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An investigation of the relationship between reproductive growth and yield loss in hazelnut

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Abstract

This study was carried out in Samsun during a 2-year period to examine the relationship between reproductive and yield loses in the 'Tombul' and 'Palaz' hazelnut cultivars. In hazelnuts, male and female flowering occur in winter after the breaking of inflorescence dormancy. In the present study, growth of the ovary of the hazelnut started in April and continued until mid-June. At the time of flowering the ovary did not form. The ovule growth showed a rapid increase at the end of June. Change in the diameter of the ovary and ovule with time showed a simple sigmoid growth curve. Fertilization occurred during the period between mid-May and the beginning of June, namely, 3.5–5 months after pollination. At this time, the diameter of the nut was 9.54 mm. Twin kernel was not observed. The ratio of double kernels was close to zero. The time period from fertilization to harvest was 89 days in 1997 and 96 days in 1998 for Tombul cultivar. For the Palaz, this period was 84 days in 1997 and 86 days in 1998. The rate of pistillate flower clusters which dropped in April–May was more than those dropped in June–August.
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Keywords: *Corylus avellana*; Hazelnut (Filbert); Ovule and embryo development; Fertilization success; Flower and fruit cluster drop

1. Introduction

The hazelnut is an edible nut species. It is essential for fruit production of both the ovule and the embryo growth. Pollination and fertilization must occur for growth of the embryo and the ovule to develop. Without fertilization, the embryo does not grow and nor does the seed (Lagerstedt, 1977; Beyhan, 1993; Germain, 1994).

As in other fruit species, all fertilized flowers of the hazelnut do not produce fruits. Different stages between fertilization and harvest, the growth of the ovule and the embryo may stop. When fertilization does not occur or when the kernel does not grow enough after fertilization, blank fruits may appear. Blank nuts decrease the yield and kernel percentage and also cause financial losses (Mehlenbacher et al., 1993; Silva et al., 1996; Beyhan and Marangoz, 1999).

For these reasons, the floral biology of the hazelnut, and the growth of its ovule and embryo have been the focus of attention of some other researchers. Thompson (1979) examined the early stages of endosperm and embryo development in ''Barcelona'' hazelnut cultivar. Me et al. (1989) studied the period from embryo sac development to harvest in the 'Tonda gentile delle Langhe' hazelnut cultivar. Silva et al. (2001) combined these two periods and examined all the periods from the end of pollination to harvest. Beyhan (1995) completed a preliminary study on the ovary, ovule and embryo development of Turkish hazelnut cultivars using the stereo microscope. The topics were considered individually and different cultivars from different ecological environments were used in each of these previous studies. However, the pistillate flower and drop rates and drop periods have not been studied in detail. The reproductive growth of the hazelnut, the development of the ovule and the embryo and also flower and fruit drops for the same cultivar and ecology have been examined together, studied in comparison to each other and discussed for the first time in this article.

''Tombul'' and ''Palaz'' are the most important cultivars among the major commercial hazelnut cultivars in Turkey and accounts for 70% of world hazelnut production. In particular, the ''Tombul'' is an important cultivar because of its excellent nut and kernel characteristics (Köksal, 2002). Although reproductive growth of the hazelnut has been examined in

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the studies mentioned above, effective solutions for nut losses and the possible problems that occur during the growth of the ovule and embryo have not been implemented. Unfortunately, not enough research has been carried out to provide the necessary background information about the embryology of Turkish hazelnut cultivars. Therefore, the objective of this study has been to determine the relationships between the pistillate flower cluster and fruit cluster drops and the development of the ovary, ovule and embryo in the major commercial hazelnut cultivars (‘‘Tombul’’ and ‘‘Palaz’’) grown in Turkey.

2. Material and methods

Pistillate flower clusters (cymule) and fruit clusters of the hazelnut cvs. Tombul and Palaz were examined in The Black See Region (Samsun, Turkey), between 1997 and 1998. The experimental unit was ocak. In Turkey, hazelnuts are grown in the ocak system (multi stemmed growing or shrub growing form). Samples were collected from five ocaks (six plants per ocak) for each variety. And this continued every 2 weeks from the end of pollination until May; and then every week from May to the end of June, and finally every 2 weeks from the end of June to harvest. During periods of rapid embryo development, samples were collected every other day. Twenty-five pistillate flower or fruit clusters were picked at each sampling date. The diameters of the ovary and ovule were measured at each collection date and a growth curve was prepared from the mean values.

Samples were fixed in FAA [70% ethanol:glacial acetic acid:formalin (18:1:1, v/v/v)] and stored in 70% alcohol at 4 °C until used (Brooks et al., 1966). A microwave oven was employed for the procedure of dehydration and paraffin infiltration of the samples. For this procedure, a method described by Aşkın et al. (1995) and Dolgun (1995) was modified in order to be applicable to the samples. The samples were dehydrated three times in 70, 80, 90 and 100% ethanol for 10 min and then they were put in a mixed solution of ethanol and xylene three times for 10–20 s (three parts ethanol + one part xylene, two parts ethanol + two parts xylene and one part ethanol + three parts xylene). After that, the samples were put in 100% xylene and paraffin was added gradually. Finally, the samples were kept in melted paraffin four times for 3 min. Changing the paraffin, the same operations were applied for another four times. Samples were embedded in paraffin, sectioned at 10 μm in a rotary microtome and stained with hematoxylin or safranin-fast green (Odabaş, 1976; Beyhan, 1993).

The counts started from March and were conducted every month until August. The pistillate flower clusters were counted in March, April and May and the fruit clusters were counted in July and August.

The data was analyzed by the Student’s ‘*t*’ test. The experimental unit was plant for the drop examination. In total, 24 plants and 4 ocaks from each variety were used to determine the number of pistillate flower cluster and fruit cluster drops. All the pistillate flower clusters and fruit clusters on one plant were counted. The average of the results for two plants was obtained and the *t*-test was applied for 12 examples (data). The counts started from March and were conducted every month until August.

3. Results

3.1. Ovary and ovule growth

In the hazelnut, male and female flowering occurs in winter after the breaking of inflorescence dormancy. At the time of flowering, the ovary is not formed. Ovary growth and the development of the pistillate flowers begin in April. In periods following April, it is determined that the ovary development of some pistillate flowers stopped and that there was a loss of functionality with these ovaries. It was observed that some of the pistillate flowers had no ovary development. The size of those ovaries that were in process of growth was 2.0 mm at the end of April, and varied between 5 and 8 mm at the end of May. The ovaries that could not continue to function were not able to grow more than 2.0 mm. Accordingly, the ovaries showed rapid development through to the end of May and the clusters began to swell externally. In May, it was determined that the average percentage of functional ovaries in one cluster was 40–60% for the Tombul cultivar and 40–55% for the Palaz cultivar.

It was observed that some of the pistillate flower clusters did not show any sign of development. These pistillate flower clusters turned yellow and started to drop in late May. The ovaries of the pistillate flowers began to grow and pistillate flower clusters that were in the progress of swelling and others that were about to drop but did not swell, could easily be noticed at the end of April and at the beginning of May (Fig. 1A).

By early May, the first sign of ovule differentiation was seen as small protuberances at the base of the stylar canal (Fig. 1B). In general, usually, each (bicarpel) ovary contains two ovules but as determined in this study that 38.93% of the Tombul cultivar and 23.52% of Palaz had more than two ovules.

The diameter of the ovules varied between 0.70 and 1.36 mm at the end of May. The ovule wall differentiated into a single integument, and proceeded with the enlargement of the chalaza, the onset of the funiculus and the nucellus and micropyle formation inside the ovules. The nucellus and surrounding integument was clearly observed (Fig. 1C). Throughout May, the ovary wall differentiated into the exocarp (soft shell) and endocarp (parenchymatous tissue). The central vascular system, extending from the floral axis through the placenta and to the ovules, and the peripheral vascular strands were evident. The ovules completed their revolution to an anatropous position. At the end of this period, differentiation of several nucellar cells as megasporocytes were different from those nucellar cells that were dark stained, were observed (Fig. 1C).

In June, hardening of the shell from the apex through to the base of the ovary was observed. The parenchymatous endocarp (large white spongy cells) still constituted the greater part of the ovary. Toward the end of July, the ovule and embryo growth was completed and the seed gradually filled the ovarian cavity

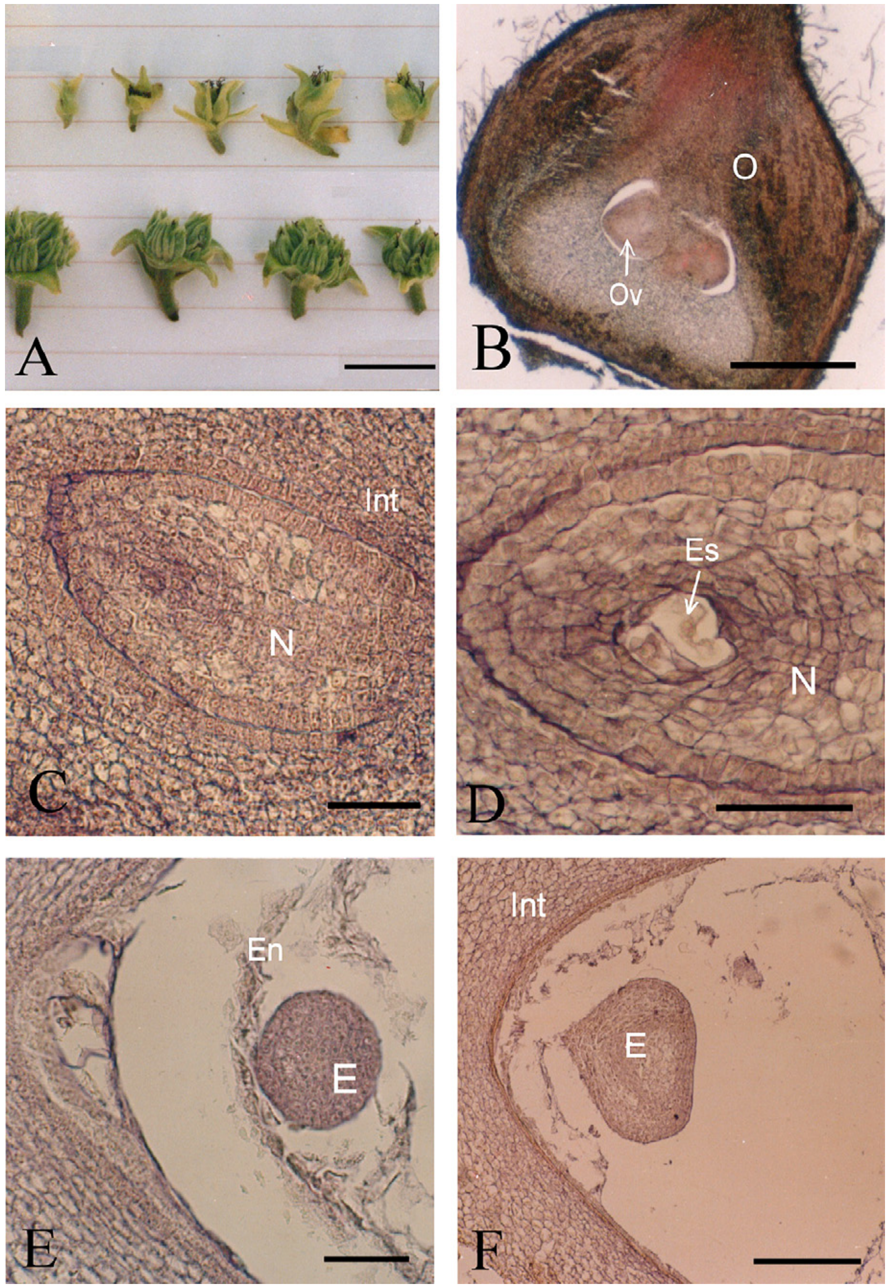

Fig. 1. Early stage ovary, ovule and embryo development. (A) Macrophotograph of the clusters from female flowers with non-developed ovary (above), and developing some of the ovaries (below), 30 April. (B) Micrograph of the ovary longitudinal section. The two ovules are visible on the placenta, 7 May. (C) Nucellus forming, 21 May. (D) Nucellus with embryo sacs, 28 May. (E) Globular embryo and cellular endosperm, 4 June. (F) Heart-shaped embryo, 13 June. Bars A, 1 cm; B, 0.5 mm; C–E, 0.05 mm; F, 0.2 mm (Es: embryo sac; O: ovary; Ov: ovule; N: nucellus; Int: integument; E: embryo; En: endosperm).

by displacing parenchyma cells. These cells gradually pressed against the shell, or outer ovary wall. Upon seed maturity, these cells appeared as a brown layer of fibers.

In 1997, a rather rapid ovary growth occurred between the last week of May and the middle of June and the ovary growth rate declined thereafter up to the end of June when it reached its final size. However in 1998, the rapid growth of the ovary occurred between mid-May and early June and the average size of ovaries nearly reached its final size by mid-June. The two ovules grew slowly during May and June. Fertilization occurred at the end of the period of rapid ovary growth and then the ovule growth rate increased after fertilization and at the beginning of the development of the embryo. By the end of June, it was observed that the ovule had grown rapidly. Ovule growth was slow by at beginning of July and was completed by the end of July.

3.2. Fertilization and embryo development stages

For 1997 and 1998, the times of observation of the stages of embryo development are shown in Table 1. In 1997, fertilization occurred between the 28 May and the 8 June in

Table 1
Observing times of the fertilization and the embryo development stages in Tombul and Palaz hazelnut cultivars

Stages	Tombul	Palaz
1997		
Fertilization	28.05.1997–08.06.1997	23.05.1997–04.06.1997
Stage I (Globular)	08.06.1997	04.06.1997
Stage II (Heart-shaped)	16.06.1997	13.06.1997
Stage III (Early torpedo)	19.06.1997	16.06.1997
Stage IV (Torpedo)	19.06.1997	19.06.1997
Stage V (Cotyledon)	23.06.1997	23.06.1997
Stage VI (Leaf)	28.06.1997	28.06.1997
1998		
Fertilization	16.05.1998–26.05.1998	16.05.1998–26.05.1998
Stage I (Globular)	26.05.1998	26.05.1998
Stage II (Heart-shaped)	07.06.1998	02.06.1998
Stage III (Early torpedo)	07.06.1998	02.06.1998
Stage IV (Torpedo)	13.06.1998	07.06.1998
Stage V (Cotyledon)	21.06.1998	13.06.1998
Stage VI (Leaf)	28.06.1998	21.06.1998

Tombul, and between the 23 May and the 4 June in Palaz. However, fertilization occurred at the same period (16–26 May) for both Tombul and Palaz, in 1998.

Mature embryo sacs were observed at the end of May (Fig. 1D), and the acellular endosperm nuclei, the first embryo development stage, globular embryo, were observed (also evident, clearly visible) between at the end of May and the beginning of June. So, the pollen tubes which were at rest at the base of the style, grew again and fertilization occurred in the period between the end of May and the beginning of June, 5 months after pollination.

In this research, an ovule with twin kernels (the occurrence of two embryos in one ovule) was not encountered. However, there was a rather low percentage of occurrence of double kernels for the Tombul and Palaz cultivars. The stages of embryo development were observed as follows:

Stage I (*globular embryo*): The globular embryo at the micropylar end of the embryo sac was clearly visible (Fig. 1E). The diameter of the globular embryo was about 0.07 mm. The length of the embryo sac increased from about 80 to 85% of the nucellus to about 100% of the nucellus a week after the first observation of the globular embryo. The average diameter of the sphere of an ovary was 9.54 mm and the ovule was still only 1.19 mm in diameter. The fruit

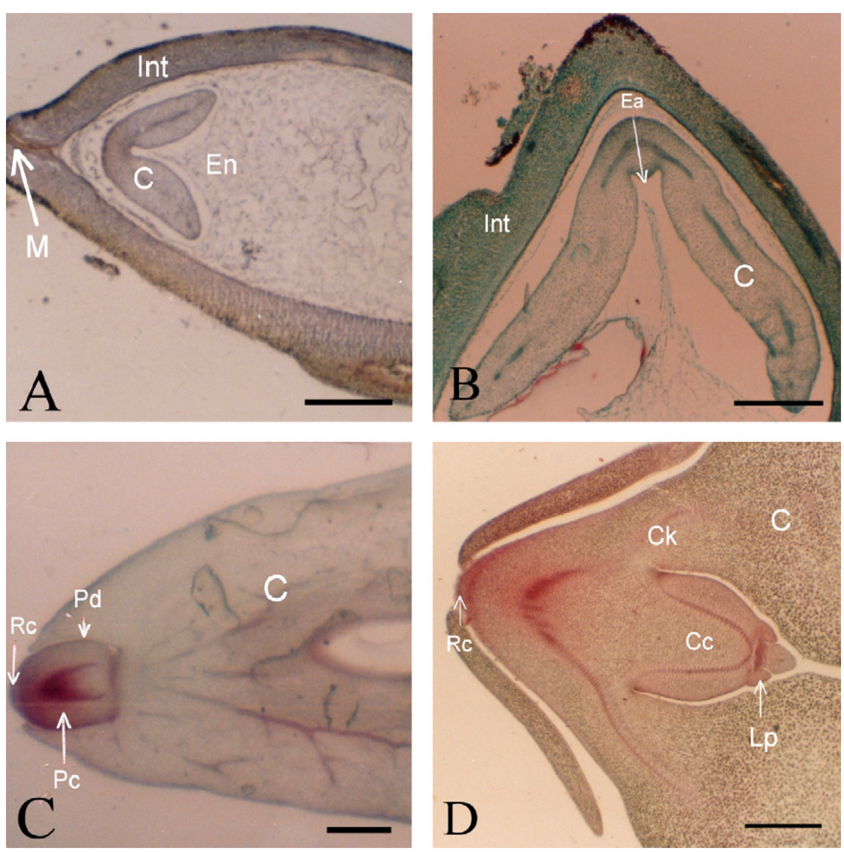

Fig. 2. Developing embryo showing second stages of embryo development in hazelnut. (A) Early torpedo stage and cotyledons, 16 June. (B) Torpedo stage, embryonal axis is differentiating, 19 June. (C) Embryo filling the entire ovule, 25 June. (D) Sagittal section of embryonal axis linked to the cotyledons by the cotyledonary knots, 25 June. Bar 0.5 mm in all panels (M: micropyle; C: cotyledon; En: endosperm; Int: integument; Ea: embryonal axis; Pd: protoderm; Pc: procambium; Rc: root cap; Ck: cotyledonary knots; Lp: leaf primordial; Cc: central cylinder).

clusters and the husk that covers the fruit were clearly distinguished externally.

Stage II (*heart-shaped embryo*): The embryo was heart-shaped and was about 0.24 mm in diameter, with the cotyledon primordia present (Fig. 1F). The embryo sac occupied the entire nucellus. The diameter of the ovary and ovule were about 14.96 and 1.93 mm, respectively.

Stage III (*early torpedo embryo*): Differentiation of the cotyledons was observed and this indicated the initiation of the torpedo embryo stage (Fig. 2A). The length of the cotyledons was about 0.63 mm. The integument was much thinner than it was in the last stage. The diameter of the ovary and ovule were about 15.84 and 2.43 mm, respectively.

Stage IV (*torpedo embryo*): The growth rate of the cotyledons increased fairly and was 2.01 mm in length. The embryonal axis was clearly observed and the vacuolated endosperm disintegrates (Fig. 2B). The diameter of the ovary and ovule were about 16.24 and 2.51 mm, respectively.

Stage V (*embryo with cotyledons*): At this stage, the embryo grew quickly and filled the entire ovule. The cotyledons completely formed. The length of the embryonal axis was close to 0.95 mm and the protoderm, the apical meristem, and the procambium were recognizable (Fig. 2C and D).

Stage VI (*embryo with leaf primordia*): At the time of the first appearance of the leaf primordial, the embryo was about 3/4 its ultimate size. Although the embryo attained full size 3–4 weeks before maturity of the nut, the embryonal axis continued to lengthen until maturity of the nut. At nut maturity the length of the embryonal axis was 2.16 mm, having an apical meristem, three to four leaf primordia, and a radicle. The root cap became distinct from the root meristem.

3.3. Pistillate flower cluster and fruit cluster drop

The results of the pistillate flower cluster drop (PFCD) and fruit cluster drop (FCD) rates from the beginning of leafing to nut maturity are shown in Table 2. The pistillate flower cluster drop occurred in April and May while the fruit cluster drop took place in June, July and August. Generally, the rate of dropped pistillate flower clusters in April was higher than it was in May. In 1997, the pistillate flower cluster drop rate of the Tombul was statistically higher than of the Palaz. But in 1998, no difference was determined between the two cultivars.

Examining the fruit cluster drop results, statistical differences can be seen among the cultivars. In 1997, the fruit cluster drop rate of the Tombul was statistically higher than that for the Palaz but in 1998, the research results did not show statistical differences among the cultivars during the period between 3rd of June and 5th of July. In the two periods after the 5th of July, the fruit cluster drop rate of the Tombul significantly increased compared to the Palaz. The early dropping of pistillate flower clusters in April–May was more significant than the fruit clusters drops in June–August. Total drop showed considerable differences in cultivars for both years. The total drops of the Tombul did not change between 1997 and 1998 it was higher for the Palaz in 1998 than in 1997.

4. Discussion

In this research, the graph of ovary and ovule growth looked like a simple sigmoid development curve. Looking at the development of the Tombul and Palaz ovary growth, we can say that development of the ovary in the Palaz was faster than that in the Tombul (Figs. 3 and 4). Differences in graphs of the ovary growth of a cultivar for different years were much more impressive than the differences in the graph of the growth of different cultivars of the same year. Accordingly, the climatically factors which of course changed from year to year were much more influential for the development than the cultivars were.

Fertilization usually occurs between the end of May and the beginning of June in France (Germain et al., 1978), between mid-May and the end of June in Oregon (Olsen et al., 2000) and in the last 10 days of May in Italy (Me et al., 1989). In the present study, fertilization occurred around the end of May or the beginning of June. Thompson (1979) and Me et al. (1989) previously reported that fertilization was difficult to observe and that the first divisions of the free nuclear endosperm which occurred a few days after fertilization, was regarded as evidence of this event. Although the development of the ovary and the ovule in the Palaz was approximately 1 week earlier than in the

Table 2
Pistillate flower cluster and fruit cluster drop in Tombul and Palaz hazelnut cultivars (%)

Drop type	Period	1997				1998			
		Tombul	Palaz	*t*-Value	Standard error	Tombul	Palaz	*t*-Value	Standard error
PFCD	1 April–1 May	17.27	10.34	10.68**	0.52, 0.38	17.27	16.40	1.50	0.51, 0.26
	1 May–3 June	14.24	11.16	4.41**	0.67, 0.20	13.69	13.21	0.84	0.41, 0.40
	1 April–3 June	31.51	21.50	15.80**	0.46, 0.44	30.96	29.61	1.32	0.85, 0.57
FCD	3 June–5 July	9.83	8.02	2.60*	0.61, 0.34	10.97	10.75	0.57	0.26, 0.28
	5 July–9 August	8.83	6.53	6.48**	0.30, 0.19	8.86	7.30	3.83**	0.29, 0.28
	3 June–9 August	18.65	14.55	6.58**	0.47, 0.40	19.83	18.05	3.15**	0.42, 0.37
TD	1 April–9 August	50.16	36.05	16.32**	0.59, 0.64	50.79	47.66	2.94**	0.83, 0.66

PFCD: pistillate flower cluster drop; FCD: fruit cluster drop; TD: total drop.
* Indicate significance at 5% significance level using *t*-test (two-sample assuming equal variances, $n = 12$).
** Indicate significance at 1% significance level using *t*-test (two-sample assuming equal variances, $n = 12$).

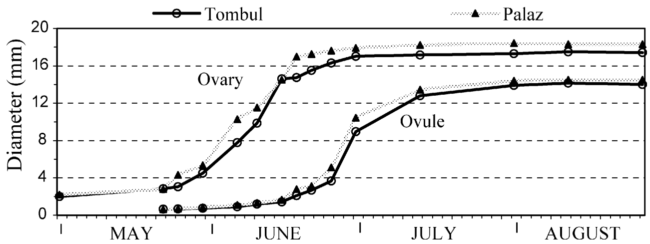

Fig. 3. Growth curves of ovary and ovule diameter of equivalent sphere for Tombul and Palaz hazelnut in 1997.

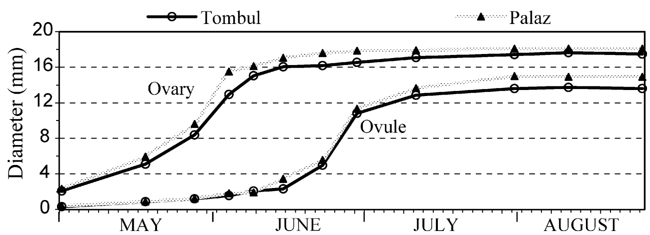

Fig. 4. Growth curves of ovary and ovule diameter of equivalent sphere for Tombul and Palaz hazelnut in 1998.

Tombul in 1997, fertilization time in both cultivars were observed at the same period in 1998. This may be explained by the fact that high temperatures prevailed during May and June in 1998.

As to the stages of the embryo and the diameters of the equivalent sphere of the ovules in this research, the ovules exceeded 1 mm at the globular embryo stage, and were close to 1 mm at the sample collect date before the globular embryo. Measuring the ovule dimensions without using the paraffin method gave an approximate result to determine the time of fertilization. However, Thompson (1979) stated that the fertilization time can also be determined by looking at the ovule dimensions.

According to our result, difference in the percentage of the pistillate flower cluster dropping between years in the same cultivar was evident. One of the reasons as to the early clusters dropping was lack of pollination. Thompson (1967) clearly indicated that growth of the ovary was dependent upon pollination. If growth is arrested in all of the flowers in a cluster, the cluster withers and falls in late April or May. Both Thompson (1967) and Beyhan and Odabaş (1996) reported that some ovaries could not grow more than 0.5 mm and these pistillate flowers dropped in April and May. On the other hand, while pollination is necessary to initiate ovary development; only a small percentage of the pollinated pistils develop into a full sized nut.

In the present study, in May, it was determined that the average number of functional ovaries in one cluster was 40–60% for the Tombul cultivar and 40–55% for the Palaz cultivar. These results showed a similarity with the findings of Beyhan (1995) in which 45–60% of the ovaries could not develop further. Germain et al. (1978) and Germain (1994) reported that, shortly after leafing, up to 70% of the flowers can stop growing.

When all the flowers in a cluster are affected by this phenomenon, the cluster drops by the end of April or in May. However, Dimoulas (1979) reported that, in general, these drops were not caused by a lack of pollination or by competition between flowers within the same inflorescence but were closely related to apical dominance which occurs along the 1-year-old shoots and the peduncles of catkins.

The ovaries and ovules of pollinated pistillate flowers continue to develop until fertilization. But not all pistillate flowers are fertilized. The diameter of the ovary was found to be 9.54 mm during this period in our study which is a critical phase for the hazelnut. As Silva et al. (1996) stated, ovules will not develop in non-fertilized ovaries and blank fruits form. On the other hand, even if fertilization occurs, the ovule and development of the embryo may cease at various times during the period from fertilization to harvest. The clusters with ovaries of both type drop. If even one ovary is fertilized and it develops into a cluster, that cluster will not drop.

Mehlenbacher et al. (1993) reported that nut and kernel defects are serious problems for the hazelnut. These include blanks, brown stain disorder, doubles, moldy kernels, kernels with black tips, shriveled kernels and poorly filled nuts. Brown stain, a poorly understood disorder that leads to kernel abortion, appears sporadically in Oregon and can result in severe crop loss. Poorly filled nuts and shriveled kernels are defects in which the kernel is smaller than in size. Small kernels are most common when the crop load is heavy or trees are stressed during the period of rapid kernel growth.

Lagerstedt (1977, 1985) reported that cluster droppings were caused by the genetic constitution of the cultivar, alternate bearing habit, pollen source, sexual incompatibility, cultural practices (nutritional deficiencies, lack of irrigation, disease and insect pests), and environmental conditions. On the other hand, Beyhan and Marangoz (1999) reported that the fruit cluster drops which occurred in June were mostly due to nutritional deficiencies while the cluster drops which occurred in July or August were caused by insufficient soil moisture and nutritional deficiencies.

Varietal differences in the frequency of blanks as well as important year-to-year variations may be greater than 25% of the crop (Lagerstedt, 1977). Romisondo (1978) mentioned year-to-year variation of from 1 to 45% for Tonda Gentile delle Langhe, while Mehlenbacher et al. (1993) reported a minimum of 5.5% for the Segorbe and a maximum of 17.1% for the Gasavay. In Turkey, Beyhan and Marangoz (1999) determined that the percentage of blank nuts varied from 5.52 to 11.64%. The results of the previous studies varied due to cultivars and the ecology.

In the present study, in 1998 the percentage of dropped pistillate flower cluster and unripened fruit cluster for Tombul hazelnut was the same as that which dropped early in 1997 (Table 2). As for the Palaz there was an increase. In this way, the percentage of both the Tombul and Palaz which dropped from the plants in 1998 was similar. The hazelnut is a biennial bearing species. Compared to Palaz, the Tombul cultivar has a slight tendency for biennial bearing.

Turkey determines world hazelnut prices. Therefore, it is important to know the drop percentages of pistillate flower

Table 3
Number of the pistillate flowers and fruits per cluster, and fruit set in hazelnut

Cultivar	Number of pistillate flowers per cluster	Number of fruits per cluster	Fruit set for pistillate flowers per cluster on plant (%)	Fruit set for total pistillate flowers on plant (%)
Tombul				
Mean	9.03	2.65	29.35	14.67
Min.	6	1		
Max.	16	6		
Palaz				
Mean	6.05	1.91	31.57	18.31
Min.	4	1		
Max.	12	5		

cluster and fruit cluster of different cultivars and the change of those percentages according to the year and to form mathematical models that would be suitable to be used for prediction of the yield and to prevent fluctuating prices.

In this study, the number of pistillate flowers and fruits per cluster were also determined (Table 3). For the Tombul and Palaz cultivars, the number of pistillate flowers per cluster was 9.03 and 6.05, respectively, and the number of fruits for cluster was 2.65 and 1.91. The number of pistillate flowers per cluster for the Tombul and Palaz were determined for the first time in this study. The number of pistillate flowers per cluster and number of fruits per cluster are cultivar characteristics. The ovary and ovule development of approximately 30% of the pistillate flowers per cluster continued until harvest (Table 3). Therefore, functional ovule rate per cluster decreased to 30% by harvest, while it was varied between 40 and 60% in April. In the period from April to harvest, only 10–20% of the ovules per cluster on the plant could not to continue their development. Consequently, the average number of pistillate flower per cluster that had the potential to become fruit was more than 30%, and so the majority of fruits of per cluster were determined until the end of April.

In the hazelnut, when examined from a distance the number of pistillate flowers per cluster may not be clearly observed. This is because some of the stigmas are concealed (covered) under the bud scales. In addition, each flower has two styles united at their the basal parts (Beyhan, 1993). From this point of view it is easier to count the number of pistillate flower clusters than the number of female flowers on the plants. The number of female flowers in the cluster can only be determined by using a stereo microscope and by opening the pistillate flower cluster. According to Table 2, 50 of 100 pistillate flower clusters turned into fruit for Tombul cultivar. Since there are 2.65 fruits per fruit cluster as average (Table 3), the number of fruits on the 50 of the fruit cluster that stays on the plant until the harvest is 132.5. So, when one examines a typical flower and if we notice that a pistillate flower cluster contains and average of 9.03 pistillate flowers then one can also assume a fruit set of 14.67%. For the Palaz cultivar there was a fruit set of 18.31%.

In the hazelnut, two ovules are usually found in an ovary. In this study, 39% of the ovaries which were examined in the Tombul cultivar contained more than two ovules. This figure was 24% for the Palaz. As the number of ovules in the ovary increase so does the number of double kernels. The Tombul and Palaz cultivars have one of the lowest quantities of double kernels. According to our observations in some years, the quantity of double kernel may rise. Additionally, some domestic cultivars like the Kalınkara can have a double kernel quantity of up to 35%. This situation can be seen in the hazelnut during March and April. The formation of double kernels reduces the quality of especially of those hazelnuts sold without their shell. In a crop of either extra or standard quality hazelnuts, a 1–5% proportion of double kernels is conceited acceptable. In order to prevent the formation of double kernels in hazelnut cultivars in the future more research most be carried out in this subject.

References

Aşkın, M.A., Dolgun, O., Yarılgaç, T., 1995. Bahçe Bitkileri Preparasyon Tekniği Uygulamalarında Yeni Hızlı Bir Yöntem, Türkiye ll. Ulusal Bahçe Bitkileri Kongresi, 3–6 Ekim Adana, Cilt 1 Meyve, pp. 489–493.

Beyhan, N., 1993. Bazı Önemli Fındık Çeşitlerinin Çiçek Gelişim Safhaları ve Çiçek Biyolojileri Üzerinde Bir Araştırma, O.M.Ü. Fen Bilimleri Enstitüsü Doktora Tezi, 175 pp.

Beyhan, N., 1995. Fındıkta Yumurtalık, Tohum Taslağı ve Embriyo Gelişimi. Türkiye II. Ulusal Bahçe Bitkileri Kongresi, 3–6 Ekim 1995 Adana, Cilt 1 Meyve, pp. 489–493.

Beyhan, N., Odabaş, F., 1996. Fındıkta Çiçek ve Meyve Dökümlerinin İncelenmesi Üzerine Bir Araştırma, Fındık ve Diğer Sert Kabuklu Meyveler Sempozyumu, Ondokuz Mayıs Üniversitesi Ziraat Fakültesi, pp. 110–118.

Beyhan, N., Marangoz, D., 1999. Fındıkta Boş Meyve Oluşumunun İncelenmesi, Türkiye lll. Ulusal Bahçe Bitkileri Kongresi, 14–17 Eylül Ankara, pp. 585–589.

Brooks, R.M., Bradley, M.V., Anderson, T.I., 1966. Plant Microtechnique Manual. Department of Pomology, University of California Davis (fifth printing), 62 pp.

Dimoulas, J., 1979. Etude de divers aspects de la reproduction sexuée chez le Noisetier, (*Corylus avellana*). Thése Docteur-Ingénieur, Univ. Bordeaux II, 162 pp.

Dolgun, O., 1995. Bahçe Bitkileri Preparasyon Tekniği Uygulamalarında Mikro Dalga Işınımlardan Yararlanabilme İmkanları Üzerinde Araştırmalar. Yüzüncü Yıl Üniversitesi, Fen Bilimleri Enstitüsü, Bahçe Bitkileri Anabilim Dalı Yüksek Lisans Tezi, 35 pp.

Germain, E., Leglise, P., Delort, F., 1978. Physiologie de la reproduction. INVUFLEC, éd. 161 pp.

Germain, E., 1994. The reproduction of hazelnut (*Corylus avellana* L.): a review. III International Congress on Hazelnut, Acta Horticulturae, No. 351, Alba (CN), Italy, September 14–18, pp. 195–209.

Köksal, A.İ., 2002. Türk Fındık Çeşitleri. Fındık Tanıtım Grubu, 136 pp.

Lagerstedt, H.B., 1977. The occurrence of blanks in the filbert (*Corylus avellana* L.) and possible causes. Econ. Bot. 31 (2), 153–159.

Lagerstedt, H.B., 1985. The relationship between yield, flowering, pollination and nut set of the filbert. Proc. Nut. Growers Soc. Oregon Washington British Columbia 70, 73–82.

Me, G., Emanuel, E., Botta, R., Vallania, R., 1989. Embryo development in ‘‘Tonda Gentile delle Langhe’’ hazelnut. Hortscience 24 (1), 122–125.

Mehlenbacher, S.A., Smith, D.C., Brenner, L.K., 1993. Variance components and heritability of nut and kernel defects in hazelnut. Plant Breeding 110, 144–152.

Odabaş, F., 1976. Erzincan’da Yetiştirilen Bazı Önemli Üzüm Çeşitlerinin Floral Gelişme Devrelerinin Tetkiki ile Gözlerin Bulundukları Yere Göre Verimliliğin Saptanması ve Bu Çeşitlerin Döllenme Biyolojileri Üzerinde Araştırmalar. Atatürk Üniv. Yayınları No. 466, Zir. Fak. Yayınları No. 219, Araştırma Serisi No. 141, Erzurum.

Olsen, J., Mehlenbacher, S.A., Azarenko, A.N., 2000. Hazelnut pollination. Hort. Technol. 10 (1), 113–115.

Romisondo, P., 1978. La fertilita nel nocciuolo. In: Seminario, ‘‘Fertilita delle Piante da Frutto’’, Bologna, pp. 424–434.

Silva, A.P., Riberio, R.M., Santos, A., Rosa, E., 1996. Blank fruits in hazelnut (*Corylus avellana* L.) cv. ‘Butler’: characterization and influence of climate. J. Hort. Sci. 71 (5), 709–720.

Silva, A.P., Santos, A., Rosa, E., 2001. Nut growth and development in ‘‘Butler’’ hazelnut. Acta Hort. 556, 377–384.

Thompson, M.M., 1967. Role of pollination in nut development. Proc. Nut. Growers Soc. Oregon Washington British Columbia 53, 31–36.

Thompson, M.M., 1979. Growth and development of the pistillate flower and nut in ‘Barcelona’ filbert. J. Am. Soc. Hort. Sci. 104 (3), 427–432.