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Original Research Article

Relative Susceptibility of Selected Apple Cultivars to Alternate Bearing

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ABSTRACT

The negative effects of alternate bearing on yield and fruit quality are a well-known. The objective of this study was to determine the sensitivity of 17 apple scions grafted onto MM106 rootstocks to alternate bearing. Quantitative evaluation of alternation was used modified alternate bearing index (MABI) which take into the flower production of the cultivars to define the alternate bearing. The lowest MABI was 0.20 in 'Braeburn', while 'Golden Reinders' and 'Kaşel41' had highest values of MABI as 0.78. Based on MABI values of 3 consecutive year of this research, cultivars were classified into four relative susceptibility groups: not susceptible: 'Braeburn' and 'Jerseymac'; medium alternance: 'Topaz', 'Granny Smith', 'Mondial Gala', 'Jonagold', 'Starkrimson Delicious' and 'Clear Red'; susceptible to alternance: 'Starkspur Golden Delicious', 'Fuji', 'Arlet', 'Redchief Delicious', 'Rajka' and 'Golden Delicious'; and high alternance: 'Kaşel 37', 'Golden Reinders' and 'Kaşel 41'. The fact that cultivar had the greatest impact on alternate bearing. Differences among cultivars in irregular cropping cycles can be used by growers and researchers to mitigate this phenomenon or improve new practices based on cultivar susceptibility.

Key Words: Irregular flowering, on year, off year, cropping cycle, fruit load

Bazı Elma Çeşitlerinin Periyodisite Hassasiyeti

ÖZET

Periyodisitenin verim ve meyve kalitesi üzerine olan negatif etkileri çok iyi bilinmektedir. Bu çalışmanın amacıda MM106 anacı üzerine aşılı 17 elma çeşidinin periyodisiteye olan hassasiyetinin belirlenmesidir. Periyodisitenin nicel olarak değerlendirilebilmesi için çiçeklenme ölçümlerine göre hesaplanan değiştirilmiş periyodisite eğilim indeksi (DPEİ) kullanılmıştır. En düşük DPEİ değeri 0.20 ile 'Braeburn' çeşidinden, en yüksek DPEİ değeri ise 0.78 ile 'Golden Reinders' ve 'Kaşel 41' çeşitlerinden elde edilmiştir. Çalışmada 3 ardışık yıl için hesaplanan DPEİ değerine göre çeşitler 4 farklı gruba ayrılmıştır. Periyodisiteye eğilimine göre Braeburn' ve 'Jerseymac' çok düşük grupta, 'Topaz', 'Granny Smith', 'Mondial Gala', 'Jonagold', 'Starkrimson Delicious' ve 'Clear Red' çeşitlerinin düşük grupta, 'Starkspur Golden Delicious', 'Fuji', 'Arlet', 'Redchief Delicious', 'Rajka' ve 'Golden Delicious' orta grupta ve son olarak 'Kaşel 37', 'Golden Reinders' ve 'Kaşel 41' çeşitleri de yüksek grupta yer almışlardır. Nitekim periyodisiteye eğilimde çeşit farklılığı önemli bir unsur olarak görülmüştür. Periyodisitenin hafifletilebilmesi ve bu konuda yeni uygulamaların geliştirilebilmesi için çeşitler arasında görülen bu farklılıkların yetiştiricilere ve araştırmacılara yardımcı olabileceği düşünülmektedir.

Anahtar Kelimeler: Çiçeklenme düzensizliği, var yılı, yok yılı, verim döngüsü, meyve yükü

INTRODUCTION

Alternate bearing is a physiological event occurred in many fruit species such as olive, avocado, mango, citrus, nut, pear and apple (Monselise and Goldschmidt 1982; Westwood 1995). In the simplest terms alternate bearing is defined as a year occur partially or wholly unfruitful then the excess year of flowering and cropping. The heavy and light years are also known as ON and OFF, respectively. In fruit crops, synchronous alternate bearing in a geographical region causes great economic loss to farmers and supporting services in the OFF year. (Smith and Samach 2013). Moreover, fruit quality is frequently lower due to reduced fruit size in ON years. Heavy weight of high fruit loads occasionally cause physical damage (limb breaking) to the tree. (Smith and Samach 2013). Although it appears that horticultural practices can mitigate the problem by reducing fruit load, alternate bearing is still one of the major constraints in annual fruit crop production of many species.

Theories about the cause of biennial bearing have been as diverse as suggestions of their remedies (Schmidt 2006). Currently, the role of gibberellins originating from young developing fruits are explained to

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prevent the formation of flower buds and gibberellins is considered to be the main cause of alternate bearing in many fruits such as apple (Buban and Faust 1982; Hoad 1984; Pharis and King 1985; Faust 1989; Dennis 2003; Tromp 2005). In apples, some cultivars have little tendency while others have high propensity towards alternate bearing (Jonkers 1979; Guitton *et al.* 2012). Defining these optimums for cultivars within a growing geographical region is an important goal as it will help stabilize markets and annual income for growers. Eventually, apple producers prefer cultivars which are capable of producing stable annual crops of high quality for subsequently years (Smith and Samach 2013).

Numerical assessment of alternate bearing tendency, an extremely complex event, could be provided more meaningful results both growers and researchers. A quantitative evaluation of alternation used alternate bearing index (ABI) had been proposed by Hoblyn *et al.* (1936). This index is calculated by dividing the sum of the individual tree yield to the differences in consecutive years. Three years are usually enough for the evaluation of the alternative bearing if the selected trees are adult. Higher index value means higher alternation. However, Racsko (2008) reported that it has not adequate to calculation of alternate bearing based on only fluctuations in yield. Then, researcher developed a new index so called “Modified Alternate Bearing Index” (MABI), which take into account of the cultivars flower production in consideration of define to alternate bearing. Indeed, in many plants, flowering is considered to be sufficient for the generative development but fruit set is a very different aspect. Actually, there are many factors such as late spring frost, lack of pollinator, bee population, preharvest dropping, irrigation, nutrition, diseases and pests influencing the amount of the fruit. In this respect, the calculation of alternation based on yield can be misleading sometimes.

The objective of this study was to determine the sensitivity of 17 apple scions grafted onto MM106 rootstocks to alternate bearing with the MABI under identical soil, climatic, and cultural conditions. .

MATERIALS AND METHODS

This study was carried out over 3 consecutive years (2010-2012) in Eğirdir Fruit Research Station in Isparta, Turkey (latitude $37^o49'$ N - longitude $80^o16'$ W - altitude 920 m). The experiment was conducted on adult trees (11 years old in 2010) of the 17 apple cultivars (‘Jerseymac’, ‘Mondial Gala’, ‘Jonagold’, ‘Rajka’, ‘Topaz’, ‘Clear Red’, ‘Redchief Delicious’, ‘Starkrimson Delicious’, ‘Arlet’, ‘Starkspur Golden Delicious’, ‘Golden Delicious’, ‘Golden Reinders’, ‘Amasya’ strains (‘Kaşel 37’ and ‘Kaşel 41’), ‘Granny Smith’, ‘Braeburn’ and ‘Fuji’) planted with 4 m x 3 m distances and grafted onto MM106 rootstock. Trees were trained to central leader system and fertilized with fertigation system at regular intervals during vegetation period. There had not been any application to flower and fruit thinning procedure (chemical, manual etc.). During the trial years (2010-2012) there are not any unfavorable conditions such as spring frost, drought etc. The design was a randomized complete block with four single-tree plots per cultivar. The counting was done on four main limbs randomly selected from the north, south, east and west sides in each tree. So 4x4=16 limbs were counted per cultivar and the same trees and the same limbs were used each year. It is hard to get accurate counts after the flowers start to open (Westwood 1995), so prior to full bloom, the number of flower clusters were counted on each tagged branch for 3 years.

Quantitative evaluation of alternation was used MABI had been proposed by Racsko (2008).

$$MABI = 1/(n-1)\ \{|(a_2-a_1)|\ /\ (a_2+a_1)+|(a_3-a_2)|\ /\ (a_3+a_2)\ldots+|(a_{(n)}-a_{(n-1)})|\ /\ (a_{(n)}+a_{(n-1)})\}$$

Where: n = number of years

$a_1, a_2, \ldots, a_{(n-1)}, a_n$ = flower cluster number per main limbs

The susceptibility of apple cultivars to alternate bearing were grouped based on the calculated value of the MABI. The intervals for each alternance groups arranged according to Racsko (2008). Alternance groups were indicated; not susceptible <0.26, medium alternance 0.26 - 0.50, susceptible to alternance 0.51 - 0.75 and high alternance 0.75<.

RESULTS AND DISCUSSION

The number of flower clusters was counted on each tagged branch at the pink bloom period, and Figure 1 shows the distribution of flower cluster numbers of trail cultivars for three years. ‘Golden Delicious’, ‘Golden Reinders’, ‘Kaşel 37’ and 'Kaşel 41’ were more conspicuous discrepancy in the number of flowers over the years, while ‘Jerseymac’ and ‘Braeburn’ were more stable. Biennial bearing by implication irregular flowering is a clearly genetic trait that is controlled by multigene as well as environmental and cultural factors (Guitton *et al.* 2011).

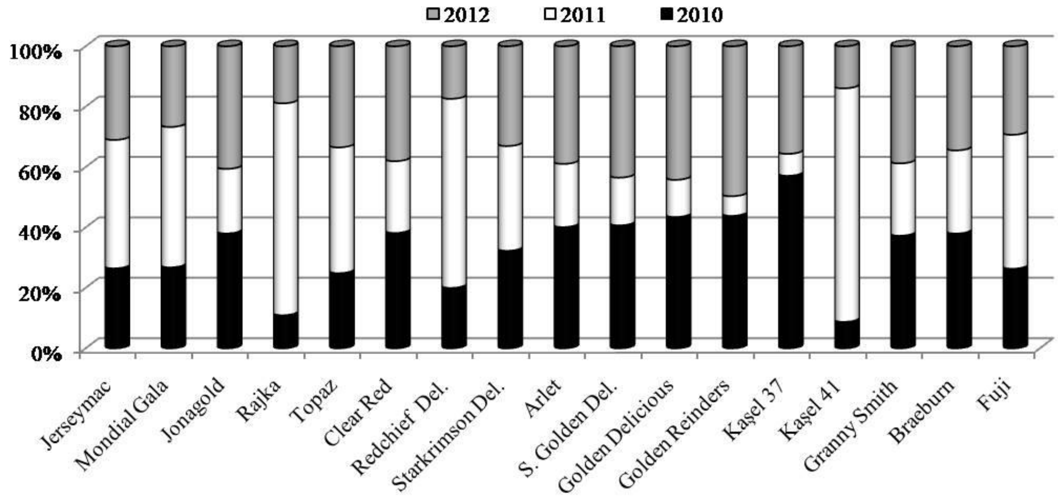

Figure 1. Distribution of the flower numbers in some apple cultivars from year to year.

The MABI values calculated from 2010 to 2012 based on the number of flower cluster were shown in Table 1. These values varied greatly depending on the cultivars ‘Braeburn’ (0.20) had the lowest while ‘Golden Reinders’ and ‘Kaşel 41’ had the highest MABI by 0.78. Other cultivars have between 0.20 and 0.78. There is a little information in the literature comparing the biennial bearing index of the cultivars. For example, Racsko (2008) evaluated the sensitivity of 33 apple cultivars to alternate bearing in Hungary. He observed the MABI value were 0.20 for ‘Braeburn Hillwell’ and ‘Braeburn Schneider’, and also 0.76 for ‘Golden Reinders’. ‘Arlet’, ‘Mondial Gala’, ‘Granny Smith’, ‘Jonagold’ and ‘Topaz’ were common cultivars both Racsko (2008) and our study. He determined the MABI value 0.71, 0.28, 0.68, 0.49 and 0.38 respectively. These data are mostly consistent with our results exception ‘Granny Smith’. However, in this study MABI value (0.35) of ‘Granny Smith’ was slightly low. Actually, ‘Granny Smith’ is the type IV cultivars classified by Lespinasse (1977) and have a more regular bearing pattern (Lauri *et al.* 2011).

Table 1. The modified alternate bearing indexes of the examined apple cultivars (2010-2012).

Cultivar	MABI
Jerseymac	0.24
Mondial Gala	0.38
Jonagold	0.42
Rajka	0.65
Topaz	0.33
Clear Red	0.49
Redchief Delicious	0.57
Starkrimson Delicious	0.45
Arlet	0.57
Starkspur Golden Delicious	0.51
Golden Delicious	0.71
Golden Reinders	0.78
Kaşel 37	0.77
Kaşel 41	0.78
Granny Smith	0.35
Braeburn	0.20
Fuji	0.56

Crassweller *et al.* (2005) evaluated the sensitivity of 20 apple cultivars including ‘Arlet’, ‘Braeburn’, ‘Fuji’ and ‘Golden Delicious’ to alternate bearing in the United States. They obtained the biennial bearing index 0.36, 0.46, 0.59 and 0.50 respectively. These data are often inconsisted with our results determined as 0.57, 0.20, 0.56 and 0.71 respectively. Because biennial bearing indexes calculated based on yield were generally lower than those of bloom data (Racsko 2008; Atay 2013). The research of Crassweller *et al.* (2005) and also the most of others generally were based on yield data for calculation of tendency of alternation.

The examined cultivars were separated into four groups based on their sensitivity to alternate bearing according to Racsko (2008) and were listed Table 2. Based on MABI values from 3 trial years, cultivars were classified into four relative susceptibility groups: not susceptible: ‘Braeburn’ and ‘Jerseymac’; medium alternance: ‘Topaz’, ‘Granny Smith’, ‘Mondial Gala’, ‘Jonagold’, ‘Starkrimson Delicious’ and ‘Clear Red’; susceptible to alternance: ‘Starkspur Golden Delicious’, ‘Fuji’, ‘Arlet’, ‘Redchief Delicious’, ‘Rajka’ and ‘Golden Delicious’; and high alternance: ‘Kaşel 37’, ‘Golden Reinders’ and ‘Kaşel 41’ (Table 2). All of the common cultivars were in the same susceptibility groups as Racsko (2008) excepted ‘Granny Smith’. ‘Granny Smith’ was in the medium alternance group in the present study, but it was concluded that in the sensitive group according to Racsko (2008). In similar with our results Lespinasse and Delort (1993) reported as less alternate ‘Granny Smith’ that acropetal cultivars with large bourses.

Table 2. Sensitivity of the examined apple cultivars to alternate bearing based on modified alternate bearing indexes (2010-2012).

Alternance groups		***MABI value***	***Cultivar***
1	Not susceptible	<0.26	Braeburn, Jerseymac
2	Medium alternance	0.26-0.50	Topaz, Granny Smith, Mondial Gala, Jonagold, Starkrimson Delicious, Clear Red
3	Susceptible to alternance	0.51-0.75	Starkspur Golden Delicious, Fuji, Arlet, Redchief Delicious, Rajka, Golden Delicious
4	High alternance	0.75<	Kaşel 37, Golden Reinders, Kaşel 41

A different grouping was proposed by Pearce and Debusek-Urbanc (1967), and they suggested that values above 0.6 indicate strong biennial bearing. According to this grouping, ‘Rajka’, ‘Golden Delicious’, ‘Kaşel 37’, ‘Golden Reinders’ and ‘Kaşel 41’ had MABI values above 0.6 indicating a stronger tendency towards alternate bearing. 'Amasya' cv. grown in Turkey is the most important local apple cultivar however, 'Kaşel 37' and 'Kaşel 41'strains of 'Amasya' are known as very strong tendency of alternance (Köksal 1981). Actually our results support this matter. Additionally, it was determined that **'**Golden Delicious' and its strains had higher tendency to alternate bearing than the strains of 'Delicious'. Spur-type 'Delicious' cultivars such as 'Starkrimson Delicious' and 'Redchief Delicious' usually have irregular pattern of fruiting and flowering (Lauri *et al.*, 2009). Conversely, Lauri and Laurens (2005) reported that 'Starkrimson Delicious' had slightly alternance although it was belonging to type II according to Lespinasse (1977). They also found that, alternate bearing is a big phenomenon for some major cultivars such as 'Fuji' but their extent can vary to different ecological areas. In current study, the MABI value of 'Fuji' was determined lower than 'Golden Delicious'. These discrepancies suggest that other criteria like cultivar architecture, climate, rootstock, training and pruning schemes, irrigation and nutritional status should be considered.

CONCLUSIONS

In conclusion, we found significant differences among 17 cultivars in susceptibility to alternate bearing. The fact that cultivar had the greatest impact on alternate bearing. Apple cultivars such as 'Jerseymac' and 'Braeburn' had very low tendency to alternate bearing must be carefully considered by breeders and researchers. Essentially they have potential as pollinators and a parent in breeding studies in addition to the commercial growing. There is a similar situation for 'Granny Smith' and 'Gala'. 'Golden Delicious' and its strains tend to be very high alternate bearing, despite the very high commercial value. Indeed, environmental and cultural practice such as pruning, artificial extinction, applications of plant growth regulators and thinning of flower or fruitlet can regulate to flower initiation in commercial apple orchard (Pellerin *et al.* 2011; Duyvelshoff 2011; Atay and Lauri 2013). Particularly, plant growth regulators has been proposed as a judicious tool to achieve an improved balance between vegetative growth and fruiting in apple production (Ramirez *et al.* 2006; Schmidth *et al.* 2009; Schupp 2011; Duyvelshoff and Cline 2013; Atay 2013). As a result, alternate bearing still is the focus of attention of many research groups around the globe (Smith and Samach 2013).

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