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Enhancement of Essential Oil Yield of Egyptian Anise, *Pimpinella anisum,* L. by Individual Plant Selection

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Abstract: Anise, *Pimpinella anisum* L. is an important medicinal plant in Egypt. It's essential oil has been used for the purposes of pharmaceuticals, food industry as well as its biological activity. The major aim of this study is to obtain new anise genotypes characterized with enhanced essential oil yield for utilization in a promising hybridization program in Egypt. Therefore 45 different phenotypic forms of anise plants were selected all over the cultivated area in El- Minia Governorate. The selected plants were cultivated for two successive seasons (2007/2008 and 2008/2009) and their characters were evaluated. Analysis of variance detected highly significant variation among the genotypes in all traits for both seasons. Three genotypes no. 31, 22 and 3 attracted the attention according to their owning the best mean values for all traits. Meanwhile, the coefficient of variation, broad sense heritability and genetic advance proved that essential oil yield is the most important trait for anise and can be good criteria for selection. Moreover, simple correlation coefficient and path analysis showed that essential oil yield is affected significantly and positively by each of fruit yield, essential oil content and no. of primary branches, respectively. Therefore, the selection for any of these traits or simultaneous selection for more than one would improve the essential oil yield in anise.

Kew words: Essential oil, Egyptian anise, *Pimpinella anisum* L

INTRODUCTION

Apiaceae (*Umbelliferae*) family comprises 300-455 genera and 3000-3750 species (Tabanca *et al.* 2006). Its members include economically important vegetables (e.g. carrot and celery) and condiments (e.g coriander, anise, caraway, cumin, parsley and dill). The genus *Pimpinella* (under *Apiaceae*) is of around 150 species, some of them were cultivated by Egyptians, Greeks and Romans since antiquity, and they are listed in British, German and European pharmacopoeia (Tepe *et al.*, 2006).

Anise, *Pimpinella anisum* L. is one of the common and important medicinal plants cultivated in Egypt. Fruits of anise have been used in medicine as carminative, appetizers, sedative, a mild expectorant, a treat dyspeptic complaints, and used in the food industry and agents to increase milk secretion (Fujimatu *et al.* 2003, Park *et al.* 2004, Abou El-Nasr *et al.* 2003a and Lubbe and Verpoorte 2011). They have been also used as bactericidal, virucidal, fungicidal, antiparasitical, anti-insecticidal, beside their cosmetic applications (Bakkali *et al*. 2008 and Lubbe and Verpoorte 2011).

Fruit and essential oil yields are the main target for anise plants, so they are the approach of the scientific research for intensification and development quality and quantity. Many means had been studied for enhancement the anise yield such as the preferable sowing time (Tuneturk and Yildirium 2006 and Yan *et al.* 2011), the best nitrogen and phosphorous fertilizers (Iran- Nejad and Schahbazian 2006), recomm- ended vermicompost fertilizers (Darzi *et al.* 2012), and essential oil content and composition (Arslan *el al.* 2004, Ozcan and Chalchat 2006, Orav *et al.* 2008 and Sharifi *et al.* 2008).

Genetic selection (baised on the main plant morphological characteristics) is one of the important and significant tool for enhancement the fruit and essential oil yields of anise. In this respection, Holm and Slinkard (2002) selected 50 individual plants of anise to evaluate the essential oil concentration. Curioni *et al.* (2003) studied the yield and yield components of anise at various locations. Abou EL-Nasr *et al.* (2003a) selected two anise groups based on the long and short internodes (contained 13 and 29 genotypes, respectively), and studied the phenotypic and genotypic variability, broad sense heritability, genetic advance and path coefficient analysis in both groups under organic fertilization conditions. Also, Abou El-Nasr *et al* (2003b) studied the correlation and path coefficient analysis in both anise groups among eight plant characters, and found significantly positive correlation between fruit yield and total branches per plant with the essential oil yield.

This investigation aims to obtain new Egyptian anise genotypes, characterized with enhanced fruit and essential oil yields, for propagation and popularization and/or for utilizing them in a promising hybridization program.

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MATERIALS AND METHODS

El-Minia Governorate has the most density of anise cultivation in Egypt. Addition to the significantly positive correlation between total branches and fruit yield per plant with the essential oil yield of anise recorded by Abou El-Nasr *et al.* 2003b, 45 different forms of anise plants were selected (based on total number of branches and fruit yield per plant) all over the cultivated area in El-Minia Governorate at the winter season (2006/2007). The fruits of the selected plants were separately harvested to form new genotypes in the next years.

Cultivation Method:

The harvested fruits of the selected plants were sown under new sandy reclaimed land at El-Minia City, El-Minia governorate, Egypt, in November for two successive seasons (2007/2008 and 2008/2009). A completely randomized blocks with there replications were designed. Each replicate had three lines of 10 m long and 70 cm wide. The plants were thinned to leave two plants per hill 50 cm space. Only organic fertilization (without any chemical nutrients) was used and all the other cultural practices were done whenever they were required. At maturity the fruits of each genotype were harvested separately. Eight quantitative characters were recorded for each season as the following:

X_1- Essential oil yield per plant. (gm/plant)
X_2- Linear growth (cm).
X_3- Plant height (cm).
X_4- Number of primary branches per plant.
X_5- Number of total branches per plant.
X_6- Number of umbellules per umbel.
X_7- Fruit yield per plant (g).
X_8- Essential oil content (%).

Statistical Procedures:

The general statistical procedures were practiced using version 11 of (SPSS software 2001). Analysis variance (ANOVA) and broad sense heritability (h^2b) were generally assigned according to Robinson *et al.* (1951). The genetic advance ΔGA % was computed according to Johanson *et al.* (1955).
The statistical analysis included calculating phenotypic and genotypic correlation coefficients according to Steel and Torrie (1980). Path coefficient analysis was performed according to Dewey and Lu (1959) and as illustrated by Singh and Chaudhary (1985) to partition the phenotypic and genotypic correlations between the traits studied into direct and indirect effects.

Determination of Essential Oils:

Twenty five grams of milled fruits were subjected for hydrodistillation in micro scale (v/w) return flow distillation apparatus (Guenther 1961) for each genotype. The volume of essential oil was estimated as essential oil content %. Essential oil yield was computed from multiplication of fruit yield per plant with essential oil content for each genotype.

Results:
Analysis of Variance:

Analysis of variance for eight characters related to the essential oil yield of 45 anise genotypes in two successive seasons is shown in Table (1). Anise genotypes appeared highly significant differences in all studied traits for both seasons. Genotypes variability was more pronounced in the second season than that in the first season for all characters except essential oil content per plant.

Table 1: Analysis of variance (MSQ) of eight quantitative characters for 45 anise genotype in two successive seasons (2006/2007 and 2007/2008).

Source of variance	D.F	Essential oil yield (gm/plant) X1	Linear growth (cm) X2	Plant Height (cm) X3	Number of primary branches/ plant X4	Number of total branches/ plant X5	Number of umbellules /umbel X6	Fruit yield/ plant X7	Essential oil content / plant (%) X8
First season									
Replicate	2	0.005	5.997	36.714	2.763	10.168	0.339	10.034	0.037
Genotype	44	0.122**	116.222**	68.933**	7.765**	255.226**	4.201**	41.861**	0.801**
Error	88	0.002	2.962	4.317	0.771	31.186	0.685	1.348	0.015
Total	134								
Second season									
Replicate	2	0.003	19.788	18.597	4.363	17.544	0.106	3.342	0.106
Genotype	44	0.169**	218.387**	132.294**	7.932**	322.917**	7.575**	50.188**	0.771**
Error	88	0.002	4.717	4.653	1.287	45.435	0.988	1.309	0.014
Total	134								

*and ** significant at P≤ 0.05 and 0.01 levels of probability, respectively.

Genotypes Performance for Mean Values:

Genotypes mean values of all studied characters in both seasons separately are illustrated in Table (2). The results indicated that genotypes 31, 22 and 3 exhibited the highest essential oil yield, 1.374 and 1.775, 1.275 and

1552 as well as 1.130 and 1.385 grams per plant in the first and second seasons, respectively. Genotypes 31 and 22, had the maximum fruit yield per plant, 31.50 and 36.50 as well as 30.17 and 34.50 grams in the first and second seasons, respectively. Meanwhile, genotypes 3 and 31 presented the maximum essential oil content, 5.30 and 5.433% , 4.367 and 4.867 in the same respection. Moreover, genotype 3 was the first one for the highest number of primary branches per plant (17 branches) and was the second for the highest number of total branches per plant (83.33 branches) in the first season. Opposite to genotype 1 which was the first for the maximum number of total branches (86.33 branches) and the second for number of primary branches (16 branches) in the same season, However, 76.33 and 63.67 cm were found to be the highest linear growth and plant height values, respectively and related to genotype 19 at the first season. While, in the second season, genotype 28 was the highest for linear growth and number of total branches per plant (80.0cm and 85.0 branches, respectively). Generally, the maximum values were higher in the second season than these in the first season for all characters except plant height and number of total branches per plant.

Table 2: Mean performance of eight traits studied in the two seasons (2006/2007 and 2007/2008) analysis of anise genotypes.

Genotypes	Essential oil yield		Linear growth		Pant height		Number of Primary branches		Number of total branches		Number of umbellules/ umbel		Fruit yield		Essential oil content (%)	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
1	0.710	0.888	52.330	67.000	43.330	47.000	16.000	13.000	86.330	53.333	17.330	12.667	26.330	29.000	2.700	3.067
2	0.785	0.942	65.330	61.667	49.670	45.000	15.000	14.333	73.330 ..	68.333	15.040	14.223	22.670	26.667	3.467	3.533
3	1.130	1.385	63.330	67.333	47.670	43.333	17.000	16.333	83.330	79.333	16.440	17.110	21.330	25.333	5.300	5.433
4	0.727	0.878	70.670	77.000	50.330	50.667	16.000	16.333	80.000	59.667	17.370	15.333	21.000	22.333	3.467	3.933
5	0.526	0.652	65.670	64.667	47.000	45.333	14.330	15.000	72.670	73.000	17.670	17.000	18.670	21.500	2.767	3.033
6	0.596	0.849	56.330	56.667	41.670	43.333	15.000	16.000	80.670	69.667	16.480	14.667	19.000	25.167	3.133	3.400
7	0.539	0.676	63.330	65.000	45.330	46.667	13.000	12.333	60.330	59.333	16.330	16.667	17.000	20.667	3.167	3.267
8	0.786	1.002	66.000	55.333	49.330	43.000	12.330	11.667	60.330	50.667	14.890	13.443	20.000	23.500	3.933	4.267
9	0.695	0.913	72.330	72.333	54.670	53.667	12.000	15.667	61.330	74.333	15.000	15.333	23.170	29.167	3.000	3.133
10	0.941	1.146	75.000	62.000	55.670	45.333	14.330	16.000	83.330	58.333	15.330	12.667	23.330	26.667	4.033	4.300
11	0.737	0.919	69.330	55.667	55.000	41.667	14.000	15.000	77.000	64.333	15.300	13.557	23.330	26.000	3.167	3.533
12	0.731	0.912	56.330	55.667	41.000	43.667	11.330	12.000	55.000	51.333	15.630	16.557	21.330	25.333	3.433	3.600
13	0.879	1.172	58.000	51.667	44.670	36.667	12.000	13.667	64.670	52.000	14.670	13.000	24.670	31.667	3.567	3.700
14	0.776	0.969	69.000	76.333	47.000	62.000	12.000	12.333	68.330	58.000	14.930	14.667	21.000	23.833	3.700	4.067
15	0.779	0.889	71.670	61.000	57.330	51.333	13.000	13.667	68.000	48.000	14.260	14.557	19.670	21.000	3.933	4.233
16	0.718	0.933	75.000	57.000	48.670	41.667	11.330	16.667	58.670	84.333	14.890	13.667	23.330	28.000	3.033	3.333
17	0.679	0.948	67.000	52.333	50.330	40.667	13.000	12.000	68.000	51.000	14.000	13.333	18.330	23.333	3.667	4.067
18	0.797	0.997	66.000	65.667	52.000	46.333	14.000	14.333	71.330	71.333	15.590	15.333	19.000	24.333	4.200	4.100
19	0.555	0.819	76.330	74.667	63.670	51.000	14.670	12.667	72.670	55.333	14.960	14.000	16.000	21.000	3.433	3.900
20	0.520	0.796	58.330	62.667	48.330	49.000	14.670	13.667	59.000	71.667	14.480	16.333	16.330	22.000	3.367	3.567
21	0.629	0.805	66.000	61.333	47.000	46.000	12.000	14.000	58.670	68.000	15.780	14.890	21.330	25.667	2.900	3.133
22	1.257	1.552	74.000	54.667	51.330	38.333	14.000	17.667	72.670	57.333	14.520	16.333	30.170	34.500	4.167	4.500
23	0.698	0.902	61.00	59.66	50.00	49.00	12.00	13.33	58.67	67.00	15.81	15.55	16.33	20.50	4.233	4.400
24	0.715	0.980	69.00	56.66	51.00	43.33	11.33	11.66	58.67	60.00	15.96	16.77	20.67	25.83	3.467	3.800
25	0.632	0.832	70.33	73.66	53.33	60.00	11.00	12.00	59.33	59.33	15.00	15.33	19.17	23.33	3.300	3.567
26	0.584	0.743	65.00	79.66	48.33	59.66	13.33	12.66	79.00	52.66	13.44	17.33	20.33	23.50	2.833	3.167
27	1.115	1.371	76.00	52.33	52.00	40.33	11.00	12.33	57.00	51.00	17.26	16.33	27.17	31.66	4.100	4.333
28	0.612	0.847	72.00	80.00	45.00	61.33	13.33	14.33	68.00	85.00	13.63	14.00	17.17	21.00	3.533	4.033
29	0.686	0.878	66.33	61.33	44.00	45.66	11.00	14.00	54.67	50.33	14.78	14.33	20.17	25.83	3.400	3.400
30	1.059	1.320	71.00	62.00	54.33	42.66	14.00	14.33	72.33	71.33	14.85	14.66	25.67	30.00	4.133	4.400
31	1.374	1.775	61.33	73.00	43.00	47.66	14.33	15.66	70.33	67.00	16.41	18.66	31.50	36.50	4.367	4.867
32	0.798	1.030	67.33	52.66	53.33	40.00	12.67	13.33	71.00	70.33	16.89	12.33	23.50	26.89	3.400	3.833
33	0.611	0.772	57.67	72.66	49.67	52.33	11.00	14.00	53.33	72.00	15.19	12.33	18.33	21.66	3.333	3.567
34	0.725	1.050	73.00	75.33	49.00	61.00	12.00	15.00	62.00	60.33	16.54	14.66	20.17	25.83	3.600	4.067
35	1.071	1.291	70.67	60.66	51.33	45.00	12.67	17.33	63.00	78.00	13.52	13.78	26.33	31.50	4.067	4.100
36	0.945	1.176	62.00	69.66	48.67	54.33	15.00	14.00	78.00	79.00	14.92	14.00	26.50	31.50	3.567	3.733
37	0.848	1.095	68.67	46.66	47.33	35.66	14.00	12.00	64.00	69.00	16.00	17.22	26.50	31.00	3.200	3.533
38	0.931	1.089	61.67	62.66	46.33	45.00	11.67	13.00	60.00	47.00	15.67	14.33	21.00	23.83	4.300	4.567
39	0.974	1.341	67.33	52.33	56.33	40.33	10.33	15.33	53.33	61.33	17.04	13.33	26.33	33.00	3.700	4.067
40	0.550	0.810	55.67	62.33	42.00	43.00	11.33	13.66	61.67	70.00	14.37	13.55	18.33	23.83	3.000	3.400
41	1.005	1.228	70.67	53.66	45.00	39.66	14.00	13.00	64.67	55.00	14.67	14.22	26.00	28.83	3.867	4.267
42	0.897	1.071	61.00	72.66	43.00	52.00	11.00	12.33	53.33	61.33	17.04	17.00	21.17	25.33	4.233	4.233
43	0.618	0.743	71.00	57.00	55.67	41.00	11.00	13.00	59.33	51.33	17.26	12.89	17.50	20.83	3.533	3.567
44	1.059	1.313	54.00	66.00	44.33	47.00	13.00	16.66	64.00	81.00	18.22	16.66	25.83	31.50	4.100	4.167
45	0.730	0.993	67.33	69.33	51.67	51.33	12.67	13.00	51.00	60.33	16.74	16.77	20.67	24.66	3.533	3.867
LSD 0.05	0.065	0.069	2.811	3.547	3.393	3.523	1.433	1.853	9.119	11.00	1.351	1.623	1.896	1.869	0.203	0.194
LSD 0.01	0.087	0.091	3.738	4.717	4.513	4.685	1.906	2.464	12.12	14.64	1.797	2.158	2.521	2.485	0.270	0.258

Genotypes Performance For Some Genetic Parameters:

Three genetic parameters: coefficient of variation (c.v. %), broad sense heritability (h^2b) and genetic advance (GA %) were evaluated for all genotype characters under study in both seasons and shown in **Table (3).** From c.v. % evaluation, it cleared that the trait of essential oil yield had more heterogeneity among genotypes, where it had the highest c.v.% in both seasons (25.42 and 23.345%, respectively). Opposite to the character of number of umbellules per umbel which gave the lowest c.v% values in both seasons (7.584 and 10.65%, respectively). Regarding to h^2b, essential oil yield gave the highest values (0.962 and 0.969) in the first and second seasons, respectively. While the lowest h^2b value (0.631) was related to the number of umbellules per umbel in the first season, and (0.632) related to number of primary branches in the second season. All h^2b values were higher in the second season than those in the first season for all characters except for both numbers of primary and total branches per plant which were higher in the first one. Furthermore , the value of GA% 19.526 was found to be the highest value in the first season and related to the number of total branches per plant, as well as 23.438% was the highest GA% in the second season and related to linear growth trait. However, essential oil yield presented the lowest GA% for both seasons (0.567 and 0.671, respectively).

Table 3: Estimates of broad sense heritability (h^2_b) and genetic advance (GA%) of mean in Essential oil yield and its attributes in two seasons (2006/2007 and 2007/2008) of anise genotypes.

Statistical parmeters	Characters								
	Seasons	X1	X2	x3	X4	X5	X6	X7	X8
Average	First	0.794	66.163	49.237	12.993	66.052	15.602	21.852	3.607
	Second	1.015	63.326	46.867	14.007	63.518	14.921	26.112	3.867
Standard Error	First	0.030	0.928	0.715	0.240	1.375	0.176	0.557	0.077
	Second	0.035	1.272	0.990	0.242	1.547	0.237	0.610	0.076
Cofficient of variation	First	25.420	9.407	9.736	12.383	13.964	7.584	17.094	14.327
	Second	23.345	13.473	14.169	11.608	16.334	10.650	15.664	13.112
Broad sense heritability	First	0.962	0.927	0.833	0.752	0.705	0.631	0.909	0.944
	Second	0.969	0.938	0.901	0.632	0.671	0.690	0.926	0.947
Genetic Advance	First	0.567	16.920	11.814	3.609	19.526	2.263	9.974	1.429
	Second	0.671	23.438	17.591	3.115	20.970	3.296	11.101	1.405

Phenotypic and Genotypic Correlation Coefficient:

As shown in **Table (4),** positive and significant phenotypic and genotypic associations were found between essential oil yield/plant with both fruit yield/plant and essential oil content and between linear growth with plant height and between no. of primary branches/plant with no. of total branches / plant in both seasons. However, essential oil yield and oil content correlated positively and significantly under phenotypic and genotypic levels with no. of primary branches and negatively and significantly with plant height in the second season only. Meanwhile, positive and significant phenotypic correlation was found between essential oil yield with no. of total branches/ plant as well as negative and significant genotypic association was estimated for linear growth with fruit yield/plant in the second season.

Table 4: Phenotypic (above diagonal), genotypic (below diagonal) correlation coefficients among all traits studied of anise genotypes in the two seasons.

	X1	X2	X3	X4	X5	X6	X7	X8
	First Season (2006/2007)							
X1		0.014	-0.019	0.135	0.124	0.130	0.824**	0.718 **
X2	0.119		0.674**	-0.060	-0.003	-0.199	0.059	0.091
X3	- 0.015	0.686**		0.009	0.046	-0.091	-0.090	0.087
X4	0.161	-0.088	-0.025		0.798**	0.020	0.136	0.089
X5	0.142	0.014	0.083	0.870**		-0.045	0.181	0.017
X6	0.110	-0.224	-0.107	0.062	-0.010		0.149	0.045
X7	0.834**	0.080	-0.078	0.148	0.190	0.119		0.212
X8	0.743**	0.094	0.084	0.125	0.028	0.067	0.258	
	Second Season (2007/008)							
X1		-0.197	-0.3021*	0.336*	0.603**	0.226	0.822 **	0.717 **
X2	-0.208		0.876**	0.082	0.176	0.174	-0.289	-0.016
X3	-0.321*	0.904**		-0.050	0.122	0.107	-0.361*	-0.090
X4	0.429**	0.081	-0.120		0.560**	-0.034	0.337*	0.160
XS	0.100	0.209	0.100	0.519**		0.024	0.107	-0.024
X6	0.222	0.227	0.141	-0.012	0.128		0.156	0.150
X7	0.833**	-0.321*	-0.400**	0.438**	0.180	0.095		0.205
X8	0.737**	-0.011	-0.088	0.207	-0.040	0.193	0.248	

*= significant at P5≤0.05, ** = significant at P≤ 0.01

Xt	Essential oil yield /plant	X_5	No. of total branches/ plant
X2	Linear growth	X_6	No. of umbellules / umbel
X3	Plant height	X_7	Fruit yield/ plant
X4	No. of primary branches/plant	X_8	% Essential oil content / plant

Path Coefficient Analysis:

The path coefficient analysis involves partitioning the phenotypic and genotypic correlation coefficients into direct and indirect effects via alternative traits. The direct and indirect effects of the seven essential oil yield/plant – related traits were computed and illustrated in **Table (5).** Fruit yield/ plant at both phenotypic and genotypic levels had the highest direct effect on the essential oil yield, 0.7019 and 0.6820 in the first season and 0.6977 and 0.6870 in the second season, respectively. Fruit yield indirect effect via essential oil content was positive of 0.1208 and 0.1475 at the phenotypic and genotypic levels in the first season and 0.1158 and 0.1361 at the same levels in the second season. The total effect (directly and indirectly) of fruit yield was 0.8245 and 0.8346 as well as 0.8227 and 0.8325 in the first and second seasons, respectively. Moreover, essential oil content had the second important direct effect on essential oil yield in both seasons at both phenotypic and genotypic levels. Essential oil content presented 0.5696 and 0.5716 as well as 0.5648 and 0.5490 as direct effect in the levels of phenotypic and genotypic in the first and second seasons, respectively. Indirect effect of essential oil content via fruit yield was positive values of 0.1488 and 0.1760 in the first season and 0.1430 and 0.1704 in the second season.

The total effect of essential oil content was 0.7188 and 0.7439 as well as 0.7171 and 0.7370 at phenotypic and genotypic levels in the first and second seasons, respectively. However, the third important trait effected on essential oil yield was no. of primary branches/ plant, where its total effect was 0.1352 and 0.1615 in the first season and 0.3366 and 0.4286 in the second season at the phenotypic and genotypic levels, respectively.

Table 5: Partitioning of phenotypic (P) and genotypic (G) correlation coefficients between essential oil yield with other yield components in the first and second season.

Sources	First season		Second season	
	P	G	P	G
(1) Linear growth vs essential oil yield				
Direct effect (P_1)	0.0263	0.0297	0.0427	0.0657
Indirect via plant height x_3	-0.0149	-0.0232	-0.0338	-0.0539
Via No. of primary branches x_4	0.000	0.0030	0.0009	0.0012
Via No. of total branches x_5	0.000	0.0004	-0.0012	-0.0049
Via No. of umbellules / umbel x_6	-0.0005	0.0008	0.0053	0.0108
Via Fruit yield x_7	0.0414	0.0546	-0.2016	-0.2205
Via Essential oil content (%) x_8	0.0518	0.0537	-0.0090	-0.0060
Total direct + indirect	0.1041	0.1189	-0.1969	-0.2077
(2) Plant height vs essential oil yield				
Direct effect (P_2)	-0.0220	-0.0339	-0.0386	-0.0596
Indirect via Liner growth x_2	0.0177	0.0204	0.0374	0.0594
Via No. of primary branches x_4	0.0000	0.0008	-0.0005	-0.0017
Via No. of total branches x_5	-0.0005	0.0024	-0.0008	-0.0024
Via No. of umbellules / umbel x_6	-0.0002	0.0004	0.0033	0.0067
Via Fruit yield x_7	-0.0632	-0.0532	-0.2519	-0.2748
Via Essential oil content (%) x_8	0.0496	0.0480	-0.0508	-0.0483
Total direct + indirect	-0.0187	-0.0151	-0.3020	-0.3207
(3) No. of primary branches vs essential oil yield				
Direct effect (P_3)	-0.0002	-0.0337	0.0106	0.0145
Indirect via Liner growth x_2	-0.0016	-0.0026	0.0035	0.0053
Via Plant height x_3	-0.0002	0.0008	0.0019	0.0072
Via No. of total branches x_5	-0.0090	0.0248	-0.0039	-0.0123
Via No. of umbellules / umbel x_6	0.0001	-0.0002	-0.0010	-0.006
Via Fruit Yield x_7	0.0955	0.1009	0.2351	0.3009
Via Essential oil content (%) x_8	0.0507	0.0715	0.0904	0.1136
Total direct + indirect	0.1352	0.1615	0.3366	0.4286
(4)No. of total branches vs essential oil yield yield				
Direct effect (P_4)	-0.0113	0.0285	-0.0069	-0.0236
Indirect via Liner growth x_2	-0.0001	0.0004	0.0075	0.0137
Via Plant height x_3	-0.0010	-0.0028	-0.0047	-0.0060
Via No. of primary branches x_4	-0.0001	-0.0293	0.0059	0.0075
Via No. of umbellules / umbel x_6	-0.0001	0.000	0.0007	0.0061
Via Fruit yield x_7	0.1270	0.1296	0.0747	0.1237
Via Essential oil content (%) x_8	0.0097	0.0160	-0.0136	-0.0220
Total direct + indirect	0.1241	0.1424	0.0637	0.09.94
(5)No. of umbellules / umbel vs essential oil yield				
Direct effect (P_5)	0.0027	-0.0034	0.0305	0.0475
Indirect via Liner growth x_2	-0.0052	-0.0067	0.0074	0.0149
Via Plant height x_3	0.0020	0.0036	-0.0041	-0.0084
Via No. of primary branches x_4	0.0000	-0.0021	-0.0004	-0.0002
Via No. of total branches x_5	0.0005	-0.0003	-0.0002	-0.0030
Via Fruit yield x_7	0.1046	0.0812	0.1088	0.0653
Via Essential oil content (%) x_8	0.0256	0.0383	0.0847	0.1060
Total direct + indirect	0.1302	0.1107	0.2269	0.2220
(6) Fruit yield vs essential oil yield				
Direct effect (P_6) x_2	0.7019	0.6820	0.6977	0.6870
Indirect via Liner growth x_3	0.0015	0.0024	-0.0123	-0.0211
Via Plant height x_4	0.0020	0.0026	0.0139	0.0238
Via No. of primary branches x_5	0.0000	-0.0050	0.0036	0.0063
Via No. of total branches x_6	-0.0021	0.0054	-0.0007	-0.0043
Via No. of umbellules / umbel x_8	0.0004	-0.0004	0.0048	0.0045
Via Essential oil content (%)	0.1208	0.1475	0.1158	0.1361
Total direct + indirect	0.8245	0.8346	0.8227	0.8325
(7) Essential oil content (%) vs essential oil yield				
Direct effect (P_7)	0.5696	0.5716	0.5648	0.5490
Indirect via Liner growth x_2	0.0024	0.0028	-0.0007	-0.0007
Via Plant height x_3	-0.0019	-0.0028	0.0035	0.0052
Via No. of primary branches x_4	0.0000	-0.0042	0.0017	0.0030
Via No. of total branches x_5	-0.0002	0.0008	0.0002	0.0009
Via No. of umbellules / umbel x_6	0.0001	-0.0002	0.0046	0.0092
Via Fruit yield x_7	0.1488	0.1760	0.1430	0.1704
Total direct + indirect	0.7188	0.7439	0.7171	0.7370

The components of essential oil yield variations determined directly and jointly under phenotypic and genotypic levels by each factor are computed and presented in **Table (6).** The main source of essential oil yield variation in order of relative importance was the direct effect of fruit yield / plant 49.142 and 44.960 % as phenotypic and genotypic levels, respectively in the first season, and 46.939 and 43.445% in the same respecting in the second season. The second source of essential oil yield variation was the direct effect of essential oil content, 32.372 and 31.574% as well as 30.759 and 27.748% in the same respection in the first and second seasons. Furthermore, the third impotent source was the positive joint effect of fruit yield /plant with the essential oil content 16.909 and 19.445% in the first season and 15.582 and 17.225% in the second season as phenotypic and genotypic levels, respectively. Hence, the direct effect of fruit yield / plant and essential oil content as well as their joint effect contributed essential oil yield /plant by 98.423 and 95.979% out of 99.022 and 99.681% total contribution of the phenotypic and genotypic levels in the first season. Addition to 93.280 and 88.418% out of 99.258 and 99.659% total contribution with the same respection in the second season.

Table 6: Components (direct + joint effects) as percentage of different contribution to essential oil yield/plant at phenotypic and genotypic levels of anise genotypes in the first and second seasons.

Source of variation	First Season				Second Season			
	Phenotypic		Genotypic		Phenotypic		Genotypic	
	CD	RI%	CD	RI%	CD	RI%	CD	RI%
Essential oil yield								
X_2	0.0007	0.0698	0.0009	0.0870	0.0018	0.1736	0.0043	0.3959
X_3	0.0005	0.0499	0.0011	0.1063	0.0015	0.1446	0.0036	0.3314
X_4	0.0000	0.0000	0.0011	0.1063	0.0001	0.0096	0.0002	0.0184
X_5	0.0001	0.0100	0.0008	0.0773	0.0000	0.0000	0.0006	0.0552
X_6	0.0000	0.0000	0.0000	0.0000	0.0009	0.0868	0.0023	0.2117
X_7	0.4926	49.142	0.4652	44.960 ,.	0.4868	46.939	0.4719	43.445
X_8	0.3245 ,<	32.372	0.3267	31.574	0.3190	30.759 <,	0.3014	27.748
Indirect effect								
X_2 x X_3	0.0008	0.0798	-0.0014	0.1353	-0.0029	0.2796	-0.0071	0.6537
X_4	0.0000	0.0000	0.0002	0.0193	0.0001	0.0096	0.0002	0.0184
X_5	0.0000	0.0000	0.0000	0.0000	-0.0001	0.0096	-0.0006	0.0552
X_6	0.0000	0.0000	0.0000	0.0000	0.0005	0.0482	0.0014	0.1289
X_7	0.0022	0.2198	0.0032	0.3093	-0.0172	1.6585	-0.0290	2.6699
X_8	0.0027	0.2694	0.0032	0.3093	-0.0008	0.0771	-0.0008	0.0737
X_3 x X_4	0.0000	0.0000	-0.0001	0.0097	0.0000	0.0000	0.0002	0.0184
X_5	0.0000	0.0000	-0.0002	0.0193	0.0001	0.0096	0.0003	0.0276
X_6	0.0000	0.0000	0.0000	0.0000	-0.0003	0.0289	-0.0008	0.0737
X_7	0.0028	0.2793	0.0036	0.3479	0.0195	1.8802	0.0328	3.0197
X_8	-0.0022	0.2195	-0.0033	0.3189	0.0039	0.3760	0.0058	0.5340
X_4 x X_5	0.0000	0.0000	-0.0017	0.1643	-0.0001	0.0096	-0.0004	0.0368
X_6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
X_7	0.0000	0.0000	-0.0068	0.6572	0.0050	0.4821	0.0087	0.8010
X_8	0.0000	0.0000	-0.0048	0.4639	0.0019	0.1832	0.0033	0.3038
X_5 x X_6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-0.0003	0.0276
X_7	-0.0029	0.2893	0.0074	0.7152	-0.0010	0.0964	-0.0058	0.5340
X_8	-0.0002	0.0200	0.0009	0.0870	0.0002	0.0193	0.0010	0.0921
X_6 x X_7	0.0006	0.0599	-0.0006	0.0580	0.0066	0.6364	0.0062	0.5708
X_8	0.0001	0.0100	-0.0003	0.0290	0.0052	0.5014	0.0101	0.9298
X_7 x X_8	0.1695	16.909	0.2012	19.445	0.1616	15.582	0.1871	17.225
Residual effect	0.0098	0.9777	0.0037	0.3189	0.0077	0.7425	0.0037	0.3406
Total	0.9902	100.0%	0.9963	100.0%	0.9923	100.0%	0.9963	100.0%
	1.00		1.00		1.00		1.00	

D= Coefficient of determination. RI = Relative importance.

Discussion:

Analysis of variance detected highly significant differences in all traits for both seasons. These results confirmed the differences in the genotypes genetics potential, and indicated that certain genotypes carried alleles with different additive and additive × additive effects and these effects were constant from season to another (Abou El-Nasr *et al*., 2003a and Curioni *et al*., 2003).

The mean values varied in all traits among genotypes in both seasons to confirm the results of analysis of variance and reflected the different genetic background of genotypes and their interaction with the seasonal variations. The same findings were reported in other *Apiaceae* plants like coriander and fennel (Tripathi *et al*., 2000, Marockiene 2002, Singh *et al* 2002, Abou El- Nasr *et al* 2004 and Telci *et al* 2009). Three characterized genotypes 31, 22 and 3 attracted more attention according to their owing the best mean values for all traits.

Comparing with all traits, essential oil yield presented more heterogeneity and the highest heritability, but it presented the lowest genetic advance. Therefore, this trait is an important trait for anise and can be good criteria for selection at the segregating generations in the future plant breeding programs. This result was in agreement with Abou El–Nasr *el al* (2003a), while Singh *et al* (2002) suggested that the improvement would be possible by exercising selection for oil yield, fruit yield and their associated traits.

Studies of simple correlation coefficients, partitioning correlation coefficients as well as direct and joint effects of different contributions at phenotypic and genotypic levels cleared that three traits (fruit yield / plant, essential oil content and no. of primary branches / plant) affecting significantly and positively on the fruit yield / plant. Therefore, the selection for any of these traits or simultaneous selection for more than one of these traits would improve the essential oil yield. This conclusion is in agreement with those of Tripathi *et al* (2000), Singh *et al* (2002), Curioni *et al* (2003) and Abou El – Nasr *et al* (2003b and 2004).

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