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"INTERNAL REPORT OF THE INSTITUTE FOR SOIL FERTILITY"

Discussion Meeting on "Bitter Pit in apples"

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Introduction

As a result of an informal discussion at Gorsem on the problems relating to Bitter Pit in apples the feeling arose that it might be worthwhile to organize a discussion on a wider basis. Dr.van der Boon, representing the Institute for Soil Fertility in Haren, took this suggestion home. The result was that the Institute for Soil Fertility undertook the task of organizing the meeting and acting as a host. The International Society for Horticultural Science accepted the sponsorship of the meeting that was held on the 15th and 16th April in Haren (Groningen), The Netherlands.

The basic idea was to convene a meeting in which a rather restricted number of specialists would discuss all problems relating to this important disorder. No papers were to be presented, but facts, figures and opinions were to be discussed.

For this purpose Dr.van der Boon, Dr.van Goor and Dr.Wiersum of the staff of the Institute drew up a list of points to be discussed. Besides that their own comments on these points of discussion were made available to the future participants, who were invited to send in their comments in advance if possible. In this manner the result was that all participants were well prepared as to the procedure to be followed. A list of publications of all participants was also made available and reprints were sent before or could be obtained at the meeting itself.

A provisional list of participants was made up, selecting those research workers that were known to be engaged in research on or related to bitter pit. Geographically the scope was limited to Western Europe. The invited workers were asked to furnish further names to complete our list.

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idem in Acta Hort.nr.16(1970)

The French scientists and a Polish specialist were unable to attend.

The following people ultimately joined in the meeting.

Belgium:

Dr.Ir.H.Clijsters, Opzoekingsstation van Gorsem, Sint-Truiden

Ir.M.Herregods, Komitee voor Onderzoek op de Bewaring van Fruit en Groenten, Vilvoorde

Ir.R.Piot, Bodemkundige Dienst, Heverlee

Ir.W.Porreye, Opzoekingsstation van Gorsem, Sint-Truiden

Dr.T.Trzcinski, Comité national pour l'étude de la culture fruitière, Gembloux

Germany:

Prof.Dr.G.Buchloh, Institut für Obstbau und Gemüsebau der landwirtschaftlichen Hochschule, Hohenheim

Prof.Dr.G.Bünemann, Institut für Obstbau der Techn. Universität, Berlin

Dr.K.Keipert, Landwirtschaftskammer Rheinland, Bonn

Dr.W.Kohl, Institut für Obstbau und Gemüsebau der Universität, Bonn

Prof.Dr.W.D.Naumann, Institut für Obstbau und Baumschule der Techn. Universität, Hannover

Dr.Schmitz, Institut für Obstbau und Gemüsebau der Universität, Bonn

Dr.K.Weissenborn, Obstbauversuchsanstalt Jork

The Netherlands:

Dr.Ir.J.van der Boon, Instituut voor Bodemvruchtbaarheid Haren (Gr.)

A.Das, Ing., Instituut voor Bodemvruchtbaarheid, Haren(Gr.)

Ir.P.Delver, Instituut voor Bodemvruchtbaarheid, Haren (Gr.), seconded to Proefstation voor de Fruitteelt, Wilhelminadorp

Dr.B.J.van Goor, Instituut voor Bodemvruchtbaarheid, Haren (Gr.)

Mr.A.Pouwer, Proefstation voor de Fruitteelt, Wilhelminadorp

Prof.Dr.M.H.van Raalte, Botanisch Laboratorium Universiteit, Groningen

Ir.G.S.Roosje, Proefstation voor de Fruitteelt, Wilhelminadorp

Ir.C.M.J.Sluijsmans, Instituut voor Bodemvruchtbaarheid, Haren (Gr.)

Dr.L.K.Wiersum, Instituut voor Bodemvruchtbaarheid, Haren (Gr.)

Switzerland:

Dr.R,Schumacher, Versuchsanstalt für Obst-, Wein- und Gartenbau, Wädenswill

United Kingdom:

Mr.M.A.Perring, East Malling Research Station (Ditton Laboratory), Maidstone, Kent

The meeting

On Tuesdaymorning, 15th April at 9.00 o'clock the director of the Institute for Soil Fertility Ir.Sluijsmans opened the session. In the first day the discussions were related to bitter pit and calcium supply and content. The second day was allotted to commenting on the aspects of bitter pit, growth and ecological conditions and the problems of storage. The last hour and a half of the second day were spent on elaborating a few ideas on the causes of bitter pit and on the most profitable ways of future research.

Thanks to the fact that all participants avoided elaborate expositions but focussed on facts, data and ideas, it indeed proved feasible to obtain a review of all up to date knowledge and experience on this disorder.

The discussions and their conclusions

A more or less complete review of the comments and discussions will be given for circulation amongst the participants and research workers on bitter pit. A more generalized review has been made for "Acta Horticulturae".

All points of discussion are here given and the conclusions we arrived at. Along with this the main themes of the discussions and facts brought forward will be presented.

Discussion Points

1. Bitter Pit and Calcium

1.1. Spraying with calcium salts

1.1.1. Can complete control be achieved in serious cases and in all years?

Conclusion: No complete control can be achieved in serious cases and in all years by spraying only. Also, its results are not completely predictable. Cox's Orange Pippin reacts much better than James Grieve, a fact which may be related to differences in their skin waxiness. The opinion is, however, that with many sprayings (>10 times) in a season much of the illness can be cured, if other factors such as fruit setting, nutrient level, orchard treatment, a.s.o. are more or less right as well.

Comment:

Perring mentions a back-transport from 1-2 mg Ca out of the fruit in dry summer months, August and September. This extra amount must be supplied by spraying. With 5 sprays a sufficient result was obtained in most years, but not in all. More sprayings are recommended. Naumann concludes that when in spite of the low leaching under dry circumstances the Ca-quantity in the fruit becomes lower, this must be caused by an alteration in Ca uptake and distribution. Schumacher found a strong reduction with three sprayings, f.i. from 73% to 25%. Complete control is possible, if fruit-setting is good. Keipert had an insufficient reduction by ten sprayings of different Ca-salts with Cox and James Grieve in the first year and with young trees. Van Goor obtained with 9-16 sprayings of $Ca(NO_3)_2$ a bitter-pit reduction of 74-93% (0-7% bitter pit in treated plots). He estimates complete control possible if the Ca status of the fruit is not too low in cases of good manuring. Van der Boon indicates that results with Cox's Orange Pippin in The Netherlands are generally good, those with James Grieve being less satisfactory and in some years very disappointing. Van Raalte assumes that no complete curing of any disease is possible. Roosje tells that fungus diseases can be controlled to a 1-2% affected fruits, a similar curing of bitter pit is for practice sufficient and can be called complete. In serious cases such a low level will be scarcely obtained.

1.1.2. What is the most effective salt?

Conclusion: The best results are obtained with $Ca(NO_3)_2$ and $CaCl_2$ solutions, both hygroscopic salts, the latter is possibly somewhat more effective. No agreement could be reached about undesirable side-effects such as leaf scorch. Further research on an equivalent Ca-base of $CaCl_2$ and $Ca(NO_3)_2$ is necessary.

Comment:

Keipert obtained with 0,6% $CaCl_2$ better results than with 0,7% $Ca(NO_3)_2$, $CaCl_2$ gave, however, more leaf damage. Schumacher also found $CaCl_2$ better, both salts giving leaf burning. He is afraid of too much N by using calcium nitrate. Kohl did not find any difference between the penetration of Ca from the two salts. Piot estimates $Ca(NO_3)_2$ to be better than Ca-lactate. Perring said that there was no difference in effect between $CaCl_2$ and $Ca(NO_3)_2$. $CaCl_2$ may be preferable, because $Ca(NO_3)_2$ gives a less good fruit colour, $CaCl_2$ improves the skin quality, but is however slightly phytotoxic. Naumann thinks that it is possible to prevent leaf-scorch by using very small drops in spraying. He suggests early sprayings with $CaCl_2$, late sprayings with $Ca(NO_3)_2$, because late $CaCl_2$ spraying promotes russetting. Cause of the good action of the above mentioned salts is the hygroscopity. Keipert did not find a difference between the two salts on the russetting of Golden Delicious. Bünemann is more afraid of chloride, which can decrease growth and affect the metabolism, than of the extra N of the nitrate.

He asks whether the better results of chloride reported by several authors might be caused by a change in leaf/fruit ratio.

1.1.3. Is Ca penetration a factor? If this is the case, what are the most effective additives:
(1) surfactants
(2) adhesives
(3) penetration stimulators?

Conclusion: It has not been proved that substances exist which increase much the action of spraying of Ca-salts. Wetting agents assist in the application of Ca-salt to the skin, but additives which really stimulate the penetration to any worthwhile extent have not be demonstrated.

Comment:

Kohl mentions his own results and those of Wieneke. Adding of other nutrients to the Ca-spray gave an increase of Ca penetration to 10%. Also mineral oils would probably have some positive effect. Van Goor did not find in research about blossom-end rot of tomatoes any significant positive effect by adding starch and agar as adhesives, dimethyl sulfoxide and the surfactant "luxan". Wiersum says that we must discern between penetration of fruit and of leaf, the permeation through the fruit skin being especially difficult. Kohl says that "anti-stipp", a trade product based on $CaCl_2$, has no better result compared with the equivalent quantity of $CaCl_2$. Naumann: Anti-stipp has the disadvantage of being more expensive. Kohl has found that with a surfactant a more homogeneous spreading and penetration of Ca^{45} happens, the spreader results however in a smaller quantity of penetrated Ca per surface unit. It is assumed that a spraying with the Ca-salts gives an increase of less than 1 µg Ca/g fruit flesh, 10-20% of this penetrates until 1 cm under the skin. In younger apples the penetration is deeper. This was in answer to the question of Wiersum if one can add enough calcium by spraying. Herregods mentions the stimulating action of diphenylamine on the Ca-penetration in post harvest experiments of Martin, his own results were, however, negative. Keipert found more russetting of Golden Delicious with a wetting agent.

1.1.4. What is the best method of application: spraying methods, times, concentration, target: leaf and/or fruit.

Conclusion: There seem to be no large differences between high-volume spraying with about 0,7% $Ca(NO_3)_2$ and low-volume spraying with about 4% of the same salt. Perhaps the concentration can be as high as 35% when certain mineral oils are added and a spray with extremely small droplets is used (100 l/ha). Serious cases can be sprayed weekly during the whole season. As there seems to be little or no transport of Ca from leaf to fruit it is evident that in any case the fruits must be hit. In case of saturation of leaves, some Ca may leach from leaf to fruit. No positive results were obtained by spraying Ca-salts on the bark of the tree in winter.

Comment:

Schumacher found no bitter-pit reduction by leaf application of $CaCl_2$, treatment of the fruits giving less bitter pit and more Ca. The treatment was repeated three times. Kohl: In Bonn no indication was found for transport from leaf to fruit. Perring: Research of Martin indicates a transport of Ca from fruit to wood-parts of the tree. Buchloh found transport of Ca from old to young leaves, interjacent fruits being passed. Naumann asks how it is possible that Ca runs here through the petiole against the transpiration-stream. Wiersum thinks it is possible in the case of "super"-saturation of a leaf with Ca or if the transpiration of the young leaf is larger. In young fruits with thin skin Ca can be supplied via xylem through transpiration, in older fruits the phloem transport is decisive, containing no or little Ca. Naumann has applied calcium nitrate on the bark of tree in winter and spring. The nitrate has been taken up, but the Ca was not transported. Kohl found no penetration of Ca in the bark.

Some experiments about concentration along with spraying method have been done. Clijsters mentions research of Pollet, who used low-volume spraying with 3,5% $Ca(NO_3)_2$ and 200 l/ha. According to Van der Boon one can go to 4%. He supposes high volume spraying is as good as low volume spraying,in both cases the fruit must be thoroughly hit. Kohl thinks it is possible to use 10% $Ca(NO_3)_2$ if the drops don't touch on the leaf surface. He sprays 10 times. Naumann mentions research of Dr.Behlen, who used 35% $Ca(NO_3)_2$ in 100 l/ha with synergid - a mineral oil - in an experiment with three sprayings. The leaching by rain would be less. Kohl thinks that there is then a close contact between mineral oil and the waxy surface-layer. Bünemann states that the possibility of using this high concentration with synergid must yet be evaluated in practice. Weissenborn obtained leaf scorch with repeated spraying in 4 and 10 times concentrated $CaCl_2$. This is in contrast to fungicides.

1.1.5. What is the most effective period for spraying?

Conclusion: In young fruits the penetration of Ca from sprayings is found to be better. Later in the season, however, more spray-fluid stays on leaf and fruit. If one has to choose late sprayings are relatively the most effective; in some cases weekly spraying from June until harvest would give still less bitter pit.

Comment:

Porreye supposes that one has to spray from June until harvest about 8 times. Keipert thinks it is better to spray early frequently and later in the season with larger intervals. Kohl has found in experiments that younger fruits (until 2,5 cm diameter) are more permeable for Ca. It is, however, not proved that this results in a better bitter pit reduction (Van der Boon). Perring says that spraying from late July on gives an efficient control. Adding early sprayings will give yet a better control. The number of sprays seems, however, more important than the time. Naumann supposes that in small fruits much Ca is necessary for the formation of new cell walls. Ca penetration of young fruits is good, but the amount of Ca deposit by spraying is little on account of the small size. Therefore late sprayings on the bigger fruits are necessary to obtain enough Ca in them. Van der Boon found late treatments to be more effective in bitter pit control. This is in accordance with results of Piot and Porreye. Schumacher agrees with this. Spraying 7, 4, 3 weeks before picking gave the same result. Kohl has found that early in the season the Ca content near the core falls rapidly, later there is a more distinct decrease in Ca content of the fruit flesh near the skin. Van Goor found in experiments with many sprayings a regularly increasing effectivity of the sprayings during the season in enhancing the Ca concentration in leaf and fruit. Roosje thinks that theestimation of the number of sprayings is more important than the spreading in time. Clijsters supposes that the less good response of James Grieve can be partly explained by the shorter growth-period.

1.1.6. What are the reasons for lack of response:
1) unfavourable circumstances, time of day
2) losses of calcium by rain.

Conclusion: No conclusive experiments have been done about this question. In general there seems to be quite a number of possibilities to explain lack of response: insufficient Ca-deposit, retarded uptake in dry weather, leaching losses of the deposit by rain, withdrawal of Ca from the fruit. Elaborate data, over which a balance of Ca applied and lost can be constructed, are however, lacking. Further research of the separate factors: rain, light, temperature, humidity on the Ca-uptake by leaf and fruit would be important.

Comment:

Wiersum: Rain gives losses in Ca from the tree. On the uptake factors as air-humidity and light would have an influence, the last being probably positive. Perring: In preliminary experiments it was found that during day-time water, sugars and K have been transported from the fruit. In afternoon Ca may move into the fruit. Van der Boon: Uptake is not only a passive process, stimulated by certain climatic conditions as higher humidity during night, but also an active metabolic process. Thus Oland found enhanced Mg-uptake by leaf at the end of the night. No clear evidence is available about which time is the best for spraying to increase the Ca-uptake.

1.2. Calcium supply of the soil

1.2.1. What correlations between calcium status of the soil, calcium content of the plant and bitter pit have been noticed?

Conclusion: There is no simple relation between calcium status of the soil and calcium content of the plant, nor is there one for calciumstatus of the soil and bitter pit in the fruit. On sandy soil the pH may be a rather good index, but not on clay soils.

Comment:

Trzcinski points to the disharmony between the high nitrogen and potassium applications in the orchard and the neglect of the calcium supply. He found a decrease of the calcium content of the leaf to an amount of 16% in the course of 6 years. Calcium could have been leached out and calcium uptake could have been inhibited by excess of the other nutrients. Yearly 500 kg CaO per ha must be given to answer the demand of the tree.

Rapid growth such as in June and such as stimulated by abundant supply of NPK promotes the competition for calcium. Less calcium reaches the fruits, more reaches the fast expanding shoots (Naumann). Following Perring: high nitrogen applications enhance the potassium content of the fruit.

A soil survey, done by the Landwirtschaftskammer Bonn (Reinken), indicated a decrease of the pH of the soil in the orchards, for the period of 1955 to 1966 from 6,5 to 6,0. The potassium content of the soil, however, increased from 30 to 48 mg K_2O per 100 g dry soil (Keipert).

Naumann did not find a simple relation between the pH of the soil and the appearance of bitter pit. Neither was there any connection with the amount of calcium as percentage of the adsorption capacity of the soil. Kohl: Orchards, high in pH, can show a fair attack of bitter pit. Only nitrogen dressing decreases it, NPK together stimulates the incidence. Piot thinks the interpretation of the pH depends on the texture of the soil. Van der Boon: On sandy soil without free calcium carbonate and with a low adsorption capacity of the soil, determined only by the humus content, the pH of the soil may be a good measure of the orchard's susceptibility for bitter pit. In an experiment on sandy soil a negative correlation was found between bitter pit and the pH: a pH-KCl of 6,0 in the top layer of 0-20 cm is a threshold figure for the health of the fruit. On clay soil there is no relation between the appearance of bitter pit and the pH of the soil. It is also important that the potassium content of the soil is not too high.

1.2.2. What is the best measure of soil calcium, available for the plant?

Conclusion: It is clear that the pH is not a good measure for the susceptibility of the orchard on any soil for the appearance of bitter pit. No clear recommendation could be given for another calcium determination.

Comment:

As already mentioned, neither the pH nor the calcium percentage of the soil on base of the adsorption capacity of the soil did appear to give a good relation in the soil survey mentioned by Naumann.

Wiersum remarks that in most cases the amount of calcium in the soil is more than sufficient for the tree. Potassium and probably magnesium also interfere with availability of calcium for the plant. Possibly the determination of pK-$\frac{1}{2}$pCa will be a good measure, p being the negative logarithm.

1.2.3. Can a critical calcium value in the soil be suggested, would a K/Ca ratio be better or a (K+Mg)/Ca?

Conclusion: It may be supposed that the (K+Mg)/Ca ratio in the soil gives the best relation with the incidence of bitter pit, but no exact figures can be given. Mg in the soil can, but need not correlate with bitter pit incidence. So the pK-$\frac{1}{2}$pCa will have to be the first thing to investigate.

Comment:

Piot points out the fact that a dressing of one nutrient influences the availability of others. Liming induced in the first two years the appearance of bitter pit, and decreased it in the following years. The soil solution should contain at first more potassium and magnesium by exchange phenomena. As another example, magnesium dressing decreased the calcium content of grass on loamy soil. The calcium content of the soil was diminished by enforced leaching. Following Naumann there may be evidence that the magnesium content of the apple fruit is enhanced by $CaCO_3$ supply to the soil.

During 6 years in an experiment of Kohl the high potassium level gave always a high incidence of bitter pit. Supply of $CaSO_4$ increased the first two years the K content of the leaf, being normal again the following years. Then the calcium content of the leaf was increased, also that in the fruit. Potassium dressing increased the incidence of bitter pit, but magnesium supply had an irregular influence. Therefore the determination of the K/Ca ratio in the soil may be better than the (K+Mg)/Ca. Piot had better results with the last mentioned ratio on loamy soil. On potassium fixing soil Weissenborn found high calcium and magnesium contents of apple leaves. Dressing with potassium decreased the high calcium and magnesium figures.

In this connection the findings of Geraldson with blossom-end rot of tomato must also be looked upon as regards the significance of the calcium/total salt content of the soil solution (Van der Boon).

1.2.4. Which fertilizer is most effective in raising the available calcium without disturbing minorelement supply?

Conclusion: It is possible to increase the calcium content of the leaf by different sources: CaO, $CaSO_4$, basic slag, the last two seem appropriate. Results on calcium contents of the fruit are less evident. The use of calciumoxide holds the risk of inducing minor elements deficiency.

Comment:

Following experiences in West-Germany, obtained by Kohl, high doses of "Hüttenkalk" (basic slag): 20.000-30.000 kg/ha resulted in an increase of the calcium content of the apple leaf without an induced deficiency of minor elements or other drawbacks. The calcium content of the fruits did not clearly respond in the first four years. Lime induced

yellowing of leaves in the first year, which could not be prevented by spraying of minor elements. The pH of the soil was changed by lime, but not, or in a far less degree, by using Hüttenkalk. Hüttenkalk contains fair amounts of minor elements, which should become available for the plant, but magnesium does not. The raise in calcium content is slow, the beneficial result of liming, a neglected procedure in fruit growing on account of risk of minor element deficiencies,fails to come for a long time. Clijsters remarks that $CaSO_4$ and $Ca(NO_3)_2$ increase the calcium content of the leaf rapidly. Piot found as the first effect of giving 2000 kg/ha gypsum on sandy soil a stimulated incidence of bitter pit by enhanced potassium availability. In the second year a decrease occurred. Van der Boon indicates, that on soils with a high pH, fertilization with $CaSO_4$ and calciumnitrate as nitrogen dressing must be recommended in case of low calcium status of the tree.

1.3. Analysis of leaf and fruit

1.3.1. Analysis of which part of the plant is most suitable for establishing the relation with bitter pit: bark, wood, leaf, fruit?

Conclusion: The calcium content of the fruit at picking gives the best correlation for appearance of bitter pit. Difficulties occur with sampling and analysis. Contents must be expressed on fresh weight base, percentage of dry matter being given as indirect measure of sugar content. For prediction, leaf analysis earlier in season can give a good indication.

No data are available for the significance of wood and bark analysis.

Comments:

Perring gives results of Sharples. The best correlation was found between bitter pit, developing in storage and the contents in fruit. Because Ca can move out of fruit, leaf content cannot give such a good correlation. The contents in leaf in July can also give an early, rough prediction of bitter pit. Sampling of leaves is easier and with lower error. Clijsters also thinks the mid-July leaf content gives a good indication. Van der Boon supposes leaf analysis gives better results on account of the smaller sampling error. Then Ca content of skin of the fruit follows as measure for pit. Van Goor stresses estimations in samples of equally large apples.

Perring states that it is better to express concentrations in fruit on fresh weight, because dry matter is more specially an index of sugar content. One sometimes finds less reducing sugars in affected fruits. Kohl indicates that the evaluation of contents of pitted areas must be done on a dry weight base. Perring proposes that it is useful to give besides the contents on a dry basis also the percentage of dry matter.

Wiersum asks if the contents in wood and bark can be an indication, because this calcium can partly become mobile.

Naumann does not confirm this. Much calcium being present in bark and leaf-and flowerbuds as calcium oxalate does not prevent the occurrence of bitter pit.

1.3.2. What part of the fruit must be chosen to obtain the best relationship?

Conclusion: The various participants have made estimations for differing purposes and have used many different methods.
For general purposes, such as predicting the appearance of bitter pit in apples from orchards, analyzing whole fruits without seeds seems the best. A random sample from all sites of the tree of at least 20 apples is necessary. For large samples two opposite parts of the apples are taken as a subsample.

Comments:

Although the outer layers of the fruit are lowest in calcium content and the bitter pit appears there mostly, it cannot be recommended to take these, because of the impossibility of standardizing. Besides bitter pit can also occur more in the middle of the fruit (Van der Boon). Schumacher thinks, however, that the skin can be removed uniformly enough with an adequate peeler. Naumann removes the skin of the apple in boiling water and takes 6 cylinders, 1 cm deep in the fruit flesh, at the calyx end of the fruit. Kohl objects that sprayed calcium could not be found.
Perring uses whole fruits without stem and seeds (containing 3% N and much magnesium) for small samples and two opposite sectors of apples for large samples. His sample consists of at least 20 apples of different sizes and from different sites of the tree (height and depth). Bünemann has also good results with taking segments of the fruit.
Van der Boon asks if it is not better to take more samples of different classes of fruit size, because from year to year the mean of the fruit weight varies, and also the appearance of bitter pit. So it may be more convenient to evaluate the value of the calcium content of the fruit over the years, according to size. Another possibility is to take the same fruit class for a certain variety in all years. Perring agrees that it may be a good idea, but would make the work laborious. A drawback of the second possibility is , that the connection with the storage behaviour of the whole fruit sample is lost in practice. Van Goor gives some results of the correlation between Ca in mg per fruit and the percentage of bitter pit. He uses whole fruits (with seeds) of the same size, matching the mean fruit weight, dries them first and does the analysis in the dried fruit powder. Following Perring the calcium content with seeds is 5-10% higher, the error of analysis being increased.

1.3.3. What are threshold values in leaf and fruit in dependence on the point of time in the season and/or fruit size?

Conclusion: Some threshold values are been given, depending on method of sampling and variety. Spraying gives a somewhat different calcium distribution and thus possibly another threshold value. The threshold value depends also on the fruit bearing of the tree and the fruit size.

The threshold value for Cox's Orange Pippin is 5 mg Ca per 100 g fresh weight. For fruit flesh, the value will be 3.4-4.5 mg Ca per 100 g, (K+Mg)/Ca (aeq) must be less than 17.

The leaf calcium in % of dry weight has to be above 1,7%, K/Ca(aeq)<0,65 and (K+Mg)/Ca(aeq) <0,75.

It is desirable to standardize sampling of leaf (time and place) and fruit and subsampling of fruit.

Comments:

Perring mentions the limit of 5 mg Ca per 100 g fresh fruit weight. If calcium level is low, appearance of bitter pit is connected also with K, Mg and P content. With less reducing sugars there would be more bitter pit. The treshold value for a mid-extension leaf Ca(% dry weight) in late August is 1,1%. Schumacher found only a slight attack of bitter pit in apples with 4,9 mg calcium per 100 g fruit without core and 3,2 mg calcium per 100 g fruit flesh (fresh weight basis). Van der Boon mentions 27 mg Ca per 100 g dry weight (± 3,4 mg per 100 g fresh weight) for the fruit flesh. (K+Mg)/Ca(aeq) must be < 17. In the basal extension leaf the calcium content in August must be >1,7%, and K/Ca(aeq) less than 0,65 and the (K+Mg)/Ca(aeq) less than 0,75. The last-mentioned ratio decreases in leaf with time and increases in fruit. Van Goor found hardly any bitter pit in apples of about 155 g weight, when 7,7 mg Ca per total fruit was present. Clijsters remarks that there is a rather good agreement between the values of the different research workers.

Van der Boon states that the treshold values must be refined in dependence on fruit cropping of the tree and fruit size. Large fruits are, according to Perring more susceptible at the same calcium content. Large fruits have normally a lower calcium level. On thinned fruits more bitter pit appears, the fruits being similar or slightly lower in calcium concentration. According to Naumann one finds more sugarsin big apples, which does not agree with the negative correlation between sugars and bitter pit. Herregods states that there can be a correlation with respiration (O_2 uptake/kg fresh weight/24 h). Large apples have a low respiration and much bitter pit. Calcium spraying enhances respiration

A better standardization ofthe analytical methods is felt to be necessary. The methods of sampling and subsampling must be screened (Perring). It is recommended that samples be sent to one good laboratory as a centre to compare analysis figures (Van Raalte).The Laboratory of Soil Chemistry at Wageningen (Ir.Van Schouwenburg) should be asked.

1.3.4. What is the connection of the effect of calcium spraying on bitter pit and the mineral composition of the plant? Is additional uptake regulated by pretreatment level?

Conclusion:In general one believes that with frequent calcium spraying the calcium level can be increased. In ± 10 sprayings one can add 3-4 mg Ca to the fruit. There may be a saturation effect: more sprayings are relatively less efficient. It is desired to find ways to increase Ca-uptake. Research about other apple varieties as James Grieve with a greasy skin seems to be necessary.

Comments:

Wiersum thinks it is important to know more about where the applied Ca arrives at. Van Goor gives some graphs of the increment of Ca in leaf and fruit under influence of many sprayings. In the leaf samples (3th and 4th leaf at base of annual shoots) an addition of about 0,3-0,5% Ca on dry matter was found, and in fruit 3-4 mg Ca per fruit. It is stated that each spraying is not equally effective. It was not possible to connect discontinuities in the curves, relating Ca-increase by spraying with the time in a simple way with the weather conditions. The total amount of calcium in the fruit, was higher than Perring normally finds. Van der Boon thinks there is a saturation effect in the case of many sprayings: more spraying gives more calcium in leaf and fruit with diminishing return.

Perring states that losses of Ca from the fruit must be supplied. He wants further research about the upper limit to which one is able to increase the quantity of Ca in the fruit by spraying. The pit reduction in James Grieve is small. Can penetration of calcium for James Grieve with a greasy skin be further increased?

2. Bitter pit, growth and ecological conditions

2.1. What is the influence of fruit size, and in which degree is it dependent on calcium level?

Conclusion: A tendency for larger fruit to have a lower Ca-content per unit fresh weight is evident and probably this is related to increased susceptibility to bitter pit.

A distinction has, however, to be made to the manner the size has arisen: irrigation, bearing and thinning have different effects, irrespective the Ca content of the fruit. It must be recommended that the effect of thinning periodically during growth should be studied.

Discussions

Kohl found that young, small apples have high Ca contents in the skin and around the core. During growth the Ca level of the core decreases the most rapidly, later the Ca content of the flesh just beneath the skin. The low Ca level, beneath the skin, especially of the large apple indicates the susceptibility for bitter pit. In reply to a question by Van Goor it is mentioned that it has not been possible to establish exact critical levels in dependence on fruit size. In total, large apples may contain more Ca than small ones.

Schumacher points to the fact that distinction must be made between large fruits derived from poor or from high bearing trees.

Perring mentions the fact that the Ca-concentration (mg Ca/100 g fresh weight) of bulk samples (at least 25 apples) always decreases with size, following a hyperbolic curve. But for individual apples the relation may be different. Hand-thinning at blossom time leads to larger apples that are high in dry matter and with similar or slightly lower Ca-concentration. Irrigation also results in larger apples, but with a lower dry matter content and with a higher Ca-content. According to Van der Boon this last point fits in with results obtained by Butijn: bigger apples with less pit by irrigation. His own results were, however, contradictory: more pit, no increased Ca-content.

Results in spraying obtained by Van der Boon show that large fruits remain more susceptible. In experiments with James Grieve later picking reduces bitter pit incidence irrespective of fruit size. In this period there was a rise in Ca content of the leaf, but not in the fruit.

Clijsters stresses the large variability of Ca-content both in fruits of the same variety as between varieties. In this respect Weissenborn brings forward that Cox's Orange Pippin has a low Ca level in the leaf and Golden Pearmain has a high leaf Ca content. Following Schumacher Golden Pearmain has a high incidence of bitter pit. Kohl could not agree to a simple relation between variety susceptibility and mineral composition.

As far as cell size is concerned the preliminary results of Sharples indicate no correlation with bitter pit. Ca-spraying reduces bitter pit equally at all cell sizes (Perring).

2.2. To what extent does leaf/crop ratio influence bitter pit incidence?

Conclusion:

A high leaf/crop ratio results in a high incidence of the disorder. There is good evidence that this can be explained on the basis of competition for water by the leaves, reducing the Ca-supply by means of the xylem to the fruit.

Discussions:

According to Schumacher it is difficult to establish definite relations between bitter pit incidence and leaf/crop ratio. This is partly caused by the variance of this ratio in different regions of the tree. Keipert suggests if it would be worthwhile to use dr.Winter's method to describe the crop-carrying intensity. Although it is a good method. Roosje mentions that its merit in other regions still has to be checked.

A physiological explanation is brought forward by Buchloh to explain the correlation between bitter pit incidence and crop level. That pears and plums have a higher Ca-content in comparison to apples is related to the difference in type of inflorescence and its more exposed place. The resulting higher transpiration brings in more water + Ca over the xylem. As long as the young shoots just emerge with the apple the young fruit is still near the top of the twigs, well exposed and well supplied. Later the young shoot takes practically all transpiration water + Ca, very little still entering the fruit.

The dominance of the supply through the sieve tubes in the rapidly growing fruit is further stressed by Wiersum. He points to the close resemblance of the composition of apple fruits (Perring) and sieve-tube sap of Yucca flaccida (Tammes and Van Die). In this comparison N, P, K, Ca, Mg, S and dry matter are taken into account.

Schumacher concludes by stating that the bad influence of heavy pruning, which stimulates shoot growth and increases bitter pit corresponds with the ideas of Buchloh and general effects of the leaf/crop ratio.

2.2.1. What is the influence of growth regulators?

Conclusion:

The preliminary trials with growth retardants such as Alar and Cyclocel seem to result in an increased Ca-content of the fruits and reduced incidence of bitter pit.

Discussions:

Buchloh has obtained some results with Alar: retarding shoot growth and increasing Ca-content in fruit. This result can be related to the favourable effect of cutting away in summer part of the newly formed shoots as mentioned by Schmitz.

Naumann discusses some results on Ca-uptake and effects of growth retardants. The best uptake of ^{45}Ca was obtained if it was supplied either as chloride or as nitrate, while calciumsulphate and carbonate are less efficient. The highest amounts of Ca are found in the highly transpiring leaves of the young annual shoots.

Three applications of a CCC spray reduced bitter pit as much as 3 sprays of $CaCl_2$. The best effect was obtained in applying CCC and $CaCl_2$ 3 times each or one spray with Alar combined with three sprays of CCC.

The different sprays, however, also influence the yield in one way or the other. The variation in results in these preliminary trials was complicated. Influence on flower bud differentiation must be further investigated.

Much will still have to be investigated before the suggested possibilities can be put into practice.

2.3. How is the incidence of bitter pit connected with picking time?

Conclusion:

The influence of picking time on bitter pit is still uncertain.

Discussions:

Dutch experience shows that late picking may be favourable, but late picking is certainly no sure method. In some years or cases deleterious effects have been found. Late picking and Ca-content of the fruit do not seem to be related.

English experience brought forward by Perring only gives evidence of a favourable effect of late picking in 1 out of 5 years. For Cox's Orange Pippin the influence is slight.

Herregods mentions that effects of picking time seem to be more pronounced in the crop from young trees.

2.4. In what manner does weather effect the occurrence of bitter pit?

Conclusion:

Dry weather in the last period of growth of the fruit is apt to increase bitter pit.

Discussions:

The severity of bitter pit is associated with the occurrence of dry weather from the end of July until September according to Perring. As the amount of rain decreases, the fruits contain less Ca and in very dry years the fruits may even show Ca-loss (1-2 mg Ca/fruit). In a preliminary experiment some of this Ca-loss from apples was prevented by bark-ringing the stem of the fruit two weeks before harvesting.

Naumann has the same experience that under heavy water stress the fruit loses water and that Ca may move out, transported to leaf without return.

According to Schumacher all weather effects, influencing leaf/crop ratio, will be of importance for the disease incidence.

Naumann points out that high humidity of the soil means a higher availability of Ca in the soil. If there is an ample, regular water supply, and transpiration is undisturbed, then a high Ca-uptake occurs. The effect on fruit size may however counteract by reducing Ca-concentration of the fruit.

The effects of rain and irrigation are not necessarily the same according to Buchloh . This may be related to the difference in air moisture-content.

Weissenborn has obtained some evidence that on clay soils more moisture may raise K-content, thus working unfavourably, in other cases Ca-level was increased.

2.5. What are the effects of other constituents of fruit and leaves than Ca on the severity of bitter pit, e.g. potassium, nitrogen, phosphorus, magnesium, sugars and organic acids?

Conclusion:

In general it may be assumed that Ca-level is the main determining factor. The occurrence of bitter pit at a low Ca-level usually increases along with more K and N, while with a high dry matter content of the fruit the disorder tends to decrease in severity. K and organic acids are highly correlated. N-excess leads to accumulation of asparagine, which chelates calcium.

Discussions:

The results obtained by Perring on large numbers of bulk samples suggest 5,0 mg % in the fruit (fresh weight) as a critical level. At Ca-levels of 6-8 mg % hardly any effect of K,N and P can be detected. Below the critical level the incidence of the disorder rises along with an increase in K and N. The influence of P is still questionable, high P-level being found with high K-content. A high dry matter content along with a high sugar content here is correlated with less bitter pit. In the leaves pit is occurring with high levels for K and Mg, high Mg being associated with low Ca. If there is enough Ca in the fruit, the K level can be increased, what is favourable to obtain a higher acidity. Thinning of apples gives a higher sugar content. Questioned on the 5,0 mg % as a critical level Perring replies that 6 mg % would be a still safer margin, but that in many cases 5,0 mg % is still sufficient.

The acid content is highly correlated with the K-content. It is not clear whether the high K or the high acid content is deleterious.

As far as N is concerned Buchloh mentions that if there is a surplus this is converted to amides (asparagine) with an unfavourable effect. Asparagine could chelate a part of the available Ca. So it seems necessary to obtain more information about the detailed occurrence of Ca and its active forms in the cell.

In regard to the organic acids Buchloh remarks that the pitted areas contain more citric and quinic acid and less malic acid. The citric acid could withdraw Ca from metabolism and from the membranes by chelation. Malic acid content increases by K supply. There seem to be quite a number of reactions of secondary influence on bitter pit and no single sequence seems to be dominant.

Following Schumacher a too high sulphate supply increases the citric acid content of the fruit, thus increasing the appearance of bitter pit.

Van Raalte asks if anything is known whether CO_2-assimilation by the young fruit contributes anything worthwhile to dry matter. According to Clijsters young fruit assimilates about as much as it respires.

2.6. What are the effects of orchard treatments (irrigation, fertilizers, cultivation, grass, herbicides, etc.) on the incidence and severity of bitter pit?

Conclusion:

It seems that many treatments affect the crop by means of their influence on fruit growth. Measures leading to a high leaf/fruit ratio should be avoided. Prevention of water shortage acts favourably. In case of grass mulching the K-status should be carefully checked. As regards N a regular supply, without shocks seems important.

Discussions:

In so far as manuring with N is concerned Bünemann stresses that not only the amount, but also the time of supply is important in relation to bitter pit. Especially large variations in N-supply to the tree are unfavourable: N in spring favours Ca-uptake, N-surplus in August is deleterious. A temporary N-excess in the plant stimulates asparagine formation (Buchloh).

Weissenborn agrees that we need more information about the influence of N-supply in different periods and suggests pot experiments to that purpose.

Experience indicates that a repeated application of N is better than one large dose of N according to Naumann. Also urea is not completely comparable to $Ca(NO_3)_2$ sprays.

The suggestion is made, that it would be worthwhile to investigate split nitrogen applications by means of sprinkling. In one experiment less pit occurred by sprinkling 8x times with nitrogen than by dressing at one time in end of March.

Weissenborn mentions that combined spraying with urea and $CaCl_2$ is investigated.

Keipert brings forward that the Office of Health in Western-Germany now officially allows the application of $Ca(NO_3)_2$ sprays.

Schumacher asks whether the possibility exists that the extra N in $Ca(NO_3)_2$-sprays above the nitrogen, released from the grassmulch could be dangerous by upsetting normal N-metabolism in certain periods. Piot answers that the possibility of disturbances would be related to whether the soils are already rich or poor in N.

The grass-strip culture system favours a high incidence of bitter pit. The increase of this disorder in the last few years corresponds with the change to this method according to Weissenborn.

Also Keipert has the idea that the grass-strip culture system by bringing about more superficial rooting in the mulched strips would make the crop more vulnerable, as heavy fluctuations in soil moisture and nutrient content might occur.

In regard to the influence of herbicides no special observations are brought forward.

3. Bitter pit and storage

3.1. Is there a difference in principle between bitter pit on the tree or bitter pit, developing after picking?

Conclusion: There seems to be no principal difference between tree pit and storage pit. Variety, soil type and picking time determine, whether tree pit occurs.

Comment:

Perring distinguishes no principal difference between tree pit such as for Worcester Pearmain and storage pit such as for Cox's Orange Pippin. York spot in the U.S.A. may be an early form, but also may be different because it can be cured not only by sprays of calcium salts, but also by sprays of boron. Bünemann thinks the difference between tree and storage pit is only a matter of showing earlier. Porreye remarks that early ripening varieties are more susceptible for tree pit. By postponing the picking of Cox's Orange Pippin tree pit can occur. Van der Boon mentions that in the Netherlands tree pit is found especially on sandy soils.

There may be some doubt, whether boron plays a role in tree pit. Following experiments of Porreye and Piot boron deficiency leads to pitting, but also to other clearly discernible symptoms. In experiments in the Netherlands bitter pit was decreased of boron at a physiologically suited time in July, spraying before and after that period enhanced the disease (Van der Boon).

with a possibly inhibiting effect on appearance of bitter pit.

3.3. Which conditions are most favourable to obtain low losses during storage?

Conclusion: Rapid cooling immediately after picking is desirable. Controlled atmosphere along with high humidity gives the best results, the last factor being a risk on account of other storage disorders.

Comment:

It is necessary to store the apples immediately after picking at low temperature (Roosje, Herregods). It is better to cool directly at $3^{\circ}C$ than to keep the apples first at intermediate stages according to an experiment of Herregods. Thus the first 14 days at $5^{\circ}C$ gave 27% more bitter pit. Perring finds that in the first period of storage a high air humidity is to be preferred, thus avoiding too high water loss: less bitter pit appears. Later no differences due to humidity can be found. High humidity results in more breakdown and Gloeosporium rotting.

Controlled atmosphere conditions are important. Pouwer recommends 15% O_2 and 5% CO_2, Naumann 15% O_2 and 6% CO_2, Perring 2% O_2 and 0% CO_2 and Herregods 3% O_2 and 3% CO_2.

The susceptibility of the apples to other storage disorders, however, determines the possibility of storing the apples at the best conditions, to avoid the appearance of bitter pit.

3.4. Which results can be obtained by immersion of fruit in calcium salt solutions, possibly with additions of detergents?

Conclusion: With dipping the picked fruit a certain effect can be obtained, but it can in no way replace Ca-spraying. The penetration of calcium in the fruits with dipping is not as good as with spraying.

Comment:

Perring said that Sharples found that immersion for a moment immediately after picking reduced the incidence of bitter pit with 60%. Wetting agent was added. For Cox's Orange Pippin fairly consistent results were obtained, although once there was no effect. Results of spraying with calcium salts were better. Dips in a solution of magnesium salt on one occasion also gave a reduction. Keipert supposes that there can be some change in the properties of the skin by immersion with wetting agent.

Kohl noted no big difference in penetration of calcium in the outer layer of the fruit by increasing the calcium nitrate concentration in the solution from 1 to 10%, nor in the reduction of bitter pit. After treatment the outer layers of the fruit became free of bitter pit, but the inside of the fruit remained affected. Dipping of fruit on the tree showed a much higher penetration of calcium than dipping after picking and also in the case of spraying.

Herregods obtained better results with $CaCl_2$ than with $Ca(NO_3)_2$. Browning of the skin occurred by 2% $Ca(NO_3)_2$, and a little by 1%. Kohl also found some damage of the skin, which was prevented by adding mineral oil.

The addition of diphenylamine had no effect in the experiments of Herregods in contrast to results in Australia and Israel. Penetration was not furthered by diphenylamine and lecithine in the research of Kohl

4. Working hypothesis about the mechanism of bitter pit.

Conclusion: Bitter pit is the result of insufficient active Ca in part of the fruit cells. The low Ca-level in the fruit is first of all the result of an insufficient Ca-uptake by the tree and heavily influenced by the peculiarities of the distribution system and competition in the plant. All measures resulting in a high leaf/crop ratio aggravate the situation. At the cellular level the Ca-deficiency results in membrane instability and disintegration of cytoplasmic constituents. Part of the cellular Ca may be inactivated.

Discussions:

In general there was good agreement concerning the ideas on the manner in which the disorder comes about. The different hypotheses brought forward during the meeting can all be fitted into the above mentioned conclusion and must be elaborated on certain details.

In discussion point 4 Buchloh described his ideas of what happens at the cellular level. Insufficiently active Ca results in unstable plasma membranes. Although Mg can replace Ca, it has no stabilizing effect. As a result of Ca-deficiency pseudovacuoles have been observed and also membrane disintegration. In the main these observations correlate well with those obtained on pre-necrotic cells of tomato fruit with blossom-end rot (Van Goor). Active Ca in the cells can be lowered by the presence of citric acid, which chelates Ca in the vacuole, and also by asparagine. Ultimately even pectate Ca could be released, resulting in maceration of cells.

By Kohl the idea is brought forward to attempt to obliterate the chelating properties of the cell sap, thus enhancing active Ca-content. In this respect attention is drawn to Fetrilon.

In regard to the spraying problems Buchloh stresses the differences in Ca-penetration as related to the waxy layers of the skin. Varieties such as James Grieve with heavy waxy secretions, absorb Ca only slightly even early in the season. K and Mg penetrate the fatty layers much better. Cl stimulates the formation of the waxy layers.

4.1. Which ideas can be developed to further progress in bitter pit research?

The main areas of research on which views were brought forward were spraying, soil Ca studies and distribution.

As far as research on spraying is concerned Wiersum was in favour of not spending much more attention to further improving the method. Spraying often being only partly effective suggests that either the amount applied is insufficient or losses occur. For the uptake by leaves a careful balance should be computed of the amounts applied, the gain and the loss by the leaf. More important, however, is the establishment of the balance for the fruit. There are already certain indications that even several sprays do not apply sufficient Ca on the skin of a single fruit to comply with the amount needed. If this generally holds true further elaborate work on stimulation of the Ca-penetration seems hardly worthwhile for practical purposes.

Kohl can agree with the view taken so long as spraying has to be carried out with low concentrations of Ca. Preliminary trials in which concentrations of $Ca(NO_3)_2$ exceeding 10% mixed with mineral oil have been used, however, warrant further research along these lines. In this manner it might be possible to deposit more Ca on the skin of the fruit, which leaches out with more difficulty.

Along with Bünemann everybody agrees that for practical purposes spraying will have to be recommended as a control measure.

The importance of more study of the soil Ca-status is stressed by Clijsters. The effectivity of different Ca-fertilizers must be better investigated. Bünemann agrees that we need more research on the problem, how to promote Ca-uptake by the plant and investigations on how to obtain a good Ca-supply in the soil.

The fear of inducing disturbances in availability and uptake of some minor elements seems to have restricted fertilizer trials with Ca according to Wiersum. Now, however, new trials have already been undertaken, e.g. in Germany. It seems worthwhile to spend more attention to establishing characteristic soil Ca-values, which will lead to trees with a reasonable Ca-status. Ca-content and pH as such seem to be of no use, and in view of the strong K-Ca interaction in uptake the suggestion is made whether a Ca potential ($pK-\frac{1}{2}pCa$, according to Schofield) might not be of significant value.

Sluijsmans mentions the fact that at the Institute for Soil Fertility it is already being considered whether research on a better characterization of soil Ca would not be necessary, also taking other problems into account.

From a purely physiological viewpoint studies on the required Ca-potential and K-Ca interaction at the root surface should start on either fast-flowing nutrient solutions or on root-spray cultures (Wiersum).Recent developments in the problem of supply of the root now seem to make it possible to translate nutrient solution data into soil characteristics.

For practical purposes Keipert mentions that the predictive value of analysis of soil samples could be improved if samples are taken only in the tree row into account in the case of grass-strip culture.

As it is often difficult to raise the Ca-status of the tree, Naumann suggests that research should concentrate on the problem of Ca-distribution in the tree. From what has already been brought forward earlier it is evident that several measures can lead to a somewhat higher fruit Ca-content.

Taking previously discussed results of preliminary trials into account Wiersum makes a few suggestions. It might be worthwhile to undertake a few experiments on fruit thinning: the thinning being carried out at different stages in fruit development. This to obtain good evidence whether the rate of growth of an apple is not more important than the ultimate fruit size obtained. Trials with leaf removal could both induce slow growth of the fruit and bring about less leaf competition. Furthermore it might be worthwhile to carry out Ca-analysis of the top-leaves of young shoots in wet and dry years to investigate to what extent Ca carried upward in the xylem is already lost by fixation in living cells on the way upward.

According to Van der Boon the influence of climatic conditions could now well be studied in those institutes having controlled growth chambers or hothouses. Study of the influence of transpiration-reducing substances might also contribute to our knowledge.

Roosje stresses the point that the knowledge of how to obtain regular cropping with less pit as a result would be of great advantage. In this respect many practical problems would have to be taken into account.

At the cellular level Bünemann feels that more information on permeability changes should be obtained.

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