

Full Length Research Paper

Studies on the chilling requirements of pecan nut (*Carya illionensis* Koch) cultivars

Ayzin. B. Kuden^{1*}, Önder Tuzcu¹, Safder Bayazit², Bilge Yildirim¹ and Burhanettin Imrak³

¹Department of Horticulture, Faculty of Agriculture, Cukurova University, Turkey.

²Department of Horticulture, Faculty of Agriculture, Mustafa Kemal University, Turkey.

³Pozanti Agricultural Research and Application Center, Cukurova University, Turkey.

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The chilling requirements of the male and female flower buds of 23 pecan nut cultivars were determined and compared for the tendency to protogeny/protandry during 2000 to 2004 winter periods by Weinberger's standard and Richardson's chill unit methods. Calculating the chilling hours below 7°C and chill unit (CU) values during the experimental winter periods, 555 to 660 h and 407 to 416 (CU) of chilling duration were obtained under subtropical conditions of Adana. There are some differences on dormancy release dates and chilling requirements of the female and male flower buds as well as some little differences between the chilling methods. In 2003 to 2004 winter period, the chilling requirements were changed between 208 to 338 CU and 250 to 436 h in male flowers, whereas, 203 to 389 CU and 250 to 484 h in female flowers. In this year, similar to the previous year, Moneymaker broke endodormancy of female buds primarily on 22nd January and showed the lowest chilling requirements (203 CU and 250 h), while male flower bud dormancy release occurred on 12th February with 300 CU and 346 h of chilling. The male flower buds of Kiowa, Schley, and Texhan were found to be the lowest chilling requiring cultivars suitable to warm climatic conditions, whereas, the others require more. For the female flower buds, Harris Super, Mahan, Moneymaker and Wichita gave the lowest chilling requirements, while Desirable, Schley and Woodard gave the highest. Considering the tendency of the male and female flower buds to protogeny and protandry, Kiowa, Schley, Texhan, Pawnee and Woodard showed protandry, while Choctow, Moneymaker, Harris Super and Western showed protogeny in both years.

Key words: Pecan nut, male and female flowers, endodormancy release, subtropical conditions.

INTRODUCTION

Pecan [*Carya illinoensis* (Wagenh.) K. Koch] is a deciduous fruit species, originated in North America (Faraçlar, 1988; Cerna-Cortés et al., 2003). This species belonged to the *Juglandaceae* family with North American, Anatolian and black walnut species (Birson, 1974). It is reported that, the pecan fruits have high nutritional value, rich in fats, carbohydrates, proteins, Calcium (Ca), Phosphorus (P), Magnesium (Mg) as well as vitamins A and B (Kays, 1991).

Chandler (1957) indicated that, Schley, Stuart, and Moneymaker pecan cultivars originated in Southern part are low chilling ones, whereas Crocker (1987) reported that, chilling requirements of the northern pecan cultivars were as high as walnut. El Deen and El Deen (1993) and McEachern et al. (1978) stated that, the chilling requirements of the pecan cultivars were; 300 to 500 h of chilling for Desirable, Mahan, Success and Schley and 600 h for Stuart. In another study, Amling and Amling (1980)

*Corresponding author. E-mail: abkuden@cu.edu.tr.

Table 1. Pecan cultivars in turkey and their origins.

Cultivar	Place of origin and the year	Introduction Turkey (year, place)	Chilling requirements (hours below 45 °F)
Big Z	Seedling, Misisipi, 1911	1983, USA	-
Burkett	Seedling, Texas, 1905	1969, Israel	-
Cheyenne	Clark × Odom, Texas, 1959	1983, USA	-
Choctaw	Success × Mahan, Texas, 1959	1969, Israel	-
Comanche	Burket × Success, Texas, 1955	1969, Israel	-
Desirable	Success × Jewt, Misisipi, 1948	1983, USA	300-500
Harris Super	Seedling, Misisipi, 1960	1969, Israel	-
Hastings	Stuart seedling, Florida, 1945	1969, Israel	-
Ideal	Seedling, Texas, 1930	1969, Isarel	-
Kiowa	Mahan × Odom, Texas, 1976	1992, Spain	-
Mahan	Schley seedling, Misisipi, 1927	1969, Israel	300-500
Mahan × Stuart	Mahan × Stuart, Florida, 1956	1969, Israel	-
Mohawk	Success × Mahan, Texas, 1965	1969, Israel	-
Moneymaker	Seedling, Lousiana 1945,	1983, USA	-
Pawnee	Mohawk × S. H. Giant, Texas, 1984	1992, Spain	-
Royal	Schley seedling, California, 1945	1969, Israel	-
Schley	Stuart seedling, Misisipi, 1898	1983, USA	300-400
Shawnee	Schley × Barton, Texas, 1968	1969, Israel	-
Stuart	Seedling, Misisipi, 1886	1983, USA	600-1000
Texhan	Mahan seedling, Texas, 1946	1969, Israel	-
Western	San Saba sedling, Texas, 1982	1969, Israel	-
Wichita	Halbert × Mahan, Texas, 1982	1983, USA	-
Woodard	Seedling, Giorgia, 1982	1983, USA	-

reported that, the chilling requirements of 'Mahan', 'Success', 'Desirable', and 'Schley' were 300 to 400 h and 700 to 1000 h for 'Stuart'.

The first pecan nut was introduced to Turkey in 1953 and fourteen more cultivars were added to the collection in 1969 from USA, Italy, Spain, and Israel through FAO and Turkish Ministry of Food, Agriculture and Livestock (Tuzcu and Yildirim, 2000). The origins and the foundation year of these cultivars are given in Table 1. They reported that, pecan is a deciduous fruit tree which needs relatively short chilling duration to set fruit commercially depending on the cultivars. They also stated that, the chilling requirements of the cultivars were assumed to be around 400 to 750 h under 7°C, while Faraçlar (1988) reported that, it was around 400 to 800 h. Similarly, El-Deen and El-Deen (1993) indicated, that the chilling requirements of the pecan cultivars were 350 to 400 h for the low chilling ones and over 700 h for the high chilling cultivars. Pecan cultivars grown in Israel such as 'Mohawk', 'Sioux Pikan', 'Western Schely', 'Money Maker', 'Cape Fare', 'Desirable', 'Delmas', 'Burkett', 'Mahan', 'Onliwon', 'Garner', 'San saba', 'Nelis', 'Wichita', 'Choctaw', 'Apache', 'J.Harris Super', 'Pensacola Culaster', 'Comanche', 'Major × Evers', 'Mahan × Odom', 'Cherokee', 'Bradly', 'Texhan', 'Sioux', and 'Kernodle' have no problem to get adequate chilling accumulation

(Homsy, 1993).

Male flowers of the monocious pecan trees are formed on the shoots of the previous year, while female flowers are formed at the apical buds of the growing shoots and very few on the lateral buds (Westwood, 1991). Since dichogamy is seen in pecan trees, cultivars cannot be self pollinated (William, 1989). Thus, it is essential to know the date of budburst which depends on the chilling requirements and total growing degree hours (GDH) values.

Different chemical applications were used to break dormancy and to improve the fruit set of low chilling requiring cultivars grown under mild climate conditions (Erez, 1987; Westwood, 1991). Likewise it is reported that, inadequate chilling on pecan trees grown under subtropical conditions negatively affects flowering and fruit set. However, chemical applications such as hydrogen cyanamide Dormex (3%), potassium nitrate, (5%), urea (10%) and water (control) on the annual shoots of 'Cherokee', 'Desirable', 'Choctaw', 'Cape Fear' and 'Graking' cultivars caused early and simultaneously flowering of female and male flowers and also increased the percentage of budbreak (Fayek et al., 2008).

Although pecan was known to be low chilling requiring species (around 400 to 700 h), the chilling requirements of all commercial pecan cultivars have not been known

Table 2. The Chilling Durations of the Experimented Years

Year	Hours below 45°F	Chill unit
2000 - 2001	660	411
2001 - 2002	555	407
2003 – 2004	581	416

yet. In this research, the chilling requirements of the male and female flower buds of 23 pecan cultivars were determined using Weinberger's "Standard Method" and Richardson's "chill unit method" (Weinberger, 1950; Richardson et al., 1974; 1986; Anderson and Richardson, 1987).

The aims of this research were to develop pecan nut growing as an alternate crop to walnut in higher elevations of the subtropical areas and also to determine the chilling requirements of the male and female flower buds to compare their flowering periods for the point view of protegeny or protandry. Although pecan nut has been introduced to Turkey since 1953, the production of this crop had not developed and expanded properly. This study will contribute to advice pecan nut production to different areas with right cultivars and pollinators.

MATERIALS AND METHODS

This study was carried out for three years (2000 to 2001, 2001 to 2002 and 2003 to 2004 winter periods) at the experimental orchards of Department of Horticulture, University of Cukurova under subtropical ecological conditions of Adana. The experiments were carried out to calculate the chilling requirements of pecan nut cultivars given in Table 1. In this research, the chilling requirements of the male and female flower buds of pecan nut cultivars were evaluated separately, except the first experimental year.

In determination of the chilling requirements of the experimented pecan cultivars, cuttings of 25 to 30 cm were taken from 1 or 2 years old shoots every 2 days and put in a water tank to observe endodormancy release dates in the controlled room temperatures of $\pm 24^{\circ}\text{C}$. Dormancy release was determined when the 50% of the buds reached to the green tip stage in 21 days (Weinberger, 1950; Küden and Kaşka, 1992).

The chilling requirements of the pecan nut cultivars were calculated from daily maximum and minimum temperatures of 24 h by using a computer program prepared by Miller and Küden in 1989 according to the Richardson's chill unit, using asymcur curve model (Richardson et al., 1982; Anderson and Richardson, 1987; Küden and Kaska, 1992; Küden et al., 1997). Besides the standard method of hours below 45°F for chilling accumulation, Richardson's chill unit model was also used to calculate the CU of the cultivars and also for the calculation of the chilling durations of the region.

RESULTS AND DISCUSSION

Calculating the chilling durations in Adana

The chilling durations of Adana (50 m elevation) is shown in Table 2. Calculating the hours below 7°C and CU

values of the region during the experimental winter periods, 555 to 660 h and 407 to 416 CU of chilling duration were obtained in Adana at the experimented years. Differences depending on the years were similarly reported by Bailey et al. (1982), who studied chilling requirements of 3 apricot cultivars for 4 years and also Küden and Kaska (1990, 1992, 1993) who studied the chilling durations of several provinces and chilling requirements of peaches.

This shows that, the ecological conditions of Adana are suitable to grow pecan nut cultivars. Also, day and night temperatures, rainfall during autumn and winter periods were also effective on the chilling accumulation and dormancy break. These results are in accordance with the results of Küden and Kaska (1990, 1992) and Küden et al. (1994).

Calculating the chilling requirements of the pecan cultivars

During 2000 to 2001 winter period, the chilling requirements of the experimented pecan nut cultivars were changed between 451 to 550 h and 291 to 333 CU. In this year dormancy breaking was occurred between 14th February and 15th March (Table 3).

In 2001 to 2002 winter period similar to the previous year the chilling requirements of the female flower buds of pecan cultivars were between 428 to 512 h and 264 to 362 CU, while it was between 428 to 541 h and 264 to 384 CU for the male flower buds (Table 4). Male flower buds broke dormancy between 18th January and 1st March, while female flower buds release endodormancy between 18th January and 21st February.

In 2001 to 2002 winter period, dormancy release of the female buds was earlier than the male buds in Choctaw, Harris Super, Hastings, Ideal, Mahan, Mohawk, Moneymaker, Royal, Western and Wichita, whereas, the others showed earlier release in male buds except Burkett and Stuart cultivars which broke endodormancy at the same dates both in male and female buds.

Comparing dormancy release dates of the cultivars, Schley pecan cultivar was the earliest to release dormancy of male flower buds on 18th of January, but late in female buds on 15th of February. Schley was followed by Big Z, Pawnee, Mahan, Comanche, Kinowa, Shawnee, Cheyenne, and Texhan cultivars for the male flower dormancy release. The endodormancy release dates of male and female flower buds were also compared to determine the tendency to protegeny/protandry case.

In 2003 to 2004 winter period, the chilling requirements were changed between 208 to 338 CU and 250 to 436 h in male flowers, whereas 203 to 389 CU and 250 to 484 h in female flowers (Table 5). In this year, similar to the previous year, Moneymaker broke endodormancy of female buds primarily on 22nd January and showed the

Table 3. The Chilling requirements of the flower buds (male and female are Mixed) of the experimented pecan nut cultivars by standard and CU methods (2000 to 2001 winter period).

Cultivar	Budbreak dates	Chill unit	Hours below 45 °F
Big Z	27 February	323	541
Burkett	14 February	291	451
Choctaw	15 March	333	550
Comanche	27 February	323	541
Desirable	15 March	333	550
Harris Super	16 February	302	469
Hastings	27 February	323	541
Ideal	14 February	291	451
Kiowa	27 February	323	541
Mahan	14 February	291	451
Mohawk	27 February	323	541
Moneymaker	14 February	291	451
Pawnee	15 March	333	550
Royal	15 March	333	550
Shawnee	01 March	325	547
Texhan	16 February	302	469
Western	27 February	323	541
Wichita	14 February	291	451
Kiowa	27 February	323	541

Table 4. Chilling requirements of the male and female flowers of the experimented pecan nut cultivars by standard and CU methods (2001 to 2002 winter period).

Cultivar	Budbreak dates		Chill unit		Hours below 45 °F	
	Male	Female	Male	Female	Male	Female
Big Z	22 February	08 February	292	341	428	499
Burkett	12 February	12 February	343	343	499	499
Cheyenne	05 February	12 February	341	343	499	499
Choctaw	21 February	05 February	362	341	512	499
Comanche	29 January	08 February	327	341	480	499
Desirable	08 February	21 February	341	362	499	512
Harris Super	26 February	18 January	371	264	521	428
Hastings	12 February	08 February	343	341	499	499
Ideal	01 March	07 February	384	343	541	499
Kiowa	29 January	08 February	327	341	480	499
Mahan	25 January	22 January	308	292	456	428
MahanxStuart	08 February	12 February	341	343	499	499
Mohawk	21 February	12 February	362	343	512	499
Moneymaker	08 February	22 January	341	292	499	428
Pawnee	22 January	08 February	292	341	428	499
Royal	12 February	08 February	343	341	499	499
Schley	18 January	15 February	264	349	428	502
Shawnee	29 January	12 February	327	343	480	499
Stuart	12 February	12 February	343	343	499	499
Texhan	05 February	08 February	341	341	499	499
Western	26 February	08 February	371	341	521	499
Wichita	01 March	22 January	384	292	541	428
Woodard	08 February	21 February	341	362	499	512

Table 5. The chilling requirements of the male and female flowers of the experimented pecan nut cultivars by standard and CU methods (2003 to 2004 winter period).

Cultivar	Budbreak date		Chill unit		Hours below 45 °F	
	Male	Female	Male	Female	Male	Female
Big Z	05 February	05 February	282	282	328	328
Burkett	05 February	12 February	282	300	328	346
Cheyenne	09 February	05 February	293	282	339	328
Choctaw	16 February	12 February	323	300	397	346
Comanche	12 February	09 February	300	293	346	339
Desirable	16 February	16 February	323	323	397	397
Harris Super	16 February	05 February	323	282	297	328
Hastings	09 February	05 February	293	282	339	328
Ideal	12 February	16 February	300	323	346	397
Kiowa	22 January	05 February	208	282	250	328
Mahan	09 February	05 February	293	282	339	328
Mahan × Stuart	09 February	12 February	292	300	339	346
Mohawk	12 February	26 February	300	389	346	484
Moneymaker	12 February	22 January	300	203	346	250
Pawnee	05 February	09 February	282	293	328	339
Royal	09 February	05 February	300	282	346	328
Schley	29 January	09 February	259	293	313	339
Shawnee	18 February	05 February	338	282	436	328
Stuart	05 February	05 February	282	282	328	328
Texhan	22 January	05 February	208	282	250	328
Western	12 February	09 February	300	293	346	339
Wichita	12 February	16 February	300	323	346	397
Woodard	05 February	12 February	282	293	328	339

lowest chilling requirements (203 CU and 250 h), while male flower bud dormancy release occurred on 12th February with 300 CU and 346 h of chilling. Protandry was seen in Kiowa, Texhan, and Schley cultivars in this year. Male flower bud endodormancy release was the earliest in Kiowa, Texhan (22 Jan.) and Schley (29 Jan.), while female flower budbreak dates of these cultivars were determined on 5th, 5th, and 9th February, respectively (Table 5). Similar to this result, the chilling requirement of the male flower buds of Kiowa was the lowest (208 CU and 250 h).

If we consider all data together for approximate chilling requirements of the pecan cultivars (Table 6), we see there are some differences on dormancy release dates and chilling requirements of the female and male buds as well as some little differences between the chilling methods. This shows that, Richardson's CU gave similar results to the Weinberger's standard method and suitable to our subtropical conditions. This result was also in accordance with the results of Finetto (2013) who stated that, statistically not much differences were obtained between Richardson's and Dynamic models.

However, Ruiz et al. (2007) stated that, in chilling requirement studies on apricots for 3 years, 26,4 % of differences were found among the cultivars according to

the standard method whereas only 7.2 % of differences were obtained by CU (dynamic model) method. The chilling requirements were reported to be effective on the flowering time of *Prunus* genus (Egea et al., 2003; Ruiz et al., 2007; Albuquerque et al., 2008).

Our results are also in accordance with the results of Mc-Eachern et al. (1978) and Amling and Amling (1980) who found similar CU for pecan nut cultivars.

Conclusion

In conclusion, male flower buds of Kiowa, Schley and Texhan were found to be the lowest chilling requiring cultivars suitable to warm climatic conditions, whereas, the others require more. For the female flower buds, Harris Super, Mahan, Moneymaker and Wichita gave the lowest chilling requirements, while Desirable, Schley and Woodard gave the highest. Considering the tendency of the male and female flower buds to protogyny and protandry case, Kiowa, Schley, Texhan, Pawnee and Woodard showed protandry, while Choctaw, Moneymaker, Harris Super and Western showed protogyny in both years.

In pecan nuts, in order to provide adequate fruit setting,

Table 6. The average chilling requirements of the male and female flowers of the experimented pecan nut cultivars by standard and CU methods.

Cultivar	Chill unit		Hours below 45°F	
	Male	Female	Male	Female
Big Z	300	300-350	300-400	300-500
Burkett	300-350	300-350	300-500	350-500
Cheyenne	300-350	300-350	350-500	300-500
Choctaw	300-350	300-350	400-500	350-500
Comanche	300	300-350	350-500	350-500
Desirable	300-350	300-350	400-500	400-500
Harris Super	300-350	250-300	300-500	300-400
Hastings	300-350	300-350	300-500	300-500
Ideal	300-400	300-350	350-550	350-500
Kiowa	200-300	300-350	250-500	300-500
Mahan	300	300	350-450	300-400
Mahan × Stuart	300-350	300-350	350-500	350-500
Mohawk	300-350	350-400	350-500	500
Moneymaker	300	250-300	350-500	250-400
Pawnee	300	300-350	300-400	350-500
Royal	300-350	300-350	350-500	300-500
Schley	250-300	350	300-400	350-500
Shawnee	300	300-350	400-450	300-500
Stuart	300-350	300-350	300-500	300-500
Texhan	200-350	300-350	250-500	300-500
Western	300-400	300-350	300-500	350-500
Wichita	300-400	250-300	350-550	400
Woodard	300-350	300-350	300-500	300-500

pollinator trees should also be planted in the orchard.

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