flat sowing (45 cm)	8.2	71.2
SEm±	0.18	2.22
C.D. at 5%	0.63	8.33
Sub-plots (Weed control treatments)		
Black plastic mulch	15.1	112.3
White plastic mulch	13.5	102.2
Hand weeding *f.b.* straw mulch (5 t ha^{-1})	11.0	94.2
Unweeded (control)	2.2	12.5
SEm±	0.27	2.22
C.D. at 5%	0.19	6.67
Interaction (A*B) C.D. at 5%	1.16	NS

Table 4: Seed yield (q ha^{-1}) as influenced by planting patterns and weed control treatments.

	Black plastic mulch	White plastic mulch	Hand weeding *f.b.* straw mulch (5t ha^{-1})	Unweeded (control)	Mean A
Two rows per bed (90 cm)	19.0	14.4	12.5	1.8	11.9
Ridge sowing (45 cm)	14.0	13.0	9.4	1.1	9.4
Flat sowing (45 cm) *f.b.* earthing up	15.4	14.9	13.9	5.2	12.4
Flat sowing (45 cm)	12.2	11.8	8.2	0.8	8.2
Mean B	15.1	13.5	11.0	2.2	
SE(m)	0.18				
C.D.(5%)	1.16				

Note: Values without parenthesis are transformed values; values within parenthesis are original values.

as compared to flat sowing (45 cm) (Table 2). Two rows per bed (90 cm) remained at par with flat sowing (45 cm) *f.b.* earthing up treatment. Since ridge or bed-sown fennel manages water and nutrients better than typical flat sowing methods, resulting in higher yields. The reason for better results in earthing up could be that it improves soil physical conditions and prevents lodging of crop (Patel *et al*., 2018). When compared to flat sowing techniques, the advantages of earthing up and bed sowing are better drainage, ability to regulate soil temperature, less weed competition, enhanced air circulation, effective water usage and optimised plant density. These findings were in line with those of Sarker *et al.* (2023). Among sub plots, black plastic mulch recorded significantly higher plant dry matter as compared to all other weed control treatments. Black and white plastic mulch significantly increased plant dry matter compared to hand weeding *f.b.* straw mulch treatment. There are many positive effects of mulching which can enhance the growth and productivity of fennel crop by improving soil moisture, soil temperature improvement, conservation of irrigation water, better nutrient uptake, less weed competition and better root and vegetative growth (Kumar and Lal, 2012).

Seed yield (q ha^{-1}) and biological yield (q ha^{-1})

The data presented in Table 3 shows the effect of planting patterns and weed control treatments on seed yield and biological yield of the crop. The seed yield in flat sowing (45 cm) *f.b.* earthing up (12.36 q ha^{-1}) was significantly higher than flat sowing (45 cm) (8.22 q ha^{-1}) and ridge sowing (9.40 q ha^{-1}). However, seed yield of two rows per bed (90 cm) was at par with the treatment of flat sowing (45 cm) *f.b.* earthing up. The seed yield in flat sowing (45 cm) *f.b.* earthing up was 33.5% higher than flat sowing (45 cm). Earthing up and bed sowing treatment produced better yield, which might be due to proper plant spacing and better agronomic practices which resulted in better use of soil and environmental factors which leads to enhanced growth and development as compared to rest of sowing methods (Patel *et al.,* 2018). The improvement in yield in earthing up was due to less germination of weeds which might have resulted in less utilization of available nutrients and moisture. Among weed control treatments, black plastic mulch recorded significantly higher seed yield (15.15 q ha^{-1}) as compared to all other treatments and significantly less yield was found in unweeded (control) (2.23 q ha^{-1}) as compared to other treatments. Seed yield in black plastic mulch was 85.28% higher in comparison to unweeded (control). Plastic and straw mulches reduce the rate of weed germination, as the mulches do not provide necessary conditions for weed seed germination and increases the overall growth and productivity of crops (Kolota and Adamczewska-Sowinska, 2013).

The biological yield was significantly higher in flat sowing (45 cm) *f.b.* earthing up as compared to flat sowing (45 cm) (Table 3). The yield in two rows per bed (90 cm) was at par with flat sowing (45 cm) *f.b.* earthing up. This might be attributed to better use of soil and environmental factors during entire period of crop growth in bed sowing than rest of sowing methods. These results are in line with those of Khorshidi *et al.* (2009). Among weed control treatments, black plastic mulch recorded significantly higher biological yield as compared to all other weed control treatments. White plastic mulch produced significantly more biological yield than hand weeding *f.b.* straw mulch. This treatment provided almost season long weed-free environment hence resulted in appreciably higher yields over unweeded plots (Choudhary *et al.,* 2021).

The interactive effect of planting patterns and weed control treatments for seed yield was found to be significant (Table 4). The data indicated that two rows per bed gave significantly more yield than flat sown *f.b.* earthing up under hand weeding *f.b.* straw mulch treatment. Also, application of white mulch in bed planted crop gave at par seed yield as under flat sowing *f.b.* earthing up treatment applied with black mulch treatment.

CONCLUSION

It can be concluded from the results that weed count and weed dry matter was found to be significantly less in flat sowing (45 cm) *f.b.* earthing up and higher number of weeds and weed dry matter was found in flat sowing (45). Black plastic mulch and white plastic mulch recorded significantly lower number of weeds and weed dry matter as compared to unweeded (control). Plant height, dry matter per plant and grain yield was significantly higher in flat

sowing (45 cm) *f.b.* earthing up as compared to flat sowing (45). Black plastic mulch and white plastic mulch recorded better results among growth and yield parameters as compared to unweeded (control). Therefore, we can say that the combination of flat sowing (45 cm) *f.b.* earthing up and black plastic mulch gave better results among all other treatments.

ACKNOWLEDGEMENT

The present study was supported under the guidance of Dr. U.S. Walia and preparation of the manuscript was done with the help of Ramandeep Singh.

Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

Informed consent

All animal procedures for experiments were approved by the Committee of Experimental Animal care and handling techniques were approved by the University of Animal Care Committee.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript.

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