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RESEARCH ARTICLE

Growth and seed yield of seven fennel cultivars with two types of ploughing systems

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Abstract

A field experiment was carried out in Abu Ghraib district-Baghdad Iraq, to evaluate 7 fennel cultivars with ploughing systems. Two tillage systems (tillage and no-tillage) were allocated to main plots, while 7 fennel cultivars: Amigo, Azuria, Dollap, Hannan, Romanesco, Sahoo and Sajjet were allocated to subplots. Characteristics that had been studied were plant height, number of branches, number of umbels, number of umbellates, number of seeds per umbellate, stem diameter, weight of 1000 grains, and seed yield per ha. Significant results were with the no-till system in plant height (134.97 cm. plant^{-1}) and number of umbels (43.56 umbel plant^{-1}). The tillage system's significant results were in the number of seeds, weight of 1000 seeds (8.72 g), and yield per ha (490.03 kg ha^{-1}). Hannan-cultivar remarks yield per ha (742.99 kg ha^{-1}) and 1000-seed weight (10.90 g). Azuria-cultivar remarks on number of seeds of umbellets (24.44 seeds umbellate^{-1}). Romanesco-cultivar remarks on the number of umbels (48.72 umbel plant^{-1}). Therefore, cultivars varied in showing their latent ability through their performance with their phenotypic characteristics. Hannan cultivar was optimal in results that gave the highest seed yield. Thus, it can be entered into a crop breeding program with other cultivars that have outperformed in other characteristics.

Keywords

fennel; cultivars; tillage; non-tillage; PCA; medicinal plants

Introduction

Some spices and herbs have unique medicinal qualities that have positive effects on human health; among these herbs is the fennel crop. In taxonomics, this crop is called *Foeniculum vulgare* Mill, which is a well-known plant. It has been used for thousands of years to treat many diseases, as a carminative, anti-muscular contraction, and a stimulant for the secretion of the mammary and sex glands and affects diuresis and increases bile production (1). However, its extract can be used as an alternative to antibiotics because it has antibacterial properties. Recent studies have proven that fennel seed oil has a significant effect on cancer cells and pulmonary tuberculosis bacteria since the oil contains carvone and fenchone (2), anti-insect (3), Anesthetic efficacy (4), and anti-COVID-19 (5).

To involve some medicinal and aromatic plants in the program of crop breeding and improvement, types need to be evaluated for their performance under crop service operations (6, 7). Therefore, it was

experienced 4 genotypes of fennel, Amigo, di Firenze, and Romanesco, and the local Iraqi Dollap found that Amigo and Romanesco were the best in crop characteristics (8).

These differences may be determined by several techniques, including molecular. Some technologies are useful and efficient in breeding and improvement programs for medicinal crops such as fennel and the preservation of its kind. These technologies can be used in the early detection of genetic material. Including a statistic, where 9 different genotypes of fennel were tested under the sudoku design, this design was unique in the differences in the performance of those genotypes (9). Genetic variation resulting from cross-breeding several strains of sweet fennel improved some traits that are a measure of the performance of these genotypes such as volatile oil content and small fruit size.

Medicinal and aromatic plants need the management of soil and crop service operations. One of these operations is the ploughing process and the application of a ploughing system that does not affect the root environment. The no-till systems also increased the grain yield by 38 and 43% over deep and conventional tillage respectively (10). Therefore, the application of the no-till farming system is an optimal and environmentally friendly solution among the ploughing technologies used to adapt and reduce the processes of climate change. Therefore, conservation tillage of zero-and minimum method enhanced soil environment and yield; as well as reducing the negative impact on the environment (11). Furthermore, it was noted that 3 cultivars of wheat were the finest among 8 cultivars in showing their ability in growth characteristics and yield with the no-till farming system under the weather conditions of Iraq. Consequently, this experiment was carried out to recognize the performance of 7 cultivars of fennel crop with conventional tillage and the no-till farming system through growth and seed yield characteristics (12).

Materials and Methods

Experimental practices

A field experiment was carried out in sandy loam soil in the Abu Ghraib district in Baghdad - Iraq for the winter season of 2020-2021 (Fig. 1). The purpose is to study the effect of 2 types of tillage systems (no-till-tillage) on the growth and seed yield of seven cultivars of the fennel crop (Sahoo, Hannan, Romanesco, Amigo, Dollap, Azuria and Sajjet). The soil surface was plowed with a moldboard plough as primary tillage on a plowing depth of 15 cm and tractor speed of 3.15 km h^{-1} and the secondary was with a Spring Spike tooth Harrow. The experiment included 14 treatments with 3 replications (2×7×3). Experimental plots were 42 with dimensions of 2 m in length and 2 m in width for each. The cultivation was applied under a plant distance of 40 by 40 cm (row by plant). Moisture content was measured by taking samples after the first irrigation before planting. Ploughing and harrowing were done when the soil moisture reached 18-20%; this process was done only for the traditional tillage. The seeds of all cultivars were sown manually in holes (2-3 seeds per hole). A randomized complete block design (RCBD) was used according to a split plot with three replicates. Crop practices were applied as required and recommended. Some soil properties are listed in Table 1.

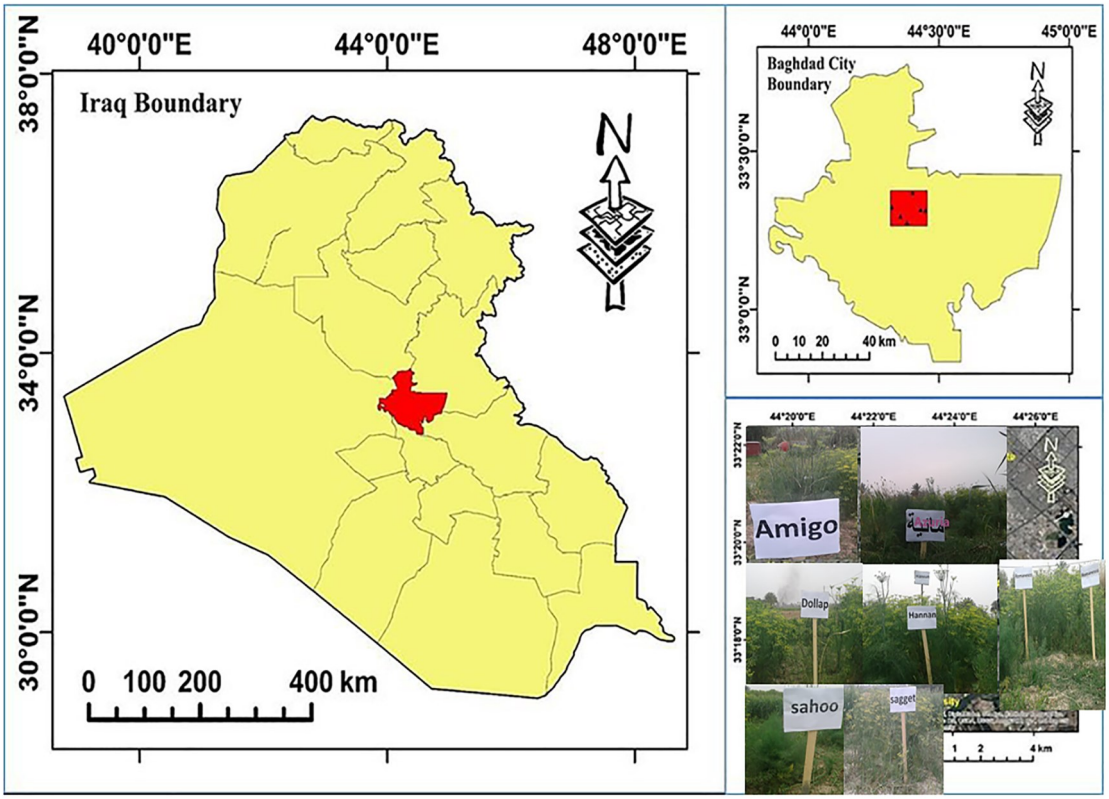

Fig. 1. Map of the location of the experiment.

Table 1. Some characteristics of the experimental soil

Parameter	pH	EC (ms)	Texture	NaCl (%)	TDS (ppm)
Value	7.6	1936	Silt	3.8	969

Statistical analysis

Results were statistically analyzed using GenStat (ed.14) under the 0.05 probability level to test the study parameters (13). The significant differences between the means were compared with the least significant difference test (LSD) as mentioned by (14). Biplot analysis and matrix plot were analyzed using PAST4.03 software (15).

Results

***Plant height (cm)*:** There are significant differences between the varieties and the cultivation systems as well as the interactions (Table 2). The Amigo variety gave the highest plant height (146.89 cm), followed by the Sahoo (144.33 cm), while the Sajjet variety gave the lowest height of 101.50 cm. There are significant differences between tillage systems. The no-tillage system was significant in increasing the plant height, as it gave the highest plant height of 134.97 cm, while the tillage system gave the lowest value for the plant height (120.33 cm). The results also indicate the Amigo variety gave the highest height of (162.78 cm) with a no-till system, followed by Sajjet (109.67) cm. The results also indicate for the interaction of cultivars with the tillage system that Sahoo gave the highest average plant height of 151.89 cm, while Sajjet gave the lowest average height of 93.33 cm.

Table 2. Effect of tillage method on plant height (cm) for seven cultivars of fennel

Cultivars	No-tillage	Tillage	Average
Sahoo	136.78	151.89	144.33
Romanesco	148.33	130.11	139.22
Hannan	128.44	121.56	125.00
Dollap	120.89	94.56	107.72
Azuria	137.89	119.89	128.89
Amigo	162.78	131.00	146.89
Sajjet	109.67	93.33	101.50
L.S.D(0.05)	3.76		2.82
Average	134.97	120.33	
L.S.D (0.05)		1.68	

*LSD: Least significant difference

Number of branches (branch plant^{-1}): Table 3 shows no significant effect on the number of branches of fennel cultivars. However, the cultivar Hannan gave the highest value for the average number of branches 4.95 branch plant^{-1}, followed by the cultivar Sahoo 4.22 branch plant^{-1}. The results also indicate no significant differences between tillage systems. However, the no-till system gave an average number of branches of 3.66 branch plant^{-1}, while using the tillage system achieved the lowest average of 3.37 branch plant^{-1}. In the interaction between the cultivars and the no-till system, the Hannan variety achieved the highest average number of branches reaching 6.22 branch plant^{-1}, while the Dollap variety gave a minimum mean of 2.44 branch plant^{-1}. Furthermore, in the interaction of the cultivars with the tillage method, the Sahoo variety achieved the highest number of branches per plant which reached 4.00 branch plant^{-1}, while the Romanesco gave the lowest number of branches at 2.67 branch plant^{-1}.

Table 3. Effect of tillage systems on branch number for seven cultivars of fennel crop

Cultivars	No-tillage	Tillage	Average
sahoo	4.45	4.00	4.22
Romanesco	3.10	2.67	2.88
Hannan	6.22	3.67	4.95
Dollap	2.44	3.33	2.89
Azuria	2.78	3.33	3.06
Amigo	2.78	3.22	3.00
Sajjet	3.89	3.33	3.61
L.S.D (0.05)	5.81		4.03
average	3.66	3.37	
L.S.D (0.05)	N.S.		

*LSD: Least significant difference

Number of umbel (umbel plant^{-1}): Results indicated a significant effect of cultivars and tillage systems on the number of umbel (Table 4), The Romanesco cultivar achieved the highest average number of umbels per plant (48.78 umbel plant^{-1}), followed by the Amigo cultivar (48.22), while the cultivar Dollap gave the lowest value of 21.11 umbel plant^{-1}. Results indicate that there is a significant difference between the two types of tillage systems. The no-tillage system achieved the highest value of the number of umbels amounting to 43.56 umbel plant^{-1}, while the tillage treatment gave the lowest value of the number of umbels reaching 36.86 umbel plant^{-1}. The results also indicate the optimum of the interaction Romanesco with the no-tillage system, as it achieved the highest average number of umbel plant^{-1}, which amounted to 56.00, followed by the Hannan variety (49.67 of umbel plant^{-1}). The interaction of the Dollap variety with the no-tillage system gave the lowest average number of inflorescences (25.55 umbel plant^{-1}). However, in the interaction of cultivars with the tillage treatment, the Amigo variety achieved the highest average number of umbel plant^{-1} which was 49.44, while the Hannan variety gave the lowest average of 31.89 umbel plant^{-1}.

Table 4. Effect of tillage systems on umbels (umbel plant^{-1}) for seven cultivars of fennel

Cultivars	No-tillage	Tillage	Average
Sahoo	43.11	44.78	43.94
Romanesco	56.00	41.44	48.72
Hannan	49.67	31.89	40.78
Dollap	25.55	21.11	23.33
Azuria	48.17	35.56	41.86
Amigo	47.00	49.44	48.22
Sajjet	35.44	33.78	34.61
L.S.D(0.05)	2.08		1.57
Average	43.56	36.86	
L.S.D (0.05)	0.82		

*LSD: Least significant difference

Number of seeds per umbellate (seed umbellate^{-1}): Results indicated a significant effect of cultivars and ploughing systems on the number of seeds per umbellate (Table 5). The Sahoo cultivar achieved the highest average number of seeds per umbellate, which amounted to 34.42 seed umbellate^{-1}, followed by the Azuria cultivar (26.44 seed umbellate^{-1}), while the Sajjet variety gave the lowest value for the average number of umbellate, which amounted to 19.65 seed umbellate^{-1}. As for the influence of the factor of tillage systems, results indicated that there is no significant difference between types of tillage systems; however, the tillage treatment achieved the highest average number of seeds in the umbellets amounted to 24.62 seed umbellate^{-1}, while the no-tillage treatment gave the lowest average number of seeds reached 23.06 seed umbellate^{-1}. The results also indicate the superiority of the interaction of Sahoo with no-till; as it achieved the highest average number of umbellet seeds of 34.40 seed umbellate^{-1}. This is followed by the interaction of Azuria with no-tillage (27.15) seed umbellate^{-1}. Despite this fact, the interaction of Amigo with no-tillage gave the lowest average number of seeds in umbellets (16.22 seed umbellate^{-1}). In the interaction of cultivars with the tillage system, Sahoo achieved the highest average number of seeds per umbellate amounting to 34.45 seed umbellate^{-1}, while the interaction of Sajjet with tillage gave the lowest average number of seeds per umbellate, which was 16.18 seed umbellate^{-1}.

Table 5. Effect of tillage systems on seeds per umbellets (seed umbellate^{-1}) for seven cultivars of fennel

Cultivars	No-tillage	Tillage	Average
Sahoo	34.40	34.45	34.42
Romanesco	19.38	28.00	23.69
Hannan	19.22	24.33	21.78
Dollap	21.93	18.44	20.19
Azuria	27.15	25.73	26.44
Amigo	16.22	25.22	20.72
Sajjet	23.11	16.18	19.65
L.S.D (0.05)	2.27		1.56
Average	23.06	24.62	
L.S.D (0.05)	N.S		

*LSD: Least significant difference

Stem Diameter (mm): Results indicated a non-significant effect of cultivars and ploughing systems in the stem diameter (Table 6). The Amigo cultivar achieved the highest average stem diameter which amounted to 23.43 mm, followed by the Sahoo variety (20.07 mm), then the Romanesco variety (18.02 mm). The cultivar Hannan gave the lowest value for stem diameter (11.47 mm). The results indicate no significant differences between the 2 types of tillage systems; nonetheless, the tillage treatment achieved the highest average stem diameter of 16.44 mm, and the no-tillage treatment gave the lowest average stem diameter of 16.12 mm. The results also indicated the non-significant for the interaction of cultivar with the tillage system. Nevertheless, the interaction of the Amigo cultivar with no-tillage and tillage systems achieved the highest mean stem diameter of 23.43 mm for both interactions. Even though, Hannan with tillage system gave the lowest average for stem diameter (11.23 mm). Likewise, Sajjet with a no-till system gave the lowest average stem diameter of 11.37 mm.

Table 6. Effect of tillage systems on stem diameter (mm) for seven cultivars of fennel

Cultivars	No-tillage	Tillage	Average
Sahoo	19.47	20.67	20.07
Romanesco	19.33	16.57	18.02
Hannan	11.70	11.23	11.47
Dollap	11.40	12.37	11.88
Azuria	16.13	17.47	16.80
Amigo	23.43	23.43	23.43
Sajjet	23.11	16.18	19.65
L.S.D(0.05)	N.S.		2.31
Average	16.12	16.44	
L.S.D (0.05)	N.S.		

*LSD: Least significant difference

Weight of 1000 seed (gm): Results indicated a significant effect of cultivars and ploughing systems and the interaction in the number of seeds in weight of 1000 seed (Table 7). Hannan cultivar achieved the highest average weight of 1000 seeds, which amounted to 10.90 gm, followed by the Azuria variety (10.54 gm), while the Amigo variety gave the lowest value of 5.29 gm. In addition, results indicated that there is a significant difference between the 2 types of tillage systems. The tillage treatment achieved the highest average weight of 1000 seeds amounting to 8.72 gm, while the no-tillage treatment gave the lowest average weight of 1000 seeds reaching 7.58 gm. Results indicated the superiority of Azuria with a no-till system, as it achieved the highest average weight of 1000 seeds at 10.60 gm, followed by Hannan at 9.95 gm. The interaction of Amigo with no-tillage gave the lowest average weight of 4.08 gm. Whereas, the interaction of cultivars with the tillage treatment, the Hannan cultivar achieved the highest average weight of 1000 seed at 11.86 gm, while Romanesco gave the lowest average weight of 5.75 gm.

Table 7. Effect of tillage systems on weight of 1000 (gm) seed for seven cultivars of fennel

Cultivars	No-tillage	Tillage	Average
Sahoo	7.11	6.38	6.75
Romanesco	7.59	5.75	6.67
Hannan	9.95	11.86	10.90
Dollap	5.25	9.69	7.47
Azuria	10.60	10.47	10.54
Amigo	4.08	6.50	5.29
Sajjet	8.48	10.35	9.42
L.S.D(0.05)	1.27		0.87
Average	7.58	8.72	
L.S.D (0.05)	1.14		

*LSD: Least significant difference

Seed yield per hectares (kg ha^{-1}): Results indicated a significant effect of cultivars and ploughing systems on the yield per ha (Table 8). Hannan cultivar achieved the highest average seed yield in ha, which amounted to 742.99 kg ha^{-1}, followed by Amigo variety (494.70 kg ha^{-1}). The Sahoo variety gave the lowest value of 132.60 kg ha^{-1}. Additionally, results indicated that there are significant differences between the 2 types of tillage systems. The tillage treatment achieved the highest seed yield in ha amounting to 490.03 kg ha^{-1}, while the no-tillage treatment gave the lowest average seed yield in ha reaching 358.61 kg ha^{-1}. The results also indicate the superiority of the Hannan with no-till interaction, as it achieved the highest seed yield in ha of 680.02 kg ha^{-1}, followed by the interaction of Amigo with no-tillage (434.77 kg ha^{-1}). The interaction of Sahoo with no-tillage treatment gave the lowest average for the yield (123.57 kg ha^{-1}), whereas the interaction of cultivars with the tillage treatments, Hannan cultivar achieved the highest mean of seed yield that reached 805.96 kg ha^{-1}; meanwhile, the interaction of Sahoo cultivar with tillage treatment gave the lowest mean for the seed yield reached 141.62 kg ha^{-1}.

Table 8. Effect of tillage systems on seed yield in hectare for seven cultivars of fennel

Cultivars	No-tillage	Tillage	Average
Sahoo	123.57	141.62	132.60
Romanesco	231.75	363.71	297.73
Hannan	680.02	805.96	742.99
Dollap	421.12	504.17	462.64
Azuria	274.42	524.42	399.42
Amigo	434.77	554.62	494.70
Sajjet	344.63	535.74	440.19
L.S.D(0.05)	9.19		6.81
Average	358.61	490.03	
L.S.D (0.05)		5.02	

*LSD: Least significant difference

Biplot analysis and matrix plot: Fig. 2 showed that the Biplot analysis was effective in distributing the cultivars on the 4 parts of the Biplot using their traits as focal points. In contrast, the 5 polygon heads represented the AmigoT_0, Hannan T, Dollap T, SahooT_0, and Sahoo T, from left to right respectively. Therefore, the finest performance cultivars were Amigo and Hannan in the 2 systems. Azuria and Romanesco were the most stable cultivars. These results were boosted by the spinning tree analysis inside the polygon, where 2 patterns of spinning trees have resulted. Firstly, it begins with the negative cultivar point of SajjetT0 and ends with amigoT0 and Hannan T. Secondly, it starts with Dollap T and finishes with sahooT0, this pattern represents the worst spinning tree. Moreover, these results are intensified by a matrix plot amongst these cultivars and their studied traits, where the difference in color means that cultivars are various (Fig. 3). Therefore, yield is the most trait thereby cultivars are different depending on color intensity.

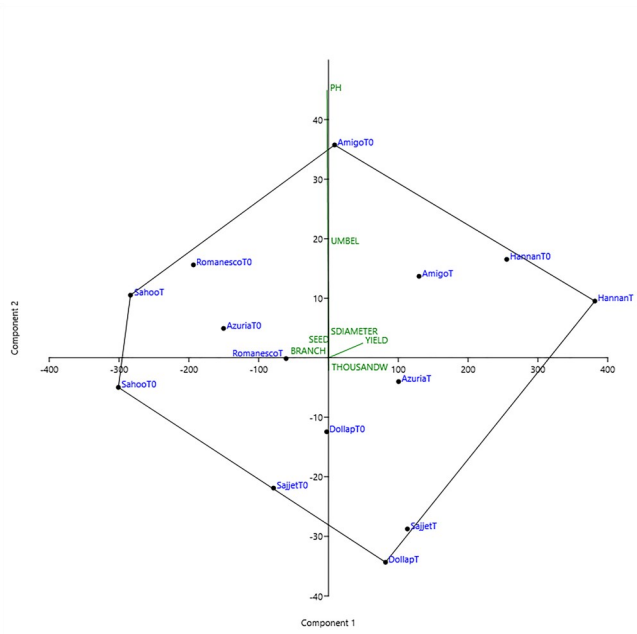

Fig. 2. Biplot distribution of seven fennel cultivars with their studied traits in two systems of tillage. T0; no-tillage, T; tillage.

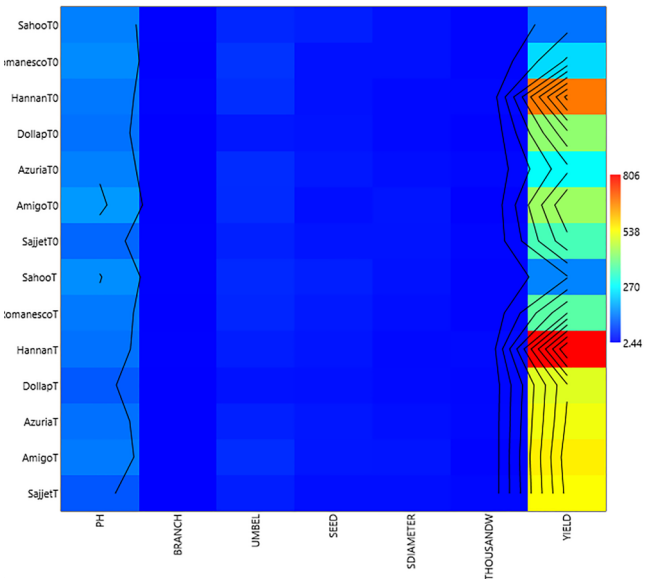

Fig. 3. Matrix plot distribution of seven fennel cultivars with their studied traits in two systems of tillage.(no-tillage in upper: T0, tillage bottom:T; red microrectangle highly correlated with trait)

Discussion

Through the results, the no-till farming system achieved a positive effect on plant height (Table 2) and numerically on the number of branches (Table 3) and the number of umbels (Table 4). It may be attributed to the improvement of soil characteristics and the preservation of its water content. There wasn't any negative effect of the no-till farming system. No-till agriculture has been found to stimulate some qualitative and chemical traits, including CO2 emission which is reflected in growth traits improvement (16). Traditional tillage had a clear effect on the weight of seed (Table 7) and the total yield in kilograms per ha (Table 8). It is attributed also to the fact that this process is more effective in preserving water in the soil (17). In contrast to what had found that no-till

farming increases the availability of N (18, 19), in the long run despite the low yield, but it is in other crops were effective in improving crop performance, the reason for the superiority of the tillage process due to the complete inversion of the soil and the inclusion of the inverted soils on some important elements such as Zn and Fe (20-22).

As for the cultivar's differences, the reason is attributed to the difference in their genetic material. Where the cultivars differed especially in grain yield (Fig. 2, 3). Accordingly, Some medicinal plants differ in their chemical components according to their genetic structure (23). The active compounds may be affected by the plant's physiological activity and some phenotypic characteristics. The volatile oil may be associated with chlorophyll which is associated with the components of the volatile oil. The genetic structures of cultivars have a lot of ability to express their potential, which is reflected in their phenotypic components, and the interaction between the genotypes and the environment is an important issue in the production of the crop. Based on it, a specific genotype is recommended for several regions or a specific region and therefore it is not possible to change the agricultural environmental conditions, but it is possible to adapt to these conditions through the correct scientific management methods of soil, water, and services. The genotypes can also be changed either by breeding and genetic improvement methods or by following appropriate and available biotechnologies and this is in line with what (2, 6, 9) confirmed that the components of the volatile oil have a high ability to combine with the small size of the fruit in the fennel crop. This has emphasized the weight of the seeds and their relation to the yield and components of the volatile oil and that these characteristics are inherited quantitatively. For this reason, plant breeders always seek to devise or adapt new genotypes to develop crops to suit the diverse climatic and agricultural regions. On this basis, a sufficient genetic variance is reflected in the economic traits (8, 24). More recently, it has been confirmed that no-tillage serves as abiotic stress that stimulates some secondary metabolites (25), especially plant growth regulators. From this particularity, the 2 systems have differed in grain yield (Table 8). These data disagreed with (26) who illustrated that no-tillage did not differ from the conventional tillage effect on the grain yield of *Nigella sativa* L.

Conclusion

The current experiment was carried out to know the performance of 7 cultivars of fennel under the traditional tillage process and the no-till farming system. The tillage process was more effective in improving some characteristics of this medicinal crop, including the yield and its components. Fennel cultivars differed in showing their phenotypic ability under the 2 cultivation systems. It varied in showing its genetic ability phenotypically and was reflected in the yield and its components. Therefore, a breeding program can be developed for it to collect these indicators in one genetic material and produce a new cultivar from it.

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Authors' contributions

BAZ carried out the experimental studies. BAZ and MSA carried out the collection of data. AFA participated in the design of the study and performed the statistical analysis. AFA and YSS conceived of the study and participated in its design and coordination. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None.

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