International Journal of Horticultural Science 2009, 15 (1–2): 17–22
Agroinform Publishing House, Budapest, Printed in Hungary
ISSN 1585-0404

Specialities of the vegetation start and level of primary fruit set affect fruit quality

Rakonczás, N., Dremák, P. & Gonda, I.

Centre of Agricultural Sciences, University of Debrecen, 138 Böszörményi Street, 4032 Debrecen, Hungary

Summary: Thinning is a highly crucial point of the apple production technology. According to results of numerous studies the earliest thinning is deemed to have the best amending effects. There can be considerable difference between trees of the same cultivar and age in a plantation in respect to their flowering, in the numbers of fruits set and also in their canopy volume. Thus it can be crucial –just like in the case of pruning- to establish a fruit thinning suited for specific characteristics of actual trees. This experiment was established to examine how does primary fruit set (fruit load before thinning) and further on specific (fruit/TCS cm^2) and absolute (fruit/tree) fruit-load of the trees affect quality attributes at harvest. Our experiment was established in a plantation on medium-tight loamy soil in north-east of Hungary. Harvest date was determined with the joint observation of the calendar date, starch-index, flesh firmness, background colour and fruit weight. Three fruit-load levels were established based on local experience and on data of several years, 10t/ha lower and higher besides the advised optimum yield in the same orchard with slender-spindle shaped 'Gala must' cultivar standing on M9 rootstock in 1m × 3,8m spacing. In the establishment of the 15, 25 and 35t/ha fruit-load levels on 20–20 apple trees total number of fruits set was counted at each tree. After this number of apples due to be removed was defined using an objective index on the basis of trunk cross sections (fruit/TCS cm^2) (Lafer, 1999). The following attributes were measured: weight (g), flesh firmness (lb/cm^2) total soluble solid content (Brix %) and total titrate-able acid content (g/l). From the data on sugar and acid content quality index (Pomona value) was determined (Thialult, 1970). We could ascertain, that in an orchard, of the same aged but in concern to trunk cross sections somewhat different trees besides the specific index (apple/TCS cm^2) the absolute fruit load (fruit/tree) can also be an important data, that has considerable effect on the internal quality. Secondly we could observe, that higher level of fruit load before thinning (primary fruit set) negatively affects quality index of the apples irrespective of the specific fruit load level (fruit/cm^2 TCS) set later. Results underlines necessity of the earliest chemical thinning.

Key words: apple, fruit load, primary fruit set, quality

Introduction

Elaboration of chemical fruit thinning technologies gets into forehead in the domestic fruit production. This method enables 50–100thousand HUF savings an hectare compared to the very demanding hand thinning. Besides this, fruit load over the optimum level has a negative effect also from its physiological side.

In case of heavy blooming, weak shooting vigour, early lesion of the foliage at vegetation start the spring time root growth get damaged. This fall back in spring time root extension can hardly be made up, furthermore the autumnal root growth will also fall back, since the consequently aged foliage can slightly supply its extension growth (*Zatykó*, 1979; *Gonda*, 1980, 1982).

In fruiting plantations the main point of the fruit thinning is establishment of the optimal fruit load corresponding to condition and fruiting potential of the trees. This practically means that in Hungary about 30–40 leaves are to feed a fruit in the late period of fruit growth in optimal case (*Kállay*, 1994; *Soltész*, 1997; *Lakatos*, 2003).

According to *Preston* (1954), *Preston & Quinlain* (1968), & *Zatykó* (1979) a more sever thinning entails higher level yield increase, than the decrease due to the reduction of fruit number.

Many literature ascertain the fact, that bigger fruits of thinned trees show lower calcium and higher potassium content, and are more prone to bitter pit and senescent break down (*Sharples*, 1964, 1968; *Sass*, 1986; *Voltz* et al., 1993; *Szűcs & Kállay*, 1979; *Kállay & Szűcs*, 1980, 2003). Researchers also agree, that these fruits show higher soluble solid content and softer flesh firmness.

Denne (1960, 1963), *Sharples* (1968), later on *Goffinet* et al. (1995) also experienced, that cell division period of the apple growth ceases 4–6 weeks after full bloom. Fruits of those trees, that were fruit thinned shortly after blooming were bigger both in their measure and their cell number. Higher level of cell number in this concern means a higher possibility for Ca-incorporation into the cell walls, thus its dilution with the fruit growth is lower, than in other cases. From this point, the provisional quality and storability could be also better, then in cases of extra fruit measures, due to extra N-supply or low fruit load.

Hrotkó et al. (2007) at evaluation of effect of various rootstocks on fruit yields of sweet cherry cultivars experienced, that comparison of their fruiting potential can not be correctly expressed on the basis of trunk cross sections of the trees. *Kállay & Szűcs* (2003) studying mineral take up of apple trees and storability of the apple ascertained, that neither expression of specific (apple/TCS cm^2) nor absolute (apple/tree) fruit load can sufficiently express conditional status of the trees. Jointly they highlighted, that higher levels of potassium and phosphorus point out their lower physiological state.

Observations of *Kállay & Szűcs* (2003) and *Hrotkó* et al. (2007) rises the question, how to express optimum fruit load. Based on the previous and also on our observation we could compose the following question:

- Is it possible to clarify quality equalizing effect of the specific fruit load (*Laffer*, 1999) on the basis of trunk cross section (TCS cm^2), or absolute fruit load (fruit/tree) of the trees has a more respectful effect on fruit measure and quality?

Through along establishment of the experiment we put emphasize on measuring fruit set of the trees. At hand thinning and establishing specific fruit loads of the trees we experienced big differences in primary fruit sets of the trees.

- In concern of the different (natural) primary fruit set, thinning severity and established specific fruit load it was questioned, that what effect do these have on fruit weight and quality.

Hypothesis of good early start (*Zatykó*, 1979) suggest that heavier fruit set could also have certain negative effect not only on spring time root growth, but also on fruit quality.

There can be considerable difference between trees of a plantation in respect to their flowering, in the number of fruits set and also in their volume (TCS cm^2) (*Westwood*, 1970; cit. Jackson, 2003; Parry & *Rogers*,1972). Thus it is crucial – just like in the case of pruning – to establish a fruit thinning suited for specific characteristics of actual trees.

Materials and methods

Our experiment was established in the apple orchard of the Kasz-Coop Ltd. in Sáránd, 20 km from Debrecen in south-southwest direction (north latitude: 47° 23'; east altitude: 21° 35'). The approximately 100ha orchard was established on medium-tight loamy soil.

The water and mineral supply of the soil is good. The fertilization is based on regular soil- and leaf-analyses results. Irrigation is backed up with data of precipitation soil water changes, air humidity and linear fruit-growth. Between row space is covered with natural weed-succession, chemical weed-control is applied in the rows. The Ltd. follows IP management.

Harvest date is determined with the joint observation of the calendar date, starch-index, flesh firmness, background colour and fruit weight.

Three fruit-load levels were established based on local experience and on data of several years, 10t/ha lower and higher than the advised optimum yield in the same orchard with 9 year old slender spindle shaped 'Gala must' cultivar standing on M9-rootstock with 1m between tree and 3,8m between row spacing.

In the establishment of the 15, 25 and 35t/ha fruit-load levels on 20–20 apple trees total number of fruits set was registered at each tree. After this, number of apples due to be removed (or those, due to be left on the trees) was defined using Laffer's curve on the basis of trunk cross sections (fruit/TCS cm^2).

Through our examinations we measured the following attributes:

- weight of the apples (g)
- flesh firmness measured with FT 327 Effegi-type penetrometer (lb/cm^2)
- total sugar content derived from soluble solid concentration with the Y = 2,1486 X + 82,591 formula suggested by The International Sugar Committee, where Y: sugar content (g/l), X: Brix %.
- total titrate-able acid content (g/l)
- starch index (1–10)
- trunk cross-section (cm^2).

From the data on sugar and acid content *Thiault*'s (1970) quality index (Pomona value) was determined (MI = total sugar g/l + 10 × total acid g/l). Streif-index was calculated from data on starch content, flesh firmness and total soluble solid content.

Mineral element content of the plant samples were measured with ICP-OES in the Institute of Food Processing, Quality Control and Microbiology.

Data was processed and visualized with EXCEL software. Differences of the treatments establishes in split-plot pattern were calculated with one way analysis of variance with the $SDp_{5\%} = tp_{5\%} * \sqrt{(2 * MqB)/n}$ formula.

Results

Figure 1 shows Streif-indices of the established fruit load levels. The index visualizes, that irrespective of fruit load levels, there was no difference in ripening stage of the examined fruits.

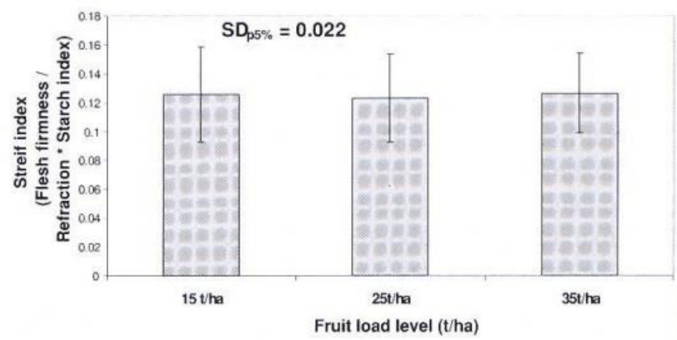

Figure 1 Streif-indices of apples of three fruit load levels (Derecske, 2006)

In the background of these values data showed, that there was no significant difference neither in flesh firmness nor in starch index of the treatments, however there was a considerable difference in sugar content (Brix %), which does not appear in the index (detailed later).

Figure 2 visualizes decreasing average fruit weight with increasing specific fruit loads (fruit load levels) of the trees.

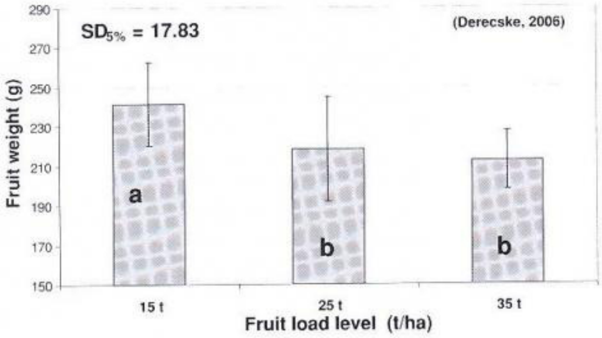

Figure 2 Average fruit weights of apples of three fruit load levels (Derecske, 2006)

It can be interesting to take into respect, that hereinafter detailed parameters of higher fruit loads represent smaller fruits.

Components of the Quality Index are represented in *Figures 3–4* in respect to the set fruit load levels

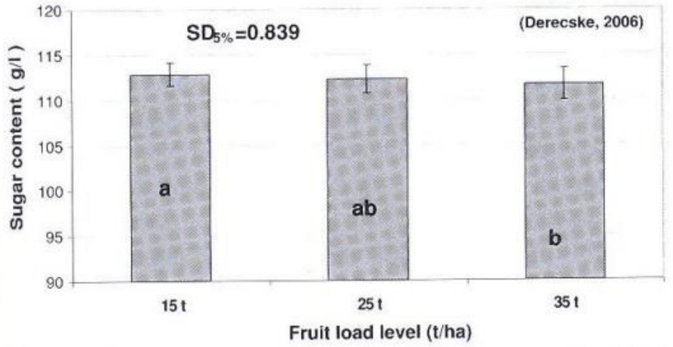

Figure 3 Average sugar content of apples of three fruit load levels (Derecske, 2006)

The effect, that along with increasing fruit load the sugar content of the apples decreases is well known..

Figure 4 visualizes second component of the Quality Index. Observing the piles, it is controversial to see, that increasing fruit load, does not entail increasing acidic content.

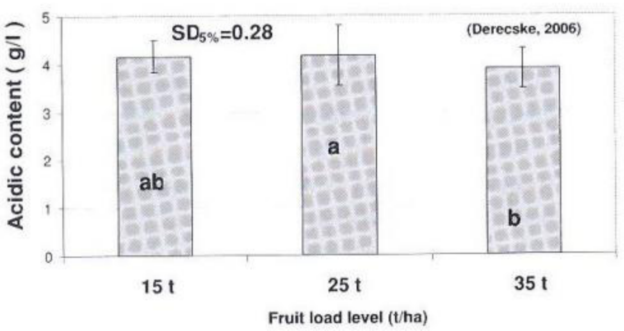

Figure 4 Average acidic content of apples of three fruit load levels (Derecske, 2006)

Putting together the components one can clearly see, that overloaded trees bred smaller, less sweet apples with a considerably lower acidic content.

Effects of fruit set and –thinning on quality parameters

Figure 5 shows relation of different absolute fruit load of the trees (fruit/tree) and average fruit weight on three specific fruit load level (fruit/TCS(cm^2).

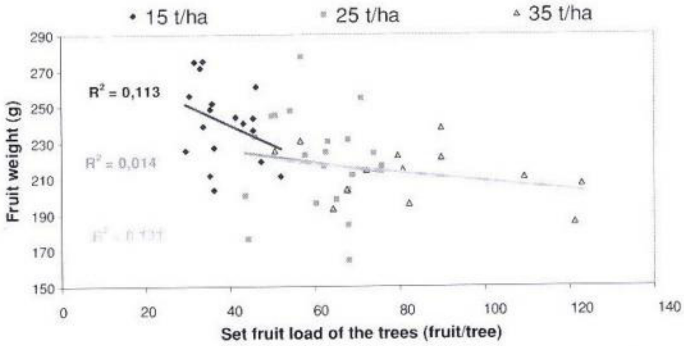

Figure 5 Average fruit weight of 'Gala must' apples in relation to the set absolute fruit load of the trees (fruit/tree) (Derecske, 2006)

It is evidently visual, that average fruit weight decreases with the established higher fruit load (fruit/TCScm^2). Furthermore it can also be observed, that within the established specific fruit load levels (fruit/TCScm^2) average fruit weight shows further considerable decrease with increasing absolute fruit load (fruit/tree). However, according to correlation quotients this relation is highly affected by other factors.

Figure 6 exhibits relation of different absolute fruit load of the trees (fruit/tree) and Quality Indices of the fruits on three specific fruit load levels (fruit/TCS(cm^2).

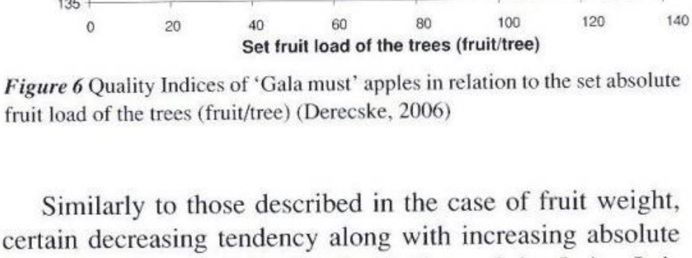

Figure 6 Quality Indices of 'Gala must' apples in relation to the set absolute fruit load of the trees (fruit/tree) (Derecske, 2006)

Similarly to those described in the case of fruit weight, certain decreasing tendency along with increasing absolute fruit load also stand for Quality Indices of the fruits. It is interesting to see, that 25t/ha specific fruit load emerges on some level, thus intermediate fruit load seems to show the best quality *(Figures 3–4)*.

Figure 7 clearly shows, that primary fruit load (before thinning) had no effect on harvest time fruit weight.

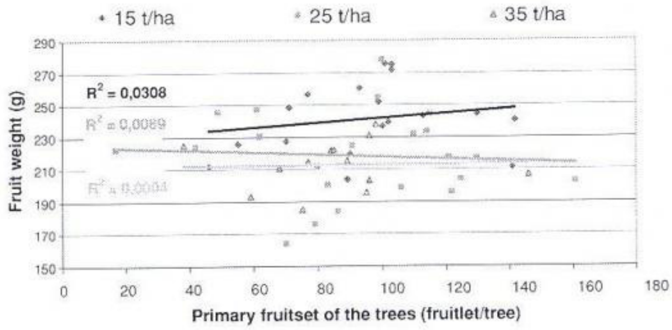

Figure 7 Average fruit weight of 'Gala must' apples in relation to the original fruit set (before thinning) of the trees (Derecske, 2006)

This Figure simply shows the significant difference in average fruit weights between the three established fruit load levels.

Figure 8 shows flesh consistency of the apples in relation to the primary fruit load (fruit set before thinning) of the trees.

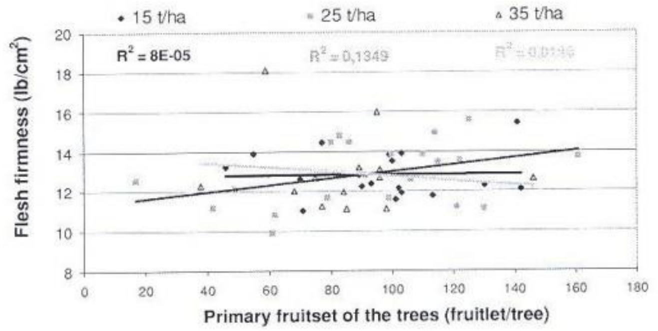

Figure 8 Flesh firmness of 'Gala must' apples in relation to the original fruit set (before thinning) of the trees (Derecske, 2006)

Based on the Figure, we can ascertain no relation in the studies concern.

Figure 9 visualizes Quality Index of the fruits in relation to the primary fruit load of the trees.

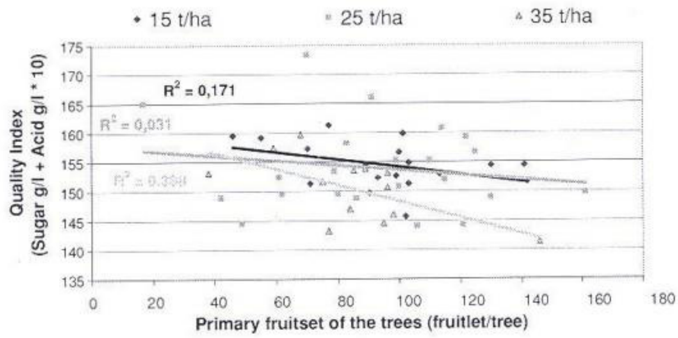

Figure 9 Quality Indices of 'Gala must' apples in relation to the original fruit set (before thinning) of the trees (Derecske, 2006)

The correlation quotient in the case of 15 and 35t/ha specific fruit load levels could be considered noteworthy. Thus, higher level of primary fruit load (fruit set) before thinning, has considerable negative effect on quality index of the fruits. This result underlines importance of chemical thinning which can be executed in earlier stage.

Fruits of trees showing higher levels of primary fruit load (fruit set before thinning) can be considered to be the same in fruit weight and flesh consistency, but lower in their quality index to those grown on tress from which fewer apples were due to be removed to set the optimum fruit load level.

Table 1 enables evaluation of the set fruit load levels based on relation of the critical mineral elements highlighted in works of *Kállay & Szűcs* (1980; 2003).

Table 1 Critical element indices characterising the set fruit load levels (Derecske, 2006)

Fruit load (t/ha)	K+Mg/Ca		K/Ca		K		Ca	
					mg/kg			
15	1,01	b	0,82	b	13199,7	b	15742	a
25	0,95	ab	0,71	ab	12623,3	b	16284,7	a
35	0,83	a	0,60	a	10405,7	a	16003,3	a
$SD_{5\%}$=	0,17		0,13		1805,6		1829,1	

With increasing fruit load potassium shows decreasing level in the foliage, and although it is not significant, calcium shows a maximum at intermediate fruit load. Foliage of trees of more sever fruit thinning can be characterized with elevated K/Ca and K+Mg/Ca levels (stable Ca besides increasing K content).

Discussion

In comparison of fruit load levels we could conclude, that overloaded trees bred smaller, less sweet apples with a considerably lower acidic content. It shall be emphasized, that acidic content has important role in physiological status and storabilityof the fruits, since it supports appropriate pH for biochemical cell-processes (*Kállay*, 1994; *Hámoriné*, 1974; *Sass*, 1986; *Kállay*, 1994).

It could be observed, that within the specific fruit load levels on the basis of trunk cross section (apple/TCS cm^2) through along the increase of the absolute fruit number (apple/ tree) the fruit weight also decreases considerably. We ascertain, that in a plantation, which is not 100% homogenous concerning trunk cross sections (tree volume) the absolute fruit load (apple/tree) could also be a respectful index. Results and observations of *Kállay* (2005) and *Hrotkó* et al. (2007) confirm this statement.

At analysing effect of primary fruit set (natural) on fruit quality index it vas visual, that within the established fruit load levels, quality showed considerable correlation with the primary (before thinning) fruit loads of the trees (set apples/tree). Higher level of fruit load before thinning negatively affect quality of the fruit irrespective of the specific fruit load level set later (apple/TCS cm^2).

Fruits set over the optimum fruit load level negatively affect quality. This result besides underlining importance of the earliest chemical thinning, reinforces theory of *Zatykó* (1979) composed about the negative effect of the heavy flowering on god vegetation start at spring time. Heavy, fragrant flowering showing god condition is negatively affects springtime root extension growth necessary for the good spring start, though it consumes lots of energy (*Zatykó*, 1979). Our results suggest, that fruit set has a similar effect. Higher level of primary fruit set negatively affected sugar and acidic content, but it did not affect fruit weight.

Results of thinning experiments of *Bedfrod & Picering* (1916), *Denne* (1960, 1963), *Sharples* (1964, 1968), and *Goffinet* et al. (1995) also drive attention to, that negative effects of explicit extremities of flowering and primary fruit set on fruit quality and tree condition shall be moderated.

Besides the chemical thinning a convenient regime for this purpose cold be establishment and prevention of conditional- and vegetative-generative harmony of the plantation with logically composed and timed pruning strategy, nutrition and irrigation.

Based on our results (and also on data not published here) we can assume, that foliar calcium values does not change, or its change is negligible due to fitotechnical measures (esp. fruit thinning, summer pruning). In a contrast foliar potassium content is highly more affected by any fitotechnical treatments, and thus its proportion to calcium is greatly affected by fruitload. This should be respected at evaluation of K/Ca indices.

A very important observation was made by *Ferguson* (1980), who stated, that mineral element content of the foliage does not correlate with that of the fruits, thus it is not possible to estimate its storage potential through this way. However, this statement is argued by many scientists (Szűcs *& Kállay*, 1979; *Szűcs*, 2000; *Porro* et al., 2004; *Nagy* et al., 2006; *Holb & Nagy*, 2009), who pinpoint the possibility to elaborate a prediction method, that suggest to give good results on storability, sometimes controversial to conventional field predictions based on tree condition and vegetative-generative harmony.

Thus, some further questions could be given presupposing further experiments. How do fitotechnican treatments (winter or early spring pruning, chemical and/or hand fruit thinning and their timing, severity and timing of shoot selection and summer pruning) alter accumulation of mineral elements into the foliage and/or into the fruits? In this concern, what kind of relation could be observed between the foliage and the fruits? Lastly, how do results of foliar analyses reflect those of fruits, and in relation to the fitotechnical measures what values and proportions do really reflect the optimal physiological state and storability?

References

Bedford, Pickering, S.U. (1916): The fruiting of trees in consecutive seasons. In. Fifteenth Report, Woburn Experimental Fruit Farm, Science and Fruit Growing. Macmillan, London. 132–140.

Denne, M.P. (1960): The growth of apple fruitlets, and the effect of early thinning on fruit development. Annals of Botany. 24: 397–406.

Denne, M.P. (1963): Fruit development and some tree factors affecting it. New Zealand Journal of Botany. 1: 256–294.

Ferguson, I.B. (1980): Movement of mineral nutrients into the developing fruit of the kivifruit (Actinidia chinensis Planch.) New Zealand Journal of Agricultural Research. 23. 349–353.

Goffinet, M.C., Robinson, T.L. & Lasko, A.N. (1995): A comparison of 'Empire' apple fruit size and anatomy in unthinned and hand thinned trees. Journal of the American Society for Horticultural Science. 102: 399–402.

Gonda, I. (1980): A metszés szerepe a gyümölcskötődési folyamatokban. (In: Nyéki, J. (ed.): Gyümölcsfajták virágzásbiológiája és termékenyülése.) Mezőgazdasági kiadó, Budapest, 150–155.

Gonda, I. (1982): Termésbiztonságot növelő metszési módok. Kertgazdaság, 14. (4) 33–40.

Hámoriné, Sz.J. (1974): A gyümölcs fejlődése és érése. In. Gyuró, F. ed.: A gyümölcstermesztés alapjai. Mezőgazdasági Kiadó. Budapest. 369–397.

Holb, I.J. & Nagy, P.T. (2009): Availability of calcium, magnesium, sulphur, copper, zinc and manganese in plant-soil system of integrated and organic apple orchard. Communications in Soil Science and Plant Analysis 40: 531–542.

Hrotkó, K., Magyar, L. & Gyeviki, M. (2007): Alanyok hatása a növekedésre és terméshozásra intenzív cseresznyeültetvényben. „Lippay János – Ormos Imre – Vas Károly" Tudományos Ülésszak előadása, Budapest, 7–8th November 2007.

Jackson, J.E. (2003): Biology of Apples and Pears. Cambridge University Press, Cambridge. 488. p.

Kállay, T. (1994): Amig az alma termékké válik. (In. Inántsy F. ed.: Az almakereskedelem gyakorlati kézikönyve.) Almatermesztők Szövetsége, Budapest, 34–82. p.

Kállay, T. & Szűcs, E. (1980): A kálium és a kalcium fiziológiai jelentősége az alma minőségében. Újabb Kutatási Eredmények. 55–67.

Kállay, T. (2005): Az alma- és körtetárolás technológiája. Érdi Gyümölcs- és Dísznövény Termesztési Kutató-Fejlesztő Kht. tanfolyama, Elvira-major, 8–9th February 2005.

Kállay, T. & Szűcs, E. (2003): Experimental approach in apple tree nutrition. International Journal of Horticultural Science. 9: (2) 9–13.

Lafer, G., Hagg, M., Ahnevainen, R., Evers, A.M. & Tiilikkala, K. (1999): Fruit ripening and quality in relation to crop load of apple trees. In: Agri-Food Quality II: Quality Management of Fruits and Vegetables – From Field to Table. Turku, Finland, (22–25th April 1998) Royal Science of Chemistry, Cambridge. 369–372.

Lakatos, T. (2003): A gyümölcsterhelés hatása az almafák vízfelhasználására. Kertgazdaság, 35/1. 17–25.

Perry, M.S. & Rogers, W.S. (1972): Effects of interstock length and vigour ont he field performance of Cox's Orrange Pippin apples. Journal of Horticultura Science. 47. 97–105.

Porro, D., Ceschini, A. & Pantezzi, T.: (2004): The importance of advisory service in predicting bitter pit using early season fruit analysis. Acta Horticulturae 721.

Preston, A.P. (1954): Effects of fruit thinning by the leaf count method on yield, size and biennial bearing of the apple 'Duchess Favourite'. Journal of Horticultural science. 29: 269–277.

Preston, A.P. & Quinlan, J.D. (1968): Effects of thinning blossom and fruitlets on growth and cropping of 'Sunset' apple. Journal of Horticultural Science. 43: 373–381.

Sass P. (1986): Gyümölcstárolás, Mezőgazdasági Kiadó, Budapest, 487.

Sharples, R.O. (1964): The effect of fruit thinning on the development of Cox's Orrange Pippin apples in relation to the incidence of storage disorders. Journal of Horticultural Science. 39: 224–235.

Sharples, R.O. (1968): Fruit thinning effects on the development and storage quality of 'Cox's Orrange Pippin' apple fruits. Journal of Horticultural Science. 43: 359–371.

Soltész, M. ed. (1997): Integrált gyümölcstermesztés, Mezőgazda Kiadó, Budapest. 843.

Szűcs, E. (2000): Tápanyag-gazdálkodás. (In: GONDA, I. ed.: Minőségi almatermesztés.) PRIMOR Vállalkozásélénkítő Alapítvány Vállalkozói Központ, Nyíregyháza. 186–200.

Szűcs, E. & Kállay, T. (1979): Tápanyagszintek és arányok hatása az almafák termőképességére és tárolhatóságára. Újabb kutatási eredmények a gyümölcstermesztésben. Gyümölcs- és Dísznövénytermesztési Kutató Intézet, Budapest 43–50.

Thiault, J. (1970): Etude de Criteres Objectifs de Qualité Gustative de Pomme Golden Delicious. Cerafer Centre, Interregional, d'Aixen-Provence. Washington Apple Maturity Handbook. (1993) Washington apple maturity program, Wenatchee, WA.

Volz, R.K., Ferguson, I.B., Bowen, J.H. & Watkins, C.B. (1993): Crop load effects on fruit mineral nutrition, maturity, fruiting and tree growth of 'Cox's Orrange Pippin' apple. Journal of Horticultural Science. 68: 127–137.

Westwood, M.N. (1970): Rotstock-scion relationship in hardiness of deciduous fruit trees. Horticultural Science. 5: 418–421.

Zatykó, I. (1979): Az almafák kondícióját és termőképességét befolyásoló tényezők összehangolása. Újabb kutatási eredmények a gyümölcstermesztésben. Gyümölcs- és Dísznövénytermesztési Kutató Intézet, Budapest 7–19.