J. Agric. Sci. Mansoura Univ., 29(7): 4089 - 4101, 2004

STUDIES ON YARROW " *Achillea millefolium* L." PLANTS: I. EFFECT OF SPRING AND AUTUMN CULTIVATION AND TIME OF HARVEST ON GROWTH, FLOWERING, AND YIELD OF THE DRIED FLOWERS AND ESSENTIAL OIL.

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ABSTRACT

Yarrow (*Achillea millefolium*, L.), locally known as "Thousand leaves" is a member of the Family "Asteraceae", and is an important medicinal and aromatic plant. The aerial parts of the plant contain high quality essential oil and is also used as an aromatic bitter and stringent herb. The flowers are the richest part of the plant in the essential oil. This study was carried out during the two successive seasons 2000/2001 and 2001/2002, at the Experimental Station of Olericulture and Floriculture, Faculty of Agriculture, Mansoura University. It aimed to compare between two planting seasons (spring and autumn) and two consequent cuts of each of them on growth, flowering, and yield of the dried flowers and essential oil of Achillea under the conditions of Dakahlia Governorate.

Data were recorded on time taken to flower, plant height, herb and flowers weight, and oil percentage in the flowers, and the yield of both the dried flowers and the essential oil. Temperature and day-length change during the course of the study were also recorded.

The results showed that plants at the 1st cut took longer time to flower, were taller, produced more herb and flower weight per plant, and yielded more dried flowers and essential oil than those at the 2nd cut in both plantings (spring and autumn).

Results also showed that, in the first season, spring planting produced shorter plants, less herb weight per plant, but produced more flower weight per plant, and more dried flowers and essential oil yield per feddan than autumn planting. In the second season, spring plants suffered from inconsistent temperature and produced less flower and oil yield than autumn. In both seasons, spring plants flowered earlier and took shorter time to be ready for the first and second cuts than autumn plants regardless of temperature changes. On basis of the meteorological data, it was concluded that flowering of Achillea was mainly dependent on day-length, but its growth and yield were greatly influenced by temperature changes. Results also showed that the planting season and time of harvest did not affect the oil percentage in the flowers, and that the increase in oil yield was a tributed to the increase in the yield of the dried flowers not in their oil content.

INTRODUCTION

Medicinal and aromatic plants are natural therapy source to replace the chemical one, and are considered as a good source of a national income as potential exportable crops. *Achillea millefolium*, L. (Asteraceae), commonly known as yarrow, which is a ative to Europe and western Asia, and is widely

naturalized in North America, Australia and New Zealand . It is a perennial plant with aerial stems up to a meter in height (Keville, 1999) .
The aerial parts of Achillea contains high quality essential oil of deep blue color and its flowers are rich source of the essential oil which contains chamazulene (Weber and Stahl, 1953). The essential oil of Achillea contains several physiologically active substances that have many medical uses and the herb is also used as an aromatic bitter and a stringent herb (Chandler *et al.*, 1982 and Keville, 1999).

There are different approaches in order to increase the yield of the active ingredient of the medicinal plants such as environmental conditions, planting date and time of harvest. Planting date is one of the most important limiting factors that plays a great role for plant production (Abdallah *et al.*, 1985 and Piccaglia *et al.*, 1993). Time of harvest also affected the essential oil percentage and composition in many aromatic plants (Bottcher *et al.*, 2000).

The aim of this work was to compare between spring and autumn cultivation of Achillea and two consequent cuts for each cultivation on growth, flowering, and the yield of both flowers and essential oil .

MATERIALS AND METHODS

This experiment was carried out during the two successive seasons 2000/2001 and 2001/2002, at the Experimental Station of Olericulture and Floriculture Dept., Faculty of Agriculture, Mansoura University. Yarrow *(Achillea millefolium*, L.) plants were cultivated using plant divisions obtained from the Farm of Medicinal and Aromatic Plants of the Agriculture faculty, Mansoura University. Planting was done at two different dates, autumn cultivation (1st and 3rd November) in the first and second season respectively, and spring cultivation (13th and 15th March) in the first and second seasons, respectively.

The experiment field was divided into 6 blocks (4 x 4 m each) containing 6 rows (each 3m long and rows were 60 cm apart). Planting was done at a distance of 50 cm between plants.

Harvesting: At the flowering stage (when at least 50% of plants flowered) plants were cut at 20 cm height from the soil surface, twice in each season. In spring cultivation, the first cut was done in the first of June, and the second cut in the middle of August. In autumn cultivation, the first cut was done in the middle of May and the second cut in the middle of August. After harvesting, each plant was divided into herb and flowers, and each group was dried separately in perforated paper bags at room temperature until constant weight.

The following data were collected:

1- **Time taken to flower (day):** As the number of days from planting or harvesting until the flowering stage.

2- **Plant height (cm):** At the time of flowering, twelve plants were chosen randomly for each block and their heights were measured starting from the soil level to the end of top spike of the main stem.
3- **Dry weight of the aerial parts (herb and flowers) (g):** The herb and flowers were dried separately in perforated paper bags at room temperature until constant weight, and their dry weights were recorded.
4- **Yield of dried flowers (kg/fed):** The yield was calculated by multiplying the dry weight of flowers per plant by number of plants per feddan.
5- **Oil percentage in flowers (%):** The essential oil percentage were determined in samples of dried flowers (50 g each) in both seasons by hydro-distillation using Clevenger apparatus according to methods described by the **Egyptian pharmacopoeia (1984)**.
6- **Oil yield (liter/fed.):** Oil yield was calculated by multiplying essential oil(%) in dried samples by the yield of the dried flowers per feddan.
7- **Meteorological data:** Meteorological measurements during the course of the study were recorded with respect to temperature and day length until the end of the experiment.

Statistical analysis:

A randomized complete block design with 3 replicates was used according to Steel and Torrie (1980). Collected data were subjected to the statistical analysis according to the analysis of variance procedure (ANOVA) using SAS computer software (SAS Institute, 1985). The treatment means were compared using the least significant difference (L.S.D) procedure as mentioned by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

I. Meteorological Data:

Achillea plant is a qualitative long-day plant with a critical photoperiod between 12-16 hrs/day at 18 °C. (Zhang *et al.*, 1996). Therefore, it was necessary to discuss the weekly temperature and photoperiod changes during the course of this study, in order to spot a light and to explain the effects of cultivation date on growth behavior of this plant under the conditions of this experiment.

A. Temperature:

1. The first cut

In the first season as shown in Fig.(1), the temperature of spring planting was lower than autumn in the first 3 weeks after planting, then became higher than autumn until the time of the 1st cut for each of them (12th week for spring and 28th week for autumn). The average temperature of autumn planting decreased gradually to reach below 15 °C by week 14, then started to rise thereafter. On 23rd week, a sudden fall down to 18 °C took place, and the temperature returned to rise until it reached 24 °C by the weeks 27 and 28 (the time of autumn 1st cut). In spring planting, the temperature started to rise by week 3 to reach 24 °C by the fifth week after planting then started to drop until it reached 20 °C by the 8th week. By the 9th

week, a gradual rise in temperature started to take place to reach its maximum (27 °C) by the time of its 1st cut (during 13th week after planting).

In the second season as shown in Fig. (2), the temperature of spring planting (17 °C) was lower than autumn planting (21 °C) for one week only after planting. The temperature of autumn planting followed same trend as the previous season, but in the second season it did not follow the smooth curve as that of the first season. In addition, it dropped to reach 12 °C during the 9th, 10th and 11th week after planting, while it was above 15 °C during similar weeks in the first season.

It is also clear from Fig. (2) that the temperature of spring planting in the second season had no stable trend starting from the 4th week until the 9th week after planting. The temperature hesitated between a rise and fall down week after another. The temperature values during most of the growth weeks were between 20 °C and 27 °C.

2. The second cut:

In the first season, the average temperature of spring planting was 5 °C higher than that of autumn one week after the 1st cut. The temperature differences between the two plantings during the following weeks were marginal and were around 2 °C only (Fig.3).

In the second season, the temperature after the 1st cut started with minor differences between spring planting and autumn ones until the fifth week. By the sixth week after the 1st cut, unlike the first season, the temperature of autumn planting was higher than that of spring ones. From 6th week after the 1st cut until the time of the 2nd cut the temperature of autumn planting ranged between 30 °C and above, while those of spring ones were between 27 °C and 30 °C (Fig.4).

B. Day length:

1. The first cut:

In spring planting, the average day length was 12 hrs/day in the first week after planting and continued to increase thereafter until the time of the 1st cut. It reached 13 hrs/day six weeks before the 1st cut.

In autumn planting, the average day length was 10.5 hrs/day in the first week after planting and started to decrease thereafter to reach 10 hrs/day by week 9 and started to increase thereafter. The average day length reached 12 hrs/day at the 20th week after planting and 13 hrs/day five weeks before the 1st cut (Fig.5).

2. The second cut

The day length after the 1st cut until the 2nd cut ranged between 13.2 and 14.2 hrs/day during both plantings Figure (6). During the first week after the 1st cut of spring planting, the day length averaged 13.6 hrs and reached little above 14 hrs for three weeks (from the 2nd to the 5th week) then started to decrease gradually to reach 13.2 hrs by the time of the 2nd cut.

On the other hand, the day length of autumn planting was similar to that of spring planting but was three weeks behind that of spring.

II. Effect of planting season on time taken to flower:

In both seasons, plants of the spring planting were ready to be cut within significantly shorter time than the plants of the autumn planting did (Table,1).

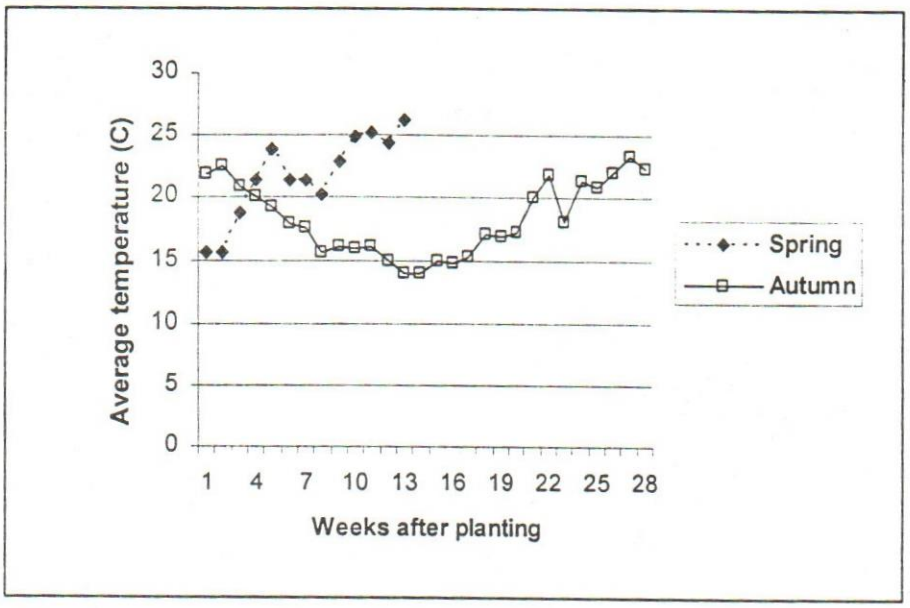

Figure (1). Average weekly temperature during growth weeks of Achillea until the first cut for spring and autumn plantings in the first season (2000 / 2001).

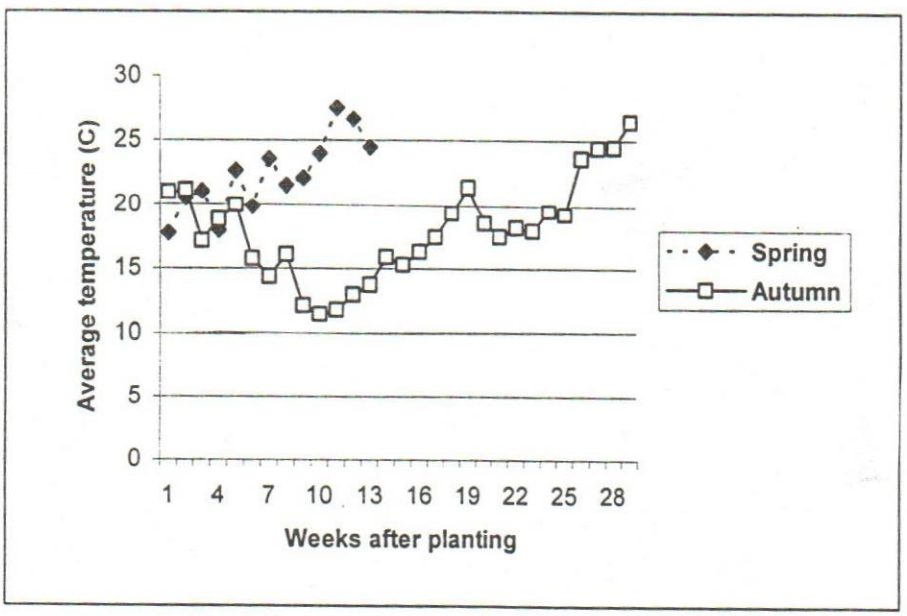

Figure (2). Average weekly temperature during growth of Achillea until the first cut for spring and autumn plantings in the second season (2001/2002).

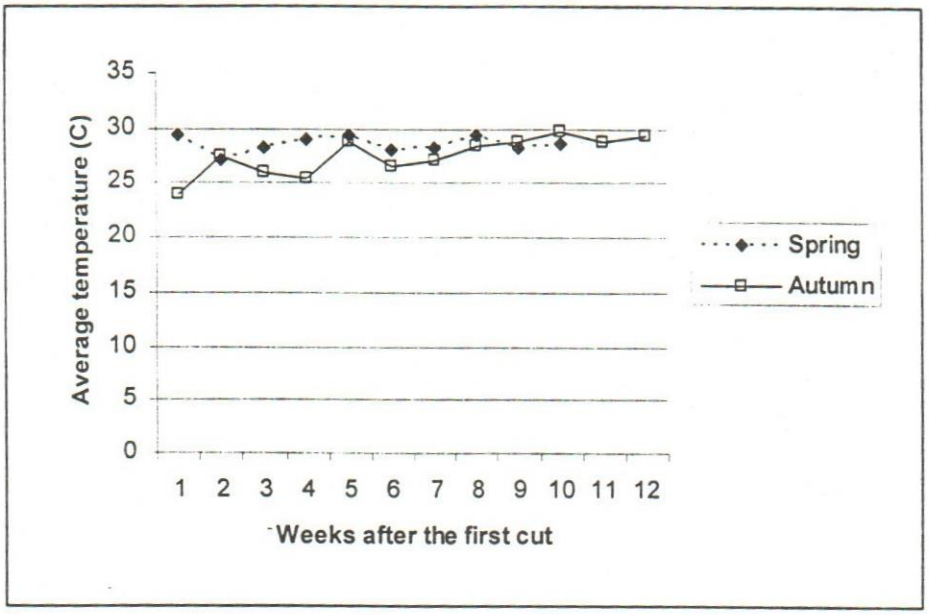

Figure (3). Average weekly temperature during growth of Achillea plants after the first cut until the second cut for spring and autumn plantings during the first season (2000/2001).

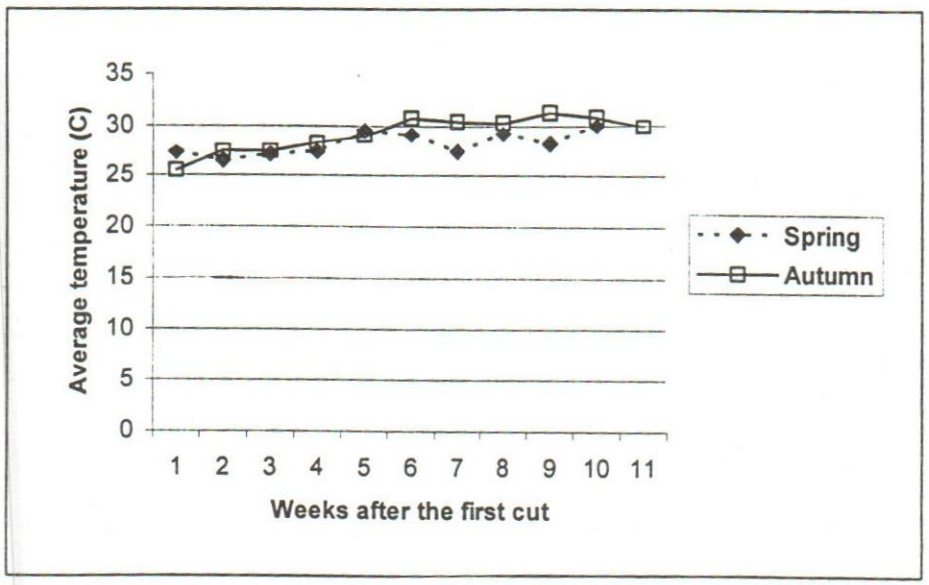

Figure (4). Average weekly temperature during growth of Achillea plants after the first cut until the second cut for spring and autumn plantings during the second season (2001/2002).

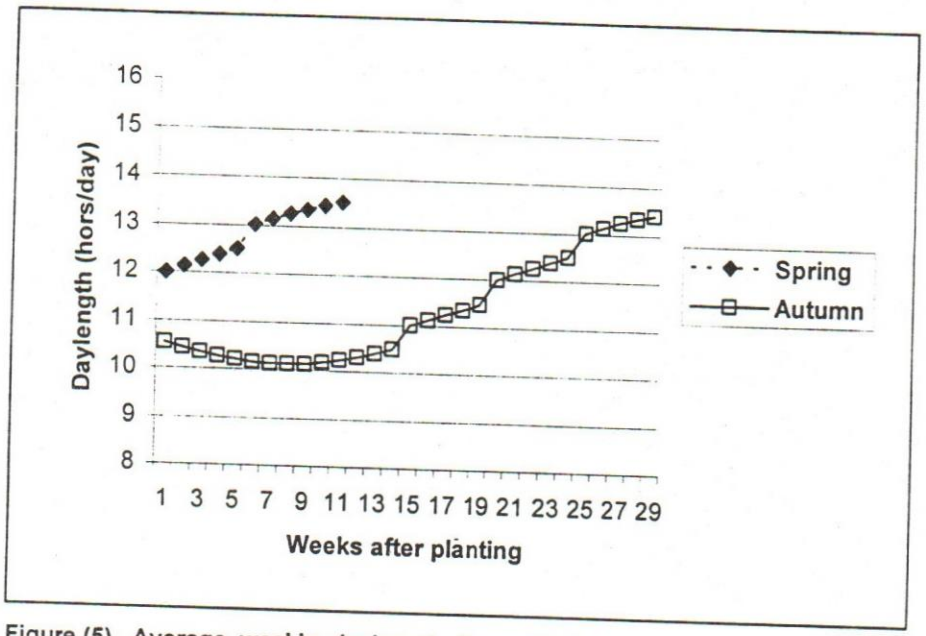

Figure (5). Average weekly daylength (hours/day) during growth of Achillea plants from sowing until the first cut for spring and autumn plantings.

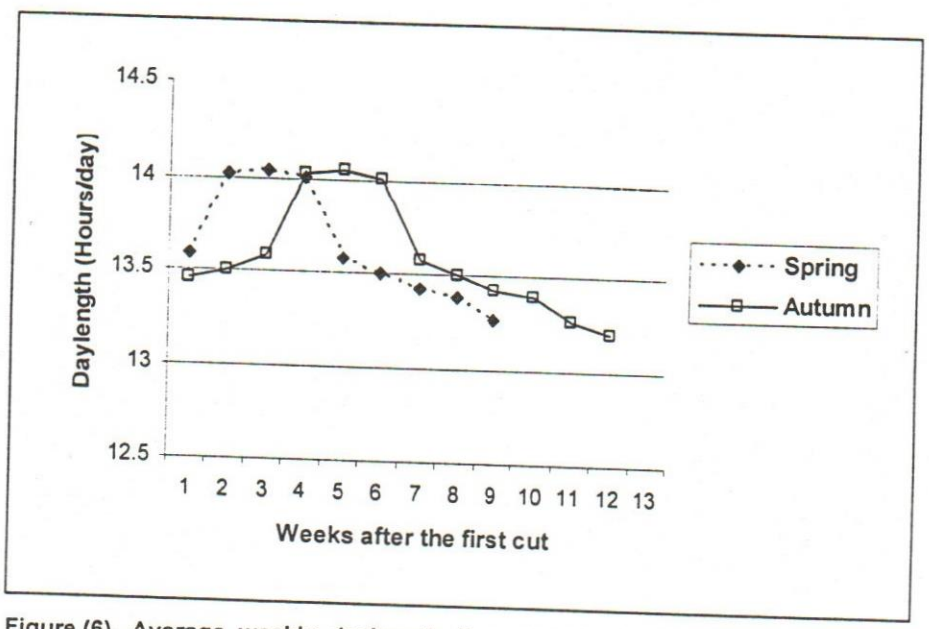

Figure (6). Average weekly daylength (hours/day) after the first cut until the second cut for spring and autumn plantings.

Plants of the spring planting needed 88 days and 76 days from planting to be ready for the 1st cut in the first and second seasons respectively, while those of autumn needed 197and 206 days in the same respective order. Similar trend was found from time of the first cut until time of the second cut. This could be explained on the basis of day-length and temperature requirements of Achillea plants, since Zhang *et al.* (1996) reported that *Achillea millefolium* is a qualitative long-day plant with a critical photoperiod between 12-16 hrs/day at 18 °C. The previously mentioned data of Fig. (5) showed clearly that spring plants were subjected to day length of 12 hrs/day from the first week after planting and reached 13 hrs/day 5 weeks before the flowering stage (1st cut). In autumn, plants took up to 20 weeks after planting to reach 12 hrs/day, and up to 25 weeks to reach 13 hrs/day
(4 weeks before flowering).

Table (1) : Effect of planting date on time taken to flower and plant height of *Achillea millefolium*, L. plants at the first and second cuts during two seasons.

Planting date	Time of harvest	Time taken to flower (days)		Plant height (cm)	
		2000/01	2001/02	2000/01	2001/02
Spring planting	First cut	88	76	67.0	71.3
	Second cut	59	72	46.0	48.3
Autumn planting	First cut	197	206	76.7	68.7
	Second cut	89	78	54.3	45.3
L.S.D at 5 %		8.8	6.7	8.7	6.0

After plants had flowered and cut for the first time after planting, both planting dates were subjected to long-day Fig. (6). but since spring ones where harvested earlier, they also flowered earlier than those of autumn ones and became ready for the 2nd cut at a shorter time.

There were also some differences between the two seasons due to the temperature differences between the two seasons. The temperature of autumn planting dropped to 12 °C for three weeks (9th, 10th and 11th weeks after planting) in the second season, while it was above 15 °C in the first season. The previously mentioned data of day length and temperature showed that flowering of Achillea plant (and subsequently its harvest) was dependent on the photoperiod, but it was also influenced by the temperature.

III. Effect of planting season on plant height:

In both seasons, plants of both spring and autumn planting at the time of the 1st cut were significantly taller than planys of the 2nd cut (Table, 1). This was related to the longer time taken to grow vegetatively to reach the time of the 1st cut than the time taken after the first cut to reach the 2nd cut.

In the first season, at the time of the 1st cut, the plants of autumn were significantly taller than spring ones, while they did not significantly differ in the second season. Plants of autumn grew vegetatively for a longer time than those of spring because they were subjected to shorter photoperiod for a

longer time than those of spring. Similarly, bdAallah *et al.* (1985) reported that autumn cultivation of Achillea resulted in an increase in plant height compared with spring cultivation.

In the second season, autumn plantings suffered a drop in temperature below 15 °C for 5 weeks (from week 9 to week 14 after planting) during their vegetative growth that ceased their growth, and thus resulted in less height. In this concern, Zhang *et al.* (1996) reported that plants of Achillea grown at 18 °C were taller than those grew at either lower (10 °C) or higher (26 °C) temperatures.

At the time for the 2nd cut, plants of spring and autumn did not significantly differ in their heights in both seasons because the differences in photoperiod and temperature were not large enough.

IV. Effect of planting season on dry weight of the aerial parts:

In both seasons, plants of both spring and autumn planting at the time of the 1st cut had significantly more dry weight than at the time for the 2nd cut (Table, 2). Achillea plants had more dry weight at the time of the 1st cut because plants grew vegetatively for a longer time (Table,2) until the 1st cut than after the 1st cut until the time of the 2nd cut (Fig. 3) resulting in more growth and weight. The results of Zhang *et al.* (1996) previously mentioned strongly supported this view. In addition the results of Fykse (1983) also showed that dry weight of *Achillea millefolium* decreased with increasing temperature levels.

At the time of the 1st cut, plants of autumn planting had significantly more weight than those of spring planting in both seasons. Since plants of autumn cultivation grew vegetatively for a longer time, it is expected that plants of autumn planting would have greater weight than spring ones. These results were similar to those of Abdallah *et al.* (1985), who reported that autumn cultivation of Achillea resulted in an increase in plant dry weight compared with spring cultivation.

Table (2) : Effect of planting date on dry weight of aerial parts and flowers of *Achillea millefolium*, L. plants at the first and second cuts during two seasons.

Planting date	Time of harvest	Aerial parts dry weight (g/plant)		Flowers dry weight (g/plant)	
		2000/01	2001/02	2000/01	2001/02
Spring Planting	First cut	86.1	30.6	29.8	9.9
	Second cut	47.0	18.4	18.9	4.8
Autumn Planting	First cut	101.7	61.3	13.0	14.4
	Second cut	20.6	33.4	3.5	11.7
L.S.D at 5 %		9.1	4.2	5.4	3.5

At the time for the 2nd cut, plants of spring had significantly more dry weight than those of autumn planting in the first season, but in the second season, plants of autumn had significantly more dry weight. Plants of spring cultivation subjected to inconsistent temperature which hesitated between a rise and a fall down from week 4 to week 9 (Fig. 2), that affected their growth and weight in the 1st and 2nd cut.

V. Effect of planting season on flowers dry weight:

In both seasons, the time of the 1st cut had significantly more flowers dry weight than at the time for the 2nd cut (Table, 2).

At the time of the 1st cut, plants of spring had significantly more flowers dry weight than those of autumn in the first season, but in the second season, autumn planting produced more flowers dry weight.

The daylight and temperature of the first season favored earlier flowering of spring cultivation than those of autumn ones did. However, in the second season, the temperature of spring cultivation during flower bud formation and flowering was inconsistent and resulted in a reduction in flower production and consequently less dry weight. At the time for the 2nd cut, plants of spring had significantly more flowers dry weight than those of autumn in the first season, but in the second season, plants of autumn had significantly more flowers fresh and dry weights. Although Abdallah *et al.* (1985) reported that autumn cultivation of Achillea resulted in an increase in flower heads dry weight compared with spring. While, earlier results by Kibalcic and Leskova (1961), showed that highest crop yield was obtained from spring sowing.

VI. Effect of planting season on yield:

Plants in this study were harvested at the flowering stage because *Achillea millefolium* contained maximum amount of oil and azulenes at this stage (Rohloff *et al.*, 2000). In addition, flowers are the most valuable part in Achillea millefolium plant because they are the richest in volatile oil and azulene content (Orav *et al.*, 2001). As a consequence, the yield in this study was measured as the yield of the dried flowers and their oil contents.

1. Effects on dried flowers yield:

The yield of the dried flowers at the 1st cut was always higher than the 2nd one for both plantings in both seasons (Table, 3). In the first season, spring planting yielded 268.6 kg/fed. in the 1st cut and 170.5 kg/fed. in the 2nd cut, and in the second season yielded 88.9 and 42.8 kg/fed. in the same order. Autumn planting yielded 116.8 kg/fed. in the 1st cut and 31.2 kg/fed in the 2nd cut in the first season and in the second season, it yielded 129.3 and 105.1 kg/fed. in the same order. These data also showed that in the first season spring planting yield was higher than that of autumn in both harvests, while the opposite was true in the second season. This difference could be explained in the light of the meteorological data previously mentioned.

Kibalcic and Leskova (1961), reported that spring cultivation of Achillea had higher crop yield than autumn, while Abdallah *et al.* (1985), on Achillea, reported that autumn cultivation had higher crop yield than spring.

Table (3) : Effect of planting date on dried flowers yield, essential oil Percentage and oil yield of *Achillea millefolium*, L. plants at the first and second cuts during two seasons.

Planting date	Time of harvest	Flowers yield (kg/fed)		Essential oil (%)		Oil yield (Litre/fed)	
		2000/01	2001/02	2000/01	2001/02	2000/01	2001/02
Spring planting	First cut	268.6	88.9	0.7	0.8	1.88	0.7
	Second cut	170.5	42.8	0.7	0.6	1.19	0.26
Autumn planting	First cut	116.8	129.3	0.6	0.7	0.7	0.91
	Second cut	31.2	105.1	0.5	0.6	0.16	0.63
L.S.D. 5%		48.6	32.4	N.S.	N.S.	0.35	0.2

2. Effect on oil percentage and oil yield:

Table (3) showed that the essential oil percentage was not affected by the planting date in both harvests (cuts). Although there were no significant differences between the planting dates or between the cuts in the percentage of the essential oil of the dr in their ied flowers in both seasons, there were differences among them yield/fed.

In both seasons, the yield of oil was significantly higher in the 1st cut than the second one in each planting. In the first season, spring planting yielded 1.88 liters/ fed. from the 1st cut and 1.19 liters/fed. from the 2nd cut, and in the second season it yielded 0.70 and 0.26 liters/fed. in the same respective order. Autumn planting, in the first season, yielded 0.70 liters/fed. from the 1st cut and 0.16 liters/fed. from the 2nd cut, and in the second season, it yielded 0.91 and 0.63 liters/fed. in the same respective order.

The trend of the oil yield is identical to that of the flower yield. Thus, the data clearly indicated that the difference in oil yield was a result of the effect of each planting date (season) on the yield of the dried flowers rather than its effect on oil percentage. Our results coincided with those of Shalaby *et al.*, (1993) who showed that all increases in the oil yields of *Melissa officinalis* were a result of increased crop yield rather than increased essential oil concentrations. In addition, other researchers showed that climatic conditions affected oil yield of many aromatic plants, but not its percentage (Piccaglia *et al.*, 1997; Gurrero and Johnson, 2000).

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دراسات على نبات الاشيليا (*Achillea millefolium* L.):
١- تأثير زراعتى الربيع و الخريف و موعد الحصاد على نمو و إزهار و محصول الزهور الجافة و الزيت العطرى

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نبات ال (*Achillea millefolium* L.) و يعرف محليا بالألف ورقة ينتمى للعائلة المركبة و هو نبات طبى و عطرى هام ، و تحتوى الأجزاء الهوائية منه على زيت طيار عالى الجودة ذو لون أزرق داكن و غنى بمادة الكامازولين، و تعتبر الزهور أغنى الأجزاء بالزيت العطرى.

و لقد تم إجراء هذه الدراسة فى الموسمين المتتاليين ٢٠٠٠/٢٠٠١ و ٢٠٠١/٢٠٠٢ فى مزرعة النباتات الطبية و العطرية بكلية الزراعة جامعة المنصورة. و هدفت إلى دراسة تأثير موسمين للزراعة (الربيع و الخريف) و حشتين متتاليتين لكل منهما على نمو و إزهار و محصول كل من الزهور الجافة و الزيت العطرى لنبات الأشيليا تحت ظروف محافظة الدقهلية. و لقد تم قياس الوقت اللازم للتزهير و الوزن الجاف لكل من العشب و الزهور و محصول الزهور الجافة و الزيت العطرى. ولقد تم تسجيل التغيرات الحادثة فى درجات الحرارة و طول النهار خلال فترة إجراء البحث.

و لقد أظهرت النتائج أن النباتات فى الحشة الأولى قد أخذت وقتا أطول لكى تزهر و كانت أكثر إرتفاعا و أنتجت وزنا أكبر من الأعشاب و الزهور للنبات و أعطت محصولا أكبر من الزهور الجافة و الزيت العطرى عن الحشة الثانية فى كل من الزراعتين(الربيع و الخريف).

أظهرت النتائج أيضا أنه فى الموسم الأول أعطت زراعة الربيع نباتات أقصر و أعطت وزنا أقل من الأعشاب ، إلا أنها أعطت وزنا أكبر من الزهور بالنسبة للنبات و محصولا أكبر من الزهور الجافة و الزيت العطرى عن زراعة الخريف. أما فى الموسم الثانى فقد عانت نباتات الربيع من عدم إستقرار درجات الحرارة و أعطت محصولا أقل من الزهور و الزيت العطرى من زراعة الخريف. و فى كلا الموسمين أزهرت نباتات زراعة الربيع مبكرا و أخذت وقتا أقصر لتصبح جاهزة للحشة الأولى و الثانية عنها فى حالة زراعة الخريف بغض النظر عن تغيرات درجة الحرارة. و بناء على المعلومات المناخية تم إستخلاص أن إزهار نبات الأشيليا يعتمد أساسا على طول الفترة الضوئية ، إلا أن النمو و المحصول يتأثران بدرجة كبيرة بالتغيرات الحادثة فى درجة الحرارة.

ولقد أظهرت النتائج أيضا أن موس الزراعة و موعد القص لم يؤثران على نسبة الزيت فى الزهور ، و أن الزيادة فى محصول الزيت كان نتيجة زيادة محصول الزهور الجافة و ليس محتواها من الزيت.