

UNIVERSITY OF DEBRECEN
Centre of Agricultural and Technological Sciences
Faculty of Agriculture
Institute for Research and Development

**INTERDISCIPLINAR AGRICULTURAL AND NATURAL SCIENCES
DOKTORAL SCHOOL**

Head of the Doctoral School:
Dr. János Nagy DSc
Full professor

Supervisors:
Dr. Zoltán Szabó DSc
Full professor

Dr. Imre Holb PhD
Associate professor

ABSTRACT OF THE THESIS

**CROP AUTOREGULATION OF APPLE ON DIFFERENT GROWTH
INDUCING ROOTSTOCKS**

Made by:
Mr. József Racskó MSc
PhD candidate

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1. AIMS OF THE RESEARCH

The main aim of my research was to get new knowledge on the crop regulation processes of apple with the use of that the regular cropping habit of the trees can be maintained for years through the balance between the vegetative and reproductive organs. To achieve this aim, laboratory and field trials was establish in spring 2003. I have set myself the following tasks:

1. Determining the values of the biological factors (flower density, flowering time, self-fertility, cross-fertility, fruit density, fruit drop, seed content of fruit and yield) playing important role in the cropping habit of trees in rootstock-scion combinations.
2. Clearing up the conceptual elements of the definition of the 'alternate bearing'. Adapting and develop new methods in order to describe and evaluate the crop autoregulation mechanisms (alternate bearing and fruit drop) more accurate.
3. Exploration and clearing up the hormonal background in more details in order to improve the thinning technologies in apple.
4. Evaluating the sensitivity of 33 apple scions each grafted on 3 different growth inducing rootstocks to alternate bearing with the Alternate Bearing Index (ABI).
5. Evaluating the dynamics and rate of fruit drop and describing its relation to the seed content of fruit. Exploration the role of the meteorological elements in fruit drop.
6. Determining the role of the primigenic dominance in the flowering, fruit set and hormonal content and fruit quality of the fruit growing from one flower cluster.

2. PRELIMINARIES OF THE RESEARCH

The quality and profitable apple production is very important for Hungary. One of its basis is the use of advanced crop regulation technologies for which it is essential to know the crop autoregulation processes of the trees. In apple, three crop autoregulation mechanisms provide the balance between the vegetative and reproductive organs:

- alternate bearing
- fruit drop
- primigenic dominance

The backwardness of regular cropping and producing of homogenous fruit quality are the major problems of the domestic apple production. In one year, growers get too large yield with low quality parameters then they can count quite a little yield in the next one because of the irregular cropping habit of cultivars. The very low rate of fruit set does not, however, be accompanied by better fruit quality i.e. we cannot account for this kind of reduction of the economic loss. This phenomena is called alternate bearing which being prevented by effective crop regulation technologies can help to achieve the continuous crop with outstanding quality. The definition of the 'alternate bearing' in the international literature sources is not exactly cleared up. There are two major views: one of those judge the phenomena of the alternate bearing based on the fluctuation of the yield and the other does on the irregular flower production. The cultivar features are the most important in the alternate bearing habit, however, the nutritional and water supply have also great importance. Late spring frosts during or after the flowering period can also come into account, for which the year 2007 is the 'best' example. The imbalance of the vegetative and reproductive organs occurs after a heavy late frost. Therefore, the rebalance between shoot growth and flower production can be made by only the use of proper crop regulation (especially with fruit thinning), phytotechnical elements (with pruning) and nutritional and water supplying technologies next year.

The basic conditions of fruit set (synchronic bloom, transfer of pollen, etc.) still do decide definitely the fate of the flower in spite of the best weather conditions. Beyond a set quantity of fruit, the tree is unable to bring up larger load. A system of autoregulation works in the background and causes the drop of a part of the fruitlets in spite of the accomplished fertilisation and the equality of physiological precedents. The further development of fruit maintained on the tree depends mainly on the growing conditions (e.g. water, supply of

nutrients, weather adversities, pruning, fruit thinning, pest damages, etc.), which may cause on their own turn fruit drop especially at the time of approaching maturity.

The drop of young fruit is an entirely different process from the natural drop of ripe fruit later in the season. Drop of fruitlets occurs on the influence of the strong correlative dominance of other fruit and growing shoots. Those fruit, which started to develop earlier, soon become dominant over the fruit starting later in development. The dominance based on this temporal precedence is the primigenic dominance, and apple is an excellent example. In the apple inflorescence, the apical flower is initiated first, and its precedence is maintained throughout the further development.

3. MATERIALS AND METHODS

3.1. Experimental site and plant material

Experiments and data collection were carried out between 2003 and 2007 during five consecutive years at the rootstock-scion experimental orchard of Alma 2000 Kft. at Nagykutas, Western Hungary. The place of Alma 2000 Kft. is located 9 km north from Zalaegerszeg at 400-450 m above sea level and is characterised with 1800-1900 sunny hours a year and 600-650 mm rainfall.

Evaluations were made on 33 apple scion cultivars (*Table 1*) planted in autumn 1999. Each scion was grafted onto 3 different growth inducing rootstocks. The planting design was 3.5 x 0,54 m, the surface between rows was covered with sod. The trees were trained to slender spindle, and the growing technology was up to the standards of integrated fruit growing methods. The samples were taken on plots of four trees in five replicates, distributed randomly, i.e. 20 trees of each combination.

Agrotechnical and phytosanitary operations of the orchard were uniformly performed, whereas phytotechnical care was adjusted to the claims of individual accessions.

Table 1. Grouping the evaluated apple cultivars based on the ripening time and the level of ploidity. Summer ripe cultivars were characterised by the ripening time before August 31, the autumnal ripe between September 1 and October 15, and the winter ripe after October 15.

	Summer ripe	Autumnal ripe	Winter ripe
Diploid	Earligold, Mollie's Delicious, Prima, Summerred, Vista Bella	Arlet, Elstar, Gala Delbard, Gala Imperial, Gala Mondial, Gala Prince, Gala Royal, Gala Galaxy, Gloster, Golden B, Golden FGA, Golden Reinders, Golden Russet, Golden Smoothee, Green Sliws, Idared, Red Elstar, Rubinette, Šampion, Topaz	Braeburn Hillwell, Braeburn Schneider, Granny Smith, Pink Lady
Triploid		Jonagold, Jonagored, Jonagold Jonica, Jonagold Novayo	Boskoop

4.2. Measured and calculated parameters from field trials

1. Flowering time (beginning of bloom, full bloom and the end of bloom)
2. Flower density (evaluated on a linear scale 0 to 10)
3. Fruit set from open pollination (the percentage of the designated flowers)

4. *Fruit set from self-pollination (the percentage of the designated flowers)*
5. *Fruit drop (date, rate and the dynamics of the drop)*
6. *Fruit density (evaluated on a linear scale 0 to 10)*
7. *Crop load (calculated from the data of the yield and TCSA)*
8. *Yield (calculated for tree, and ha units)*
9. *Alternate Bearing Index:*

$$AI = 1/(n-1) \times \{ |(a_2-a_1)| / (a_2+a_1) + |(a_3-a_2)| / (a_3+a_2) \dots + |(a_n-a_{n-1})| / (a_n+a_{n-1}) \}$$

where: n = number of years

a₁, a₂, ..., a_(n-1), a_n = yield [kg/tree]

10. *Modified Alternate Bearing Index:*

$$AI_m = 1/(n-1) \times \{ |(b_2-b_1)| / (b_2+b_1) + |(b_3-b_2)| / (b_3+b_2) \dots + |(b_n-b_{n-1})| / (b_n+b_{n-1}) \}$$

where: n = number of years

a₁, a₂, ..., a_(n-1), a_n = flower density of flower number [flower/tree]

4.3. Laboratory measurements and analysis

4.3.1. Fruit quality parameters and seed content

1. *Fruit weight (measured with a digital calliper)*
2. *Fruit diameter (measured with a digital calliper)*
3. *Fruit height (measured with a digital calliper)*
4. *Flesh firmness (measured with a penetrometer)*
5. *Skin colour (estimated on a linear scale 0 to 100%)*
6. *Dry matter content (measured with digital refractometer)*
7. *Seed number per fruit (counted the undeveloped and fully developed ones)*

4.3.2. Hormonal content analysis

1. *Gibberellic acid content (GA₁, GA₃, GA₄ and GA₇) of the seeds was determined with HPLC technology*

4. MAIN RESULTS OF THE THESIS

4.1. Alternate bearing

Alternate bearing did not affect the flowering time of apple during the 5-year experiment. The beginning of flowering could occur earlier or later both in the on- and off-year and differences varied by cultivars.

In contrary, significant differences in flower density were found between on- and off-year trees. The cycles of the alternate bearing and thus the values of flower density was fluctuating during 2003-2007 for the heavily alternate-bearing 'Summerred' cultivar. Flower production of the off-year trees was usually not enough, on-year trees have had so many flowers and fruitlet that caused natural fruit drop and decreased their quality. The regular-bearing 'Green Sliws' showed almost the same amount of flowers and fruit every year.

The seasonal course of fruit set can be characterised with a hyperbolic function for both on- and off-year trees. Difference was found only in the slope of the function, because the fruit set is steep especially during the first two months after flowering. Thus, the amount of the dropped fruit is higher and the date of the dropping waves are sometimes not expressed by on-year trees. Two waves was observed for 'Green Sliws' and four for 'Summerred' in both the on- and off-years. These two or four peaks can be found easily by on-year trees, those by off-year trees are generally overlapped. The first dropping wave of the on-year trees occurs at the beginning of May and the second in the middle of June. The third one appears the middle to the end of July and then the fourth wave directly before harvest. This pre-harvest fruit drop is peculiar to 'Summerred'. In contrary, the first drop can be found at the end of May by off-year trees. The second wave is almost in the same period as observed by the on-year trees.

We cleared up the special role of seed content in crop regulation. By the on-year trees, the difference in seed number per fruit between the dropped and persisting fruit was significant, and it decreased getting closer to the harvest. After fruit set, the persisting fruitlets have 3.9 seeds in average for the regular-bearing 'Green Sliws'. In the abscised ones, 1.9 seeds were counted only. At harvest, persisting fruit contained 5.6 seeds and dropped ones 4.3. This shows that those fruit are shed which contain the fewest number of seeds and thus the persisting fruit have higher number of seeds with lower dispersion. The seasonal changes of seed content in fruit can be characterised by a quadratic polynomic function for both cycles of alternate bearing. Fruit from off-year trees generally contain higher number of seeds compared to those of the on-year trees. There was not so important difference in seed content

between dropped and persisting fruit as was observed in on-year and the seed number per fruit was almost the same at harvest. The seed count of persisting fruit was 4.2 after fruit set and we counted 2.4 seeds in the dropped ones. At harvest, persisting fruit have 6.8 seeds only. The last dropped fruit were collected in the middle of August which had 5.2 seeds in average. The standard deviation of seed number showed decreasing tendency for both abscised and persisting fruit. The seasonal change of this measure for fruit on the tree could be best described by a quadratic polynomial function while for the dropped fruit the linear function proved to be the best.

Fruit yield varied in the different cycles of the alternate bearing. On-year trees have higher yield 5-6 times than off-year ones. In the case of the regular-bearing 'Green Sliws', no extreme differences were found between the on- (8.2 kg/tree) and off-year (7.5 kg/tree) trees. However, for 'Summerred' the yield per tree can be significantly increased if thinning is used and as a consequence, the trees have a regular yield. In this cultivar, the alternate bearing trees had a yield of 4.3 kg per tree, while those with regular yield (i.e. thinned) had 7.4 kg per tree.

Biennial bearing had a significant effect on fruit quality parameters. In the case of on-year trees, fruit weight, diameter and height were significantly lower than those on off-year trees. A similar but less significant trend was observed for flesh firmness, skin colour and dry matter content. The reason for the differences was probably the crop load. 'Summerred' was more sensitive to differences in crop load. Fruit quality was improved in almost all cases in the off-year as compared to that of on-year. The average value of increase for 'Golden Reinders' was 5%, 3.8% and 6.6% fruit weight, diameter and fruit height, respectively. Flesh firmness was 3.9% higher in average in the off-year cycle than in the on-year one. Skin colour was thrice as high in the off-year cycle. In dry matter content, the increase was 3.8%. In 'Summerred', the increase in the above parameters was higher. The indices of fruit size (fruit weight, diameter and height) in the average of years were higher by 15.4%, 17.8% and 9.9%, respectively, as compared to the high cropping cycle. The increments were +16.3% for skin colour in the off-year cycle. Dry matter content was 15.8% higher in the fruit of off-year trees.

To describe the sensitivity to alternate bearing of the examined rootstock-scion combinations, so called Alternate Bearing Index (ABI) was calculated for the period of 2003-2007. Its value, however, did not represent the sensitivity of cultivars to alternate bearing i.e. the irregularity of flower production for example for 'Golden Reinders' and 'Summerred'. So, this index numbers represent the yield fluctuation by years only. Thus, we developed another index (Modified Alternate Bearing Index – MABI) for describing the alternate bearing more exactly then grouped the cultivars based on its values (Table 4). MABI can characterise the

sensitivity of cultivars to alternate bearing and flower production ability. Its values varies by cultivars and rootstocks. 'Braeburn' mutants, 'Gala' cultivars, 'Pink Lady', 'Šampion' and 'Topaz' on M.9 rootstock showed a little ability to alternate bearing. 'Elstar', 'Red Elstar', 'Summerred' and 'Vista Bella' had high values of MABI, therefore strong ability to alternate bearing. The cultivar order was similar on MM.106 and seedling stocks, the MABI values were, however, higher than those on M.9. The lowest value was 0.18 on M.9 rootstock ('Gala Delbard'), 0.2 and 0.29 on MM.106 ('Braeburn Hillwell' és 'Braeburn Schneider') and on seedling ('Gala Mondial'), respectively. The highest value was for 'Vista Bella' 0.79 on M.9 and 0.86 and 0.94 on MM.106 and seedling, respectively. Clear consequence can be established regarding the effect of the vegetative vigour of rootstocks on the sensitivity of alternate bearing of scions, that is the growth habit of rootstock is the stronger, the ability of scions to alternate bearing or irregular flower production is also the stronger. The ripening time of the cultivars did not affect their ability to alternate bearing. Maybe the shorter fruit development can affect the flower number and quality positively. We did not, however, observe that, and it is important to note that the examined summer ripening cultivars ('Earligold', 'Mollie's Delicious', 'Prima', 'Summerred' és 'Vista Bella') were sensitive to alternate bearing. Alternate-bearing and regular-bearing cultivars can be found in the groups of autumn ripening and winter ripening.

Table 4. Sensitivity of the examined cultivars on three different growth inducing rootstocks to alternate bearing grouped on the values of the Modified Alternate Bearing Index (Nagykutas, 2003-2007)

	M.9	MM.106	Seedling
1. Not sensitive	Braeburn Schneider, Gala Delbard, Gala Imperial, Gala Mondial, Gala Prince, Gala Royal, Gala Galaxy, Green Sliws, Pink Lady, Šampion	Braeburn Hillwell, Braeburn Schneider, Gala Imperial, Green Sliws, Pink Lady	
2. Moderately sensitive	Braeburn Hillwell, Gloster, Golden Smoothee, Granny Smith, Idared, Jonagold Jonica, Jonagold Novayo, Mollie's Delicious, RubINETTE, Topaz	Earligold, Gala Delbard, Gala Mondial, Gala Prince, Gala Royal, Gala Galaxy, Idared, Jonagold Jonica, Jonagold Novayo, Mollie's Delicious, RubINETTE, Šampion, Topaz	Braeburn Hillwell, Gala Delbard, Gala Imperial, Gala Mondial, Gala Prince, Gala Royal, Gala Galaxy, Green Sliws, Idared, Pink Lady, RubINETTE
3. Sensitive	Arlet, Boskoop, Earligold, Golden B, Golden FGA, Golden Reinders, Golden Russet, Jonagold Jonagored, Prima	Arlet, Boskoop, Gloster, Golden B, Golden FGA, Golden Russet, Golden Smoothee, Granny Smith, Jonagold Jonagored, Prima	Arlet, Boskoop, Braeburn Schneider, Earligold, Gloster, Golden B, Golden FGA, Granny Smith, Jonagold Jonagored, Jonagold Jonica, Jonagold Novayo, Mollie's Delicious, Prima, Šampion, Topaz
4. Strongly sensitive	Elstar, Red Elstar, Summerred, Vista Bella	Elstar, Golden Reinders, Red Elstar, Summerred, Vista Bella	Elstar, Golden Reinders, Golden Russet, Golden Smoothee, Red Elstar, Summerred, Vista Bella

Our studies on gibberellic acids made the role of GA₁, GA₃, GA₄ and GA₇ in the alternate bearing clear. Significant difference in GA₁ between the on- and off-year trees was not observed for the heavily alternate-bearing 'Vista Bella'. Similar tendency was found for the regular-bearing 'Royal Gala'. It is interesting that the amount of the flowering inhibitor GA₁ was higher in the seeds of 'Royal Gala' than that of 'Vista Bella'. This has two interpretations: flower, fruit and seed productions of the on-year trees of 'Vista Bella' were lower than those of 'Royal Gala'. Therefore, lower rate of GA₁ was produced which had lower effect. Another interpretation is that GA₁ act as not a single inhibitor but it regulates the flower development through complicated mechanisms. The pattern of the inhibitor of flower induction GA₃ was different by the on- and off-year trees of 'Vista Bella'. Seeds of fruit from on-year trees contains higher amount of GA₃, and it was significantly different from that of the off-year trees on the 32nd and the 40th dAFB. This shows that the GA₃ content in the fruit from the on-year trees has hindering effect on the flower initiation in the previous year. Therefore, this is the reason of the appearance of the off-year cycle. This kind of difference was not found for the regular-bearing 'Royal Gala' and the values were lower than those of 'Vista Bella'. In the seasonal course of the only flower-initiating GA₄, significant difference was measured for 'Vista Bella' 4-5 weeks AFB between the on- and off-year trees. This also supports the theory on the positive role of GA₄ in flower development. In contrary, the seasonal pattern and the amount of GA₄ was quite similar for the regular-bearing 'Royal Gala'. Therefore, flower producing ability of this cultivar was almost the same every years. The seeds of fruit from on-year trees of the alternate-bearing 'Vista Bella' contained GA₇ in significantly higher amount than that of the off-year trees. The pattern of the function was similar to that observed by GA₃ and its role in flower initiation is also very similar. This has a double hindering effect on flower formation by on-year trees. Seasonal pattern of GA₇ for 'Royal Gala' by on- and off-year trees was not the same however, significant difference was not found. Measured values were lower than those of 'Vista Bella'. This also supports the regular flower producing ability of 'Royal Gala'.

4.2. Fruit drop

There were 3 fruit dropping periods on the trees grafted on M.9 and MM.106 rootstocks, but in the case of seedling, only 2 were found. There was a decided difference between persisting and abscised fruit on all three stocks and this difference decreased coming closer to harvest. After fruit set, persisting fruit contained 4.2, 4.3 and 3.8 number of seeds in

average on M.9, MM.106 and seedling rootstocks, respectively. In contrast, 1.9, 1.7 and 1.5 number of seeds per abscised fruit were counted on M.9, MM.106 and seedling, respectively. At harvest, 7.9, 8.2 and 6.9 number of seeds were characteristic for persisting fruit and only 6.9, 7 and 5.8 for abscised ones on above rootstocks, respectively. Seasonal changes of seed content of both types of fruit can be estimated well with a polynomial curve of the second order.

Vegetative vigour of the studied different growth inducing rootstocks was dissimilar to each other. Leaf number per fruit was the lowest on trees on M.9 rootstock. The rise of its curve is important during the first period of fruitlet development, in especially at the end of June and in the beginning of July indicated that first and second wave of fruit drop was occurred in this period and strong shoot growth was also observed. Increasing leaf/fruit ratio after this period is a result of fruit drop exclusively. The rise of the curve of MM.106 is very similar to that of M.9 because of the similar tendency in fruit drop. Values are higher indicating the increased vegetative vigour. The highest values of leaf/fruit ratio during the test period were by trees grafted on seedling. The running of its curve is differ compared to those on other stocks. The rise of the curve of seedling is important at two times: in the beginning of June and at the end of July. The highest amount of fruit drop was occurred at these times. Fruit quality parameters (fruit weight, diameter, height, dry matter content) were the highest on M.9 except flesh firmness which was the highest on seedling. In this case, that principle was predominated that the highest fruit size, the lowest fresh firmness. Skin colour was mostly influenced by the vegetative vigour of the rootstocks. The ratio of red surface colour was the highest on fruit from trees grafted on M.9 with the weakest vegetative vigour, and the lowest ratio was observed on fruit surface from tree on seedling. Differences between skin colour on weak and strong growth inducing rootstocks come from the different canopy microclimate of these stocks. Generally, rootstocks had little effect on dry matter content. Significant differences between dry matter content of fruit from trees on M.9 and MM.106 were not observed. Less values were measured for seedling.

A close positive relationship between fruit set and seed content of fruit was found in the 33 apple varieties. The higher the rate of fruit set, the higher the number of fully developed seeds in the fruit. So, cultivars with ability for high fruit set can be characterised with high number of seeds in their fruit. The correlation between fruit set and seed content was the closest ($R^2_{(2004)}=0,7993$, $R^2_{(2005)}=0,8554$) for the variety 'Golden Smoothee'. In other words, it means that to stay on the tree, the individual fruit are competing among themselves and the fruit of relatively higher seed content will win the race. The correlation between the

number of flowers per tree and the rate of fruit set is negative. The 33 apple varieties produced $R^2=0.3748$ in 2004 and $R^2=0.3508$ in 2005. This means that the greater the number of flowers per tree, the lower the rate of fruit set or the higher the rate of fruit shed until harvest. There was a positive correlation between the flower number per tree and the fruit number per tree at harvest. No significant correlation was found between the number of fruit set (and maintained) until harvest and the number of ripe fruit. The relationship is positive although very loose in the examined years.

4.3. Primigenic dominance

The expression of the primigenic dominance in the flowering time was examined for selected cultivars each grafted on three different growth inducing rootstocks. The difference in time of the opening among the individual flowers growing in a flower cluster was 2-4 days. Firstly, king bloom opened then the lateral flowers in centripeatl order. There was no significant difference among the effects of rootstocks on the flowering time of the individual flowers. The functions representating the different rootstocks had the same slope until the 5th flower, only difference was found for the 6th flower on MM.106 stock. This difference was not significant.

Based on the results of our two-year-study, significant difference was observed in the fruit set of the individual flowers of a cluster. The highest rate of fruit set from open-pollination was by the firstly-opening king bloom on M.9, MM.106 and seedling rootstocks, the values are 19.4%, 20.4% and 13.6%, respectively. There was no significant difference among above three rootstocks, so, stocks did not affect the fruit set from open pollination. Significant difference in fruit set was found between the first and second flowers on all stocks.

In a flower cluster, in all cases the number of seeds in fruit growing from the king bloom was the highest. Seed content of fruit had decreasing tendency according to the flowering order. This trend did not mean significant differences among fruit. Significant difference was generally found between the firstly and secondly opened flowers, however, there was no significant difference between the secondly and thirdly opened ones except for 'Royal Gala' and 'Pink Lady'. This shows, that the expression of the primigenic dominance is very clear between the central and lateral flowers but is not between/among lateral ones.

The certain gibberellic forms (GA_1 , GA_3 , GA_4 és GA_7) have no specific role in the primigenic dominance, only cumulative effect they have. So, we analysed the total gibberellic

acid content. The total gibberellic acid content occurred in the significantly highest amount in the seeds of the king fruit on all three rootstocks. This supports the hypothesis that is the auxin outcome from the fruit growing from the firstly opened flower is the highest and this hinders the formation of the abscission layer and the drop. Significant difference in the total amount of the gibberellic acids among the periferal fruit was not found. Significant difference among the effects of rootstocks was also not observed. So, rootstocks had the same effect on the total gibberellic acid content of fruitlets growing from a flower cluster i.e. the expression of the primigenic dominance.

Regarding the expression of the primigenic dominance in fruit quality, quality paramters of the fruit growing from the king bloom were generally higher on all three rootstocks. This difference was significant in fruit weight, height, shape index and dry matter content.

5. NEW SCIENTIFIC RESULTS OF THE THESIS

5.1. Alternate bearing

The definition of the alternate bearing was discussed and exactly defined based on the experiment results and the literature sources. Clearing up this definition was necessary because of the importance of this phenomenon. The conceptual elements are mixed in the literature sources and often make results uncomparable. By the description and the definition of the alternate bearing, authors take only the yield fluctuation i.e. the visual consequence of the phenomenon into consideration. In the yield fluctuation, cultivar sensitivity to alternate bearing plays role, the measure of the phenomenon, however, depends several factors. We, according to Soltész (1982), took the flower bud and flower production into consideration to define the alternate bearing.

Based on five consecutive year data, sensitivity to alternate bearing of 33 apple scions grafted onto 3 different growth inducing rootstocks (M.9, MM.106 and seedling) was established and described. Alternate Bearing Index was also calculated to characterise the sensitivity more accurately. This index could not represent the ability of cultivars to the irregular flower production, the so called Modified Alternate Bearing Index was developed which take the flower production of the cultivars into consideration to define the alternate bearing. Cultivars on three rootstocks were grouped into 4 groups based on their sensitivity to alternate bearing.

Firstly in Hungary, the relationship between the vegetative and generative (flower production and fruit yield) production of cultivars and rootstocks was shown.

The effect of three different growth inducing rootstocks in the alternate bearing was also described through the gibberellic acid content of the seeds in fruit. Significant difference in GA₃, GA₄ and GA₇ between the on- and off-year trees was found for the strongly alternate bearing cultivars on all three rootstocks. This kind of difference was not observed for the regular bearing cultivars. The important regulator role of the flower inhibitor GA₁ could not be supported in our experiments probably because the GA₁ act as not a single inhibitor but it regulates the flower development through complicated physiological mechanisms. The role in the flower formation of the other members of this phytohormone group needs to be clear up.

5.2. Fruit drop

We described firstly and compared the effect of three different growth inducing rootstocks (M.9, MM.106 and seedling) on the fruit drop of 33 apple scion cultivars. The

comparison was done through the date, rate and the dynamic of the drop. We observed that the ability to fruit drop is genetically defined feature of the cultivars, however it can vary in years and meteorological conditions.

The relationship between the ability to fruit drop and vegetative shoot growth was also presented.

We supported that relation exists between the number of fully developed seeds per fruit and the fruit drop, its values were made on rootstocks more accurate. Describing the role of seed content of the fruit, a new parameter called 'specific seed number' was developed. For its calculation, we used the trunk cross section area (TCSA) and the total number of seeds per tree.

5.3. Primigenic dominance

In Hungary, the expression of the primigenic dominance in the flowering time, seed content and fruit quality was examined firstly. The research on the fruit set and gibberellic acid content of the individual flowers in a cluster has importance at international level. The different growth inducing rootstocks did not seem to have significant effect on the expression of the primigenic dominance, they only modified it.

6. USE OF THE RESEARCH RESULTS IN THE GROWING PRACTICE

Our research aimed to clear up the crop autoregulation process of apple mainly, so its nature is expressed in basic research. The research results are, however, touch some practical points of the apple growing and can be used in the technology.

The knowledge of the sensitivity of rootstock-scion combinations to alternate bearing and to fruit drop serves important background information for breeding researches. The study on these cultivar features enriches our deficient knowledge regarding cultivar selection and training system development.

The our-defined 'alternate bearing' definition and our-developed Modified Alternate Bearing Index (MABI) can not only be used for pome fruits but for other strongly alternate-bearing species also.

Results of our hormone researches show that every treatments for eliminating or reducing alternate bearing (e.g. pruning, thinning) should modify the gibberellic acid level in the seeds of fruit. However, how the external gibberellic acid application can affect on the irregular flower production, we still do not have exact and consequent experience.

Scientific results on fruit drop can be adopted into the growers' practice. Consequences from the dynamics of the fruit drop can be used in the thinning practice (timing, rate and methods of thinning). This knowledge serves as the basic of the crop regulation technology. The knowledge of meteorological data and the seasonal pattern of fruit drop contributes to making crop estimation accurate.

The knowledge of the flower number in a cluster and of the expression of the primigenic dominance in flowering time provides necessary information for fruit thinning especially for its timing. The knowledge of the difference in fruit set and quality among fruit growing from flowers in a flower cluster serves the hand thinning practice i.e. the removing of the king bloom or fruitlet from the cluster is suggested for cultivars with low flower density in order to eliminate the primigenic dominance. This provides that the remaining fruit have same quality. In the cases of cultivars with high flower density, the removing of the lateral flowers is suggested.

7. PUBLICATIONS

7.1. Scientific papers in journals

- RACSKÓ, J.** (2004): Effect of auxin-synergistic preparation and fertilization on fruit setting and fruit quality of apple. *J. Agr. Sci.* 15: 21-26.
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