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RESEARCH ARTICLE

Effect of nitrogen and FYM on growth and yield of fennel (*Foeniculum vulgare* Mill.) under variable weed control strategies

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Abstract

The field experiment was conducted at the Research Farm of Lovely Professional University, Phagwara, Punjab, India, during the *Rabi* season 2023-24 to evaluate the response of fennel (*Foeniculum vulgare* Mill.) to nitrogen and FYM in relation to weed control strategies. A split-plot design with three replications was used as the experimental design. In main plots, four weed control treatments were applied, i.e., black plastic mulch, one-hand weeding followed by straw mulch, pendimethalin at 0.45 kg ha^{-1} followed by one-hand weeding and unweeded (control) treatment. In the sub plots four nutrient levels i.e., N_1- 25 kg nitrogen ha^{-1}, N_2- 25 kg nitrogen ha^{-1} + FYM 15.0 t ha^{-1}, N_3- 50 kg nitrogen ha^{-1} and N_4- 50 kg nitrogen ha^{-1} + FYM 15.0 t ha^{-1} were kept. The results revealed that weed density and dry matter accumulation were significantly lower in black plastic mulch treatment compared to other weed management treatments and were significantly higher in the unweeded (control). Plant height, crop dry matter per plant, seed yield and biological yield were significantly higher in the black plastic mulch treatment than in other treatments. Among the nitrogen levels, growth and yield parameters were significantly higher in the 50 kg ha^{-1} of nitrogen + FYM 15.0 t ha^{-1} treatment compared to nitrogen alone @ 25 kg ha^{-1}. It was concluded that black plastic mulch combined with 50 kg ha^{-1} of nitrogen + FYM 15.0 t ha^{-1} resulted in better growth and yield parameters compared to all other treatments.

Keywords: fennel; FYM; nitrogen levels; plastic mulch; straw mulch; weed control

Introduction

Fennel (Foeniculum vulgare Mill.) is one of the most prominent seed spices cultivated on a large scale in India. It is a robust-growing, a fragrant annual herb native to Southern Europe and the Mediterranean region, locally known as "Saunf" (1). Fennel is currently cultivated on 82000 ha in India, representing a significant increase over previous years, with production reaching 137000 tonnes and an overall productivity of 16 q ha^{-1} (2). More than 80 % of total seed spice production comes from both Rajasthan and Gujarat. This belt is also known as the "seed spice bowl" of India. Gujarat alone accounts for 82 % of India's fennel production, with 14500 hectares under cultivation, a total yield of 21200 tonnes and productivity of 14.6 q ha^{-1} (3).

Fennel often requires 7-10 days to germinate and grows slowly at first, which frequently results in intense competition with weeds (4). Weeds negatively impact growth and result in substantial yield losses if not controlled immediately. As much as 91 % of the crop yield could be lost due to weed infestation. Therefore, weed management is essential for achieving optimal yields. To keep weeds under check, manual weeding is a typical practice in fennel. Mulches are applied to cultivated crops after the main crop is planted or before the weed seeds begin to emerge. According to (5), mulching with the right materials, such as plastic mulch or organic mulch, enhances soil temperature, preserves soil moisture and reduces weeds, pests and diseases. A typical nutrient that encourages the vegetative growth of field crops is nitrogen. The leading cause of low yield and poor quality is the improper and unbalanced application of nutrients. One of the most significant and commonly used bulky organic manures is farmyard manure (FYM), which has an NPK content of 0.5:0.2:0.5 %. It provides micronutrients for plants, enhances the physical characteristics of the soil and promotes nutrient availability (6). To evaluate the impact of weed control treatments, along with nitrogen and FYM, on the growth and productivity of fennel, this study was conducted.

Materials and Methods

The field experiment was carried out at the Research Field of Lovely Professional University, Jalandhar, Punjab, India, during the Rabi season 2023-24. The experiment design was a Split Plot Design with 3 number of replications. In main plots, four weed control treatments, i.e., T_1- black plastic mulch, T_2- one-hand weeding followed by straw mulch, T_3-pendimethalin @ 0.45 kg per ha followed by one hand weeding and T_4- unweeded (control) and in subplots, four nutrient levels, i.e., N_1

- 25 kg of nitrogen/ha, N_2- 25 kg of nitrogen/ha+ FYM 15.0 t/ha, N_3- 50 kg of nitrogen/haand N_4- 50 kg of nitrogen/ha+ FYM 15.0 t/hawere kept.

The variety of fennel used was Ajmer fennel-2 with a seed rate @ 10 kg ha^{-1} and a spacing of 45 × 20 cm. The gross plot size was 5 m × 3 m. The sowing was done on the 28th of October using the dibbling method. Four equal splits of Nitrogen were applied with 1/4th dose in each split. However, a complete dose of phosphorus (25 kg ha^{-1}) was applied as a basal application. The FYM application was done four weeks before sowing at 15 t ha^{-1}. Hand weeding was done as per treatments at 45 DAS, followed by straw mulching (5 t ha^{-1}).

For weed data collection, a 30 x 30 cm quadrant was used and randomly thrown twice per plot to ensure precise reading. Weeds were counted, dried in an oven and weighed to obtain dry matter content. For the crop growth and yield attribute data, five plants were randomly selected for observation recording. The crop matured 180 DAS and plants were harvested with the help of a sickle from a net area of 1.8 m^2. Seeds were shade-dried for two days and then manually threshed by beating them with a stick.

The collected data was then entered into MS Excel for averaging and other calculations. Analysis of Variance was performed using OPSTAT software, with significance tested at p= 0.05 and CD and SEM values provided in Table 1, 2, 3 and 4.

Results and Discussion

Weed count (per sq. m.) and dry matter of weeds (q/ ha)

The data presented in Table 1 shows the weed density and dry matter accumulation of weeds at 120 days after sowing. The results showed that among weed control treatments, weed count was significantly less in black plastic mulch than in straw mulching and pre-emergence herbicide spray. Significantly higher weed density was observed in the unweeded (control) treatment. The unweeded (control) treatment recorded the highest weed density due to the unrestricted growth of weeds during the entire crop period. Mulching effectively suppressed weed growth while maintaining optimal soil moisture and temperature (5). The unweeded treatment recorded the highest weed density due to unrestricted growth. However, mulching reduces weed germination (7). In subplots, a significantly lower number of weeds was found, with significantly fewer weeds in the 25 kg nitrogen ha^{-1} treatment compared to all other nutrient treatments. Significantly more weed count was found in nitrogen @ 50 kg ha^{-1} + FYM @ 15.0 t ha^{-1} as compared to nitrogen @ 25 kg ha^{-1} + FYM 15.0 t ha^{-1} . The higher weed density observed in nitrogen @ 50 kg ha^{-1} + FYM 15.0 t ha^{-1} may be due to the presence of weed seeds in FYM. The use of organic manures resulted in the highest weed density, while the use of chemicals produced the lowest weed density as organic manures can contain certain weed seeds (8).

Weed dry matter in main plots (weed control treatments) was found to be significantly lower in black plastic mulch as compared to other treatments. Significantly higher weed dry matter was recorded in unweeded (control) as compared to other weed control treatments. As weeds do not get sunlight and favourable conditions under plastic and straw mulches, which results in lesser weed seed germination, which ultimately reduces the weed dry matter (9). Among subplots, the weed dry matter was found to be significantly higher in 50 kg ha^{-1} of + FYM 15.0 t ha^{-1} than nitrogen @ 25 kg ha^{-1}. The weed density and weed dry matter under no FYM treatments were much lower than under other treatments. Most of the weed seeds found in farmyard manure originate from grain or fodder that has passed through the digestive systems of animals. These weed seeds have survived ingestion, which causes more weed seeds in the field and increases the weed density and weed dry matter (10).

Plant height (cm) and dry matter of crop (g / plant)

The plant height and dry weight/plant at 120 days after sowing is presented in Table 2. The results conclude that among weed control treatments, plastic mulch (black) recorded significantly more plant height in comparison to straw mulching and pendimethalin spray and significantly lower plant height was recorded in unweeded (control). The increased growth and production under mulching treatments might be due to better weed control, which reduced weed competition and improved utilization of the nutrients and moisture by crops (11). Application of mulch for weed management results in significant improvement in plant height as compared to control (12).

Table 1. Effect of weed control treatments and different nitrogen levels on weed count (m^{-2}) and weed dry matter (q ha^{-1}) at 120 DAS

Treatment details	Weed count (m^{-2})	Weed dry matter (q ha^{-1})
Main plots (Weed control treatments)		
Plastic mulch (black)	3.2 (9.1)	1.9 (2.9)
One-hand weeding followed by straw mulch	5.0 (24.3)	3.3 (10.2)
Pendimethalin (0.45 kg ha^{-1}) followed by one-hand weeding	4.8 (22.1)	2.9 (7.8)
Unweeded (control)	17.9 (319.6)	10.3 (105.2)
SEm±	0.17	0.06
C.D. at 5 %	0.60	0.22
Sub-plots (Nitrogen levels)		
25 kg N ha^{-1}	7.0 (83.5)	4.2 (26.9)
25 kg N ha^{-1} + FYM 15.0 t ha^{-1}	8.0 (97.7)	4.7 (33.3)
50 kg N ha^{-1}	7.4 (86.1)	4.4 (28.6)
50 kg N ha^{-1} + FYM 15.0 t ha^{-1}	8.4 (107.8)	5.2 (37.2)
SEm±	0.14	0.12
C.D. at 5 %	0.41	0.34
Interaction (A*B) C.D. at 5 %	**NS**	**NS**

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

Table 2. Effect of weed control treatments and different nitrogen levels on plant height (cm) and plant dry matter per plant (g) at 120 DAS

Treatment details	Plant height (cm)	Dry matter per plant (g)
Main plots (Weed control treatments)		
Plastic mulch (black)	163.9	125.3
One-hand weeding followed by straw mulch	127.7	72.3
Pendimethalin (0.45 kg ha^{-1}) followed by one-hand weeding	143.2	102.3
Unweeded (control)	96.3	20.5
SEm±	2.08	1.52
C.D. at 5 %	7.35	5.38
Sub-plots (Nitrogen levels)		
25 kg N ha^{-1}	122.0	64.1
25 kg N ha^{-1} + FYM 15.0 t ha^{-1}	137.9	85.2
50 kg N ha^{-1}	130.5	75.3
50 kg N ha^{-1} + FYM 15.0 t ha^{-1}	140.7	95.8
SEm±	1.02	2.55
C.D. at 5 %	3.00	7.48
Interaction (A*B) C.D. at 5 %	**NS**	**NS**

Among subplots, plant height was significantly higher in 50 kg nitrogen ha^{-1} along with FYM 15.0 t ha^{-1} than other treatments (without FYM) and nitrogen @ 25 kg ha^{-1} along with FYM 15.0 t ha^{-1} was at par with the former treatment. The plant height was the lowest in the treatment with a lower level of nitrogen (25 kg ha^{-1}) than all other nutrient combinations. The application of FYM resulted in a significant increase in plant height as compared to those without FYM treatments. Absorption and utilization of radiant energy with the application of FYM might have increased, which lead to an increase in photosynthesis rate and thereby plant height, dry matter accumulation and finally results in better growth (13).

The dry matter per plant (g) in the main plots (weed control treatments) was significantly higher in the black plastic mulch treatment than in all other weed control treatments. A considerably lower dry matter per plant was observed in the unweeded (control) treatment compared to other treatments. This was due to extensive weed infestation, which suppressed dry matter accumulation of the crop under the unweeded (control) (14). Among sub plots, the dry weight/plant was found to be significantly higher in nitrogen (50 kg ha^{-1}) + FYM (15.0 t ha^{-1}) and the lowest was recorded in alone nitrogen @ 25 kg ha^{-1} (without FYM). The improved nitrogen dose helps in better dry matter accumulation as it is the principal element of crop growth. Moreover, FYM releases its nutrients slowly for a longer duration, which might have resulted in nitrogen availability for a longer duration and thus improving the dry matter of the crop (15).

Seed and biological yield (q / ha)

The data presented in Table 3 represents the seed yield and biological yield of the crop at harvest. The results conclude that among weed control treatments, black plastic mulch produced a significantly higher grain yield (18.4 q ha^{-1}) compared to straw mulching and pendimethalin spray. A significantly lower seed yield was recorded in the unweeded (control) treatment (1.2 q ha^{-1}) than in all weed control treatments. The seed yield in black plastic mulch increased by 93.48 % compared to unweeded control. The reason for the lower seed yield in the unweeded control may be due to crop-weed competition. The increase in seed yield due to straw mulch was 90.40 % higher than the control and remained comparable to plastic mulch (12). Mulching provided better soil conditions and lesser weed competition, which improves the crop yield than non-mulched soil (5). Among subplots, grain yield (13 q ha^{-1}) was significantly higher in nitrogen (50 kg ha^{-1}) + FYM 15.0 t ha^{-1} than alone nitrogen (25 kg ha^{-1} and 50 kg ha^{-1}) without FYM. Significantly less seed yield (9.8 q ha^{-1}) was found at a nitrogen level of 25 kg ha^{-1} as compared to other treatments. In nitrogen (50 kg ha^{-1}) along with FYM 15.0 t ha^{-1}, seed yield was 24.62 % higher in comparison to 25 kg ha^{-1} dose of nitrogen. Higher levels of nitrogen lead to an increase in the biomass of fennel plants and hence, the growth and yield parameters were significantly increased (16).

Table 3. Effect of weed control treatments and different nitrogen levels 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 (Weed control treatments)		
Plastic mulch (black)	18.4	137.5
One-hand weeding followed by straw mulch	12.5	91.3
Pendimethalin (0.45 kg ha^{-1}) followed by one-hand weeding	14.1	102.8
Unweeded (control)	1.2	1.8
SEm±	0.3	2.2
C.D. at 5 %	1.12	8.89
Sub-plots (Nitrogen levels)		
25 kg N ha^{-1}	9.8	66.9
25 kg N ha^{-1} + FYM 15.0 t ha^{-1}	12.3	88.4
50 kg N ha^{-1}	11.2	83.4
50 kg N ha^{-1} + FYM 15.0 t ha^{-1}	13.0	94.7
SEm±	0.2	2.8
C.D. at 5 %	0.64	8.33
Interaction (A*B) C.D. at 5 %	**1.39**	**NS**

The biological yield was significantly higher in black plastic mulch compared to other weed control treatments. Unweeded treatment reduced biological yield due to unrestricted weed growth, resulting in increased crop-weed competition (17). Among subplots (nutrient levels), the biological yield was significantly higher in the treatment with 50 kg ha^{-1} of nitrogen level + FYM 15.0 t ha^{-1} than in all other nutrient combinations. The results of nitrogen @ 25 kg ha^{-1}+ FYM 15.0 t ha^{-1} were at par with the former treatment. The biological yield was significantly less in 25 kg nitrogen ha^{-1} than in other treatments. The growth and yield attributes like plant height, number of primary, secondary and tertiary branches along the grain and biological yield of fennel improved with enhanced levels of nitrogen. Nitrogen fertilization leads increase in plant metabolism improving food production rate which enables crop to grow quickly, therefore, leads to grow quickly leads to grow quickly increase in plant metabolism, improving the food production rate, which enables crops to grow quickly and, therefore, leads to improved crop yield (18).

The interaction effect of weed control and nutrient combinations on yield was found to be significant (Table 4). The use of plastic mulch along with nitrogen @ 25 kg ha^{-1} + FYM @ 15.0 t ha^{-1} produced seed yield at par with the nitrogen level of 50 kg $ha^{-1}$with plastic mulch. Additionally, nitrogen @ 25 kg ha^{-1} + FYM 15.0 t ha^{-1}, in combination with pre-emergence pendimethalin followed by one-hand weeding, produced significantly higher grain yield than nitrogen @ 50 kg ha^{-1}in combination with hand weeding followed by straw mulch treatment.

Conclusion

The study demonstrated that black plastic mulch effectively reduced weed density and biomass compared to the unweeded (control). The growth and yield parameters were highest in black plastic mulch and lowest in the unweeded treatment. Among the fertilizer treatments, the application of nitrogen @ 50 kg ha^{-1}+ FYM 15.0 t $ha^{-1}$and nitrogen @ 25 kg ha^{-1}+ FYM 15.0 t ha^{-1}showed better results than nitrogen @ 25 kg ha^{-1}. Thus, the application of FYM along with nitrogen levels (25 and 50 kg ha^{-1}) and black mulch can be highly effective for improving the crop yield, which will give more production to the farmers.

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Authors' contributions

MC carried out the field experiment, collected and analyzed the data, participated in sequence alignment and drafted the manuscript. USW participated in the design of the study, supervised the entire research and contributed to compiling the manuscript. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: The authors declare that they have no conflict of interest.

Ethical issues: None

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Table 4. Seed yield (q ha^{-1}) as influenced by weed control methods and nitrogen levels

	25 kg N ha^{-1}	25 kg N ha^{-1} + FYM 15.0 t ha^{-1}	50 kg N ha^{-1}	50 kg N ha^{-1} + FYM 15.0 t ha^{-1}	Mean A
Plastic mulch (black)	17.1	18.8	18.8	19.1	18.4
One-hand weeding followed by straw mulch	9.7	13.6	12.9	13.8	12.5
Pendimethalin (0.45 kg ha^{-1}) followed by one-hand weeding	11.2	15.6	12.2	17.4	14.1
Unweeded (control)	1.0	1.3	0.8	1.8	1.2
Mean B	9.8	12.3	11.2	13.0	
SE(m)	0.32				
C.D. (5 %)	1.39				

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