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Relationship Between Essential Oil Content, Fruit Yield and Yield Component in *Foeniculum vulgare* Mill.

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Abstract

Foeniculum vulgare Mill. naturally spread in Turkey flora, and it's also cultivated. Its cultivation is widely carried out in Burdur and Denizli region. Especially, it is used as a milk enhancer when drunk as tea for breastfeeding mothers and as a carminative and relaxing for babies. The aim of the study was to determine the relationship between yield and quality characteristics of *F. vulgare* L. is cultivated and used in Turkey. For this purpose, correlation analysis and path analysis were applied to essential oil content (EOC) and fruit yield. EOC was significantly and positively associated with the number of umbellet (0.684 **), number of fruit (0.589*), Thousand Fruit Weight (TFW) (0.563*) and plant height (0.530*). The highest positive correlation was obtained among with fruit yield and biological yield (r=0.929**). Fruit yield has a significant correlation also between fruit number (0.805**), TFW (0.726**), plant height (0.696**) and umbellet number (0.609**). Branch number has a negative and unsignificant correlation between all the characteristics, but also has a negative and significant correlation among plant height. According to the path analysis results, the highest direct influence on EOC were the biological yield (-33.02%), but negative and fruit yield (30.23%) parameters. The maximum positive effects on fruit yield in fennel belongs to biological yield (59.88%), TFW (29.41%) and plant height (20.16%). In addition, fruit number, plant height and TFW showed the maximal indirect effects on fruit yield through biological yield. The same traits also affected the essential oil content and indirectly and positively. Therefore, these traits can be evaluated as selection criterion to attain higher essential content and fruit yield in *F. vulgare* L.

Key Words: Fennel, Umbel, Umbellet, Correlation, Path, Thousand Grain Yield.

1. Introduction

Three main varieties of fennel, which is an element of the *Apiaceae* family, have been described by Seidemann (2005); *F. vulgare* Mill. var. *piperitum* (bitter fennel), *F. vulgare* Mill. var. *dulce* (sweet fennel) and *F. vulgare* Mill. var. *azoricum* (Florence fennel). Sweet fennel is a native of southern Europe, the Mediterranean region. It has also been naturalized in many parts of northern Europe, Cyprus, the USA, southern Canada and Asia, the Far East and Australia (Malhotra, 2012). *Foeniculum vulgare* Mill. grows naturally spread in Northern, Western and Eastern Anatolia (Avci, 2013). It's also cultivated various provinces such as Antalya, Gaziantep, Manisa, Bursa, Denizli, and the most produced around Burdur province (Baydar, 2009). Fennel is cultivated especially for its fruits and for the essential oil taken from fruits, as well as for its bulbs and foliage. Essential oil content, components and their ratios vary according to ecological and growing conditions such as sowing time and density, irrigation, fertilization. Sweet fennel fruits contain 2-5.8% essential oil, the components are trans-anethole, fenchone, limonene, methyl chavicol, α- phellandrene and anisaldehyde.

The purpose of breeding in medicinal and aromatic plants, as in other plants is high yield, resistance to biotic and abiotic stress; however, the amount and quality of the active ingredient are also important. Obtaining varieties with high grain yield, essential oil content and component ratios is the main goal of fennel breeding. The yield and essential oil content are polygenic characters affected by environmental conditions. For this reason, it will be more advantageous to carry out breeding studies on yield components that affect essential oil content and fruit yield. Path coefficient analysis determines the direct and indirect contribution of various characters to yield. Correlation analysis supply knowledge about the relationships between yield components. In breeding studies, selection is successful when there is a strong relationship among essential oil content, composition, and morphological and agronomic characteristics. Therefore, it is considered to be more advantageous to investigate the morphological and agronomical properties that affect the content of essential oil, rather than directly increasing the content of essential oil in medicinal plants. (Avcı and Giachino, 2019). For all these reasons, in this study, it was aimed to determine the relationship between yield and quality characteristics of fennel cultivated and used in Turkey.

2. Material and Methods

Sweet fennel (*Foeniculum vulgare* Mill.) seeds used as study material were obtained from producers of Burdur province. The experiment was planned as two vegetation years with three replications accordingly the randomized block design in Isparta, Turkey. The plots were designed in six rows of 300 x 40 cm. Irrigation, weed control and fertilization were carried out regularly.

The characteristics examined in the study are plant height (cm), number of branches per plant, number of umbels per plant, number of umbellets per umbel, number of fruits per umbel, fruit yield (kg ha^{-1}), biological yield (kg ha^{-1}), thousand fruit weight (g) and essential oil content (%). EOC was obtained by hydro distillation with Neo-Clevenger apparatus (Wichtl, 1971). Path analysis was used to determine the meaningful traits influencing essential oil content and fruit yield and their direct and indirect effects. Correlation and path analysis were conducted according to method followed by Singh & Chaudhary (1979) and Dewey & Lu (1959), respectively. Evaluation of the obtained data was made utilization of the TARIST software (Açıkgöz et al., 2004).

3. Results and Discussion

The correlations between the studied traits of fennel (*Foeniculum vulgare* Mill.) are given in Table 1. When Table 1 is examined; the highest positive correlation revealed fruit yield and biological yield with the correlation coefficient *r = 0.929***. The fruit yield also, was considerably and positively associated with number of fruits (*r = 0.805 ***), Thousand fruit yield (TFW) (*r = 0.726 ***), plant height (*r = 0.696***) and number of umbellets (*r = 0.609***). These traits are considered major components for fruit yield. This result is compatible with those obtained by Al-korddy (2000), Singh and Mittal (2003), Bahmani et al (2012) and Singh et al. (2014) who reported significant and positive relationship between seed yield and plant height. Similarly, Dashora and Sastry (2011), found a favorable and important correlation between seed yield and number of umbellets (0.43**), seed number (0.46**), biological yield (0.84**) and harvest index (0.45**).

Biological yield showed a very high correlation with fruit yield as cited above (*r=0.929***). Biological yield, also related with number of fruit (*r=0.667***) at the P < 0.01 level. Furthermore, it exhibited significant positive correlations with plant height (*r=0.498**) and TWF (*r=0.468**) at the P < 0.05 level. This is in accord with the results of Cosge et al. (2009) who found a very high positive relationship among biological yield and single plant yield (r=0.915).

Plant height demonstrated a notable positive relationship with number of umbellets (r = *0.748***), number of fruits (*r = 0.771***), fruit yield (*r = 0.696***) and TWF (*r = 0.671***) at the P < 0.01 level, and with biological yield (*r = 0.498**) and essential oil content (*r = 0.530**) at the P <0.05 level. Similarly, Singh and Mittal (2003) showed that there is a positive and important relationship between seed yield and plant height, umbels number, TWF in sweet fennel. Conversely, Patidar et al. (2017) found that plant height was importantly and negatively related with only the number of umbellate per umbel (-0.29*). In this study, it was determined that there is a significant but negative correlation at P <0.05 level between plant height and branch number (*r = -0.570**). There was no statistically significant relationship between plant height and the number of umbels. The fact that plant height, which contributes indirectly to seed yield, shows a positive correlation with other traits except for these two, indicating that it may be important for genotype selection.

The significant and positive correlations were detected among the number of umbellets with TWF (*r=0.825***), number of fruits (*r=0.750***), plant height (*r=0.748***), EOC (*r = 0.684 ***) and fruit yield (*r =0.609***) at the P <0.01 level. These results are consistent with the results of Kalleli et al. (2019) for number of fruits per umbel and TFW.

The number of fruits was remarkably and positively associated with fruit yield (*r = 0.805***), plant height (*r=0.771***), number of umbellets (*r=0.750***), TFW (*r = 0.670***) and biological yield (*r = 0.667***) at the P <0.01 level and with EOC (*r = 0.589**) at the P <0.05 level.

A significant positive correlation was observed between TFW and number of umbellets (*r=0.825***), fruit yield (*r= 0.726***), plant height (*r= 0.671***), number of fruits (*r=0.670***) at the P <0.01 level and EOC (*r=0.563 **) and biological yield (*r= 0.468 **) at the P <0.05 level. It displayed negative insignificant correlation with the remaining two traits.

The number of branches showed a negative but statistically non-significant relationship with all other traits examined except the plant height (*r= -0.570**). The number of umbels could not show a meaningful and significant relationship with all the other properties examined. In contrast, Yadav et al. (2013) found a positive relationship between seed yield and the number of umbels and branches. Again, Kalleli et al. (2019) also found a positive association between seed yield plant height and number of branches, considered these characteristics as the main components for seed yield. This situation may be due to ecological conditions and sowing frequency.

Essential oil content was markedly associated with number of umbellets (*r=0.684***) at the P <0.01 level, and with number of fruits, TFW and plant height at P <0.05 level (*r=0.589*, 0.563** and *0.530**, respectively). Further, it had a positive but insignificant correlation with fruit yield, number of umbels and biological yield, and a negative non-significant relationship with the number of branches. Meena and Dhakar (2017) in fennel observed significant positive relationships between essential oil ratio and parcel seed yield, days to germination, king umbel anthesis, number of branches secondary, number of umbellets per umbel while they found a significant but negative correlation with number of umbels per plant. Lal (2007), emphasizing that seed yield is in a significant and positive association with essential oil and t-anethole content at both genotypic and phenotypic levels, revealed that these two characteristics are good criteria for selection.

Table 1: Correlation coefficients and significance between traits studied in fennel.

	Plant height	Number of branches	Number of umbels	Number of umbellets	Number of fruits	Fruit yield	Biological yield	TFW
Number of branches	**-0.570***	1.000						
Number of umbels	0.121ns	-0.170ns	1.000					
Number of umbellets	**0.748****	-0.251ns	-0.029ns	1.000				
Number of fruits	**0.771****	-0.404ns	0.373ns	**0.750****	1.000			
Fruit yield	**0.696****	-0.299ns	0.041ns	**0.609****	**0.805****	1.000		
Biological yield	**0.498***	-0.186ns	0.062ns	0.371ns	**0.667****	**0.929****	1.000	
TFW	**0.671****	-0.274ns	-0.220ns	**0.825****	**0.670****	**0.726****	**0.468***	1.000
Essential oil content	**0.530***	-0.289ns	0.205ns	**0.684****	**0.589***	0.357ns	0.086ns	**0.563***

**: significant at the 0.01 probability level; *: significant at the 0.05 probability level; ns: non-significant

In order to identify the direct and indirect effects of examined traits on essential oil content of *Foeniculum vulgare* Mill., path analysis was applied based on the average of two vegetation years and are presented in Table 2. Path analysis demonstrated that only fruit yield (30.23 %) had strong direct effect on the EOC while number of umbellets (1.05%) had negligible positive direct effects. The correlation coefficients of this traits on EOC were similarly positive, but fruit yield (r= 0.357ns) was non-significant whereas number of umbellets (r=0.684**) was statistically significant, unlike path analysis. In addition, the relationship of these two characters with each other was significant and positive (r=0.609**) (Table 1). Fruit yield displayed the supreme direct influence (30.23 %), also positive indirect efficacy on EOC via plant height (25.54%), number of umbels (8.27%), number of umbellets (24.11%), number of fruits (27.40%), biological yields (32.28%) and thousand fruit weight (25.37%). However, the positive direct influence of fruit yield on EOC was equilibrated by relatively high minus indirect effect through the number of branches (-23.90%). Coşge et al. (2009), similar to ours, stated that the highest direct influence on essential oil percentage was the single plant yield (32.95%), and unlike us, the plant height (24.60%) and the number of branches (15.11%) had the highest direct effect. According to Faravani et al. (2018), plant biomass, number of umbellate in umbel, canopy cover and 1000-seed weight had the most direct effect on essential oil yield of cumin.

Table 2. Path coefficient and percentages of the direct and indirect effects of investigated properties on the essential oil content of *Foeniculum vulgare* Mill.

	DIRECT EFFECTS		INDIRECT EFFECTS							
	Essential oil content (EOC)		Plant height		Number of branches		Number of umbels		Number of umbellets	
	Path coefficient	Path %	Path coeff.	Path %	Path coeff.	Path %	Path coeff.	Path %	Path coeff.	Path %
Plant height	-0.56	8.29	-	-	0.05	0.79	-0.03	0.43	0.05	0.73
Number of branches	-0.09	2.99	0.32	10.29	-	-	0.04	1.31	- 0.02	0.53
Number of umbels	-0.24	19.39	- 0.07	5.52	0.02	1.29	-	-	- 0.002	0.16
Number of umbellets	0.07	1.05	- 0.42	6.70	0.02	0.37	0.01	0.11	-	-
Number of fruits	-0.10	1.41	- 0.44	5.93	0.04	0.52	- 0.09	1.22	0.05	0.68
Fruit yield	2.50	30.23	- 0.39	4.76	0.03	0.34	- 0.01	0.12	0.04	0.49
Biological yield	-2.37	33.02	- 028	3.91	0.02	0.24	- 0.02	0.21	0.03	0.34
TFW	-1.73	24.26	- 0.38	5.29	0.03	0.36	0.05	0.74	0.06	0.76
	DIRECT EFFECTS		INDIRECT EFFECTS							
	Essential oil content (EOC)		Number of fruits		Fruit yield		Biological yield		Thousand fruit weight	
	Path coefficient	Path %	Path coeff.	Path %	Path coeff.	Path %	Path coeff.	Path %	Path coeff.	Path %
Plant height	-0.56	8.29	-0.08	1.17	1.74	25.54	-1.18	17.35	-1.16	17.08
Number of branches	-0.09	2.99	0.04	1.34	-0.75	23.90	0.44	14.09	0.47	15.18
Number of umbels	-0.24	19.39	-0.04	3.13	0.10	8.27	-0.15	11.96	0.38	30.81
Number of umbellets	0.07	1.05	-0.08	1.23	1.52	24.11	-0.88	13.96	-1.43	22.69
Number of fruits	-0.10	1.41	-	-	2.01	27.40	-1.58	21.57	-1.16	15.83
Fruit yield	2.50	30.23	-0.08	1.01	-	-	-2.20	26.70	-1.26	15.25
Biological yield	-2.37	33.02	-0.07	0.96	2.32	32.28	-	-	-1.81	11.30
TFW	-1.73	24.26	-0.07	0.97	1.81	25.37	-1.11	15.54	-	-

Table 3. Path coefficient and percentages of the direct and indirect effects of investigated properties on the fruit yield of *Foeniculum vulgare* Mill.

	DIRECT EFFECTS		INDIRECT EFFECTS							
	Fruit yield		Plant height		Number of branches		Number of umbels		Number of umbellets	
	Path coeff.	Path %	Path coeff.	Path %	Path coeff.	Path %	Path coeff.	Path %	Path coeff.	Path %
Plant height	0.25	20.16	-	-	-0.02	1.39	0.004	0.34	-0.08	6.28
Number of branches	0.03	5.23	-0.14	24.62	-	-	-0.01	1.03	0.03	4.52
Number of umbels	0.04	13.09	0.03	11.32	-0.01	1.93	-	-	0.03	1.14
Number of umbellets	-0.11	8.96	0.19	16.10	-0.01	0.65	-0.001	0.09	-	-
Number of fruits	0.04	3.18	0.19	14.60	-0.01	0.93	0.01	0.99	-0.08	5.92
Biological yield	0.75	59.88	0.13	10.02	-0.01	0.45	0.02	0.18	-0.04	3.11
TFW	0.37	29.41	0.17	13.30	-0.01	0.66	-0.01	0.61	-0.09	6.81
Essential oil content	0.12	15.14	0.13	17.37	-0.01	1.15	0.01	0.94	-0.07	9.33
	DIRECT EFFECTS		**INDIRECT EFFECTS**							
	Fruit yield		Number of fruits		Biological yield		Thousand fruit weight		Essential oil content	
	Path coeff.	Path %	Path coeff.	Path %	Path coeff.	Path %	Path coeff.	Path %	Path coeff.	Path %
Plant height	0.25	20.16	0.03	2.61	0.37	29.86	0.25	20.05	0.06	4.94
Number of branches	0.03	5.23	-0.02	2.93	-0.14	23.86	-0.10	17.53	-0.03	5.78
Number of umbels	0.04	13.09	0.02	5.87	0.05	17.36	-0.08	30.50	0.02	8.86
Number of umbellets	-0.11	8.96	0.03	2.71	0.28	23.76	0.31	26.33	0.08	6.80
Number of fruits	0.04	3.18	-	-	0.50	37.57	0.25	18.81	0.07	5.15
Biological yield	0.75	59.88	0.03	2.25	-	-	0.17	13.98	0.01	0.81
TFW	0.37	29.41	0.03	2.23	0.35	27.63	-	-	0.07	5.16
Essential oil content	0.12	15.14	0.03	3.23	0.07	8.43	0.21	27.34	-	-

The most negative and direct influence on EOC was by biological yield, TFW and number of umbels (-33.02, -24.26, -19.39%, respectively). In addition, plant height (-8.29%), number of branches (-2.99%) and number of fruit (-1.41%) also had a negative direct but low-level effect on EOC. Aharizad et al. (2013) reported that citral content, leaf width and total dry weight had an almost positive direct effects on essential oil percentage in their study on lemon balm populations. In contrast, they reported that the number of tillers, leaf length and dry weight of leaves had a direct negative effect on essential oil percentage.

Biological yield had the highest negative direct influence on EOC (-33.0.2%). Our findings show similarity with the Cosge et al. (2009)'s outcomes (35.16 %). Only the number of branches (14.09 %) had a positive indirect effect on EOC via biological yield. It also gave high indirect negative effects via plant height (-17.35 %), number of umbels (-11.96 %), number of umbellets (-13.96 %), number of fruits (-21.57 %), fruit yield (-26.70 %) and thousand fruit weight (-15.54 %).

TFW indicated that the second most negative direct influence (-24.26%) on EOC. Cosge et al., (2009) were determined the most negative direct influence on essential oil ratio as the one thousand seed weight (68.74%). It had high positive indirect influence on EOC through number of umbels (30.81%) and number of branches (15.18%). However, also exhibited negative indirect effects on EOC through plant height (-17.08%), number of umbellets (-22.69%), number of fruits (-15.83%), fruit yield (-15.25%) and biological yields (-11.30%).

The plant height, number of umbels, number of fruits, biological yield and TFW were positively correlated with EOC, but only plant height, number of fruits and TFW showed a significant association with EOC. In addition, the direct effects of these three traits on EOC were negative. This indicates that the observed positive correlations of these traits with EOC were due to their indirect positive effects on EOC through number of branches (10.29%, 1.34% and 15.18%, respectively) and number of umbel (30.81%). In other words, number of fruits (27.40%), plant height (25.54%) and TFW (25.37%) showed high indirect positive effects on EOC via fruit yield. Prominence should be given to the indirect influences when a character has a positively correlated and considerably positive indirect influence, but a direct negative effect on economic characteristics such as grain yield or essential oil content (Singh and Chaudhary 1979). This shows the importance of identifying genotypes with considerable EOC by indirect selection for the above-mentioned traits in the breeding program.

The most indirect positive effects of plant height, number of umbellets, number of fruits, biological yield and TFW were on EOC through fruit yield while number of branches and number of umbels has provided the most indirect positive effects on EOC through TFW. Also, fruit yield exhibited most positive indirect effect via number of umbellets but insignificant. According to Bahmani et al. (2012), the highest indirect influences on EOC were obtained for dry biomass weight over leaf number (0.3949). Interestingly, all traits affected EOC negatively indirect via plant height, number of fruits and biological yield, except number of branches. That is, the indirect effects of the number of branches on the EOC were positive and low to moderate. The highest negative indirect effect was revealed by fruit yield (-26.70%) through biological yield. This was followed by the number of branches (-23.90%) through fruit yield and the number of umbellets (-22.69%) via TFW.

The path coefficients related to the direct and indirect effects of the investigated characters on fruit yield are given in Table 3. All traits, viz plant height, number of branches, number of umbels, number of fruits, biological yield, TFW and EOC displayed a positive direct effect on fruit yield, just number of umbellets with a -8.96 % contribution ratio had a direct negative effect on fruit yield. Biological yield (59.88 %) provided the highest positive direct contribution. The direct effect of biological yield on seed yield of fennel was affirmed by Bahmani et al. (2015). Whereas, opposite to our result, biological yield has negative influence on seed yield in sweet fennel (Coşge et al., 2009). TFW (29.41 %), plant height (20.16 %), EOC (15.14 %), number of umbels (13.09 %), number of branches (5.23 %) and number of fruits (3.18 %) followed the biological yield. These results are consistent with the results of Patel and Patel (2015) for number of branches per plant, number of umbels per plant and test weight and Singh et al. (2020) for umbels per plant, seeds per umbels and plant height in normal environment and for umbels per plant, test weight and plant height in drought environment. Majority of these traits also exerted positive and significant correlation with fruit yield. Biological yield (r = 929**), number of fruit (r = 0.805**), thousand fruit weight (r=0.726**), plant height (r=0.696**) and number of umbellets (r=0.609**) had positive and highly significant ($p < 0.01$) correlation with fruit yield. It showed that, the positive and significant correlations of traits with fruit yield were due to the direct effects. Therefore, it is possible to propose that the characters could be used for indirect selection of genotypes for the yield. When we examine the indirect effects of biological yield, all traits have a highly positive indirect influence on fruit yield except the branches number (-23.86%). The maximal indirect positive effect on fruit yield through biological yield was shown by the number of fruits (37.57%), followed by plant height (29.86 %), thousand fruit weight (27.63%), number of umbellets (23.76%), number of umbels (17.36%) and EOC (8.43%).

Thousand fruit weight (29.41%) revealed the next highest positive direct effect on fruit yield. It also exhibited high indirect effects on fruit yield through essential oil content (27.34%), number of umbellets (26.33%), plant height (20.05%), number of fruit (18.81%) and biological yield (13.98%). But the positive direct impact of TFW on fruit yield was stabilized by the rather elevated indirect inverse influence via the number of umbels (-30.50%) and number of branches (-17.53%). This agrees with earlier reports of Cosge et al. (2009) whereas, Sefidan et al. (2014) reported positive and low direct effect of the TFW on fruit yield and negative indirect effect of the TFW on yield via number of umbel and number of fruits per umbel. In addition, Kumavat (2010) informed that TFW had a weak and positive direct effect on fruit yield.

Another character that has a high direct effect on fruit yield is plant height (20.16 %). When the indirect effects of plant height on fruit yield were examined, it was noticed that all traits had a positive indirect effect on fruit yield, of which EOC (17.37 %), number of umbellets (16.10 %), number of fruit (14.60 %), thousand fruit weight (13.30 %), number of umbels (11.32 %) and biological yield (10.02 %) were balanced by the relatively high negative indirect influence of the number of branches (-24.62%).

The number of umbellets (-8.96%) was the only trait that had a negative direct effect on fruit yield. However, this trait positively and significantly correlated with fruit yield at the 0.01 probability level (r=0.609**) (Table 1). In this case that is required to examine the indirect effects of this trait. Here, it is seen that the number of branches and the number of umbels have positive indirect effects on fruit yield via the number of umbellets. When the correlation coefficient is considerably positive and the direct influence is negative, a limited concurrent selection pattern will be applied, that is, constraints will be enforced to override the unwanted effect to profit the direct effect. (Sing and Kakar 1977; Rashid et al., 2010).

The most indirect positive effects of plant height, number of umbels, number of fruits, and TFW were on fruit yield through biological yield while number of umbellets, biological yield, and EOC has provided the most indirect positive effects on fruit yield through TFW. Among the traits, just the number of branches had the positive and small indirect influence on fruit yield via the number of umbellets, while it had a negative indirect effect through all other traits. In addition, while the simple correlation between the number of branches and fruit yield was negative and insignificant, the number of branches directly affected the fruit yield positively but low. Therefore, it is clear that indirect effect of this trait through other variables is negative. Similar situation was reported by Sefidan et al. (2014) for the relationship between 1000 grain weight and grain yield. Further, the most indirect effect was related to number of fruits (37.57 %), plant height (29.86 %), and thousand fruit weight (27.63 %) which was applied on fruit yield via biological yield. Bahmani et al. (2012) reported that the most indirect influence on seed yield were detected for number of leaves through weight of dry biomass (0.4135). All traits affected fruit yield negatively indirect and at a negligible level via number of branches. The most indirect negative effects on fruit yield were related to number of umbels (-30.50%) via TFW and number of branches (-24.62 %) via plant height and number of branches (-23.86 %) via biological yield.

4. Conclusion

When the results were evaluated in general, the correlation of EOC with umbrella number, fruit number, TFW and plant height was positive and quite significant. All these characters are the advantageously traits which are important to coordinate selection stage to improve the EOC in fennel. Path coefficient analysis showed that among the causal (independent) traits; fruit yield and umbellet number had positive direct effect on EOC. In addition, plant height, number of fruits and TFW also affected the essential oil content indirectly and positively. Therefore, these properties can be used as efficient selection criterions to achieve high yields in improvement programs to increase the EOC of fennel.

The correlation of fruit yield with biological yield, number of fruits, TFW, plant height and number of umbellet was positive and highly significant. In addition, all these traits exhibited positive and significant relationships with each other. Therefore, these characters can be taken as selection criteria to obtain higher fruit yield in fennel. In addition, all traits except the number of umbellets had a direct positive effect on fruit yield. The most important positive influence was determined on fruit yield through biological yield, TFW and plant height. In addition, fruit number, plant height and TFW showed the highest indirect effects on fruit yield thought biological yield. Therefore, these traits can be evaluated as selection criterion to attain higher seed yield in fennel.

Author Contribution

R.R.A.G and A.B.A contributed equally to the design and implementation of the research, to the analysis of the results and to the writing of the manuscript.

Conflicts of Interest

The authors declares that they have no conflict of interest.

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