seemed to be genotypic dependence. The percentage of blind nodes within the same genotypes was correlated showing a high correlation coefficient ($r = 0.54^{*}$). Removing 'Sunhome' from the observation in which one tree had very poor growth due to drought stress, the correlation coefficient was 0.72^{***}. This meant that the degree of blind nodes within a genotype was consistent under the same environment.

Conclusions

Visual rating for blind node propensity was shown to be an accurate prediction of blind node percentage ($r = 0.84$). The preferred method was based on the section parameter which rated the proportion of blind nodes on one-year-old shoots. Since this method is quick and reliable, it is usefull for field evaluation of blind node propensity. The blind node propensity was genotype specific which would indicate that selection against high levels of blind nodes would lead to the development of peach cultivars with less blind nodes.

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Chilling Requirements of Apple and Pear Cultivars

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Abstract

The chilling requirements of 43 apple and 38 pear cultivars were estimated over a two year period (1990-92), by weekly sampling and forcing field-grown shoots. The results were expressed in terms of chill units (CU). In apples, the estimates ranged from 490 CU ± 1 for 'Dorsett Golden' to 1320.5 CU ± 8 for 'Cortland,' 'Marshall McIntosh' and 'Starking Delicious.' In pears, the estimates ranged from 749 CU ± 9 for 'Batjarka' to 1320.5 CU ± 8 for 'Poirier Fleurissant Tard.'

Introduction

Deciduous fruit trees of temperate zone origin enter a period of endogenously-controlled rest which must be overcome before growth can resume. In order to resume normal growth, buds must be exposed to chilling temperatures, the amount of which varies among cultivars and has been termed as the chilling requirement. The chilling requirement is, then, a limiting factor for commercial production of temperate zone fruit trees in areas with mild winters. Cultivars whose chilling requirements are fulfilled regularly in a given location must be selected in order to ensure successful production. This requires knowledge of the chilling requirements of the cultivars to be planted, as well as the chill unit accumulation that one can expect in the region where the cultivars are to be grown (15).

In warm regions, chilling accumulation is often insufficient to meet the chilling requirement of deciduous trees, resulting in uneven blossoming and reduced yield (2, 19, 21). Rest-breaking practices are usually needed to ensure uniform budbreak and growth. The ability to predict the termination of dormancy (estimate the chilling requirement) is of utmost importance

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in these regions, as the optimal time for the application of rest breaking chemicals may last only a few days (3).

Quantitative measurements of the chilling requirement have been reported for many species and cultivars (7, 14, 21). Chill units were calculated according to the Utah model (1, 11).

The objective of the study was to estimate the chilling requirements of apple and pear cultivars grown under field conditions in Corvallis, OR, USA.

Materials and Methods

The experiment was conducted during a two year period (1990-92) at the USDA Clonal Repository collection and the OSU horticulture research farm in Corvallis, OR, USA (45° latitude), which has a mild climate. Forty-three apple and thirty-eight pear cultivars were used.

To determine when the chilling requirement has been satisfied, several indices have been used, the most currently used being when 50% of the buds have broken following 30 days of forcing (6, 21).

Three shoots (each 2-25 cm long each) were collected weekly from each cultivar, from October 2, 1990 to January 18, 1991 and October 16, 1991 to January 18, 1992 (17 and 14 sampling times). On each date, the cut shoots were placed in the greenhouse under forcing conditions (24C day/19C night) with their cut ends in distilled water. Water was changed and shoot ends were cut weekly to prevent contamination. Rest was considered completed when 50% or more of the buds had reached at least the green tip stage in 2 out of the 3 shoots at the end of four weeks. Using temperature data provided by the USDA-ARS Plant Germplasm Repository, Corvallis, OR, the amount of chilling accumulated was calculated based on the Utah Chill Unit model (13). A computer program was used to convert the 24 hour daily temperature data to the corresponding number of chill units. The results were checked using the Omnidata Biophenometer (TA45-P) (13).

Since samples were collected weekly, the chilling requirement was considered to have been satisfied between the cutting date when the rest was completed and the cutting date one week prior to rest completion. The chilling requirement was then calculated as follows:

CR = [CU (rest completion) + CU (one week before rest completion)]/2

where:

CR: chilling requirement of the cultivar.

CU: (rest completion): the number of chill units that had accumulated at rest completion.

CU: (one week before rest completion): the number of chill units that accumulated one week prior to rest completion.

Chilling requirements were estimated for each cultivar in each year and then averaged over the 2 year period.

Results and Discussion

Chilling accumulation: Chilling started accumulating earlier in the fall of 1990 (October 2) than in the fall of 1991 (October 16). However, the overall amount of chilling that accumulated was higher for the 1991-92 than for the 1990-91 season, due to freezing temperatures that occurred from mid December 1990 to the beginning of January 1991 and prevented any chilling accumulation. The amounts of chilling that accumulated in each of the two years of the experiment were sufficient to satisfy the chilling requirement of all the cultivars tested, as no symptoms associated with the lack of chilling (delayed foliation, uneven blossoming, etc.) were observed the following spring.

Chilling requirement of apple cultivars: The mean values of chill units required to break dormancy of the different cultivars tested are listed in Table 1. They range from 490 CU ± 1

Table 1. Chilling requirements and dates of rest completion of apple cultivars grown under field conditions at Corvallis, OR. (1990/91 and 1991/92).

Cultivar (Country of origin)	1990/91 season Date of rest completion	1990/91 season Chill units	1991/92 season Date of rest completion	1991/92 season Chill units	Mean ± SD
Dorsett Golden (Bahamas)	11/04-11/11	490.5	11/18-11/25	489	490 ± 1
Arlet (Switzerland)	11/18-11/25	742.0	12/09-12/16	880.5	811.5 ± 98
Idared (USA, ID)	11/18-11/25	742.0	12/09-12/16	880.5	811.5 ± 98
Mutsu (Japan)	12/02-12/09	983.5	12/09-12/16	880.5	932 ± 73
Red Gold (USA, WA)	12/02-12/09	983.5	12/16-12/23	1005.5	994.5 ± 16
NJ 109 (USA, NJ)	12/02-12/09	983.5	12/16-12/23	1005.5	994.5 ± 16
Coromandel Red (New Zealand)	12/02-12/09	983.5	12/16-12/23	1005.5	994.5 ± 16
Criterion (USA, WA)	12/23-12/30	1147.0	12/09-12/16	880.5	1014 ± 188
Jerseymac (USA, NJ)	12/30-1/6	1165.5	12/09-12/16	880.5	1023 ± 202
Earligold (USA, WA)	12/09-12/16	1075.0	12/16-12/23	1005.5	1040.5 ± 49
Green Gravenstein (Germany)	12/09-12/16	1075	12/16-12/23	1005.5	1040.5 ± 49
NJ 56 (USA, NJ)	12/09-12/16	1075	12/16-12/23	1005.5	1040.5 ± 49
Fuji (Japan)	12/09-12/16	1075	12/16-12/23	1005.5	1040.5 ± 49
Stayman (USA)	12/09-12/16	1075	12/16-12/23	1005.5	1040.5 ± 49
Granny Smith (Australia)	12/09-12/16	1075	12/16-12/23	1005.5	1040.5 ± 49
Shamrock (Canada, BC)	12/09-12/16	1075	12/16-12/23	1005.5	1040.5 ± 49
Red Jonagold (USA, NY)	12/16-12/23	1127	12/16-12/23	1005.5	1066 ± 86
Red Fuji (Japan)	12/16-12/23	1126.5	12/16-12/23	1005.5	1066 ± 86
Golden Supreme (USA, ID)	12/02-12/09	983.5	12/23-12/30	1155	1069.5 ± 121
Nicobel Jonagold (USA, NY)	12/30-1/6	1165.5	12/16-12/23	1005.5	1085.5 ± 113
Summered (Canada, BC)	12/30-1/6	1165.5	12/16-12/23	1005.5	1085.5 ± 113
Gala (New Zealand)	12/09-12/16	1075	12/23-12/30	1155	1115 ± 57

Table 1. (Continued).

Cultivar (Country of origin)	1990/91 season Date of rest completion	Chill units	1991/92 season Date of rest completion	Chill units	Mean ± SD
Bell de Boskoop (Holland)	12/09-12/16	1075	12/23-12/30	1155	1115 ± 57
Holstein (United Kingdom)	12/09-12/16	1075	12/23-12/30	1155	1115 ± 57
Braeburn (New Zealand)	12/16-12/23	1126.5	12/23-12/30	1155	1141 ± 20
Rioton Jonathan (USA)	12/16-12/23	1126.5	12/23-12/30	1155	1141 ± 20
Melrouge (USA, OH)	12/16-12/23	1126.5	12/23-12/30	1155	1141 ± 20
Stark Summer Treat (USA, NJ)	12/23-12/30	1147	12/23-12/30	1155	1151 ± 6
Royal Gala (New Zealand)	12/23-12/30	1147	12/23-12/30	1155	1151 ± 6
Stark Gala (New Zealand)	12/30-1/6	1165.5	12/23-12/30	1155	1161 ± 8
Chieften (USA, WA)	12/30-1/6	1165.5	12/23-12/30	1155	1161 ± 8
Discovery (United Kingdom)	12/30-1/6	1165.5	12/23-12/30	1155	1161 ± 8
State Fair (USA, MN)	12/30-1/6	1165.5	12/23-12/30	1155	1161 ± 8
Brock (USA, ME)	1/6-1/13	1239.5	12/23-12/30	1155	1197 ± 60
Elstar (Holland)	1/6-1/13	1239.5	12/23-12/30	1155	1197 ± 60
Spartan (Canada, BC)	1/6-1/13	1239.5	12/23-12/30	1155	1197 ± 60
Empire (USA, NY)	1/13-1/18	1326.5	12/23-12/30	1155	1241 ± 122
Empire (USA, NY)	1/13-1/18	1326.5	12/23-12/30	1155	1241 ± 122
Cox's Orange Pippin (UK)	1/6-1/13	1239.5	12/30-1/6	1314.5	1277 ± 53
Jonamac (USA, NY)	1/6-1/13	1239.5	12/30-1/6	1314.5	1277 ± 53
Golden Delicious (USA, WV)	1/6-1/13	1239.5	12/30-1/6	1314.5	1277 ± 53
Cortland (USA, NY)	1/13-1/18	1326.5	12/30-1/6	1314.5	1320.5 ± 8
Marshall McIntosh (USA, NY)	1/13-1/18	1326.5	12/30-1/6	1314.5	1320.5 ± 8
Starking Delicious (USA, IO)	1/13-1/18	1326.5	12/30-1/6	1314.5	1320.5 ± 8

for 'Dorsett Golden' to 1320.5 CU ± 8 for 'Cortland,' 'Marshall McIntosh' and 'Starking Delicious.' The major apple cultivars ('Golden Delicious,' 'McIntosh,' 'Belle de Boskoop,' 'Granny Smith,' 'Gravenstein,' etc.), as well as the new and potentially important cultivars ('Gala,' 'Fuji,' 'Elstar,' etc.) have rather high chilling requirements (>1000 CU). They differ in their adaptation to mild winter conditions, however, with cultivars such as 'Gala,' 'Granny Smith,' 'Fuji' having a better adaptation than 'Golden Delicious,' 'McIntosh' and others (7, 10, 14).

Our results support the findings of others. 'Delicious' required 1275 CU and 'McIntosh' 1300 CU to break rest (16, 18) found that 'Delicious' and its subclones had a chilling requirement of approximately 1200 CU. 'Dorsett Golden' is known to behave normally with only 400-450 hours of chilling (7). Low chilling cultivars under cooler conditions (Geneva, NY) had higher chilling requirements (4). In contrast, the only low chilling cultivar ('Dorsett Golden') we tested did not show that trend, and the results were consistent for the two year experiment.

Strains of a cultivar have similar chilling requirements as illustrated by comparing the estimates for 'Red Fuji' (1066 CU ± 86) with to 'Fuji' (1040.5 CU ± 49), and 'Royal Gala' (1151 CU ± 6) with 'Stark Gala' (1161 CU ± 8).

It is interesting to note that 'Arlet,' a cross between 'Idared' and 'Golden Delicious,' had a chilling requirement that was closer to the lower chilling requirement parent ('Idared'). Winter chilling requirement in the F1 was, as a rule, distinctly nearer to the short chilling parent (5). Earliness in budbreak might be dominant (8).

Chilling requirement of pear cultivars: The chilling requirements of the cultivars tested ranged from 749 CU ± 9 for 'Batjarka' to 1320.5 CU ± 8 for 'Poirier Fleurissant Tard' (Table 2.). Few data are available on the chilling requirement of the pear (14). The number of chilling hours below 7.2C required to break rest in pear cultivars varied between 1100 and 1600 chilling hours (7, 9). In a study of the relationship between chilling requirement, heat requirement and flowering date in *Pyrus communis* cultivars (17) 'Poirier Fleurissant Tard' had the highest chilling requirement and bloomed latest. Our results also showed that 'Poirier Fleurissant Tard' has a high chilling requirement.

The chilling requirement could be used to select late flowering cultivars for regions with frequent spring frosts. Several studies (17, 18) have shown that late blooming cultivars have higher chilling and heat requirement than early blooming cultivars. In our study, field observations showed that cultivars with higher chilling requirements bloom much later than cultivars with lower chilling requirements, probably due to their higher heat requirements too. For example, 'Poirier Fleurissant Tard,' having the highest chilling requirement among the cultivars tested, reached the full bloom stage 9 days later than 'Batjarka,' which had the lowest chilling requirement. Late blooming cultivars could be used either for commercial purposes or as a part of a breeding program for avoidance of late spring frost. 'Rome Beauty,' a late blooming apple cultivar with a high chilling requirement, has not missed a crop due to spring frost in 100 years in Western Oregon (20).

We noticed variations in the year-to-year estimations of the chilling requirement of apple and pear cultivars. Among the possible explanations for these variations:

—Interval of sampling. We believe that, by shortening the interval between 2 sampling times, more accurate results would be obtained and the variation would be reduced.

—The accumulation of CU is not the only factor involved in releasing plants from dormancy. There

Table 2. Chilling requirements and dates of rest completion of pear cultivars grown under field conditions at Corvallis, OR. (1990/91 and 1991/92).

Cultivar (Country of origin)	1990/91 season		1991/92 season		
	Date of rest completion	Chill units	Date of rest completion	Chill units	Mean ± SD
Batjarka (Yugoslavia)	11/18-11/25	742.0	12/02-12/09	755.5	749 ± 9
Karamanlika (Yugoslavia)	11/25-12/02	871.5	12/09-12/16	880.5	876 ± 7
Farmingdale (USA, IL)	11/18-12/02	871.5	12/09-12/16	880.5	876 ± 7
Messire Jean (France)	12/02-12/09	983.5	12/09-12/16	880.5	932 ± 73
Luscious (USA, SD)	11/25-12/02	871.5	12/16-12/23	1005.5	938.5 ± 95
Anjou-Russet (USA, OR)	11/25-12/02	871.5	12/16-12/23	1005.5	938.5 ± 95
H.E.S. 25021 (Canada, OT)	12/02-12/09	983.5	12/16-12/23	1005.5	994.5 ± 16
Lukavanski (Czechoslovakia)	12/02-12/09	983.5	12/16-12/23	1005.5	994.5 ± 16
Hofrath's Birne (Germany)	12/02-12/09	983.5	12/16-12/23	1005.5	994.4 ± 16
Warren (USA, MS)	12/09-12/16	1075	12/09-12/16	880.5	978 ± 137
Chien-Pa-Li (China)	12/09-12/16	1075	12/09-12/16	880.5	978 ± 137
Urechelnite (Romania)	12/09-12/16	1075	12/16-12/23	1005.5	1040.5 ± 49
Bergamote Tardive De Ganzel (UK)	12/09-12/16	1075	12/16-12/23	1005.5	1040.5 ± 49
Kair Aarmund (Czechoslovakia)	12/09-12/16	1075	12/16-12/23	1005.5	1040.5 ± 49
Dawn (USA, MD)	12/09-12/16	1075	12/16-12/23	1005.5	1040.5 ± 49
Lubenicarka (Yugoslavia)	12/09-12/16	1075	12/16-12/23	1005.5	1040.5 ± 49
Marks (USA, NY)	12/09-12/16	1075	12/23-12/30	1155	1115 ± 57
Krolewka (Poland)	12/09-12/16	1075	12/23-12/30	1155	1115 ± 57
Merricourt (USA, TN)	12/09-12/16	1075	12/23-12/30	1155	1115 ± 57
Cincinis (France)	12/09-12/16	1075	12/23-12/30	1155	1115 ± 57
Suzette de Bavay (Belgium)	12/09-12/16	1075	12/23-12/30	1155	1115 ± 57
Burkeft (USA, IL)	12/09-12/16	1075	12/23-12/30	1155	1115 ± 57
Hourdequin (France)	12/09-12/16	1075	12/23-12/30	1155	1115 ± 57

Table 2. (Continued).

Cultivar (Country of origin)	1990/91 season Date of rest completion	Chill units	1991/92 season Date of rest completion	Chill units	Mean ± SD
Iwate Mukaku (Japan)	12/09-12/16	1075	12/23-12/30	1155	1115 ± 57
Bera Wysmienita (Poland)	12/16-12/23	1126.5	12/23-12/30	1155	1141 ± 20
Marqueza (Portugal)	12/16-12/23	1126.5	12/23-12/30	1155	1141 ± 20
Southworth (USA, MN)	12/16-12/23	1126.5	12/23-12/30	1155	1141 ± 20
Hendre Huffcap (U.K.)	12/16-12/23	1126.5	12/23-12/30	1155	1141 ± 20
Kansu Pear (China)	12/16-12/23	1126.5	12/23-12/30	1155	1141 ± 57
Vineland 29018 (Canada, OT)	12/23-12/30	1147	12/23-12/30	1155	1151 ± 6
Rosii Untoase (Romania)	12/30-01/06	1165.5	12/23-12/30	1155	1161 ± 8
Prague No. 2 (Czechoslovakia)	12/30-1/06	1165.5	12/23-12/30	1155	1161 ± 8
Windorska (Czechoslovakia)	12/30-01/06	1165.5	12/23-12/30	1155	1161 ± 8
Lesnaia Krasavitza (USSR)	12/16-12/23	1126.5	12/30-01/06	1314.5	1220.5 ± 133
Tonkowietka (USSR)	12/23-12/30	1147	12/30-01/06	1314.5	1231 ± 118
Rotkottig Frau Ostergotland)	12/23-12/30	1147	12/30-01/06	1314.5	1231 ± 118
Duchesse de Brissac (France)	12/30-01/06	1165.5	12/30-01/06	1314.5	1240 ± 105
Poirier Fleurissant Tard (France)	01/13-01/18	1326.5	12/30-01/06	1314.5	1320.5 ± 8

are important interactions among cultivars and environmental factors other than CU accumulation alone that are responsible for terminating bud dormancy (4).

—Coastal effect: The 'Utah' model, which assumes a daily Gaussian temperature distribution, shows some discrepancies when used in maritime climates where coastal land-sea breezes result in a daily change in airmass (12). It could be that the climatic conditions in Corvallis (in a valley 50 miles from the coast under the influence of the Pacific Ocean but separated by a low range of mountains), make the results obtained from the 'Utah' model less accurate. Additionally, the much higher rainfall at Corvallis would tend to maintain lower bud temperatures at the same ambient air temperatures measured on a sunny day in Utah.

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Red Color Changes Following Irradiation of 'Royal Gala' Apple Scions

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Abstract

A study was made on the variation in fruit red color in a population of 'Royal Gala' apple developed from buds irradiated with gamma rays. A wide range of coloration was observed between the clones, however except for one clone the range of variation within clones was small.

Introduction

'Royal Gala' apple is the result of a spontaneous mutation of 'Gala' apple for more red pigmentation in the hypodermis (LII derived) layer of the fruit skin (3).

Plantings of 'Royal Gala' exhibit considerable variability in the amount of red color coverage on the fruit. A survey of several large orchards in Canterbury, New Zealand (Alan Robson, Pers. Comm.), 11% of 'Royal Gala' trees were considered to have suffi-

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