



SOIL SCIENCE

IMPROVING CROP COMPETITIVE ABILITY OF FENNEL (*FOENICULUM VULGARE* MILL.) AGAINST WEEDS THROUGH INTEGRATION OF SOWING AND WEEDING TECHNIQUES

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ABSTRACT

A field experiment was conducted to improve the crop competitive ability of fennel against weeds under rainfed conditions through integration of different sowing and weeding techniques at University Research Farm Chakwal Road Rawalpindi, Pakistan during the winter seasons of 2020- 21 and 2021-22. There were four methods of sowing (Ridge sowing, bed sowing, broadcast sowing and line sowing) and four methods of weeding (Control, manual, mechanical and chemical). The data was analyzed statistically by using statistics 8.1 software and results showed that weed free plot (two hand weeding at 45 and 75 DAS) was found more effective to control weeds in fennel and recorded lowest weed density, weed dry weight and highest weed mortality and weed control efficiency. Weed mortality percentage (29.3 %) and weed control efficiency (81.8 %) was maximum in manual weeding method and they were found non-significant in sowing methods. In case of production the maximum yield of fennel (493.1 kg/ha) was observed under line sowing method and minimum (64.3 kg/ha) in ridge sowing whereas, in case of weeding methods the maximum yield (509.9 kg/ha) was recorded in manual weeding method and minimum (220.7 kg/ha) under weedy check plot. Similarly, the benefit cost ratio (1.98 & 1.90) and net profitability (98.13 % & 89.88 %) was higher in line sowing method and manual weeding method respectively. So, line sowing with manual weeding method is recommended to decrease the crop weed competition under rainfed conditions for obtaining higher yield of fennel.

KEYWORDS: *Foeniculum vulgare* mill; sowing methods; weeding methods; weed control; efficiency; yield; economics; Pakistan



INTRODUCTION

Agriculture is essential not only for food supply but also for the provision of raw materials for further industries such as sugar, textiles, vegetable oils, medicinal and spices. Agriculture is a profession for people as well as a way of life. Fennel (*Foeniculum vulgare* Mill.) has numerous medicinal usages. It is used to treat heartburn, intestinal gas, bloating, lack of appetite, and baby colic. The various chemical components in the fennel plant provide it significant qualities (Kooti *et al.*, 2015). Fennel contains anethole (33.94%) which have a sweet aroma and it is an organic compound and broadly used as a flavoring substances. The apiaceae family includes fennel, often known as 'Saunf' (Khorshidi *et al.*, 2010). It is cultivated for medicinal, sweet-smelling and economic value. Sauces, pickles, perfumes, scenting soaps, and medicinal sectors all utilize fennel fruit. It is also used to treat coughs and infections of the upper respiratory tract.

Farmers in Pakistan grow fennel on a limited scale for home use. Fennel seeds include source of nutritional fiber, anti- oxidant capacity, essential oils having digestive, carminative, and anti-flatulent qualities are found in compounds that assist to release congestion (Liu *et al.*, 2021). Due to fennel deficiency, Pakistan imported fennel 22243 tons in 2017, 23676 tons in 2018 and 22237 tons in 2019 (FAO, 2021). The roots, stems, and leaves of the fennel plant, particularly the seeds, are fragrant and may be utilized in a several methods (Badgujar *et al.*, 2014).

Due to a lack of water, fennel has not been grown in Pakistan's rainfed areas. In Pakistan agriculture sector is facing many challenges such as deficiency of organic matter in soil, shortage of water in Pothwar region and nutrient deficiency in soil. In rainfed areas of Pakistan water scarcity and climate change threaten farming through increased susceptibility to droughts and further extremes of weather conditions. Along with different

unfavorable weather situation and climate extreme events, drought is a major abiotic factor that affects crop yields. Plant growth and development are harmed by it. Grain yield is also decreased by the drought stress. It decreases the plant height and damages the grain yield of crop.

Fennel is mostly cultivated in irrigated areas of Pakistan. In Pakistan, fennel is not grown on a commercial basis. Fennel is only grown for home consumption. The product gained from certain small-scale farming is insufficient to fulfill the national need and close the gap between supply and demand (Ayub *et al.*, 2008). Cultivation strategies such as sowing method, plant density, and harvesting date have influenced the fennel production and quality (Moosavi *et al.*, 2014). The method of sowing is seen to be the most essential that can increase the yield. In 2000-01, Pakistan bought 33,768 kg of fennel seed from India, valued Rs.1.378 million.

Infestation of weeds is the main aspect of crop yield reduction. Weeds may reduce the yield. Weeds grow quickly as compared to crop and compete for water, light and nutrients. Weeds are more toxic and dangerous in rainfed areas of Pakistan as compared to other pests. It reduces the plant production. Weed management strategies are aimed at increasing the crop's capacity to compete against weeds, either directly or indirectly. When compared to alternative weed management methods, herbicides typically provide a three to fourfold economic return (Ngow *et al.*, 2020). Herbicide treatment has been proven to successfully suppress weeds while also increasing seed production by 43.2 to 86.9%, according to studies (Patel *et al.*, 2017).

The general objective of this study was to improve the crop competitive ability of fennel against weeds under rainfed conditions through integration of different sowing and weeding techniques at University Research Farm Chakwal Road Rawalpindi, Pakistan. Other specific objectives were to analyze the effect of different sowing and weeding methods on growth and productivity of fennel under rainfed conditions.

MATERIALS AND METHODS EXPERIMENTAL SITE

The experiment was conducted at University Research Farm Chakwal Road Rawalpindi, Pakistan located at 33.116° N latitudes and 73.0111° E longitudes.

MATERIALS AND METHODS

This experiment was sown on 15th of November during the winter 2020-21 and 2021-22 and on 1st November in 2021-22. There were four methods of sowing (Ridge sowing, bed sowing, broadcast sowing and line sowing) and four methods of weeding (Control, manual, mechanical and chemical). Therefore, the experiment

consisted upon 16 treatments with three replications. A split plot design was used for experimentation. Sowing methods were retained in the major plots, while weeding methods were kept in the sub plots. The distance was 45 cm in line sowing, ridge sowing and bed sowing and P×P distance was maintained 20 cm in all ridges, beds and line sown plots. There was one meter path between each replication. Net plot size of each treatment was 21 m² having 6 × 3.5 m. Gross plot size was 1342 m² having 22 m width and 61 m length. The recommended seed rate of fennel was used @ 10-12 kg/ha. At the time of sowing, the entire dose of phosphorus and nitrogen was applied @ 56:86 kg/ha, respectively. Different parameters on weeds, crop and economics were studied. Randomly ten plants were chosen from each plot and recorded the crop data of number of branches per plant, number of umbels per plant and number of seeds per umbel. Weed density, plant population, crop growth rate, biological yield and grain yield were recorded by putting a quadrat of 1m² at three random places in each plot. By using formula weed mortality percentage and weed control efficiency was calculated. For different inputs and outputs in economic analysis, current market prices were used. Harvesting was done on 25th of May in 2020-21 and on 15th of May in 2021-22. All other agronomic practices were applied uniformly. Weather data was collected from the nearest meteorological observatory located at SAWCRI (Soil and Water Conservation Research Institute) Chakwal. The data recorded of the different parameters was subjected to the analysis of variance to determine the significance of differences between treatments. Least significant difference (LSD) of the means was also calculated at 5% probability level using Statistics 8.1 software package (Steel & Torrie, 1980).

Treatments methods of sowing

S1= Ridge Sowing S2= Bed Sowing

S3= Broadcast Sowing (Control) S4= Line Sowing

Methods of weeding

W1= Control (Weedy check plot) W2= Manual (Twice hoeing)

W3= Mechanical (Twice inter-cultivation)

W4= Chemical (Once pre emergence spray of herbicide (Pendimethaline)/ Stomp)

Soil sampling: The soil sampling was done before the start of the experimental study for soil testing and analysis of different physiochemical properties of soil. The sampling was done from two soil depths i.e. 0-15, and 15-30 cm with the help of soil sampler. 3 samples were collected from each depth and different locations of experimental field and composite samples were made for each soil depth and that composite samples were used for soil testing.

RESULTS AND DISCUSSION

Physiochemical properties of soils: The research was carried out at University Research Farm, Chakwal Road Rawalpindi, during Rabi season of 2020-21 and 2021-22 on loamy soil series having

E.C. 3.0 dSm-1 and 2.7 dSm-1, pH 8.3 and 8.2, available phosphorus 7.8 mg/kg and 6.8 mg/kg, available potassium 132 and 130, organic matter 0.76% and 0.55% at 0-15 cm and 15-30 cm soil depth. The soil was having E.C. 3.1 dSm-1 and 2.9 dSm-1, pH 8.0 and 7.9, available phosphorus 7.9 mg/kg and 7.2 mg/kg, available potassium 144 and 138, organic matter 0.81% and 0.63% at 0-15 cm and 15-30 cm soil depth in 2021-22 (Table 1).

Weather data of experimental period Data regarding mean temperature (Orange line) and total rainfall (blue column) of experimental period during 2020-21 has been shown in (Fig. 1-a). It was observed that mean temperature was increased up to 26.8°C in the month of May during experimental period while the lowest temperature was recorded in the month of January, i.e., 9.05°C. Maximum rainfall of whole growing season in 2020-21 was recorded 65.8 mm in the month of March while no rainfall was recorded in the month of October.

Similarly, data regarding mean daily temperature and total rainfall during experimental period of 2021-22 has been shown in (Fig. 1-b). It was observed that mean temperature was increased up to 29.95°C in the month of May during experimental period while the lowest temperature was recorded in the month of January, i.e., 9.8°C. Maximum rainfall of whole growing season in 2021-22 was recorded 73.7 mm in the month of January while no rainfall was recorded in the month of November and December.

Effect on weeds: Predominant weeds in experimental fennel field were: *Euphorbia heliophila*, *Rumex dentatus*, *Chenopodium album*, *Avena fatua*, *Phalaris minor*, *Convolvulus arvensis* and *Cirsium arvense* (Table 2).

The year-wise effect of sowing and weeding methods on weeds has been depicted in Table (3). In pooled data of two years (Fig. 2a, b, c, d, e, f, g & h) all the treatments significantly reduced the density and dry weight of weeds compared to control. However, the minimum density of weeds was recorded in manual weeding (6.15) and ridge sowing (18.2) method and similarly the dry weight was also minimum under manual weeding (1.15 g) and ridge sowing (2.9 g)

Table 1. Physiochemical properties of experimental soil in 2020-21 and 2021-22

Years	Depth	Ph	EC (dSm ⁻¹)	Phosphorus (mg/kg)	Potassium (mg/ kg)	Organic matter	Texture
2020-21	0-15 cm	8.3	3	7.8	132	0.76	Loamy
	15-30 cm	8.2	2.7	6.8	130	0.55	Loamy
	0-15 cm	8.0	3.1	7.9	144	0.81	Loamy
2021-22	15-30 cm	7.9	2.9	7.2	138	0.63	Loamy

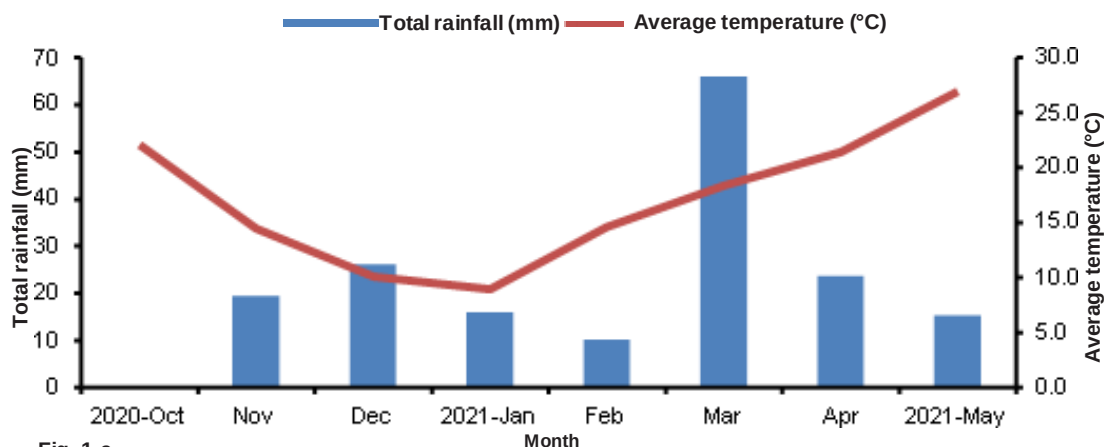


Fig. 1-a.

Temperature and rainfall data during experimental season in 2020-21

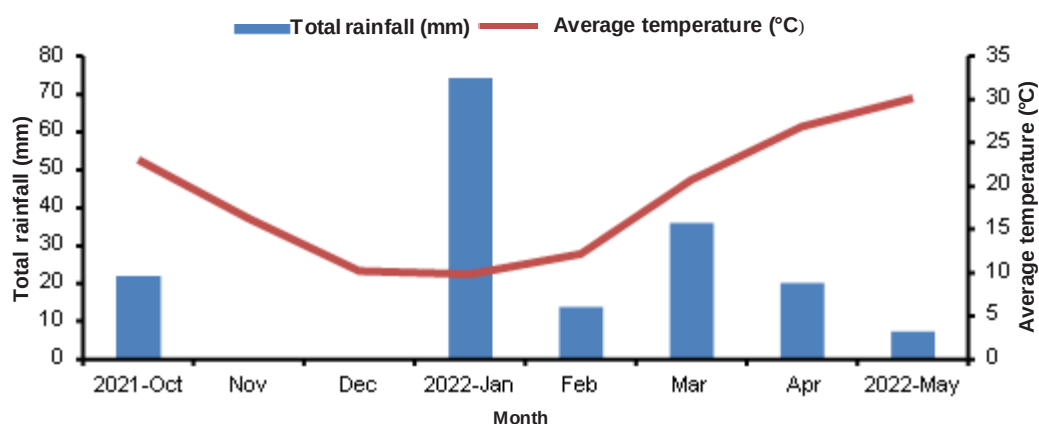


Fig. 1-b. Temperature and rainfall data during experimental season in 2021-22

Table 2. Scientific classification of weeds prevailing at the experimental site

English Name	Botanical Name	Family	Order	Genus	Species
Sun spurge	<i>Euphorbia helioscopia</i>	Euphorbiaceae	Malpighiales	<i>Euphorbia</i>	<i>E. helioscopia</i>
Toothed dock	<i>Rumex dentatus</i>	Polygonaceae	Caryophyllales	<i>Rumex</i>	<i>R. dentatus</i>
Wild spinach	<i>Chenopodium album</i>	Amaranthaceae	Caryophyllales	<i>Chenopodium</i>	<i>C. album</i>
Wild oat	<i>Avena fatua</i>	Poaceae	Poales	<i>Avena</i>	<i>A. fatua</i>
Bunchgrass	<i>Phalaris minor</i>	Poaceae	Poales	<i>Phalaris</i>	<i>P. minor</i>
Bindweed	<i>Convolvulus arvensis</i>	Convolvulaceae	Solanales	<i>Convolvulus</i>	<i>C. arvensis</i>
Creeping thistle	<i>Cirsium arvense</i>	Asteraceae	Asterales	<i>Cirsium</i>	<i>C. arvense</i>

method respectively. Whereas maximum weed density was recorded in weedy check plot (49.95) and broad cast sowing method (19.35) and dry weight was maximum under weedy check plot (6.1 g) and line sowing method (3.4 g) respectively. This lower density and dry weight in manual weeding might be due to the efficient control of weeds through manual weeding as the weeds are directly hoed and pulled by identifying weeds plants physically and likewise the ridge sowing method might have suppressed the weeds due to less availability of rain water to the weeds on ridges. Similar findings regarding weeds density were obtained by (Mamatha, 2021; Kumar, 2017) who stated that the minimum number of weeds were recorded in hand weeding treatment and maximum number of weeds were recorded in weedy check plot. Similarly, regarding dry weight, Kumar (2017) stated that the minimum weed dry weight was recorded in hand weeding treatment and maximum weed dry weight was recorded in weedy check plot due to the maximum growth of weeds.

Likewise, highest mean weed mortality percentage (29.3 %) and weed control efficiency (81.8 %) were

observed under manual weeding method and lowest (- 207) and (45.65) in chemical weeding method (Table- 3, Fig. 3a, b, c, d). In case of sowing methods weed mortality percentage and weed control efficiency was non-significant. The highest control efficiency and mortality in manual weeding might be attributed to weed free plot that was kept manually. The minimum weeds mortality and control efficiency in chemical treatment might be due to the reason that we had applied chemical treatment only as pre-emergence spray but post emergence chemical treatment was not applied due to unavailability of post emergence herbicide for the studied crop in the market. Similar findings were recorded by (Kumar, 2017) who stated that the highest weed-control efficiency (WCE) was recorded in hand weeding treatment as the plots were manually kept free from weeds.

Effect on crop parameters: The year wise effect of sowing and weeding methods has been depicted in Table (4 & 5). The mean data of two years about crop parameters (Fig. 3a, b, c, d, e, f, g, h, i, j, k, l, m, n, o, p) showed that the maximum plant population (13.4),

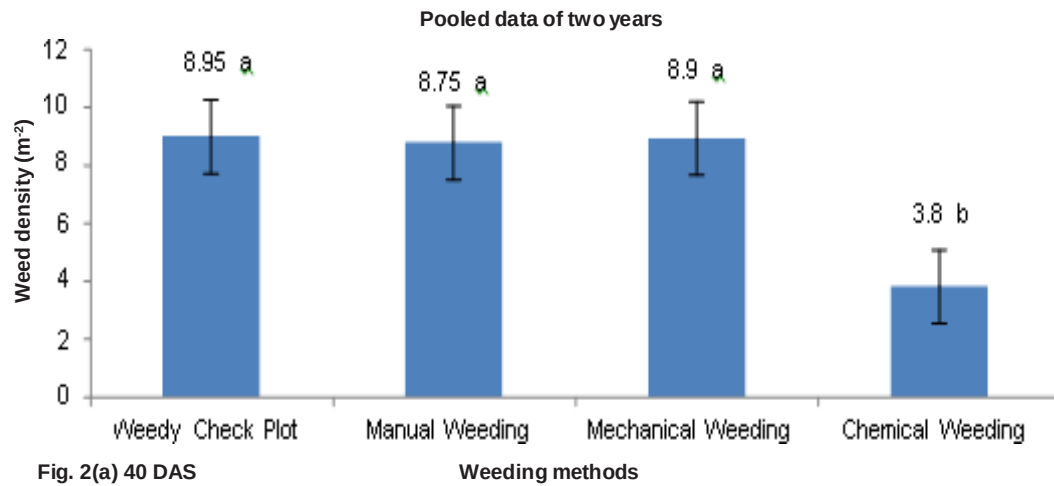


Fig. 2(a) 40 DAS

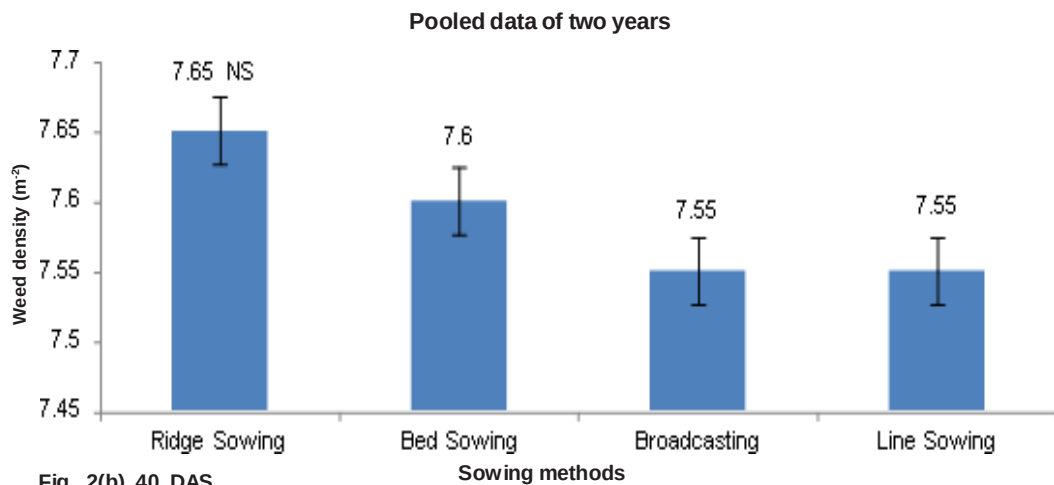


Fig. 2(b) 40 DAS

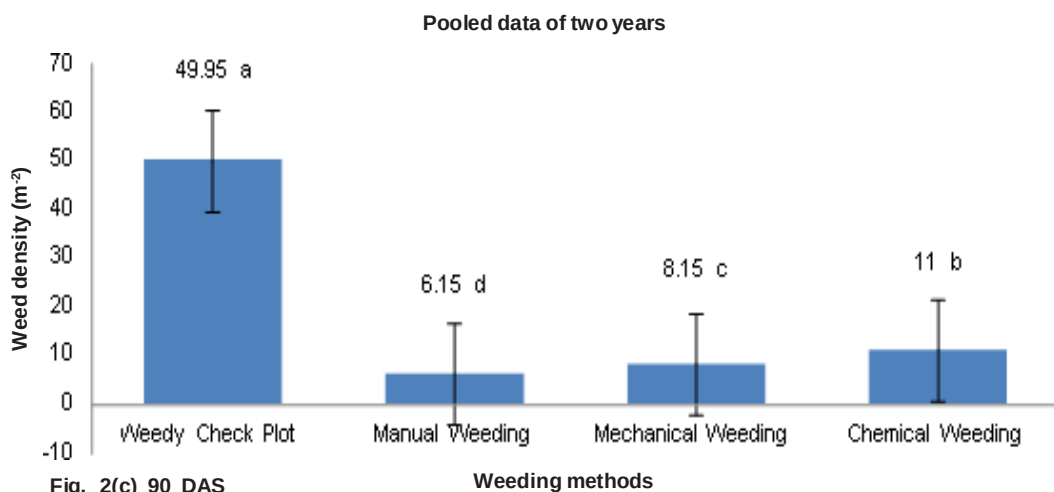
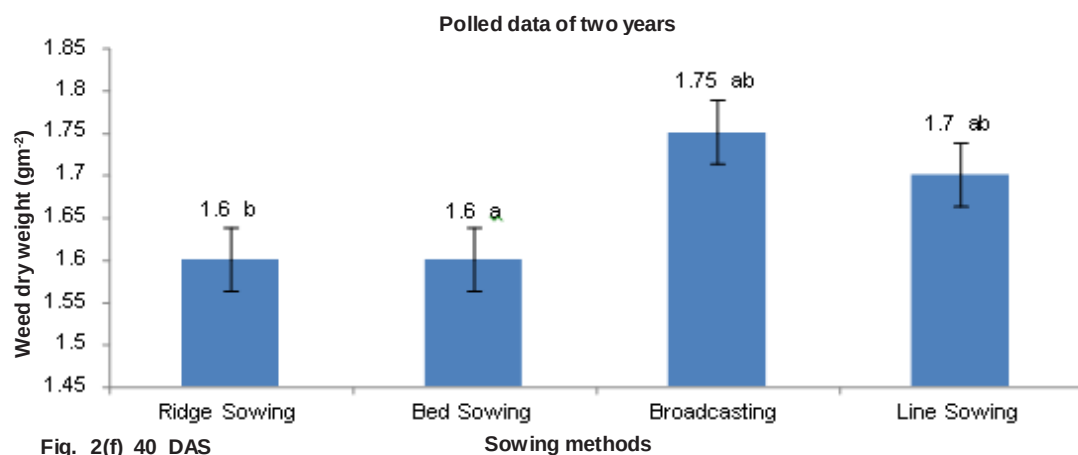
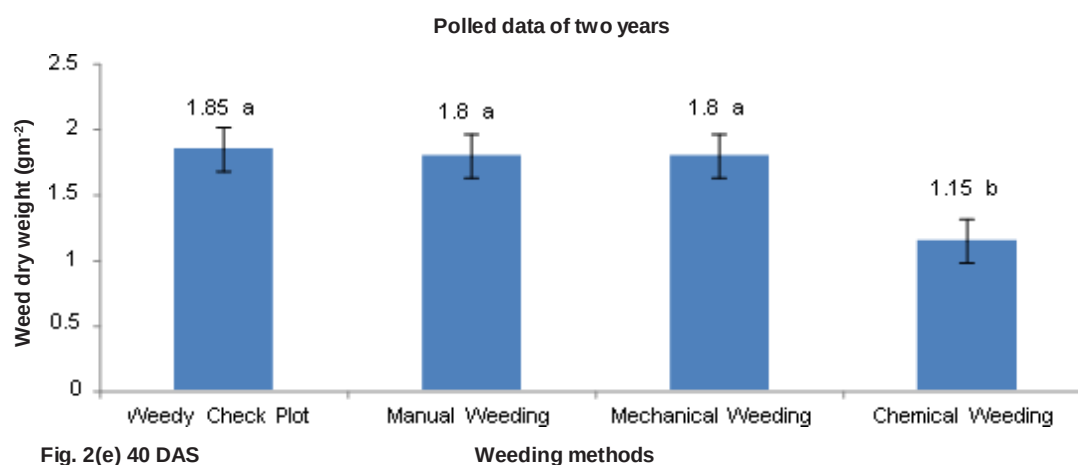
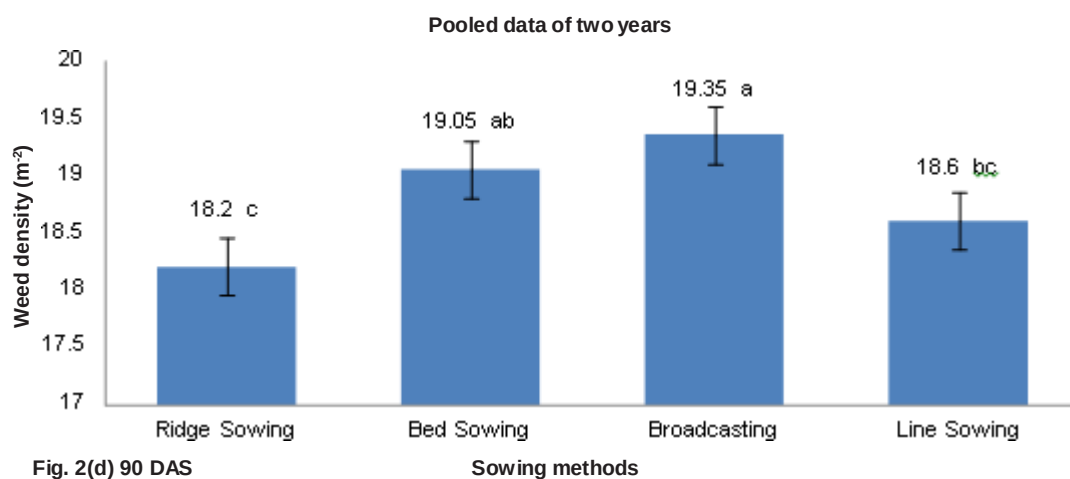


Fig. 2(c) 90 DAS



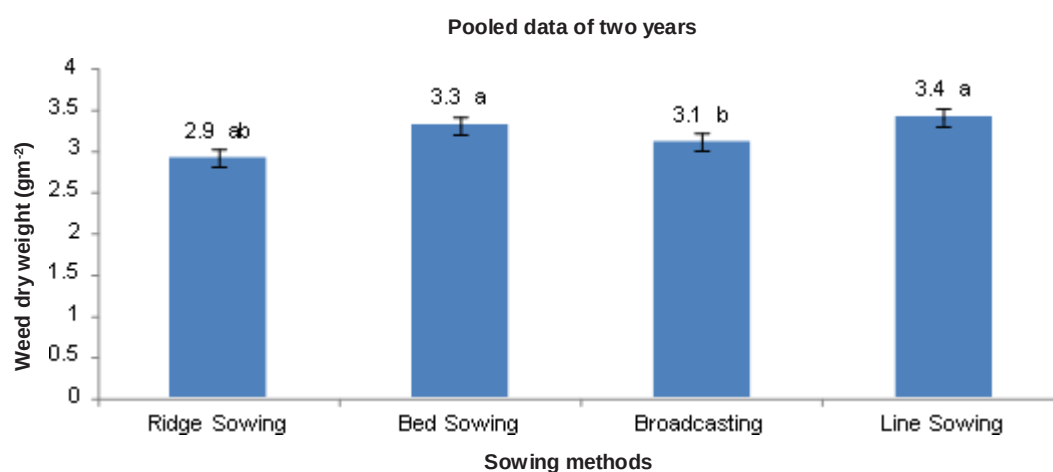
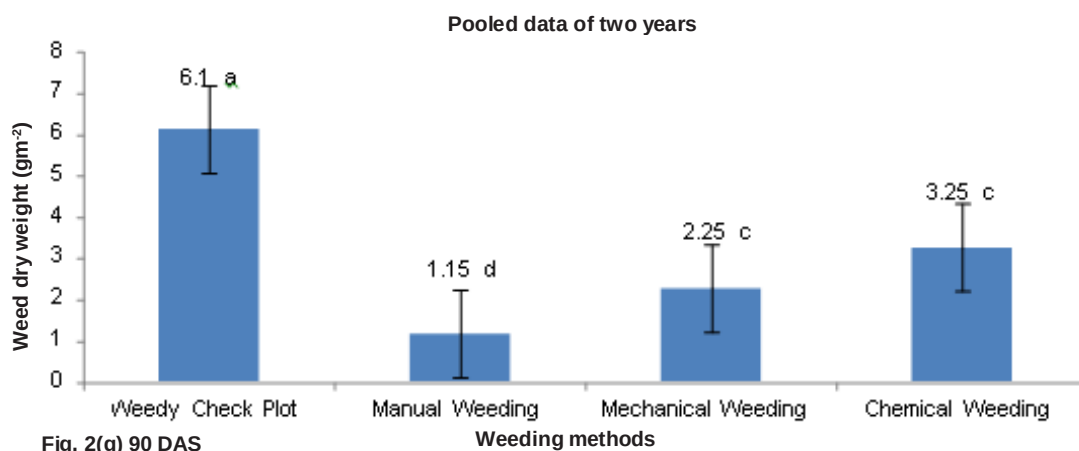


Fig. 2: Mean weed density (m⁻²) and dry weight (g) as affected by different weeding and sowing methods

Table 3. Effect of different sowing and weeding methods on weeds control in fennel

	Weed density (m-2) 40 DAS		Weed density (m-2) 90 DAS		Weeds dry weight (g) 40 DAS		Weeds dry weight (g) 90 DAS		Weed mortality percentage (%)		Weeds control efficiency (%)	
	2020- 21	2021- 22	2020- 21	2021- 22	2020- 21	2021- 22	2020- 21	2021- 22	2020-21	2021-22	2020-21	2021-22

Sowing Methods												
Ridge sowing	8.0 NS	7.3 NS	21.3 b	15.1 a	1.8 NS	1.4 NS	1.8 NS	1.4 NS	-196.3NS	-109.9 NS	62.7 NS	61.9 NS
Bed sowing	8.1	7.1	22.7 ab	15.4 a	1.8	1.4	1.8	1.4	-190.2	-123.0	63.4	62.4
Broadcast	7.8	7.3	23.4 a	15.3 a	2.0	1.5	2.0	1.5	-217.1	-116.7	63.3	70.1
Line sowing	8.0	7.1	22.9 a	14.3 b	2.0	1.4	2.0	1.4	-189.3	-106.8	51.4	74.0

Weeding Methods

Weedy Check Plot	9.6 a	8.3 a	64.0 a	35.9 a	2.1 a	1.6 a	7.1 a	5.1 a	-	-	-	-
Manual	9.3 a	8.2 a	6.5 d	5.8 d	2.0 a	1.6 a	1.3 d	1.0 c	30.2 a	28.5 a	81.8 a	81.8 a
Mechanical	9.6 a	8.2 a	8.2 c	8.1 c	2.0 a	1.6 a	2.7 c	1.8 b	15.7 a	3.8 b	63.8 b	63.5 b
Chemical	3.4 b	4.2 b	11.7 b	10.3 b	1.3 b	1.0 b	4.4 b	2.1 b	-263.0 b	-151.0 c	35.2 c	56.1 c

NS= NON-SIGNIFICANT

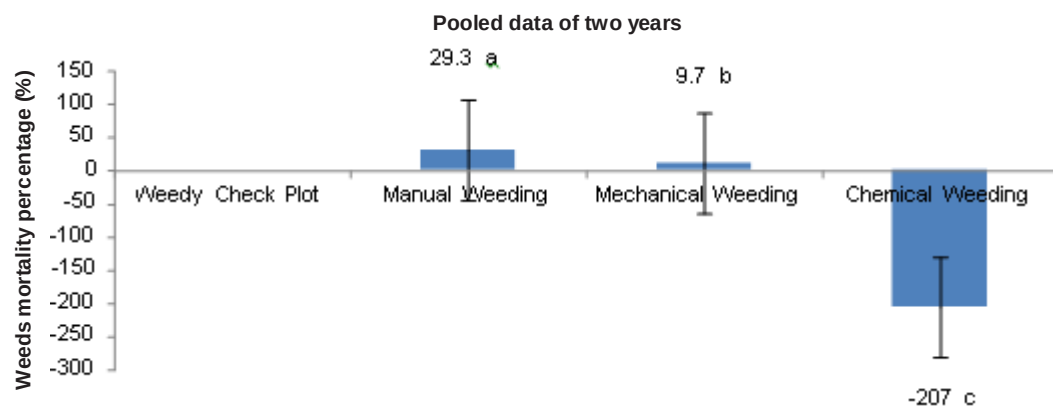


Fig. 3(a)

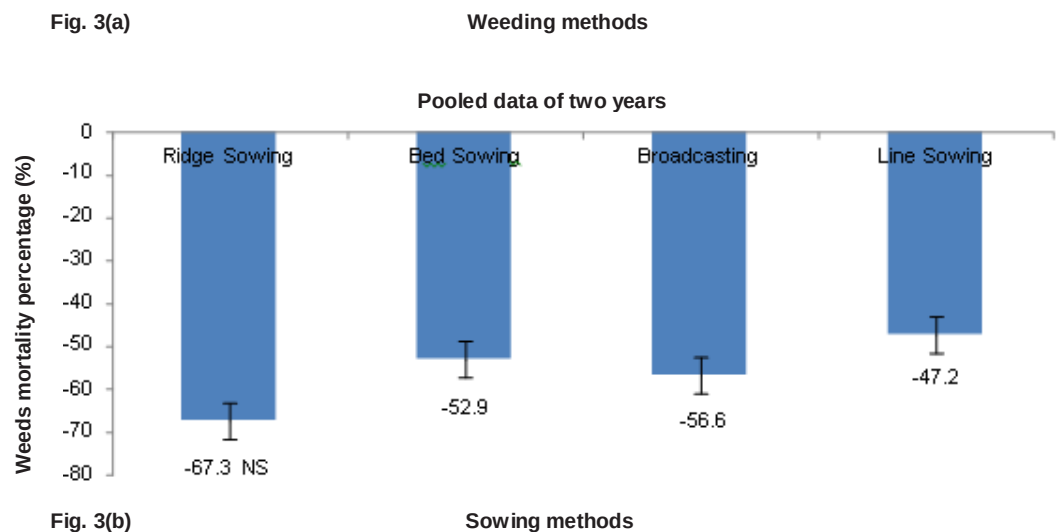


Fig. 3(b)

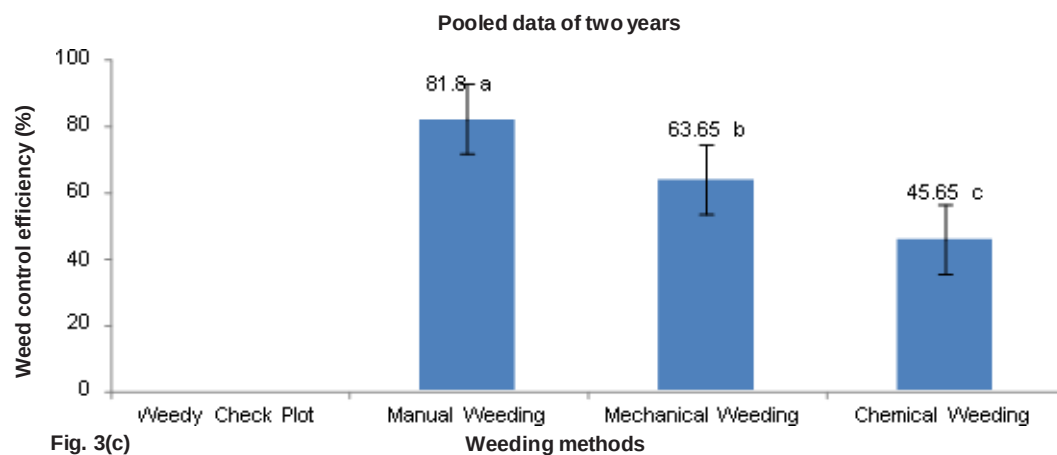


Fig. 3(c)

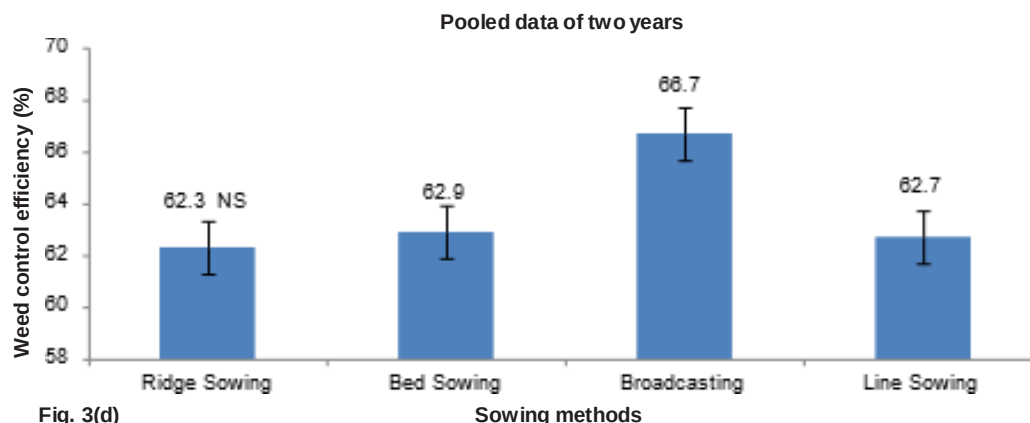


Fig. 3(d) Sowing methods
Fig. 3. Mean weed mortality (%) and weeds control efficiency (%) as affected by different sowing and weeding methods

number of branches per plant (17.85), number of umbels per plant (17.5), crop growth rate ($0.22 \text{ gm}^{-2} \text{ day}^{-1}$), seeds per umbel (17.5), thousand seed weight (8.35 g), biological yield (5103.2 kg/ha) and grain yield (599.9 kg/ha) were recorded under manual weeding method and lowest (13.05, 9.1, 6.3, $0.08 \text{ gm}^{-2} \text{ day}^{-1}$, 19.85, 7.7 g, 625.1 kg/ha and 64.3 kg/ha) in weedy check plots respectively. The plant population and thousand seed weight of manual weeding was statistically at par with mechanical and chemical weeding methods. These higher values for manual weeding may be attributed to the best weed control efficiency and mortality percentage of this method and lower weed crop competition which ultimately did not permit the nutrients and other natural resources to be consumed by the weeds and made directly available to the crop plants. Similar findings were obtained by (Mamatha *et al.*, 2021; Kumar *et al.*, 2017), who stated that the maximum number of branches and number of umbels per plant was recorded in hand weeded plot and lower in weedy check plot. Similar results were researched out by Choudhary *et al.* (2022) who claimed that the manual weeding method produced highest biological yield and grain yield but weedy check plot produced lowest biological yield and grain yield due to the higher weeds crop competition.

Similarly, in case of sowing methods, maximum number of branches per plant (15.4), number of umbels per plant (14.65), crop growth rate ($0.195 \text{ gm}^{-2} \text{ day}^{-1}$), seeds per umbel (66.85), biological yield (4156.35 kg/ha) and grain yield (509.9 kg/ha) was recorded under line sowing method but plant population was maximum (19.2) under broad casting method. Whereas, thousand seed weight was non-significant. Here the number of branches of line sowing method was also statistically at par with ridge and bed sowing methods. However, minimum number of branches per plant (13.95), number of umbels per plant (12.8) and seeds per umbel (59.35) were observed under broad casting method.

Whereas, minimum plant population (8.8), crop growth rate ($0.105 \text{ gm}^{-2} \text{ day}^{-1}$), biological yield (2475.6 kg/ha) and grain yield (220.7 kg/ha) were recorded under ridge sowing method but thousand seed weight was found non-significant. The higher number of branches per plant, number of umbels per plant, crop growth rate, seeds per umbel, biological yield and grain yield in line sowing may be due to balanced availability of rainfall and other natural resources to the crop plants whereas they might be fluctuated in other sowing methods due to unlevelled seed bed. Even the plant management measures were efficiently applied in line sowing method also. The lower plant population in all sowing methods compared with broadcasting might be due to the maintenance of plant to plant distance in line sowing, ridge sowing and bed sowing method by thinning. Similar results were researched out by (Ayub *et al.*, 2008), who also claimed that the number of plants and number of umbels per plant was highest under broadcast method and the number of seeds per umbel, biological yield and grain yield was significantly higher in line sowing method but the effect of sowing methods was non-significant on 1000 seed weight.

Effect on economics: While considering the economic returns, the year wise effect of sowing and weeding methods has been depicted in Table (6). The mean data of two years about benefit cost ratio and net profitability (Fig. 5a, b, c, d, e, f) showed that the maximum mean benefit cost ratio (1.98) of fennel was observed in line sowing method and minimum (0.79) in ridge sowing method. Similarly, in case of net profitability the maximum net profitability (98.13 %) of fennel was observed in line sowing method and minimum (-21.01 %) in ridge sowing method. The higher benefit cost ratio and net profitability under line sowing may be due to higher grain yield and other supporting attributes in line sowing which ultimately resulted in the higher availability of natural resources and fertilizers under flat sown crop and conversely

Table 4. Effect of different sowing and weeding methods on growth of fennel

	Plant Density (m-2)		Number of Branches per Plant		Umbels per Plant		Crop growth rate (gm ² day ⁻¹)	
	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22
Sowing methods								
Ridge sowing	8.8 c 12.5 b	8.8 c 13.0 b	15.2 a 15.5 a	14.9 a 14.6 a	14.6 b 14.1 bc	13.7 a 13.2 a	0.10 c 0.15 b	0.11 c 0.16 b
Bed sowing	19.3 a	19.1 a	14.2 b	13.7 b	13.8 c	11.8 b	0.14 b	0.15 b
Broadcast Line sowing	12.6 b	13.2 b	15.8 a	15.0 a	15.3 a	14.0 a	0.18 a	0.21 a
Weeding methods								
Weedy checkPlot	12.8 NS	13.3 NS	10.3 d	7.9 d	7.3 d	5.3 d	0.07 d	0.09 D
Manual	13.5	13.3	17.9 a	17.8 a	18.3 a	16.7 a	0.21 a	0.23 A
Mechanical	13.4	13.7	15.7 c	15.6 c	15.6 c	15.0 c	0.12 c	0.12 C
Chemical	13.3	13.8	16.8 b	16.9 b	16.8 b	15.7 b	0.16 b	0.18 B

NS= NON-SIGNIFICANT

Table 5. Effect of different sowing and weeding methods on yield and productivity of fennel

	Seeds per umbel		1000 seed weight (g)		Biological yield (kg/ha)		Grain yield (kg/ha)	
	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22
Ridge sowing	59.9 b	68.1 b	8.2 NS	8.2 NS	2540.4 d	2410.8 c	226.4 d	215.0 d
Bed sowing	59.0 b	68.0 b	8.2	8.2	3836.1 b	3638.1 b	411.1 b	467.4 b
Broadcast	55.6 c	63.1 c	8.1	8.1	3609.2 c	3490.0 b	364.0 c	381.1 c
Line sowing	62.6 a	71.1 a	8.2	8.2	4188.0 a	4194.7 a	504.6 a	559.8 a
Weeding methods								
Weedy check plot	19.6 d	20.1 d	7.6 b	7.8 b	602.7 d	647.5 d	59.63 d	69.00 d
Manual	73.8 a	84.7 a	8.4 a	8.3 a	5150.6 a	5055.8 a	589.26 a	610.50 a
Mechanical	71.3 c	82.3 c	8.4 a	8.3 a	3992.2 c	3704.4 c	374.82 c	440.08 c
Chemical	72.4 b	83.4 b	8.4 a	8.3 a	4428.1 b	4325.8 b	482.35 b	503.75 b

NS= NON-SIGNIFICANT

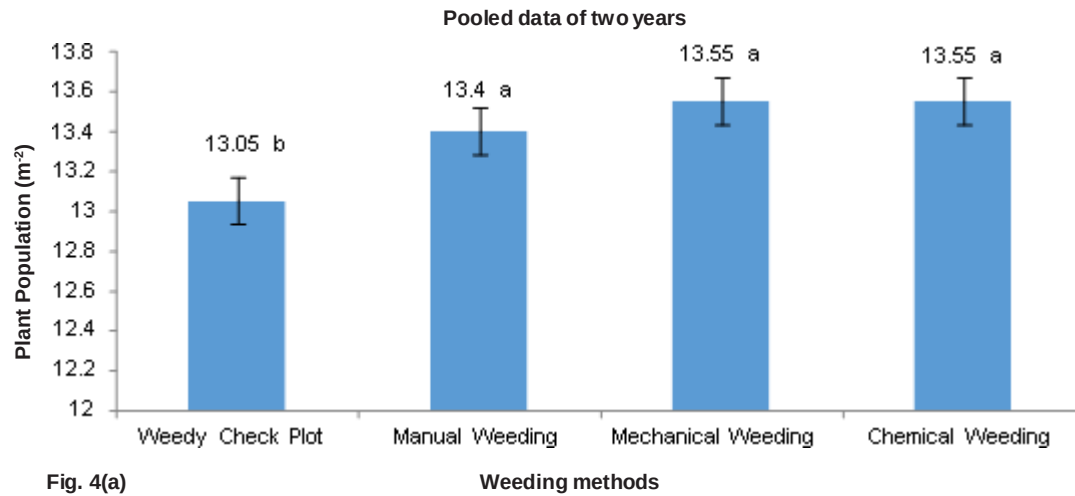


Fig. 4(a)

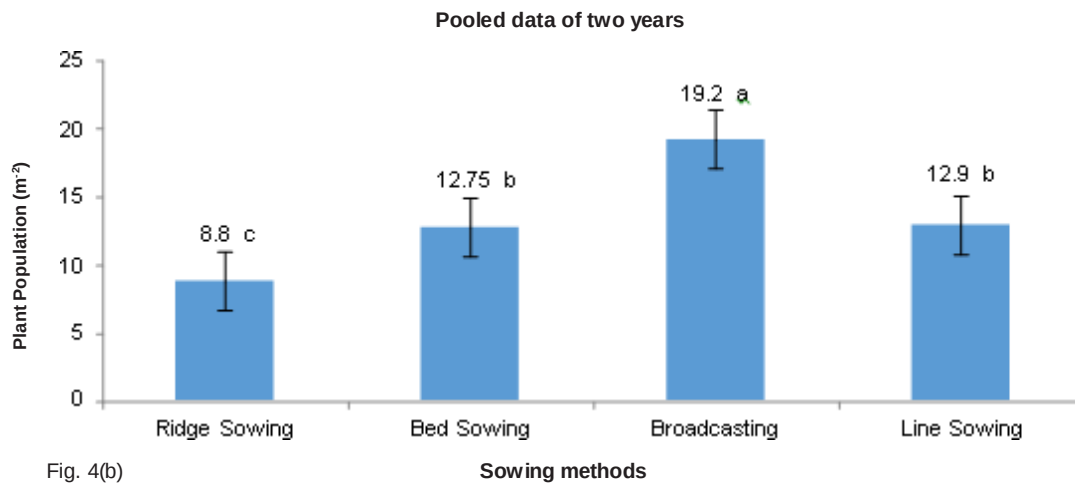


Fig. 4(b)

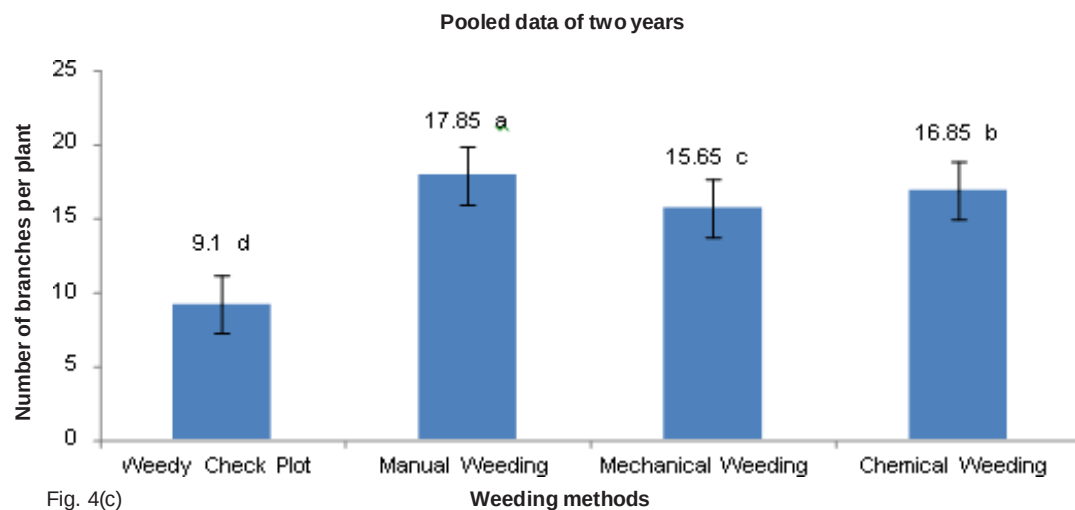
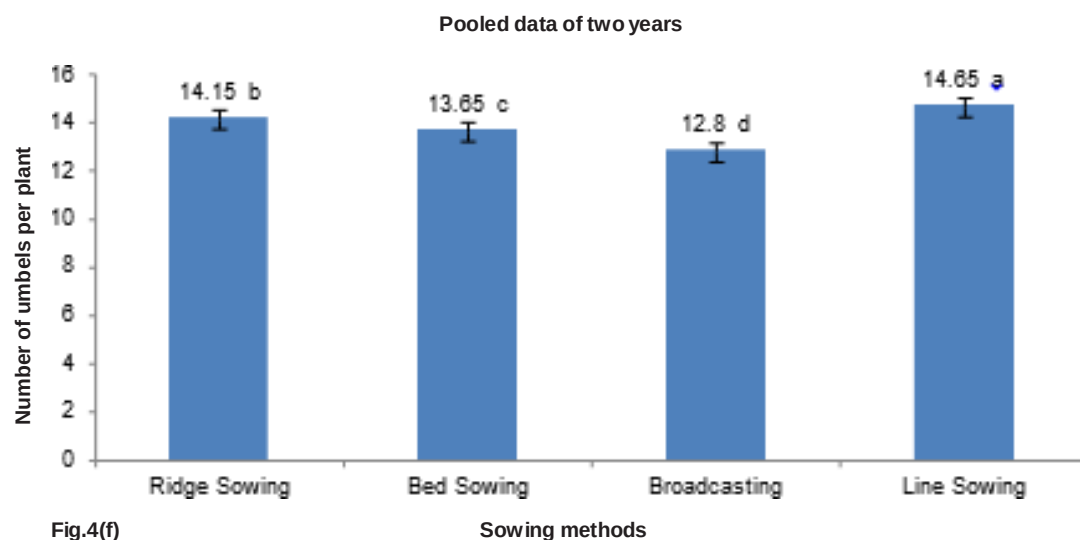
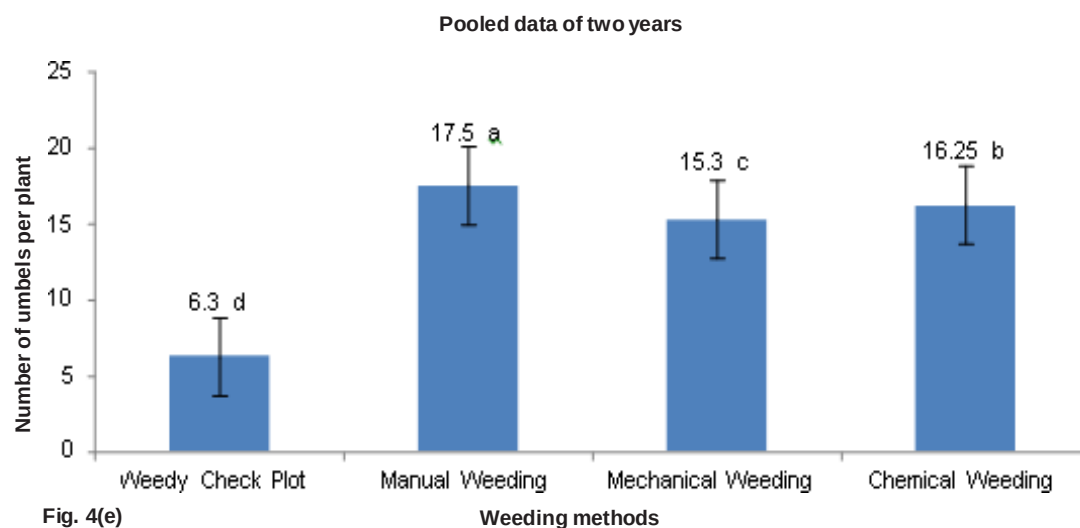
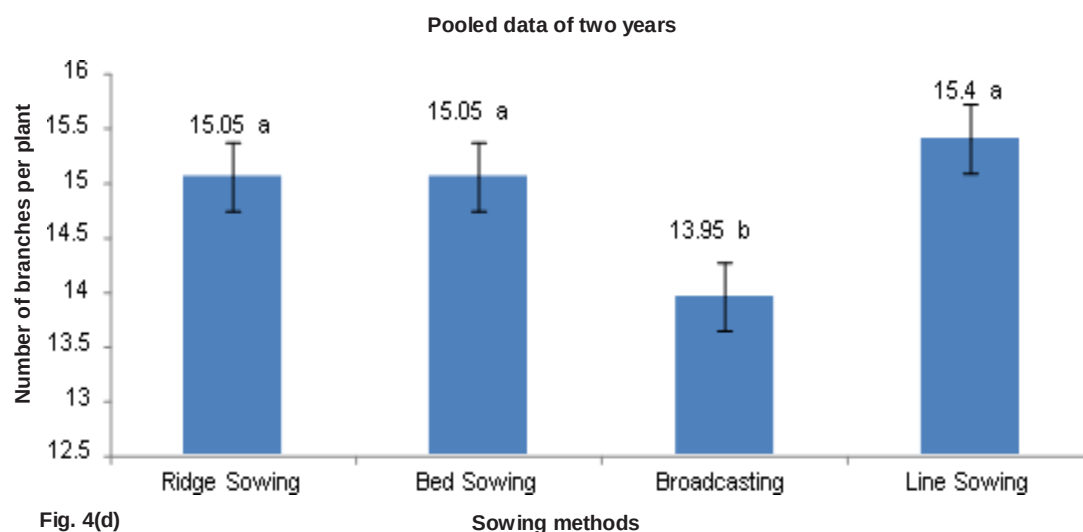


Fig. 4(c)



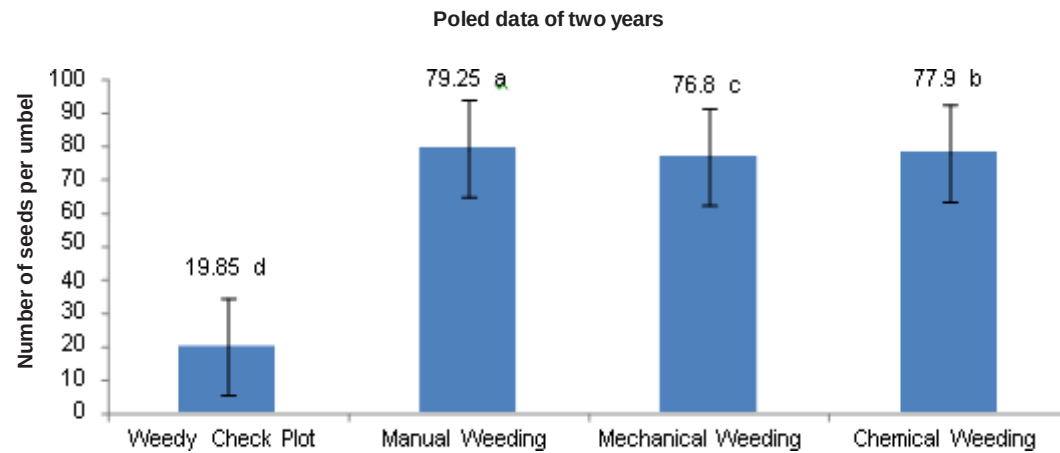


Fig. 4(g)

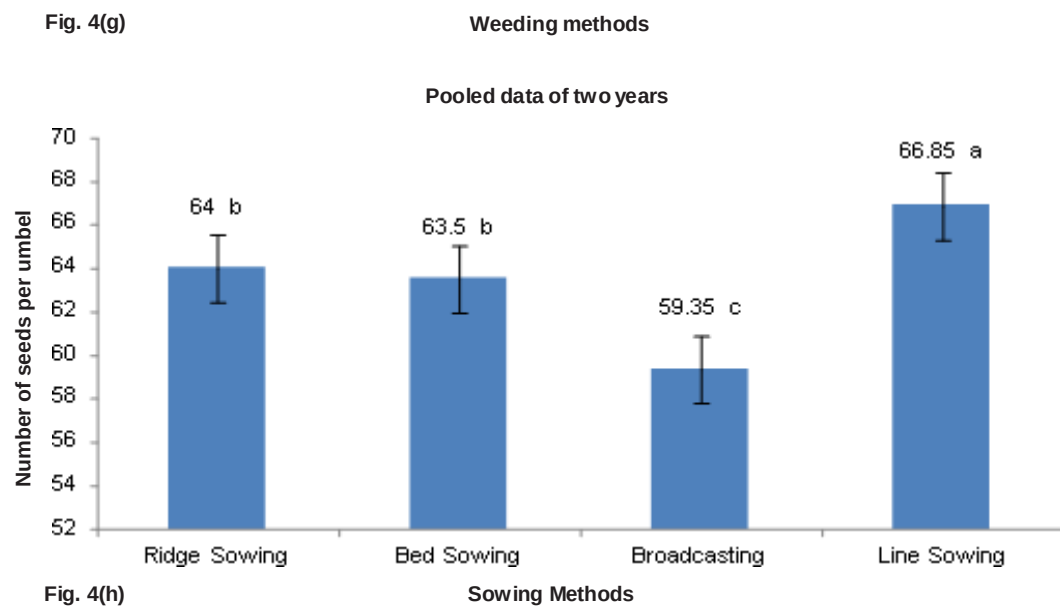


Fig. 4(h)

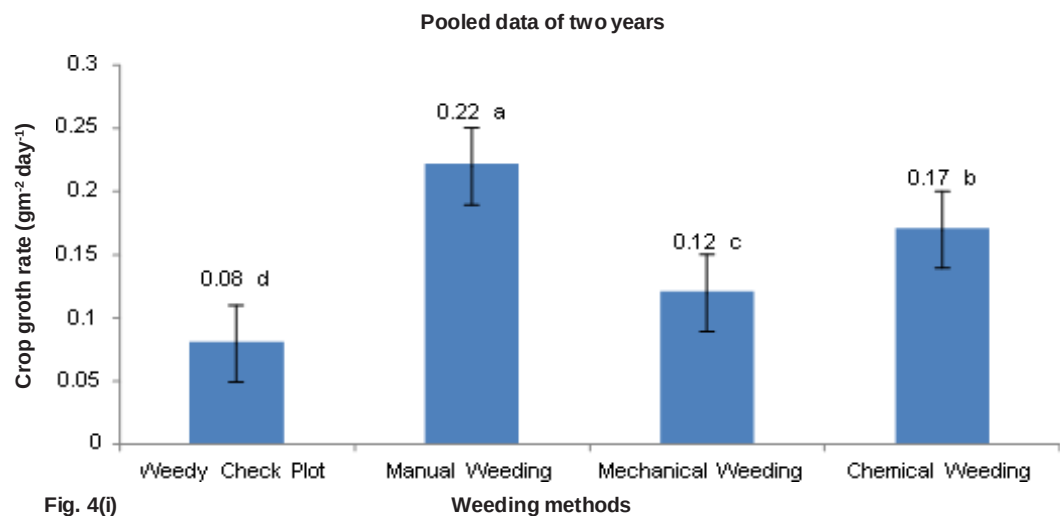
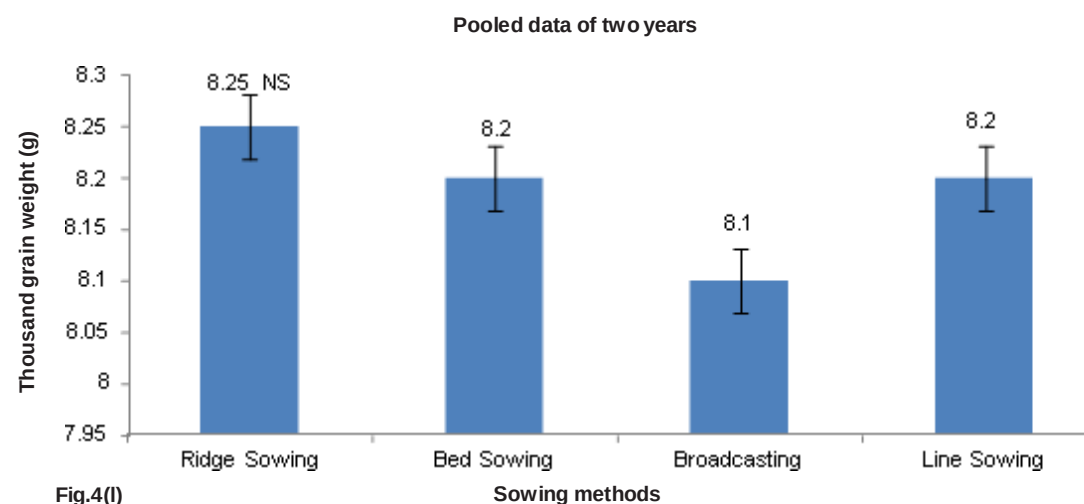
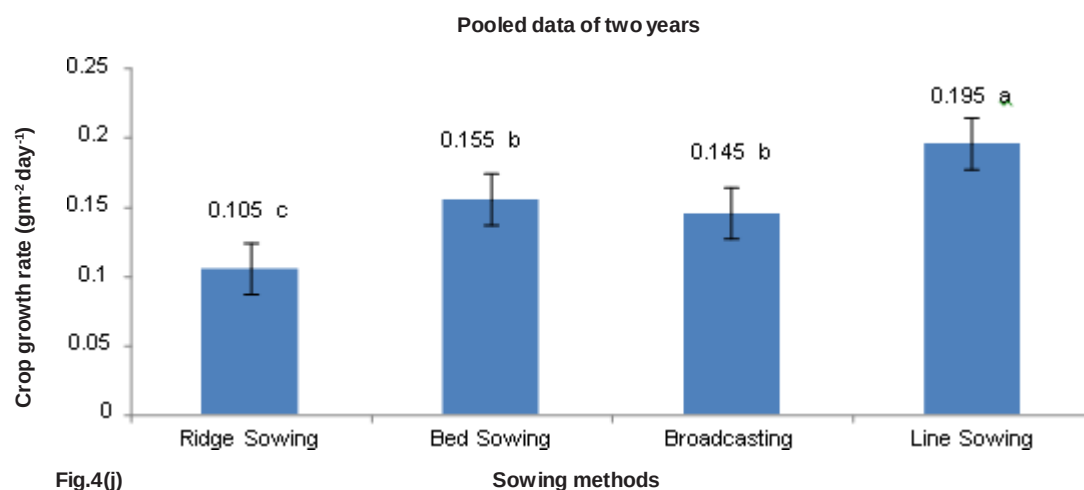


Fig. 4(i)



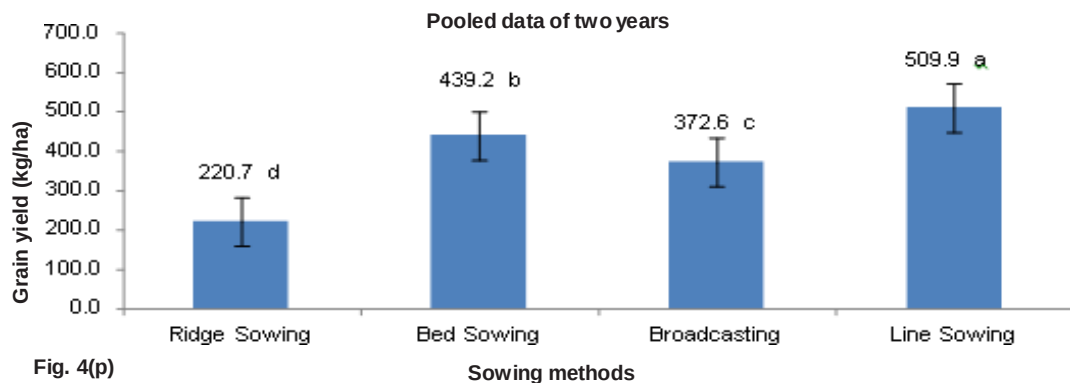
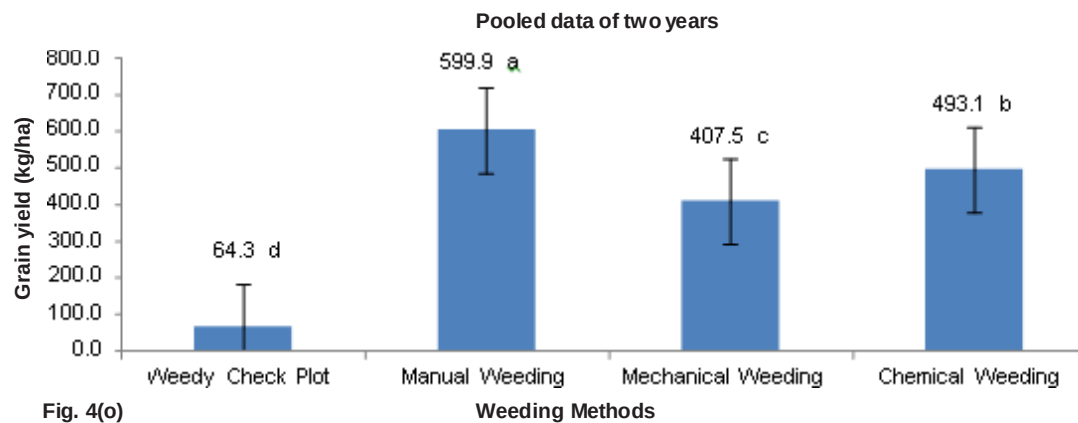
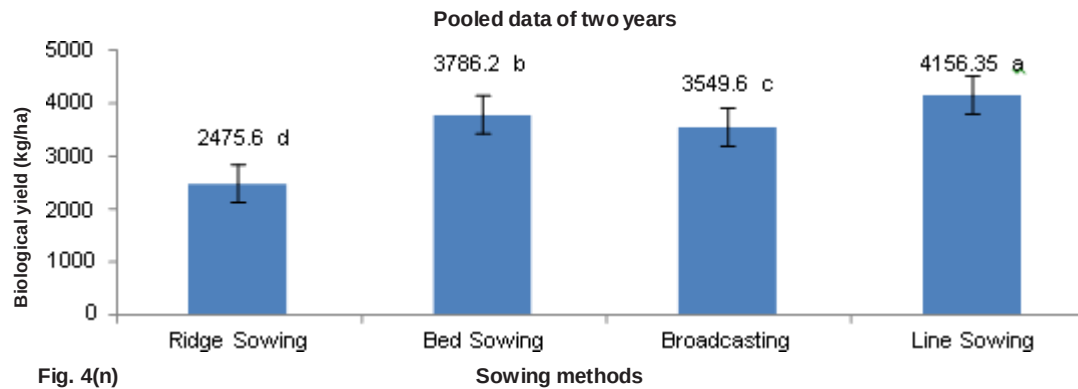
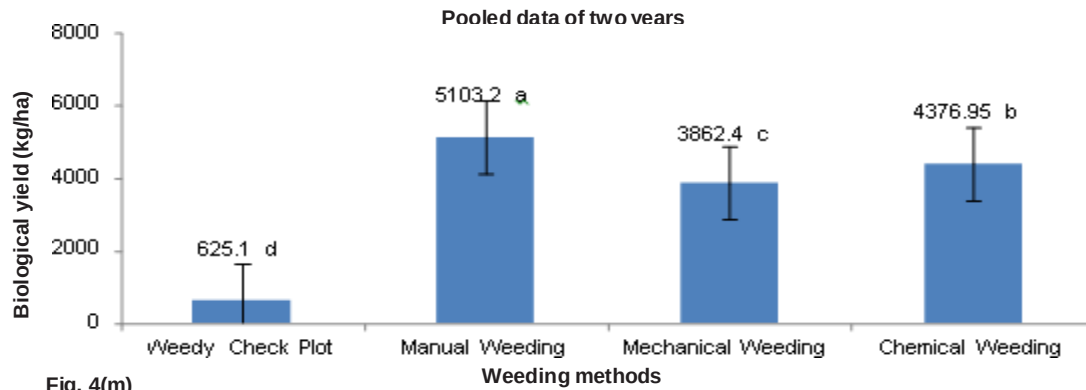


Fig. 4. Mean fennel growth and yield parameters as affected by different weeding and sowing methods

Table 6. Economic return of fennel (benefit cost ratio and net profitability)

	Benefit cost ratio (BCR)		Net profitability (%)	
	2020-21	2021-22	2020-21	2021-22
Sowing methods				
Ridge sowing	0.86	0.72	-13.72	-28.24
Bed sowing	1.56	1.57	55.53	56.74
Broadcast	1.39	1.27	38.61	27.38
Line sowing	2.01	1.95	100.75	95.44
Weeding methods				
Weedy checkPlot	0.26	0.26	-74.28	-73.76
Manual	2.10	1.89	110.15	88.99
Mechanical	1.48	1.54	47.77	53.76
Chemical	1.98	1.82	97.53	82.34

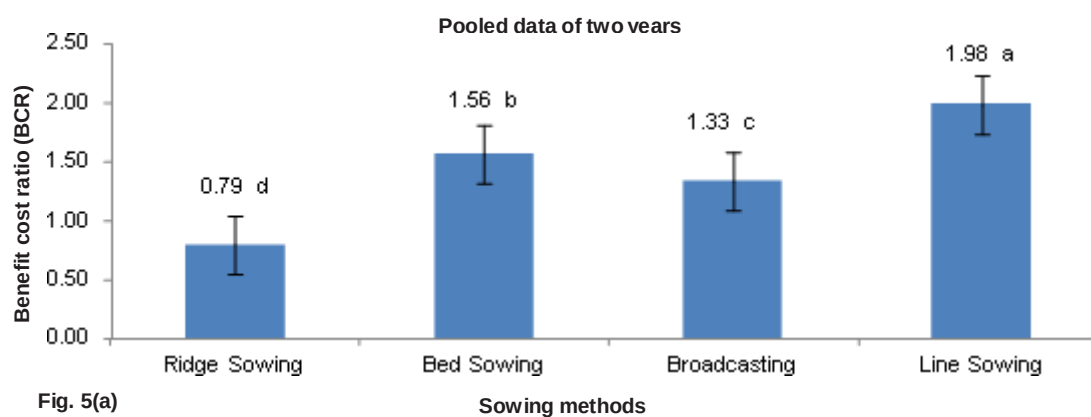


Fig. 5(a)

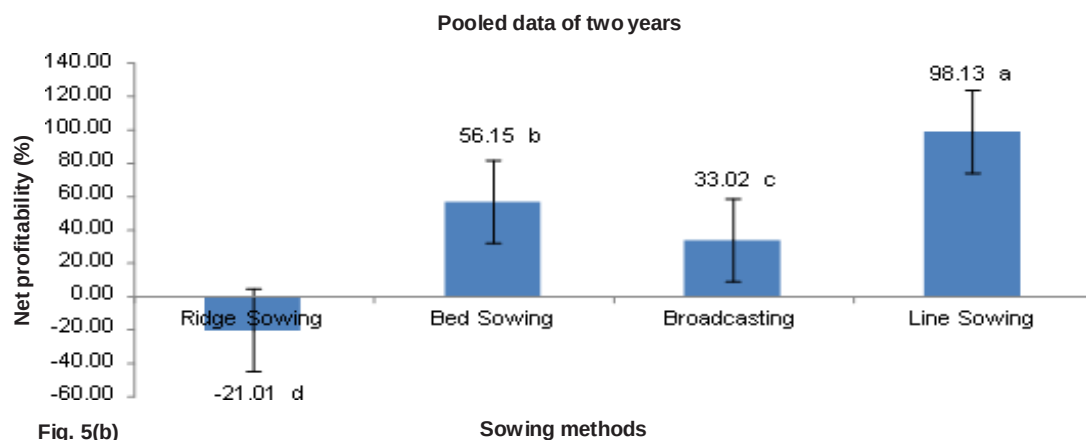


Fig. 5(b)

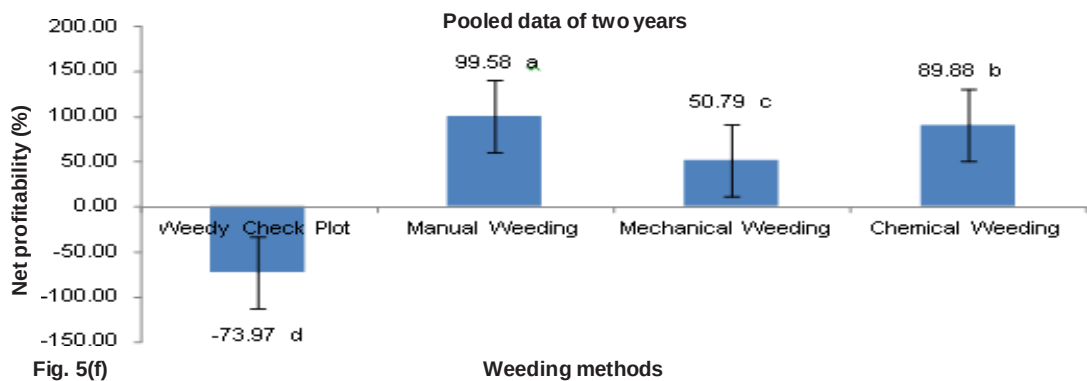
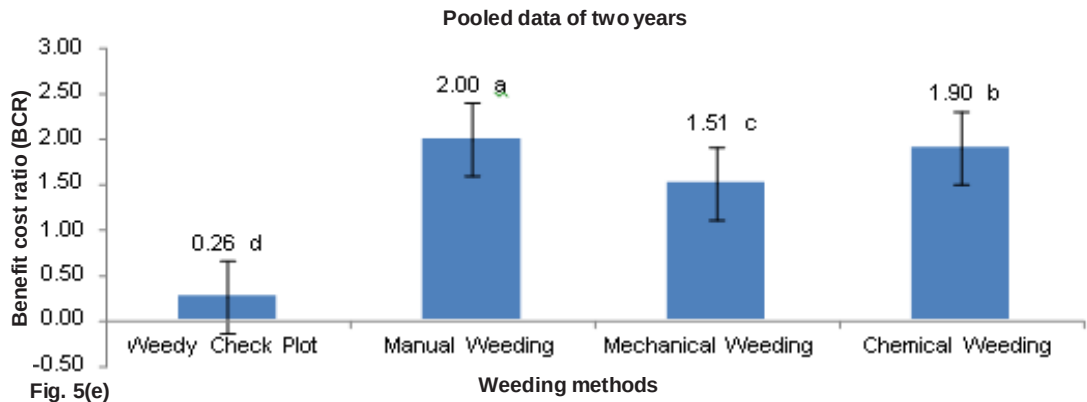
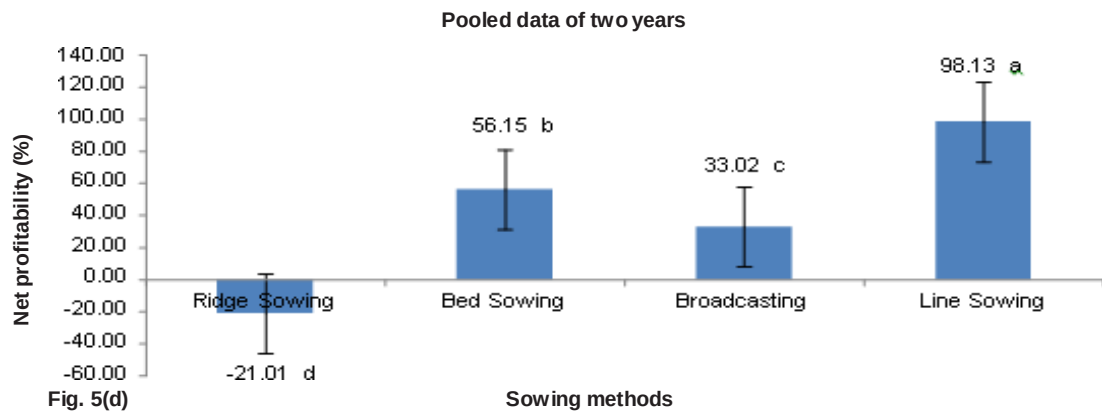
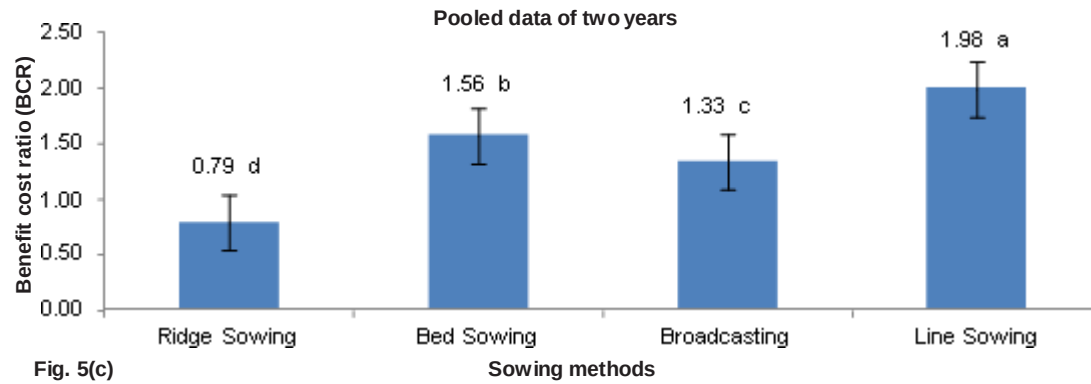


Fig. 5. Mean benefit cost ratio (BCR) and net profitability of different weeding and sowing methods

they could not be availed better in ridge sown plots. Similarly, the higher BCR under manual weeding may be attributed to the best weed control efficiency and mortality percentage of this treatment where weeds could not establish themselves and ultimately nutrients and other resources were availed by the crop plants. Similar findings were reported by Shahzad *et al.* (2017) who stated that economic returns and benefit cost ratio (BCR) was increased by flat sowing method.

Whereas, in case of weeding methods the highest benefit cost ratio (2.0) was recorded in manual weeding method and minimum (0.26) in weedy check plot. Likewise, in case of net profitability the highest net profitability (99.58 %) was calculated in manual weeding method and minimum (-73.97 %) in weedy check plot. The higher benefit cost ratio and net profitability under manual weeding may be due to highest biological and grain yield as well as best weed control efficiency and mortality percentage in this treatment which let provided nutrients and other natural resources to the crop plants only whereas it could not happen in other treatments. Similar findings were reported by (Iqbal *et al.*, 2010) who stated that the highest benefit cost ratio was recorded in the hand weeding twice (Table 6 and Fig. 4a, b, c, d, e, f).

CONCLUSION

Results indicated that sowing and weeding methods significantly affected the growth, yield and economic return of the fennel. Weed mortality percentage (29.3 %) and weed control efficiency (81.8 %) was maximum in manual weeding method and it was found non-significant in sowing methods. Similarly, in case of production, the maximum yield (509.9 kg/ha) was recorded in manual weeding method and minimum (220.7 kg/ha) under weedy check plot whereas in case of sowing methods, the maximum yield of fennel (493.1 kg/ha) was observed under line sowing method and minimum (64.3 kg/ha) in ridge sowing. Likewise, the benefit cost ratio (2.0 & 1.98) and net profitability (99.58% & 98.13%) was higher in manual weeding and line sowing method respectively. So, line sowing with manual weeding method is recommended to decrease the crop and weeds competition under rainfed conditions for obtaining higher yield of fennel.

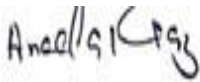
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2.	Muhammad Kashif	Reviewed the manuscript	
3.	Kamran Akram	Conducted the experiment and wrote the manuscript	
4.	Muhammad Arif	Statistically analysed the data	
5.	Muhammad Aftab	Provided guideline during research work and data analysies	
6.	Aneela Riaz	Assisted in result and discussion write up	
7.	Iqra Nawaz	Helped in data collection	