J. Plant Production, Mansoura Univ., Vol. 8 (1):127 -133, 2017

Influence of Different Maturity Stages on Fruit Yield and Essential Oil Content of Some Apiaceae Family Plants
B: Fennel (*Foeniculum vulgare* Mill.)

Seham M. A. El-Gamal [1] and H. M. I. Ahmed [2]

[1] Medicinal and Aromatic Plants Research Department, Horticulture Research Institute, Agricultural Research Center, Giza, Egypt.

[2] Vegetable Crops Seed Production and Technology Research Department, Horticulture Research Institute, Agricultural Research Center, Giza, Egypt.

[1] Corresponding author e-mail: s_elgamal99@yahoo.com

ABSTRACT

This study was conducted at El- Baramoon Research Farm, Mansoura Horticulture Research Station, HRI, ARC, Egypt during two successive winter seasons of 2013/2014 and 2014/2015. The objective of this study was to determine the effect of harvesting stages on the quality of fennel fruits. The experimental design was a randomized complete block design with four replications. Variations of fruit yield per plant, seed index, germination behavior and essential oil content and composition were studied during different maturation stages. The obtained results indicated that, maximum yield and quality of fennel fruits in terms of fruit yield, thousand fruit weight (seed index) and germination percentage were reached their maximum at stage 4 (the primary umbel was matured completely). Essential oil percentage was higher in the early harvesting stages, while essential oil yield per plant reached its maximum when fruits were harvested at stage 4. The composition of volatile components of the essential oils extracted from fruits at eight stages of maturity was studied by gas chromatography and five main compounds were identified. The first major component was Methyl chavicol ranged from 72.34% to 88.67% and increased gradually with increasing fruit age to reach its maximum at stage8 (the primary umbels were falling). It could be recommended from the previous results the highest fruit yield and quality as well as essential oil yield were obtained in fennel when fruits harvested at stage 4 under the condition of this experiment.

Keywords: *Fennel, fruit yield, germination, essential oil, harvest stage, maturity.*

INTRODUCTION

Foeniculum vulgare Mill, commonly is known as fennel and important medicinal and aromatic plant belonging to the family of Apiaceae and originating from the Mediterranean region. Plant widely used as carminative, digestive, lactogogue, diuretic and in treating respiratory and gastrointestinal disorders. Dried fennel fruit is widely used in many of the culinary traditions of the world. Phenols, phenolic glycosides and volatile aroma compounds have been reported as the major phytoconstituents of this species. Essential oil of fennel is used as flavoring agents in food products. It is also used as a constituent of cosmetic and pharmaceutical products. Herbal drugs and essential oils of fennel have hepatoprotective effects as well as antispasmodic effects (Marotti *et al.*, 1993; Piccaglia and Marotti,1993; Cavaleiro *et al*.,1993). Fennel fruits contain 0.79 % essential oil, 5.82 % fixed oil and total phenolic compounds 1.17 mg/g dry weight. According to their analysis, the major constituents of essential oil are α-pinene (0.37 %), δ-limonene (0.07 %), 1,8-cineole (5.09 %), fenchone (4.13 %), anethone (86.11 %) and estragole (methyl chavicol) (0.05 %) (El-Awadi and Hassan (2010). However, Brender *et al.* (1997) reported that the major constituents were trans-anethole (50–70 %), fenchone (12–33 %), methyl chavicol (estragole) (2–5 %), α-pinene, camphene, ρ-cymene, myrcene, liomonene, α-and β-phellandrene, γ-terpinene, terpineol, cis-ocimene and γ-fenchone. The dried distillation residue of fennel fruits contains 14–22 % protein and 12–18 % fat and is suitable for use as stock feed (Weiss, 2002).

Essential oil composition depends upon internal, environmental and agricultural practices as well as factors affecting the plant such as genetics, and ecological conditions (Telci *et al.*, 2006 and 2009). Time of harvest based on maturity indices is very important for fruit yield ,essential oil content as well as composition and biochemical constituents in some Apiaceae family plants. Fruits harvested before optimum maturity may not ripe adequately and may not develop essential oil composition, while fruits harvested late (over-matured) have a shorter postharvest life and deteriorate rapidly. According to Msaada *et al*, (2007) maturation stages play an important factor influencing essential oil composition, while suitable environmental and agricultural practices would also help in improving yield and quality. Maturation stages constitute an important factor affecting fruit yield, essential oil content and composition and biochemical constituents in some plants. Gupta *et al.*, (1995) indicated that protein content decreased significantly with the advancement of fruit development. Oil yield increased with fruit development. The essential oil yield was greater in mature fennel fruits. Fruit yield per plant and 1000-fruit weight regularly increased from immature to mature periods. Moreover, Majid *et al.*, (2014) reported that harvesting time had significant effect on some of traits including fruit thousand weight, fruits yield, fruit essence content and essence yield. Delayed harvests can result in fruits on the primary umbel shattering. Early harvesting also causes yield losses due to premature fruits. Thus, this research was conducted to determine the effect of different stages of fruits maturity on the quality of fennel fruits principal traits (fruits yield, thousand fruit weight and total germination) and on essential oil content and composition in order to minimize the harvesting loses and to maximize the essential oil quality.

MATERIALS AND METHODS

Two field experiments were carried out during two successive winter seasons of 2013/2014 and

2014/2015, at El- Baramoon Research Farm, Mansoura Horticulture Research Station, HRI, ARC, Egypt. Soil was silt clay loam in texture with pH 8.13 and organic matter 1.7%. Fennel seeds were obtained from the Department of Medicinal and Aromatic Plants, HRI, ARC, Egypt. The experimental filed was prepared and shaped to ridges of 75 cm apart. Seeds were sown on mid October in both seasons in hills at 35 cm apart then thinned for one plant/hill after 21 days from sowing. Agricultural practices were done as recommended by Egyptian Ministry of Agriculture. The experimental design used was a randomized complete block design with four replications. Each harvesting stage formed a different plot as follows:-

1. **Stage 1:** The primary umbel was at the beginning of waxy stage (waxy stage) .
2. **Stage 2:** The primary umbel colour was changed (late waxy stage).
3. **Stage 3:** The secondary umbels colour was changed (half ripe stage).
4. **Stage 4:** The primary umbel was matured completely (ripe stage).
5. **Stage 5:** The primary umbel became brown (full ripe).
6. **Stage 6:** The secondary umbels were brown (full ripe).
7. **Stage 7:** The primary umbel was easily dropped off (over ripe).
8. **Stage 8:** The primary umbel was falling (over ripe).

The plots were harvested at eight different maturation stages using a sample size of 5 plants per replicate. Harvesting was carried out when the fruits in the primary umbel reached the waxy stage and a total of eight harvest stages were made. Harvesting started at 7 am and comprised cutting the stems at ground level and storing the cut material in jute bags to prevent fruits loss. The plants harvested were dried at ambient temperature in shade. After hand rubbing of the dried plants, the fruits were separated from stalks by sieving and weighed. The following data were recorded:

1- **Fruit yield and seed index**: The dried fruits were weighed to determine yield and the thousand fruit weight (seed index).

2- **Germination precentage**: was determined (ISTA, 2011).

3- **Volatile oil percentage**: was determined using a modified Clevenger apparatus (Guenther, 1961).

4- **Essential Oil Constituents**: The GC analysis of the second season volatile oil samples were carried out using Gas chromatography instrument , Dept. of Medicinal and Aromatic Plants Laboratory, HRI., with the following specifications: DsChrom 6200 Gas Chromatograph equipped with a flame ionization detector, Column: BPX-5, 5% phenyl (equiv.) polysillphenylene-siloxane 30m x 0.25mm ID x 0.25µm film., Sample size: 1µl, Temperature program ramp increase with a rate of 10º C / min from 70º to 200º C, Detector temperature (FID): 280 °C, Carrier gas: nitrogen, Flow rate: N2 30 ml/min; H2 30 ml/min; air 300 ml/min. Main compounds of the volatile oils were identified by matching their retention times with those of the authentic samples injected under the same conditions. The relative percentage of each compound was calculated from the area of the peak corresponding to each compound.

5-**Total carbohydrate**: was determined (Gul and Safdar ,2009).

6-**Crude protein**: was determined (AOAC, 2000) .

7-**Crude fat**: was extracted from ten grams of each powdered sample using a continuous extraction apparatus (Soxhlet) with a solvent of petroleum ether (b.p.60-80^{O}C) for sixteen hours. Each extract was dried over anhydrous Na_2SO_4 and evaporated to dryness. The residue was dried at 80^{O}C for ten minutes, cooled, weighed and expressed as percent lipid (AOAC, 2000).

8-**Total ash**: content was determined as follows: Two grams of sample were added into previously weighed porcelain crucible, place in muffle furnace at 600^{O}C for 2 hours, and then placed in desiccators, cool and weigh. The weight of the residue was calculated and expressed as percent ash (AOAC, 2000).

9-**Mineral content**: Nitrogen, phosphorus, and potassium in fruits were determined (Cottenie *et al.*, 1982).

Statistical analysis:

The obtained data were subjected to analysis of variances, and the significant differences among treatment means were compared using the LSD test according to Gomez and Gomez 1984.

RESULTS AND DISCUSSION

Fruit yield and quality

Variations in fruit yield, 1000-fruit weight (seed index) and germination percentage of fennel plants harvested at eight different maturation stages from immature fruit to full matured periods were statistically significant (Table 1). Fruit yields and its index had the same trend and increased regularly form early periods to reach their maximum values when fruits were harvested at stage 4 (the primary umbel was matured completely). Maximum fruit yield per plant values were 82.53 and 85.18 g/plant, while the highest values for seed index were 12.07 and 12.24 for the first and second seasons, respectively. Fruit yield at stage 4 (the primary umbel was matured completely) was higher than by 47 % when compared with the first maturity stage (the primary umbel was at the beginning of waxy stage) and higher by 54% when compared with the stage 8 (the primary umbels were falling). This may be because that, in early harvesting a large amount of the fruits was immature and in late harvesting fruit yield declining mainly due to fruit shattering. Seed index at stage 4 (the primary umbel was matured completely) was higher by 45% when compared with the first maturity stage (the primary umbel was at the beginning of waxy stage) and higher by 21% when compared with stage 8 (the primary umbels were falling).

Thousand fruit weight (Seed index) is an important yield parameter which has direct impact on the crop's final yield and quality of the fruit .By observing the average thousand fruit weight value for 8

harvesting stages. The weight of thousand fruits varied between 8.19 to 12.07g in the first season and 8.53 to 12.24g in the second season. It can be concluded that there were significant differences between different maturity stages.

Table 1. Effect of maturity stages on fennel fruit yield, seed index and germination percentage during 2013/2014 and 2014/2015 seasons.

Treatments	Fruit Yield g/plant		Seed Index g		Germination Percentage	
	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season
Stage 1	55.91	57.86	8.19	8.53	68	69
Stage 2	62.55	64.98	9.48	9.61	72	74
Stage 3	72.31	74.04	10.65	10.73	88	88
Stage 4	82.53	85.18	12.07	12.24	96	97
Stage 5	71.28	73.08	11.81	11.96	96	97
Stage 6	67.11	68.85	11.24	11.51	96	96
Stage 7	59.59	61.89	10.26	10.32	95	96
Stage 8	53.65	54.93	10.03	10.08	96	95
LSD 5%	2.28	2.11	1.04	0.76	1.0	2.0

The highest values were obtained in at the fourth harvesting stage (the primary umbel was matured completely) in both growing seasons. The lowest values were noted at the first harvesting stage (the primary umbel was at the beginning of waxy stage) in both growing seasons. This may be due to dominance of immature and small fruits which light in weight. In this concern, Harrington, (1972) reported that harvesting seeds before physiological maturity as defined the point when fruit reaches maximum dry weight resulted in lighter fruit, reduced viability and low fruit yield. Moreover, Özel, (2009) observed that there was a positive correlation between seed index and the fruit yield for anise. Our results are in harmony with Majid et *al.* ,(2014) they reported that delaying anise harvesting time, fruit yield and seed index significantly decreased.

Germination percentage was 68 and 69 % from fruits harvested at stage 1(the primary umbel was the beginning of waxy stage) and increased to reach a maximum of 96 and 97 % at stage 4 (the primary umbel was matured completely) for the first and second seasons ,respectively. The remaining 4 and 3 % of frits did not germinate after that. There were no significant changes in germination of fruits after stage 4 (Table 1). As germination percentage reached its maximum at stage 4 (the primary umbel was matured completely), it did not decrease significantly after that till the last maturation stage (the primary umbels were falling). Delaying the harvest had no detrimental effect on fruit germination but a reduction in fruit yield was likely to occur. Results of our present study are similar to the findings of Callan *et al.,* (2007) on dill and Telci *et al.,* (2009) on fennel.

Essential oil percentage, oil yield and GC mass of essential oil

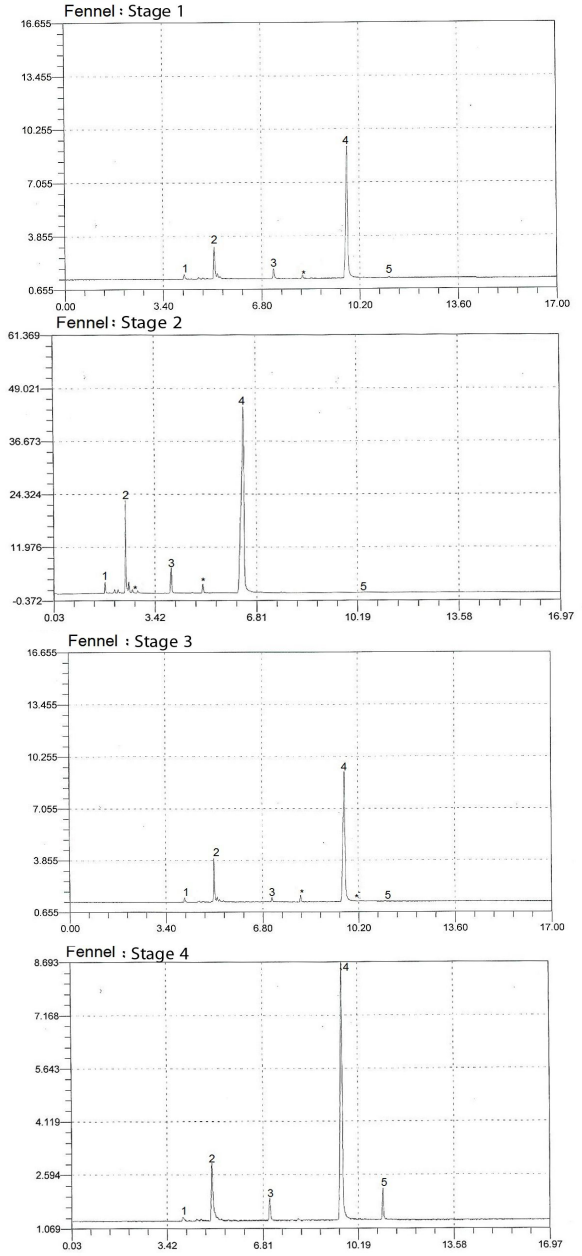
The presented results in Table (2) and figures (1and 2) revealed the effects of the different fruit maturity stages on essential oil percentage, oil yield per plant and the essential oil composition of fennel. As shown the essential oil percentage and essential oil yield (ml/plant) were significantly affected by the fruits development stages in both seasons. In addition, it was noticed that the essential oil percentage was decreased gradually from the first stage (the primary umbel was the beginning of waxy stage) to the last stage (the primary umbels were falling). Stage1 had over two times (2.37) essential oil than stage 8 (as an average of two seasons). On the other hand, the most favorable maturation of fruits for the highest oil yield (1.82 and 1.90 ml/plant) was the stage 4 (the primary umbel was matured completely) followed by stage 3 (the secondary umbels colour was changed) (1.75 and 1.80 ml/plant) in both seasons, respectively. However, the stage 8 (primary umbels were falling) was the unfavorable stage for essential oil yield (0.65 and 0.67 ml/plant) in the first and second seasons, respectively.

The composition of fennel essential oil for the different fruit development stages in the second season was presented in the same table and figures (1 and 2). Five main compounds were identified and varied during the fruits maturity. The first major component was Methyl chavicol ranged from 72.34% to 88.67%. It seems that delaying harvest till the last harvest stage led to higher values of Methyl chavicol beginning from stage 5 (the primary umbel became brown) to stage 8 (the primary umbels was falling) and this is not favorable for market demand. Stage 4 (the primary umbel was matured completely) followed by stage 3 (the secondary umbels colour was changed) were the better maturity stages for Methyl chavicol values under this work condition. The second major component was Limonene ranged from 5.27% to 16.80% and took the same trend of essential oil percentages. The third component was 1,8 cineol ranged from 2.02% to 7.11% . The fourth one was Anethole ranged from 0.16% to 6.65%, stage 4 (the primary umbel was matured completely) had the highest Anethole percentage (6.65%) followed by stage 3 (the secondary umbels colour was changed) (2.25%). The last component was α- pinene ranged from 0.36% to 2.03%. Based on the previous results from Table 2 and figures (1and 2) the best fruit development stage for essential oil yield per plant and composition was stage 4 (the primary umbel was matured completely) followed by stage 3 (the secondary umbels colour was changed). The high percentages of essential oil in early stages of fruit development could be attributed to that the accumulation in the oil tubes (vittae) are found in the fruits of early maturity stages with high amount than other advanced stages (Telci *et al.*, 2009). One possible reason for variation of essential oil composition could be due to the different metabolism in plants led to different types of metabolites (as secondary metabolism

products) during the fruits development (Anwar *et al.*, 2009). The essential oil of fennel from mature and intermediate fruits had high activities as antioxidant, hypolipidemic , and antimicrobial (Anwar *et al.*, 2009).Our results were in harmony with those obtained by Marotti *et al.*, (1994), Saharkhiz and Tarakeme (2011) and Telci *et al.*, (2009) on fennel, Msaada *et al.*, (2007) on coriander, and Olle and Bender (2010), on Apiaceae crops.

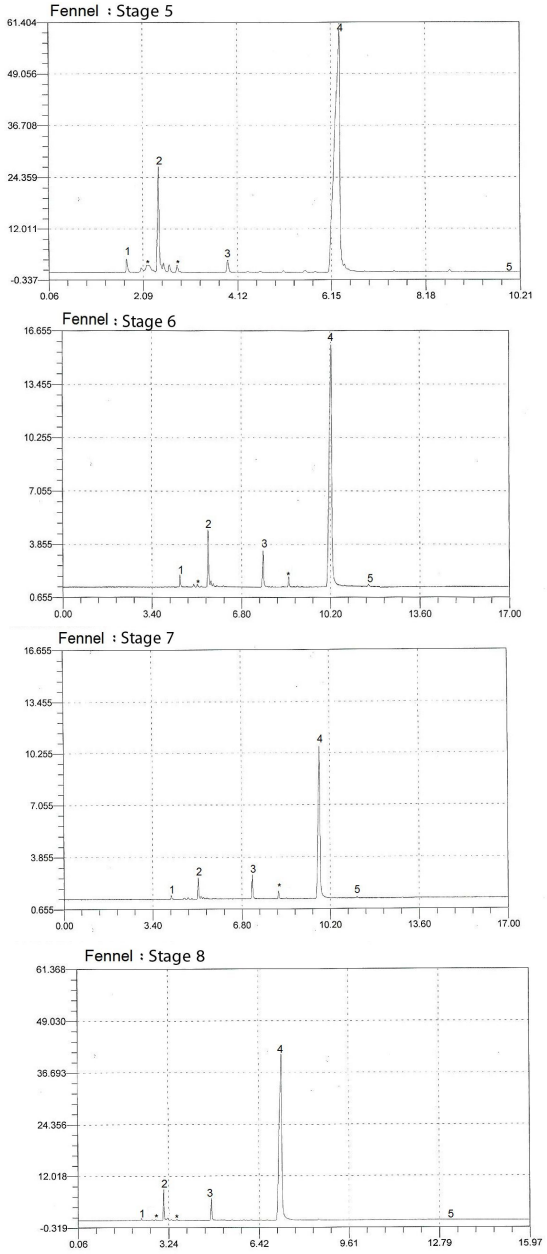
Table 2. Effect of maturity stages on fennel essential oil percentage , essential oil yield and GC during 2013/2014 and 2014/2015 seasons

Treatments	Essential Oil %		Oil Yield ml /plant		Essential Oil Constitutes				
	1st Season	2nd Season	1st Season	2nd Season	α- pinene	Limonene	1,8 Cineol	Methyl chavicol	Anethole
Stage 1	2.85	2.88	1.59	1.67	1.52	16.80	3.69	76.13	0.16
Stage 2	2.71	2.74	1.70	1.78	2.03	15.02	4.55	77.96	0.22
Stage 3	2.42	2.43	1.75	1.80	1.19	14.37	2.09	72.90	2.25
Stage 4	2.21	2.23	1.82	1.90	1.08	14.00	5.93	72.34	6.65
Stage 5	1.87	1.9	1.33	1.39	1.35	13.20	2.02	79.48	0.59
Stage 6	1.56	1.58	1.05	1.09	1.89	9.34	5.83	79.19	1.33
Stage 7	1.39	1.41	0.83	0.87	1.32	7.39	7.11	81.53	0.31
Stage 8	1.21	1.22	0.65	0.67	0.36	5.27	4.78	88.67	0.44
LSD 5%	0.19	0.11	0.12	0.10			-		



1= α– pinene 2= Limonene 3= 1,8 Cineol
4= Methyl chavicol 5= Anethole *= Unknown compounds

Figure 1. Effect of harvesting stages (1-4) on the essential oil components (%) of fennel during 2014 / 2015 season.



1= α– pinene 2= Limonene 3= 1,8 Cineol
4= Methyl chavicol 5= Anethole *= Unknown compounds

Figure 2. Effect of harvesting stages (5-8) on the essential oil components (%) of fennel during 2014 / 2015 season.

Biochemical constituents

The results in Tables 3 and 4 demonstrated that the different biochemical constituents were influenced significantly by the different fruits development stages. As seen in Table (3) total carbohydrates % and total fat % had the same trend, in other words as fruits development advanced as the two compounds increased. They ranged from 17.14% (stage 1) to 42.86% (stage 8) for total carbohydrates and 9.15% (stage 1) to 16.64% (stage 8) for total fat in the first season. The second season took the same trend of the first season. On contrast crude protein took opposite trend ranging from 20.27% (stage 1) to 10.32% (stage 8) and 20.69% (stage 1) to 10.45% (stage 8) in the first and second seasons, respectively. However Ash% did not had a constant trend but varied during the different maturity stages to reach its maximum value (10.97% and 11.21%) at the stage 4 in both seasons, respectively. The increase in total fat% with the advancement maturity of fruits and decrease in immature fruits could be attributed to that the accumulation of it was affected by the intervention of and activity of the (fatty acid synthetase) enzymatic system (Msaada *et al.,* 2009b).

Table 3. Biochemical constituents of fennel fruits as affected by harvesting stages during 20113/2014 and 2014/2015 seasons.

Treatments	Total Carbohydrates		Crude Protein		Total Fat		Ash	
	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season
Stage 1	17.14	17.18	20.27	20.69	9.15	9.29	4.45	4.99
Stage 2	17.45	17.94	19.32	19.85	9.95	10.12	6.52	6.81
Stage 3	18.11	18.69	16.12	16.37	10.78	11.54	10.19	10.39
Stage 4	19.33	19.82	15.82	15.99	12.19	12.37	10.97	11.21
Stage 5	25.97	26.47	14.17	14.27	13.02	13.12	9.7	9.86
Stage 6	32.09	32.78	13.01	13.18	14.09	14.18	8.45	8.59
Stage 7	37.01	37.32	11.97	12.16	15.98	16.17	7.69	7.86
Stage 8	42.86	43.32	10.32	10.45	16.64	16.71	5.27	5.56
LSD 5%	1.87	2.00	1.52	1.44	1.1	1.2	0.65	0.93

Concerning the effect of fruits development on nitrogen, phosphors and potassium percentages data in Table 4 showed that there was a significant effect on N%, P% and K% during the two seasons. The percentage of nitrogen ranged from 3.24% at stage 1 (the primary umbel was at the beginning of waxy stage) to 1.65% at stage 8 (the primary umbels were falling) and 3.31% at stage 1 to 1.67% at stage 8 in the first and second seasons, respectively. While P and K percentages took ash percentage trend and varied during fruits development stages. The maximum values of P% (0.376% and 0.381%) and K% (1.99% and 2.04%) were obtained when fruits harvested at stage 4. Our previous results were in the same trend with those of Msaada *et al.,* 2009a and Nguyen *et al., a* (2015) on coriander and Gupta *et al.,* 1995 on fennel. It seems that harvesting fruits at stage4 (the primary umbel was matured completely) had high value for healthy nutritional and industry of medicine and food.

Table 4. Nitrogen, phosphorus and potassium percentages of fennel fruits in response to harvesting stages during 2013/2014 and 2014/2015 seasons

Treatments	N%		P%		K%	
	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season
Stage 1	3.24	3.31	0.303	0.307	1.27	1.32
Stage 2	3.09	3.18	0.319	0.323	1.53	1.56
Stage 3	2.58	2.62	0.367	0.371	1.91	1.96
Stage 4	2.53	2.56	0.376	0.381	1.99	2.04
Stage 5	2.27	2.28	0.352	0.355	1.84	1.86
Stage 6	2.08	2.11	0.344	0.346	1.74	1.77
Stage 7	1.92	1.95	0.332	0.337	1.61	1.64
Stage 8	1.65	1.67	0.314	0.318	1.41	1.45
LSD 5%	0.24	0.30	0.014	0.013	0.067	0.065

The correlation coefficient for the relationship between fruits yield per plant and seed index (R=0.809), essential oil yield per plant (R=0.594), phosphorus percentage (R=0.936) and potassium percentage (R=0.933) was high and positively correlated to the different maturation stages of fruits Table (5). In addition, the results of the present study showed positively correlation between essential oil yield per plant and essential oil percentage (R=0.895) and crude protein (R=0.836) but high and negatively correlation between essential oil yield per plant and total carbohydrates (R= - 0.978).On the other hand, the correlation coefficient for the relationship between the germination percentage and seed index was high and positively (R=0.852) at the different fruit development stages. So, from the results of correlations it could be determine the favorite stage of fruits for achieving functional fruits for human health, future of food and medicine industries and seed germination.

Table 5. Correlation coefficients for the relationships between the different characters (as average of the two seasons) of fennel at different maturity stages.

	FY	S. index	G%	E. Oil%	OY/p	TC	CP	TF	Ash	N%	P%	K%
FY	1	.809*	.395	.180	.594	-.453-	.091	-.209-	.936**	.091	.936**	.933**
S. index	.809*	1	.825*	-.398-	.032	.120	-.466-	.345	.877**	-.466-	.858**	.889**
G%	.395	.825*	1	-.825-*	-.493-	.627	-.874-**	.799*	.582	-.874-**	.588	.600
E. Oil%	.180	-.398-	-.825-*	1	.895**	-.956-**	.985**	-.989-**	-.043-	.985**	-.044-	-.066-
OY/p	.594	.032	-.493-	.895**	1	-.978-**	.836**	-.891-**	.384	.836**	.390	.367
TC	-.453-	.120	.627	-.956-**	-.978-**	1	-.917-**	.960**	-.248-	-.917-**	-.241-	-.223-
CP	.091	-.466-	-.874-**	.985**	.836**	-.917-**	1	-.977-**	-.145-	1.000**	-.159-	-.172-
TF	-.209-	.345	.799*	-.989-**	-.891-**	.960**	-.977-**	1	.011	-.977-**	.019	.033
Ash	.936**	.877**	.582	-.043-	.384	-.248-	-.145-	.011	1	-.145-	.987**	.996**
N%	.091	-.466-	-.874-**	.985**	.836**	-.917-**	1.000**	-.977-**	-.145-	1	-.159-	-.172-
P%	.936**	.858**	.588	-.044-	.390	-.241-	-.159-	.019	.987**	-.159-	1	.990**
K%	.933**	.889**	.600	-.066-	.367	-.223-	-.172-	.033	.996**	-.172-	.990**	1

FY=fruit yield/plant, S. index=seed index, G%=germination percentage, E. Oil%=essential oil percentage, OY/p=essential oil/plant, TC=total carbohydrates, CP=crude protein, TF=total fat
***. Correlation is significant at the 0.05 level (2-tailed).**
****. Correlation is significant at the 0.01 level (2-tailed).**

CONCLUSION

Despite obtaining high essential oil percentage in early periods, harvesting fennel fruits at stage 4 (the primary umbel was matured completely) is the suitable harvesting stage for obtaining maximum fruit yield, high seed index, best germination behavior and high essential oil yield.

REFERENCES

Anwar F, Hussain A I, Sherazi S T H and Bhanger M I. (2009).Changes in Composition and Antioxidant and Antimicrobial Activities of Essential Oil of Fennel (Foeniculum vulgare Mill.) Fruit at Different Stages of Maturity. Journal of Herbs, Spices & Medicinal Plants, 15:187–202.

AOAC (2000). Association of Official Analytical Chemists, 17th ED. published by A.O.A.C. International Maryland, U.S.A.

Brender, T., Gruenwald, J. and Jaenicke, C. (1997). Herbal Remedies, 2nd ed. Phytopharm Consulting Institute for Phytopharmaceuticals, Schaper & Brümmer GmbH & Co., Salzgitter, Berlin.

Callan, N.W., Johnson, D.L., Westcott, M.P., Welty, L.E. (2007). Herb and oil composition of dill (Anethum graveolens L.): effects of crop maturity and plant density. Ind. Crop. Prod. 25, 282–287.

Cavaleiro, C.M.F., Roque, O.L. , Proença, D. A. and Cunha, A. (1993). Contribution for the characterization of Portuguese fennel chemotypes. Journal Essential Oil Research, 5, 223-225.

Cottenie, A.; Verloo M., Kiekens L., Velghe G., and Camerlynck R. (1982). Chemical Analysis of Plant and Soil Laboratory of Analytical and Agrochemistry, State Univ., Ghent, Belgium.

El-Awadi, M.E. and Hassan, E. A. (2010). Physiological responses of fennel (Foeniculum vulgare Mill) plants to some growth substances. The effect of certain amino acids and a pyrimidine derivative, J. Am. Sci., 6(7): 120–124.

Gomez, K.A. and Gomez, A.A. (1984). Statistical Proceedings for Agricultural Research. Second Edition. John Wiley, New York.

Guenther, G. (1961). The volatile oils VIII. Robert E.D. Nastrand Comp. Inc. Toronto, New York, London.

Gul, S. and Safdar, M. (2009). Proximate Composition and Mineral Analysis of Cinnamon. Pakistan Journal of Nutrition .8(9): 1456-1460.

Gupta, K., Thakral, K.L.K., Gupta, V.K., Arora, S.K. and Gupta, K. (1995). Metabolic changes of biochemical constituents in developing fennel seeds (Foeniculum vulgare). J. Sci. Food & Agricult. 68(1):73-76.

Harrington, J.F. (1972). Seed storage and longevity. In Seed Biology, Vol. 3, (ed., T.T. Kozlowski), pp. 145-155. Academic Press, New York.

ISTA (2011). International Rules for Seed Testing. Seed Science and Technology, 39:1-333.

Majid, P.; Ali, R. and Khalil, J. (2014). The effects of irrigation intervals and harvesting time on grain yield and essential oil of anise (Pimpinella anisum L.). Iranian Journal of Agricultural Sciences), 45 (3): 453-460.

Marotti M, Piccaglia R and Giovanelli E (1994). Effect of variety and ontogenic stage on the essential oil composition and biological activity of fennel. J Essent. Oil Res., 6: 57-62.

Marotti, M.; Dellacecca, V., Piccaglia, R., Giovanelli, E., Palevitch, D. and Simon, J.E. (1993). Agronomic and chemical evaluation of three “varieties” of Foeniculum vulgare Mill. Acta Horticulturae, 331, 63-69.

Msaada K, Hosni K, Ben Taarit M, Chahed T, Hammami M, Marzouk B (2009b). Changes in fatty acid composition of coriander (Coriandrum sativum L.) fruit during maturation. Industrial Crop Products 29, 269-274

Msaada K, Hosni K, Ben Taarit M, Ouchikh O, Marzouk B (2009a). Variations in essential oil composition during maturation of coriander (Coriandrum sativum L.) fruits. Journal of Food Biochemistry 33, 603-612

Msaada, K., Hosni, K., Taarit, M.B., Chahed, T., Kchouk, M.E. and Marzouk, B. (2007). Changes on essential oil composition of coriander (Coriandrum sativum L.) fruits during three stages of maturity. Food Chemistry :102, 1131–1134.

Nguyen, Q. H, Talou, T., Cerny, M. , Evon, P and Merah, O. (2015). Oil and fatty acid accumulation during coriander (Coriandrum sativum L.) fruit ripening under organic cultivation. The Crop Journal 3(4): 366-369.

Olle M and Bender I (2010).The content of oils in umbelliferous crops and its formation. Agronomy Research 8 (Special Issue III), 687-696.

Özel, A. (2009). Anise (*Pimpinella anisum*): changes in yields and component composition on harvesting at different stages of plant maturity. Expl Agric. 45, 117–126.

Piccaglia, R. and Marotti, M. (1993). Characterization of several aromatic plants grown in northern Italy. Flavour Fragrance Journal, 8, 112-115.

Saharkhiz, M. J. and Tarakeme, A. (2011). Essential oil content and composition of fennel (Foeniculum vulgare L.) fruits at different stages of development. Journal of Essential Oil Bearing Plants. 14 ,605 – 609.

Telci, I.; Toncer, O.G.; Sahbaz, N. (2006). Yield, Essential oil content and composition of Coriandrum sativum cultivars (var. vulgare Alef. and var. microcarpum DC.) grown in two different locations. J. Essent. Oil Res. 18, 189-193.

Telci I, Demirtas I and Sahin A. (2009). Variation in plant properties and essential oil composition of sweet fennel (Foeniculum vulgare Mill.) fruits during stages of maturity. Industrial Crops and Products 30: 126–130

Weiss, E. A. (2002) Spices Crops. CABI, Wallingford, 356–360.

تأثير مراحل النضج المختلفة على المحصول الثمرى و محتوى الزيت الطيار فى بعض نباتات العائلة الخيمية ب ـ الشمر

سهام محمد عبد الحميد الجمل[١] و حمدينو محمد إبراهيم أحمد[٢]

[١] قسم بحوث النباتات الطبية و العطرية - معهد بحوث البساتين- مركز البحوث الزراعية – الجيزة – مصر.

[٢] قسم بحوث تكنولوجيا تقاوى الخضر - معهد بحوث البساتين- مركز البحوث الزراعية – الجيزة – مصر.

أجريت هذه الدراسة بالمزرعة التجريبية البحثية بالبرامون- محطة بحوث البساتين بالمنصورة- معهد بحوث البساتين – مركز البحوث الزراعية- مصر خلال موسمي الشتاء ٢٠١٣/ ٢٠١٤ و ٢٠١٤/ ٢٠١٥ وكان تصميم التجربة هو القطاعات كاملة العشوائية بأربعة مكررات. وكان الهدف من هذه الدراسة هو تحديد تأثير مواعيد الحصاد المختلفة على جودة ثمار نبات الشمر. وذلك بدراسة محصول الثمار للنبات ومحتوى الزيت الطيار ونسبة الإنبات خلال مراحل النضج المختلفة للثمار. و لقد أشارت النتائج المتحصل عليها إلى أن أعلى إنتاجية وجودة لمحصول الشمر و جودته متمثلة فى المحصول الثمرى للنبات ووزن الألف ثمرة و كذلك نسبة الإنبات وصل قمته عندما تم حصاد الثمار فى المرحلة الرابعة لنضج الثمار. كذلك النسبة المئوية للإنبات حققت أعلى القيم لها عندما حصدت ثمار الشمر فى المرحلة الرابعة لنضج الثمار. وكانت أعلى نسبة مئوية للزيت الطيار عندما تم حصاد ثمار الشمر مبكرا فى المرحلة الأولى، ولكن أعلى محصول زيت طيار للنبات كان عندما تم حصاد الثمار فى المرحلة الرابعة من مراحل نضج الثمار. وقد تمت دراسة المكونات الأساسية للزيت الطيار خلال الثماني مراحل المختلفة لنضج الثمار وتم تحديد خمس مركبات رئيسية الأول فيها هو المثيل شافيكول و هو المكون الرئيسى للزيت الطيار والذى تراوحت نسبته بين ٧٢.٣٤٪ إلى ٨٨.٦٧٪ . حيث إزدادت نسبته تدريجيا (المثيل شافيكول) مع التأخر فى مراحل نضج الثمار حتى وصل أعلى قيمة له فى المرحلة الثامنة و الأخيرة من مراحل نضج الثمار. من النتائج السابقة يمكن التوصية للحصول على أعلى محصول من ثمار الشمر و جودته من حيث محصول الزيت الطيار و جودته وكذلك نسبة الانبات ووزن الالف بذرة بحصاد ثمار الشمر فى المرحلة الرابعة من مراحل نضج الثمار تحت ظروف هذه الدراسة.

الكلمات الرئيسية : الشمر ، المحصول الثمري ، الإنبات ، الزيت الطيار ، مراحل الحصاد ، النضج .