UNIVERSIDADE ESTADUAL DE PONTA GROSSA
PRÓ-REITORIA DE PESQUISA E PÓS-GRADUAÇÃO
PROGRAMA DE PÓS-GRADUAÇÃO EM AGRONOMIA

ALEXANDRE POZZOBOM PAVANELLO

COMPARAÇÃO DE MÉTODOS DE RALEIO MANUAL, QUÍMICO E MECÂNICO DE FRUTOS.

PONTA GROSSA
2016

ALEXANDRE POZZOBOM PAVANELLO

COMPARAÇÃO DE MÉTODOS DE RALEIO MANUAL, QUÍMICO E MECÂNICO DE FRUTOS.

Tese apresentada ao Programa de Pós-Graduação em Agronomia – Doutorado – da Universidade Estadual de Ponta Grossa. Área de concentração: Agricultura. Linha de Pesquisa: Fisiologia, Melhoramento e Manejo de Culturas.

Orientador: Prof. Dr. Ricardo A. Ayub

PONTA GROSSA
2016

Ficha Catalográfica
Elaborada pelo Setor de Tratamento da Informação BICEN/UEPG

Pavanello, Alexandre Pozzobom

P337 Comparação de métodos de raleio manual, químico e mecânico de frutos/ Alexandre Pozzobom Pavanello. Ponta Grossa, 2016.
68f.

Tese (Doutorado em Agronomia - Área de Concentração: Agricultura), Universidade Estadual de Ponta Grossa.
Orientador: Prof. Dr. Ricardo A. Ayub.

1.Prunussalicina. 2.Malus domestica. 3.Tecnologias em raleio. I.Ayub, Ricardo A.. II. Universidade Estadual de Ponta Grossa. Doutorado em Agronomia. III. T.

CDD: 634.11

UNIVERSIDADE ESTADUAL DE PONTA GROSSA
SETOR DE CIÊNCIAS AGRÁRIAS E DE TECNOLOGIA
PROGRAMA DE PÓS-GRADUAÇÃO EM AGRONOMIA

CERTIFICADO DE APROVAÇÃO

Título da Tese: **"Comparação de métodos de raleio manual, químico e mecânico de frutos".**

Nome: Alexandre Pozzobom Pavanello

Orientador: Ricardo Antônio Ayub

Aprovado pela Comissão Examinadora:

Prof. Dr. Ricardo Antônio Ayub

Dr. Michael Zoth

Dr. Fernando José Hawerroth

Prof. Dr. Renato Vasconcelos Botelho

Dr. André Amarildo Sezerino

Data da Realização: 10 de junho de 2016.

DEDICATÓRIA

À Deus,
meu grande amigo e parceiro!

À Minha esposa e familiares,
por estarem ao meu lado em todos os momentos desta caminhada.

AGRADECIMENTOS

Agradeço a Deus, patrão velho, pela saúde, pelas bênçãos e me iluminar todos os dias. Pela sabedoria no desenvolvimento deste trabalho.

À minha esposa Cristina, pelo amor, companheirismo, parceria, paciência e ajuda no desenvolvimento do trabalho.

Aos meus Pais, Ítalo, Rosani e meu irmão Guilherme e toda família pelo amor, apoio e incentivo aos estudos.

In memoriam ao meu querido avô Olindo Pozzobom que sempre me incentivou no desenvolvimento de trabalhos e pesquisas com frutíferas.

Ao sogro Evaldo e sogra Inês, pelo amor, incentivo aos estudos e por proporcionar os colaboradores e o material necessário para o desenvolvimento de parte deste trabalho.

Ao amigo Gilmar Boff, pela amizade, confiança e apoio durante o trabalho.

Ao amigo e professor Ricardo A. Ayub, pela paciência e ideias que vieram a contribuir muito para o desenvolvimento do trabalho.

Aos amigos Michael Zoth, Andreas Riehle e Daniel Neuwald e aos demais colaboradores do instituto KOB-Alemanha, pela ajuda, paciência, confiança e ensinamentos no desenvolvimento dos trabalhos realizados na Alemanha.

Ao amigo Hendrik Slaney pela ajuda na correção da parte escrita em inglês deste trabalho.

À Universidade Estadual de Ponta Grossa, aos professores e ao Programa de Pós Graduação em Agronomia, pelas disciplinas ministradas durante o curso.

À Coordenação de Aperfeiçoamento de Pessoal Nível Superior (CAPES) e a Fundação Araucária, pela concessão da bolsa de doutorado e a bolsa do projeto desenvolvido na Alemanha.

Aos colaboradores do Pomar Campos Floridos, pela disposição e ajuda nas avaliações a campo.

Todos que de uma forma ou de outra contribuíram para o desenvolvimento desta pesquisa e para conquista do título de Doutor em Agronomia.

RESUMO

PAVANELLO, A.P. **Comparação de métodos de raleio manual, químico e mecânico de frutos.** 2016. 68 p. Tese (Doutorado em Agronomia) – Universidade Estadual de Ponta Grossa. Ponta Grossa, 2016.

A colheita de frutos com qualidade proporciona ao produtor agregar valor na venda da fruta. Realizar o raleio dos frutos de maneira eficiente é uma das práticas que proporcionam ao fruticultor melhorar a rentabilidade na produção. Devido as frequentes chuvas de granizo no período de produção de frutas, alguns fruticultores optam por implantar telas antigranizo. Neste contexto, os objetivos deste trabalho foram avaliar os efeitos do raleio químico e mecânico em ameixeira e do raleio manual, químico e mecânico em macieiras sobre diferentes telas antigranizo. Para os raleios em ameixeira, os tratamentos com raleio mecânico foram mais eficientes comparados aos tratamentos com raleio químico. O raleio mecânico reduziu o pegamento de frutos, o número de frutos e a produtividade. Entretanto, proporcionou aumento no tamanho e peso dos frutos e maior crescimento vegetativo, o que pode evitar a alternância de produção. Para o raleio em macieiras, o raleio mecânico foi o mais efetivo. Para o tratamento com benziladenina, foram necessárias mais de 300 horas por hectare de raleio manual para alcançar um raleio eficaz. A utilização de tela preta proporciona redução na coloração vermelha dos frutos de maçã. O Valor da Eficácia do Raleio (VER) para o tratamento com raleio manual foi de 93%, com raleio mecânico de 74%, com raleio químico Metamitron de 62% e o raleio químico Benziladenina 54%.

Palavras-chave: *Prunus salicina. Malus domestica.* Tecnologias em raleio.

ABSTRACT

PAVANELLO, A.P. **Comparison of hand, chemical and mechanical thinning methods for fruit.** 2016. 68 p. Tese (Doutorado em Agronomia) – Universidade Estadual de Ponta Grossa. Ponta Grossa, 2016.

The harvest of fruits of high quality provides increased market value for the fruit grower. A effective fruit thinning is of the most important steps to provide good commercialization. The increased occurrence of hail storms during the growing period resulted in the installation of protective hail nets. This study aimed to evaluate the effects of chemical and mechanical thinning in plums and hand, chemical and mechanical thinning in apples for different hail nets.. For thinning in plums, mechanical thinning was more efficient when compared to chemical thinning. The mechanical thinning treatment reduced fruit set, number of fruit per tree and yield, however it increased fruit size, fruit weight and promoted higher vegetative growth, an important factor to avoid alternating production every year. For apple thinning, mechanical thinning was an effective fruit thinner. It was observed that some treatments like CT-BA required around 300 hours or more per hectare of hand thinning to achieve a satisfactory thinning efficacy. The black hail nets showed a reduction in red colour in apples. The thinning efficacy value (TEV) for hand thinning was 93%, for mechanical thinning was 74%, for chemical thinning with Metamitron was 62% and for chemical thinning with Benzyladenine was 54%.

Keywords: *Prunus salicina. Malus domestica.* Thinning technology.

LISTA DE FIGURAS

CAPÍTULO I

LISTA DE FIGURAS

CAPÍTULO II

LISTA DE TABELAS

CAPÍTULO II

SUMÁRIO

INTRODUCÃO

O Brasil é um dos três principais países em produção de frutas. Em 2014, a produção brasileira de maçãs foi de 1.378.617 toneladas em 37.121 hectares. Em 2013, a produção de ameixa no Brasil foi estimada em 42.000 toneladas (ANDRADE, 2013; CHAGAS, 2008).

Atualmente, para se comercializar frutas '*in natura'*, a qualidade, é o principal fator para se obter sucesso. Entretanto, a qualidade de frutos é determinada por várias características, incluindo, cor, sanidade, sabor e tamanho.

Uma das principais práticas do manejo cultural para a produção de frutos de qualidade é o raleio. Entretanto, essa prática exige grande quantidade de mão de obra qualificada, refletindo significativamente na elevação do custo de produção (NACHTIGAL; KERSTEN, 2010).

Para ajustar a carga de frutos em fruteiras de clima temperado podem ser utilizados o raleio manual, mecânico ou químico. No entanto, como há incertezas sobre a disponibilidade e o custo viável da mão-de-obra para o raleio manual, é necessário foco em pesquisas direcionadas a alternativas de métodos de raleio químico e mecânico (MCARTNEY; OBERMILLER, 2012).

Devido a um aumento na ocorrência de chuvas de granizo durante o período de produção de frutas no campo, tem resultado na instalação de telas antigranizo com as cores branca e preta, objetivando proteger o pomar e as frutas dos danos de granizo (BIAMONETE et al., 2015).

Cobrir o pomar com tela pode proporcionar mudança no microclima e reduzir a interceptação de luz, assim podendo causar consequências negativas na qualidade das frutas. A tela tem apresentado diferença em alguns aspectos ligados ao sistema de produção. No entanto, segundo Amarante et al., (2009) que estudou os efeitos das telas antigranizo nos pomares de macieira, apresenta que os resultados dependem da cor e espessura da tela, variedade, densidade de plantio, vigor das plantas, manejo do pomar e o clima da região produtor. Com isso, mais estudos sobre os efeitos entre as telas antigranizo e a produção devem ser realizados.

OBJETIVOS

Gerais

Avaliar:

- Métodos de raleio químico e mecânico em ameixeiras;
- Métodos de raleio químico, mecânico e manual em macieiras.

Específicos

- Desenvolver tecnologia de raleio químico e mecânico para ameixeiras Europeias;
- Desenvolver tecnologia de raleio químico, mecânico e manual para diferentes variedades de macieiras;
- Avaliar os efeitos no raleio e na produção da utilização de diferentes tipos de telas antigranizo;
- Avaliar os efeitos, resultados, vantagens e desvantagens de cada fator dentro do sistema de produção.
- Reportar experiências e informações sobre a produção de frutos de maçã e ameixa na Alemanha.

CAPÍTULO I

CROP LOAD CONTROL TO IMPROVE FRUIT QUALITY IN PLUMS

ABSTRACT

The crop load of European plums must be adjusted to achieve high quality with adequate size and colouring to agree with market requirements. The present study investigated the effects of different methods of thinning, both chemical and mechanical, alone and in combination, using various chemical thinning agents at different phenological stages of plum growth in southern Germany. The following thinners were tested: mechanical thinning, chemical thinning with Ammoniumthiosulfate - ATS, Ethephon, Prohexadione-Calcium and Gibberellin. Mechanical thinning treatments significantly decreased fruit set, number of fruits per tree and yield, although it did increase fruit size and fruit weight compared to the control plants. Among the chemical treatments no effects were observed for chemical thinning treatments compared to the control plants. However, Ethephon presented reduced results for fruit set and increased fruit size compared with control plants. Another factor that we take into consideration is that the plum plants used in this experiment were young specimens with reduced productive capacity, therefore by evaluating yield with mechanical thinning they show a satisfactory production.

Keywords: *Prunus domestica*. Mechanical thinning. Chemical thinning. Fruit set.

INTRODUCTION

Fruit trees bear an abundance of flowers, but they cannot retain then all until fruit ripening. Nevertheless, nearly 7% of flowers are necessary in apple trees for a commercially profitable harvest (UNTIEDT; BLANKE, 2001) while approximately 20-25% of flowers are needed in peach trees (COSTA; VIZZOTO, 2000).

Many fruit species require a reduction of fruit load to reach a vegetative and reproductive balance, normally this objective is attained through fruit thinning methods. This operation is performed yearly, mainly in stone-fruit and pome-fruit species (COSTA; BLANKE, 2013).

Fruit thinning helps to achieve high quality fruit with adequate size and colouring for class one marketing; to overcome alternate fruit bearing by providing regular moderate yields and higher sugar content and pulp firmness as a parameter for good storability (SEEHUBER et al., 2011).

Nevertheless, the adoption of hand-thinning by farmers will progressively diminish due to shortage of labour and increasing labour cost (AHRENS et al., 2014). The commercial criterion for Japanese plum fruit thinning is the regular distribution of fruit at 15-20 cm apart on the branches (GONZÁLEZ-ROSSIA et al., 2006).

Hand fruit thinning is one of the most labour-intensive, costly practices for peach growers, often costing as much as US$ 2,470 per hectare (MILLER et al., 2011) and US$ 3,705 in California (BAUGHER et al., 2009). In Canada, hand thinning can require between 100 – 150 hours.ha^{-1} depending on tree vigor, age, size, and fruit set, resulting in an estimated cost of about US$ 1,235 ha^{-1} per year (TAHERI et al., 2012).

Chemical thinning has long been established, but the choice of registered chemical products drastically diminishes in many countries. The efficacy of the few remaining products such as: (Lime Sulphur, Ammoniumthiosulfate (ATS), Ethephon (Ethrel), and Benzyladenine (BA)) are dependent on air temperature, cultivar, flowering dynamics and tree age (BANGERTH, 2000; SEEHUBER et al., 2013; PAVANELLO; AYUB, 2014).

Among these products, ATS is the only remaining chemical allowed in Germany, registered as a foliar fertilizer, but not for fruit thinning. Carbaryl cannot be used in almost every country and Naphthyl acid (NAA/NAAm) has been banned in many European countries, including Germany (DAMEROW; BLANKE, 2009; SEEHUBER et al., 2013). Futhermore, while pome fruits are relatively easy to thin, stone fruits fail to react to chemical thinning with lime sulphur and NAA (SEEHUBER et al., 2011).

According to Zhang and Whiting (2011) an alternative approach to thinning to improve source-sink balance and fruit quality is manipulating source-sink activity with exogenous plant growth regulators, such as Prohexadione-Ca and Gibberellins.

Gibberellins, such as GA_3, GA_4 and GA_7 has been applied in apples, peaches, nectarines and plums for fruit thinning and fruit quality (EROGUL; SEN, 2015). Gibberellins are thought to move from the fruit to the nearby nodes, where they inhibit the initiation of new floral primordial is which usually initiated about 6-8 weeks after fruit set (WEBSTER; SPENCER, 2000).

Prohexadione-calcium (calcium 3-oxido-4-propionyl-5-oxo-cyclohexene carboxylate, ProCa), an inhibitor of Gibberellins biosynthesis, showed potential for manipulating flower density and reducing seasonal vegetative extension growth in sweet cherry and apple (ELFVING et al., 2003).

The inactivation of exogenously applied GA_3 and GA_4 by 2β-hydroxylation can be inhibited by simultaneous treatment with ProCa, resulting in increased GA-like activity (NAKAYAMA et al., 1990). The hypothesis that applications of ProCa plus GA_3 or GA_4 increase the concentration of $GA_{4/7}$ and GA_3 in fruit mesocarp tissue, which promotes cell enlargement, a critical component of final fruit size in sweet cherry (OLMSTEAD et al., 2007).

According to Guak et al., (2001), an application foliar of $GA_{4/7}$ to the prohexadione-calcium-treated plants one day later restored elongation growth to a level even exceeding the control without any lag phase in growth.

Mechanical blossom thinning could be a solution, allowing the reduction of the chemical impact on the environment (GREENE; COSTA, 2013; WEBER, 2013). Mechanical blossom thinning is a new environmentally friendly technology and an alternative to the standard chemical blossom thinning and is suitable for both integrated as well as organic fruit cultivation (SOLOMAKHIN; BLANKE, 2010).

According to Baugher et al., (2009), mechanical thinners diminish peach crop load up to 36% and may decrease follow-up hand thinning time by 20% to 42%. The net economic impact (economic savings) of mechanical thinning versus hand thinning ranged from US$ 175 to 1,966 per hectare.

Numerous mechanical approaches have been attempted including limb and trunk shakers, rotating arms in the canopy and manually hitting limbs. There were varying degrees of success but no one method has been commercially adopted on a wide scale. The new technology recently made available, named the 'Darwin machine' appears to show real promise for more widespread commercial use (BAUGHER et al., 2010; MILLER et al., 2011; SCHUPP et al., 2011).

The 'Darwin machine' is consisted of a tractor-mounted frame with a 2.0m tall vertical spindle in the center of the frame. Attached to the spindle were 24 bars with 9 strings on each one, securing total of 216 plastic injection strings measuring 60cm long. The speed of the clockwise rotating spindle is adjusted with a hydraulic motor and the height and angle of the frame is adjustable to conform to the vertical inclination of the tree canopy, and the intensity of thinning is adjustable by tractor speed and rotation speed of the spindle (Figure 1) (JOHNSON et al., 2010; FRUIT TEC® COMPANY, 2016).

Figure 1. Darwin Machine, Fruit Tec® (Bavendorf, Germany, 2014)

Miller et al., (2011), reported removal of 30% to 46% flowers by a mechanical string thinner in peach trees. Furthermore, reduced crop load and time required for follow-up hand thinning compared with hand thinning alone. Weber (2013) verified significant reduction in hand thinning labour near to half when using the association of chemical (ATS and Ethephon) and mechanical thinning.

The main objective of this study was to evaluate the response of different methods of thinning, both chemical and mechanical, alone and in combination, using various chemical thinning agents at different phenological stages of plum growth in southern Germany.

MATERIALS AND METHODS

Field Conditions

The experiment was carried out in a experimental orchard at Competence Centre For Fruit Growing at Lake Constance (KOB) in Bavendorf, South Germany. The four-year-old ´Katinka´ plum trees (*Prunus domestica* L.), were grafted on Wangenheim/Wavit, spaced in 4.0m x 2.1m and conducted in a spindle system (Figure 2).

Figure 2. ´Katinka´ plum trees (Bavendorf, Germany - 2014).

Treatments

The following thinners were tested: mechanical thinning with the Darwin-200 machine (Fruit Tec®, Germany); Chemical thinning with Ammoniumthiosulfate - ATS (15% Nitrogen (Total - N), 67% Ammonium NH_4 and 22% Sulfur) - (Agro-N-Fluid Plus, Proagro®, Germany), Ethephon (Flordimex® 420, Spiess-Urania, Germany), Prohexadione-Calcium – 10% ProCa (Regalis®, BASF, Germany) and Gibberellin - 1% $GA_{4/7}$ (Novagib®, Fine Agrochemicals, UK), all sprayed with 1000 litres of water per hectare. The experimental design was in completely randomized block with sixteen treatments and three or four plots per treatment and one tree per replication.

The treatments were applied as follow:

1. Unthinned control (Untreated);
2. Mechanical thinning;
3. Mechanical thinning followed by chemical thinning with one sprayed with ATS 1.0% ig in full bloom;

4. Mechanical thinning followed by chemical thinning with one sprayed with ATS 2.0% ig in full bloom;
5. Mechanical thinning followed by chemical thinning with one sprayed with ATS 1.5% ig in early fruit stage (+- 1.0 cm length);
6. Mechanical thinning followed by chemical thinning with one sprayed with ATS 1.5% ig at middle fruit stage (+- 1.5 – 2.0 cm length);
7. ATS 1.0% ig in full bloom;
8. ATS 2.0% ig in full bloom;
9. ATS 3.0% ig in full bloom;
10. ATS 1.5% ig in early fruit stage (+- 1.0 cm length);
11. ATS 1.5% ig in middle fruit stage (+- 1.5 – 2.0 cm length);
12. ProCa 150 $mg.L^{-1}$ + $GA_{4/7}$15 $mg.L^{-1}$ thirty days after full bloom;
13. ProCa 250 $mg.L^{-1}$ + $GA_{4/7}$ 25 $mg.L^{-1}$, thirty days after full bloom;
14. Ethephon 100 $\mu L.L^{-1}$, thirty days after full bloom;
15. ProCa 150 $mg.L^{-1}$ + $GA_{4/7}$15 $mg.L^{-1}$, forty days after full bloom;
16. ProCa 250 $mg.L^{-1}$ + $GA_{4/7}$ 25 $mg.L^{-1}$, forty days after full bloom;

The mechanical thinning was performed with a tractor at 6 $km.h^{-1}$ and 200 rpm with fifty percent strings (meaning soft, ZOTH (2011)) was used in full bloom (BBCH Scale 65, MEIER, 2009) on April 02, 2014. The chemical products were sprayed with a manual machine.

Evaluations

1) **Fruit set (%):** two branches were selected per tree and 200 flowers were counted for each one. After the June drop the number of fruits on each branch was counted, and the percentage of fruit set was estimated.
2) **Fruit retention:** In the commercial harvest (July 21, 2014), the fruits of selected branches were collected and the fruits were counted and weighed.
3) **Yield (kg ha^{-1}):** Each plant was totally harvested and all the fruits were weighed and counted.
4) **Fruit quality:** average fruit weight, diameter and fruit firmness was recorded from twelve fruits randomly collected from each tree. Firmness was measured using a nondestructive device FirmTech II (BioWorks, Wamego, KS, USA).

5) **Production per Trunk Cross Sectional Area (TCSA):** Trunk tree diameter was measured twenty centimeters above graft point and the number and weight of fruits per trunk cross sectional area was calculated.
6) **Yearly vegetative growth:** Strength of growth was measured using a visual rating scale: (1 = very weak; 3 = weak; 5 = medium; 7 = strong; 9 = very strong) and estimated during fruit development (BBCH Scale 91, MEIER, 2009).

Results were statistically processed using analysis of variance, *t* test and Bonferroni test at a 95% probability level for significance, using IBM® SPSS® Statistics 21 statistical software (IBM, Armonk, USA).

RESULTS

Mechanical thinning treatments associated or not to chemical treatments with ATS, significantly decreased fruit set compared to the control (Fig 1). No effects were found for the majority of chemical treatments. Ethephon 200 $\mu L.L^{-1}$ applied at full bloom presented intermediary values for fruit set, without significant differences compared to mechanical thinning. Mechanical thinning was the most effective treatment with reduction in fruit set near to 20%.

Mechanical thinning significantly decreased the number of fruits per tree at harvest reducing 80% of total fruits per tree compared to control plants (Fig 2). Almost all mechanical thinning treatments associated with chemical thinning also presented the same effect, except for the use of ATS 1.5% applied later (fruits with 1.75 cm). Among the chemical treatments, only the application of Pro-CA + $Ga_{4/7}$, 45 DAFB significantly decreased the number of fruits, with a reduction of 65% in total fruits per tree compared to control plants. It was observed the same result for the number of fruits per TCSA.

Mechanical thinning treatments associated or not to chemical treatments with ATS, and the ethephon 200 $\mu L.L^{-1}$, significantly increased fruit size compared with control plants (Fig 3). All these treatments did not present differences in response, increasing fruit diameter up to 20%. Fruit size is an important requirement for commercialization of plums. In general, the minimum diameter/weight in the international market is 30mm / 20g.

Mechanical thinning was also effective for increasing fruit weight, either associated or not to chemical thinning with ATS, compared with the control treatment (Fig 4). For these treatments, the increment was up to 72%, and no effects were observed for chemical thinning treatments. It was observed the same result for weight of fruits per TCSA.

Mechanical thinning treatments were the only ones that significantly decreased the yield of ‘Katinka’ plum trees compared to control plants (Fig 5). Moreover, no differences were found between mechanical thinning and the majority of the treatments with chemical thinning agents. Yield of mechanical thinning plants was almost one-third compared to control treatment.

For variable firmness of fruits, thinning with mechanical treatments showed a tendency for lower fruit firmness, and exhibited a lower number of fruits per tree as well bigger fruits with less firmness (Fig 6).

Mechanically thinned plants, associated or not to chemical treatment with ATS, significantly showed more branches than the other treatments, except for ATS 2% and ethephon 200 $\mu L.L^{-1}$ (Fig 7).

DISCUSSION

According to Sauerteig and Cline (2013), the percentage of removed flowers increased linearly proportionally to the mechanical thinning intensity in peach trees removing 42-75% of flowers. In a trial with chemical thinning in ‘Victoria’ plum trees, Meland (2007), reported reduction in crop load and improvement of fruit quality with the applications of ATS 1.5%, or ethephon 250 $\mu L.L^{-1}$ at full bloom or NAA 10 $mg.L^{-1}$ + Ethephon four weeks after bloom. Similar results were observed in ‘Opal’ plum trees by the application of ATS 1% or Lime Sulphur 5% at full bloom.

Furthermore Taheri et al., (2012), in a trial with Ethephon and AVG in ‘Redhaven’ peach trees, applied at 30 DAFB, observed linear decrease in fruit set the increase of ethephon concentration (0 – 400 $\mu L.L^{-1}$) and significantly reduced fruit set compared to the control and AVG treatments. At this phenological stage for AVG, perhaps elevated concentrations of ethylene-mediated synthesis of polygalacturonase enzymes had already been initiated in the fruit abscission zone.

Similarly to the present results, Seehuber et al., (2011) reported reduction in number of fruits with a concomitant enhancement of fruit growth in ‘Ortenauer’ plum trees submitted to mechanical thinning. Sauerteig and Cline (2013) also verified in peaches cv. ‘All-star’ a linear reduction in the number of fruit harvested per tree and fruit size with increasing speeds in mechanical thinning rotor, using a Darwin (Fruit Tec®) machine.

In Japanese plums (*Prunus salicina*) some authors also verified increase in fruit size by the application of Ethephon 30 DAFB (PAVANELLO; AYUB (2012); PAVANELLO;

AYUB (2014)). Compared to the other authors who achieved good results in plums, peaches and cherries, no effects were observed for chemical thinning treatments. Although Ethephon presented reduced results for fruit set and increased fruit size compared with control plants.

In contrast with our findings, Meland (2007) reported an increase in fruit weight of plums cv. Victoria by the application of chemical thinning agents. Such as, Armothin® (Ethyl alkylamine) 1%, ATS 1.5%, NAA 10 $mg.L^{-1}$ + Ethephon 75 $\mu L.L^{-1}$ and Ethephon 250 $\mu L.L^{-1}$. Interestingly, the combination of ProCa + $GA_{4/7}$, sprayed 30 days after anthesis, improved fruit weight by about 15% in sweet cherry plants (ZHANG; WHITING, 2011).

The reduction in production and number of fruits per plant brings benefits such as, increase in fruit size and weight, balances and assimilate distribution between vegetation and production. As a result, the plant can distribute energy to the developing fruit and branch formations, preventing alternating yields. Another factor that we took into consideration was that the plum plants used in this experiment were young plants with reduced productive capacity, therefore by evaluating yield with mechanical thinning this showed a satisfactory production.

In contrast Taheri et al., (2012) reported reductions in yield in the ‘’Redhaven’’ peach trees treated with ethephon proportionally to the increases in concentration of the treatment applied. The treatments with ethephon significantly reduced the yield per tree compared to the control and AVG treatments, where increasing concentrations of ethephon was linearly associated with reduced yield per tree.

Treatment 3 (MTsoft + 1% FB) for various parameters evaluated compared to the other treatments with mechanical thinning had a tendency to give a higher rate of fruit set, higher number of fruit per tree and also had a tendency for a greater fruit mass and yield per tree, showing that low concentration of ATS may have fertilization effects, unlike the chemical thinner.

Treatment 14 (Ethephon), presented reduced results for fruit set, however, in the other assessments of size, number of fruit per tree, and mainly fruit mass, this had no significant results not differing from the control results.

Taheri et al., (2012), determined that firmness was significantly influenced by the ethephon which resulted in softer fruit. In contrast, Zhang and Whiting (2011), in sweet cherry, with a combination of ProCa + $GA_{4/7}$, sprayed 30 days after anthesis, improved fruit firmness from 245 g/mm in untreated control to 280 g/mm.

Mechanically thinned plants showed more branches than the others treatments, these findings suggested lower number of fruits per tree, promoted better nutrients and carbohydrates distribution between stems and fruit, and allowed growth of new branches, important for the next season of fruit production. Furthermore, broken branches were observed in plants with excessive fruit set. In contrast, Zhang and Whiting (2011), in sweet cherry plants, with a combination ProCa + $GA_{4/7}$, sprayed 30 days after anthesis, reduced vegetative vigor and current season extension shoots were less than half the length of untreated extension shoots after terminal buds set.

In apples, an application foliar of 200 $mg.L^{-1}$ $GA_{4/7}$ to the 250 prohexadione-calcium-treated plants one day later restored elongation growth to a level even exceeding the control without any lag phase in growth (GUAK et al., 2001). Differently to our findings, 15-25 $mg.L^{-1}$ $GA_{4/7}$ was used and did not show significantly more branches than the other treatments.

CONCLUSION

- Mechanical thinning was more efficient when compared to chemical thinning.
- The MT treatment reduced fruit set, number of fruits per tree and yield, however, increased fruit size and fruit weight and promoted higher vegetative growth, an important factor to avoid biannual bearing.
- No effects were observed for chemical thinning treatments.
- Ethephon presented reduced results for fruit set and increased fruit size compared with control plants.
- This was the first year in which the experiments were carried out with mechanical thinning.

FIGURES 1-7

Fig 3. Effects of thinning on fruit set in 'Katinka' plums (Bavendorf - Germany, 2014). Two branches were selected per tree and 200 flowers were counted for each one. After the June drop the number of fruits on each branch was counted, and the percentage of fruit set was estimated. Vertical bars represent standard errors. The letters mean the difference between treatments with Bonferroni test at 95% probability level for significance.

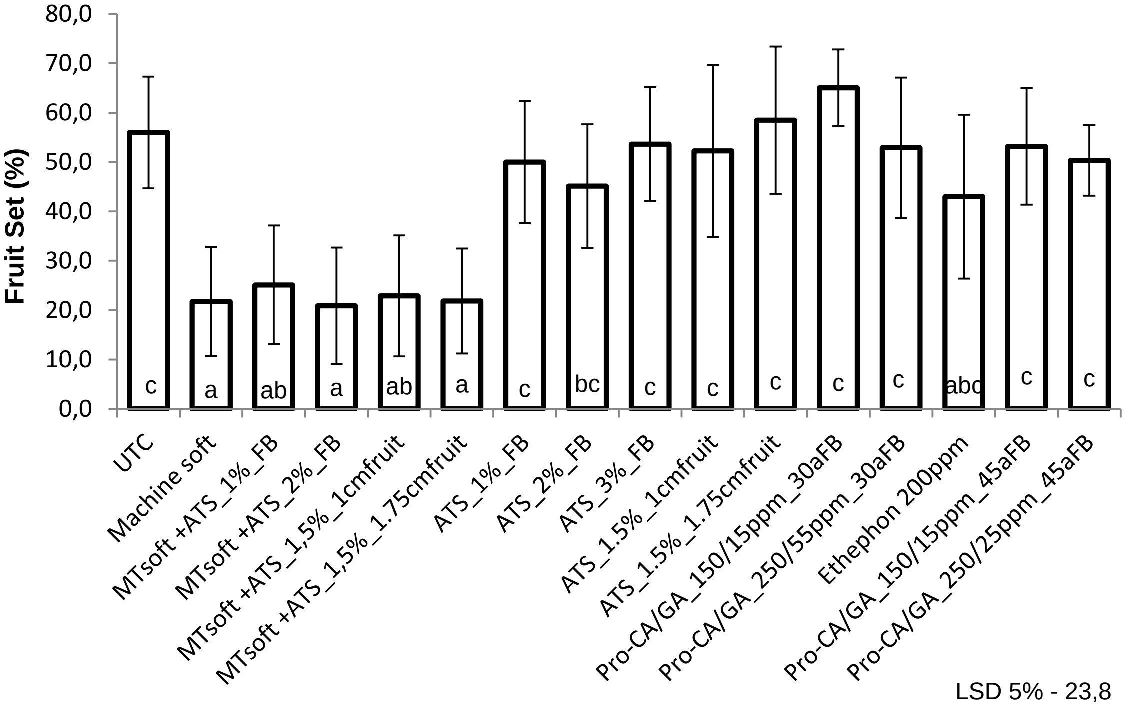


Fig 4. Effects of thinning on total number of fruits per tree in ‘Katinka’ plums (Bavendorf, Germany, 2014). Each plant was totally harvested and all the fruits were counted. Vertical bars represent standard errors. The letters mean the difference between treatments with Bonferroni test at 95% probability level for significance.

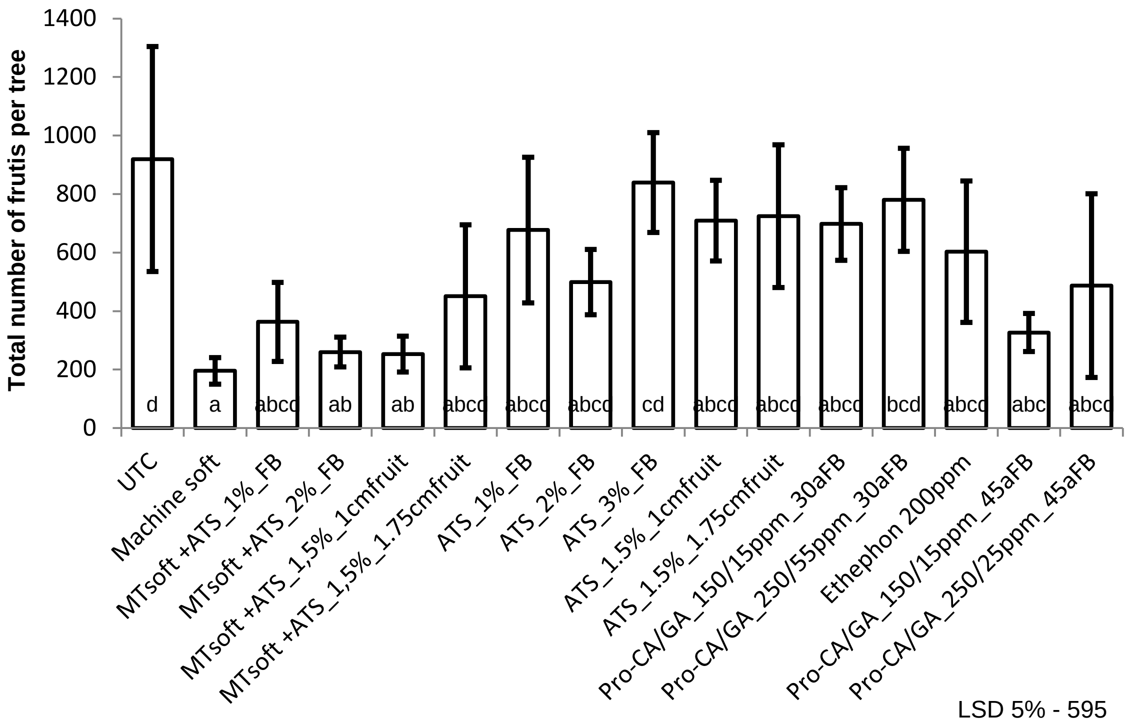


Fig 5. Effects of thinning on fruit size in 'Katinka' plum (Bavendorf - Germany, 2014). The diameter was recorded from twelve fruits randomly collected from each tree. Vertical bars represent standard errors. The letters mean the difference between Bonferroni test at 95% probability level for significance.

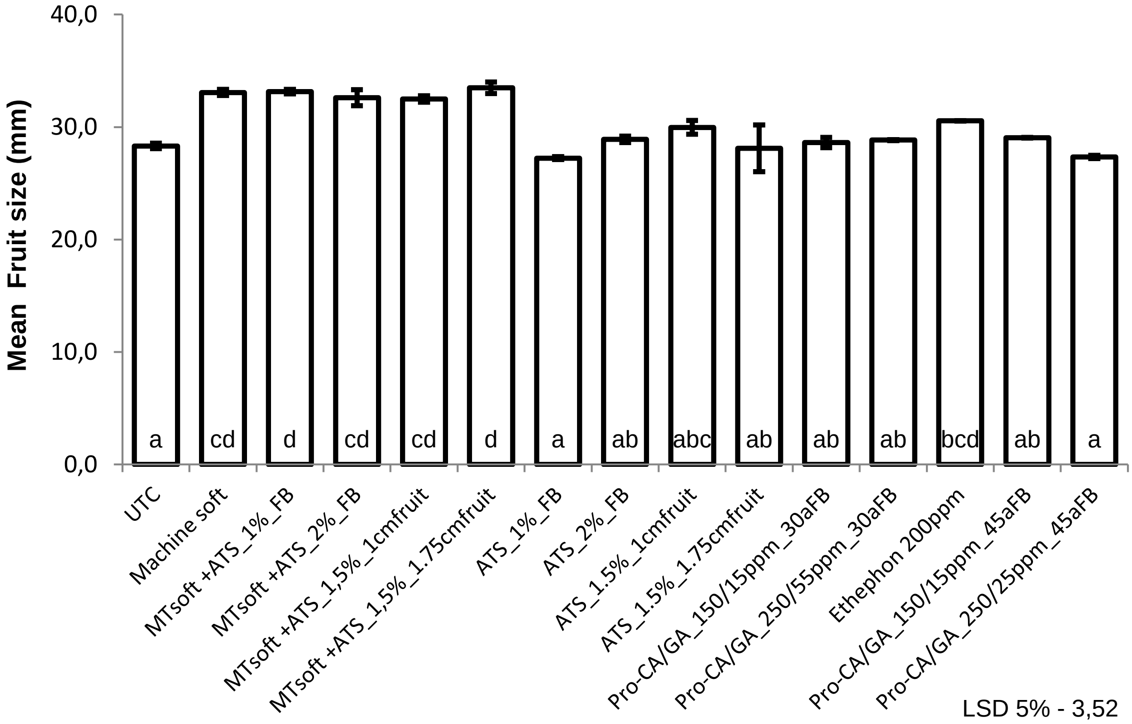


Fig 6. Effects of thinning on fruit weight in 'Katinka' plum (Bavendorf - Germany, 2014). Was recorded from total number of fruits divided by total yield per tree. Vertical bars represent standard errors. The letters mean the difference between Bonferroni test at 95% probability level for significance.

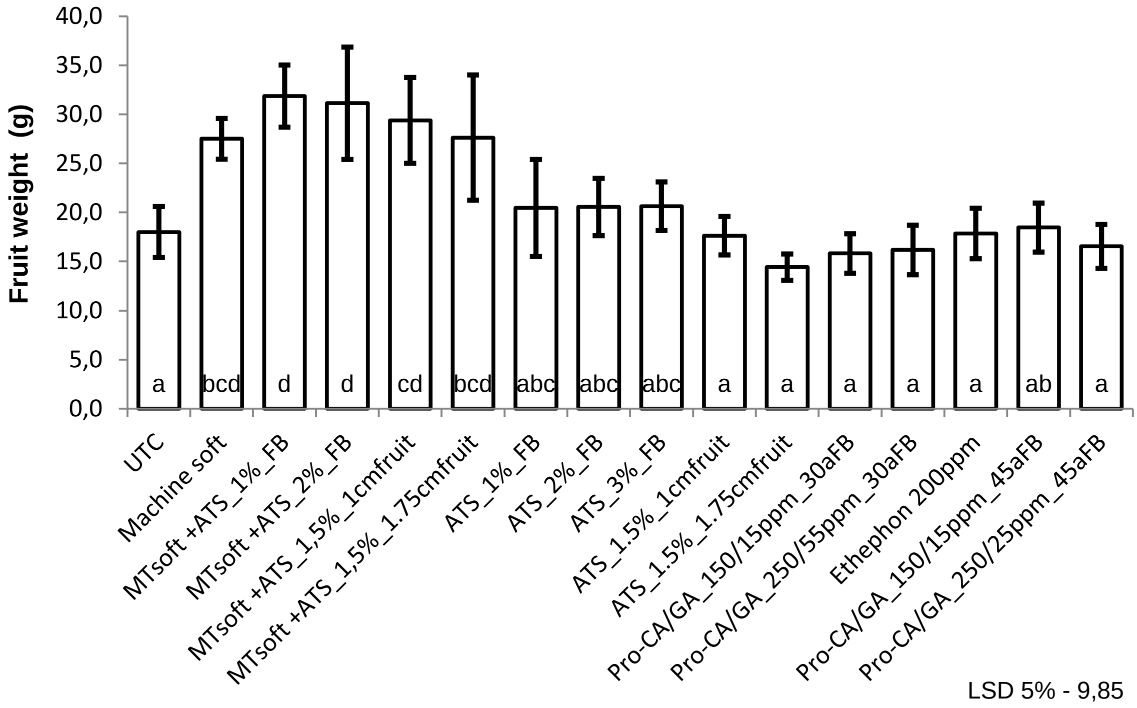


Fig 7. Effects of thinning on Yield in 'Katinka' plum (Bavendorf, Germany, 2014). Each plant was totally harvested and all the fruits were weighed. Vertical bars represent standard errors. The letters mean the difference between treatments with Bonferroni test at 95% probability level for significance.

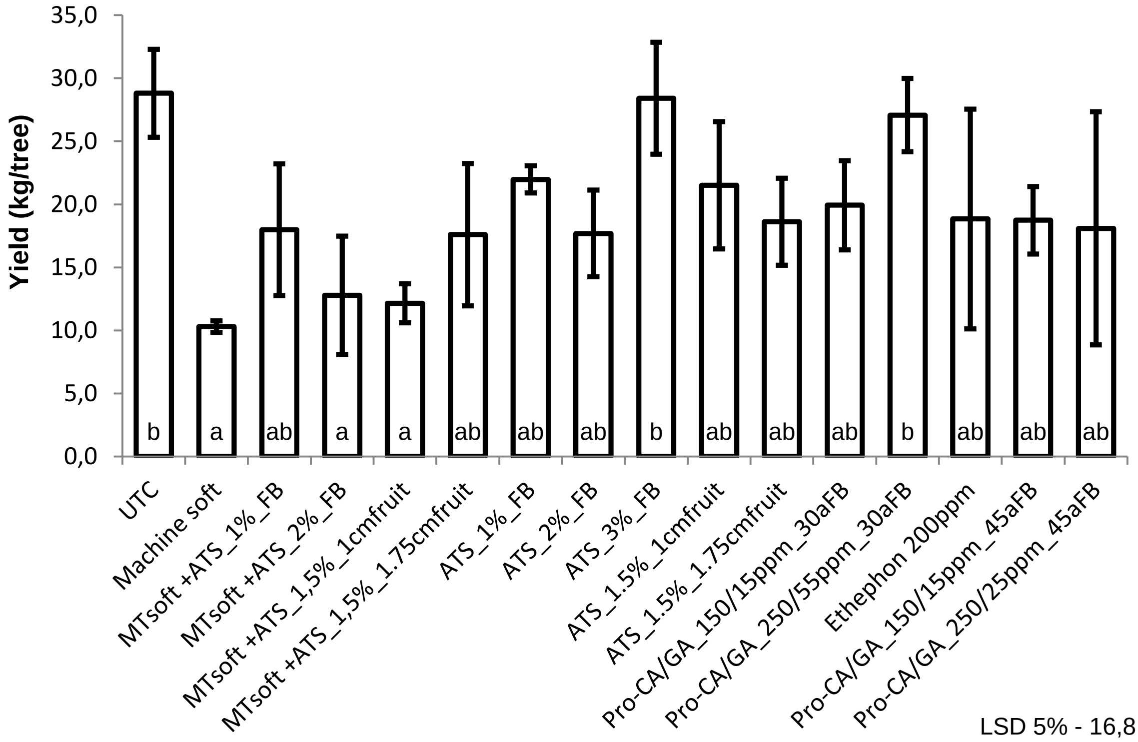


Fig 8. Effects of thinning on fruit firmness in ''Katinka'' plum (Bavendorf, Germany, 2014). The firmness was recorded from twelve fruits randomly collected from each tree. Vertical bars represent standard errors. The letters mean the difference between Bonferroni test at 95% probability level for significance.

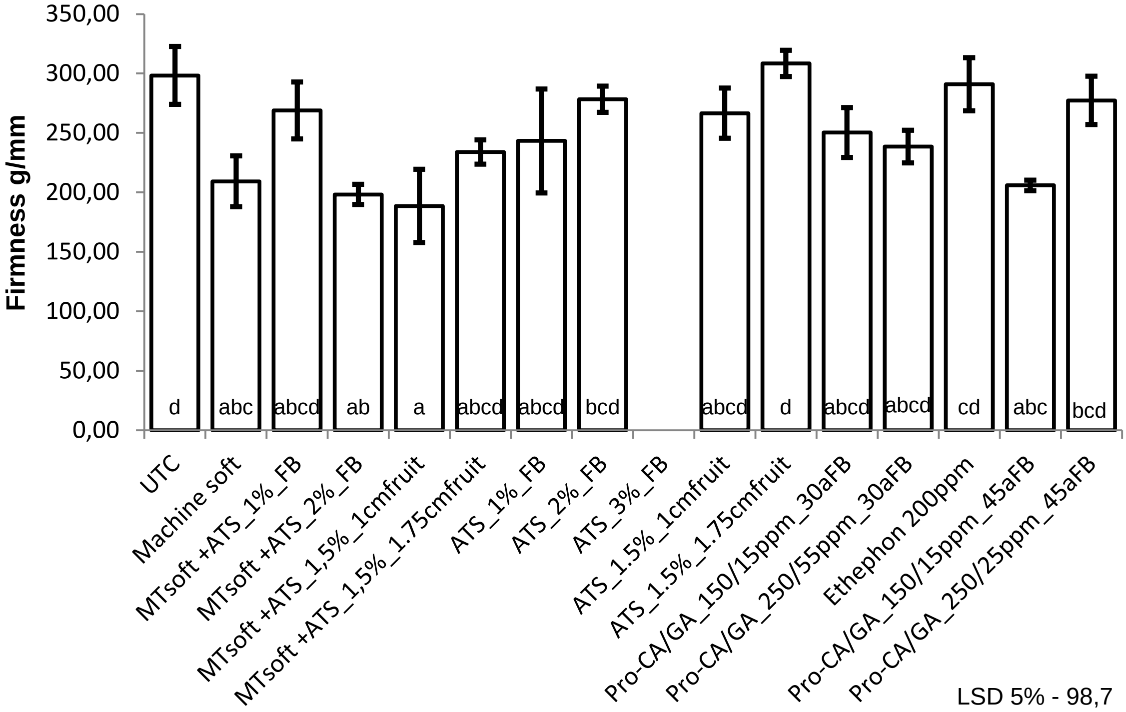
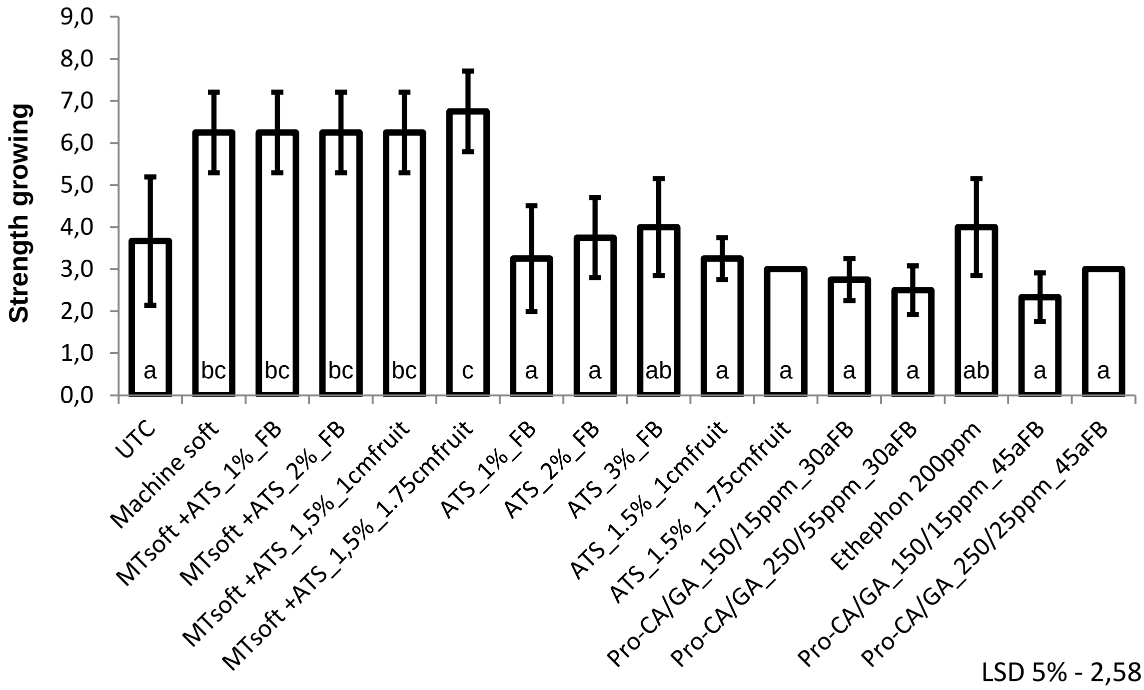


Fig 9. Effects of thinning on strength growing in ''Katinka'' plum (Bavendorf, Germany, 2014). Strength of growth was measured using a visual rating scale: (1 = very weak; 3 = weak; 5 = medium; 7 = strong; 9 = very strong). Vertical bars represent standard errors. The letters mean the difference between treatments with Bonferroni test at 95% probability level for significance.



REFERENCES

AHRENS, R. B.; PAVANELLO, A. P.; DIRK, C.; FRANCISCO, A. C.; AYUB, R. A. Análise Econômica do Raleio Químico e Manual em Ameixeiras. **Interciência**, v. 39, n. 10, p. 723-726, oct, 2014.

BANGERTH, F. Abscission and thinning of young fruit and their regulation by plant hormones and bioregulators. **Plant Growth Regulation**, v.31, p.43-59, 2000.

BAUGHER, T. A.; SCHUPP, J. R.; LESSER, K.M.; REICHARD, K.H. Horizontal String Blossom Thinner Reduces Labor Input and Increases Fruit Size in Peach Trees Trained to Open-center Systems. **HortTechnology**, v.19, p.755-761, 2009.

BAUGHER, T. A.; SCHUPP, J. R.; ELLIS, K.; REM,CHECK, J.; WINZELER, E.; DUNCAN, R.; JOHNSON, S.; LEWIS, K.; REIGHARD, G.; HENDERSON, G.; NORTON, M.; DHADDEY, A.; HEINEMANN, P. String Blossom Thinner Design for Variable Tree Forms Increase Crop Load Management Efficiency in Trials in United States Peach-Growing Regions. **HortTechnology**, v.20, p.409-414, 2010.

COSTA, G.; VIZZOTO, G. Fruit thinning of peach trees. **Plant Growth Regulation**, v.31, p.113-119, 2000.

COSTA, G.; BLANKE, M. M.; WIDMER, A. Principles of Thinning in Fruit Tree Crops – Needs and Novelties. **Acta Horticulturae**, v. 998, 2013.

DAMEROW, L.; BLANKE, M. M. A Novel Device for Precise and Selective Thinning in Fruit Crops to Improve Fruit Quality. **Acta Horticulturae**, v. 824, 2009.

EROGUL, D.; SEN, F. Effects of gibberellic acid tratments on fruit thinning and fruit quality in Japanese plum (*Prunus salicina* Lindl). **Scientia Horticulturae**, v.186, p.137-142, 2015.

ELFVING, D, C.; LANG, G. A.; VISSER, D. B. Prohexadione-Ca and Ethephon Reduce Shoot Growth and Increase Flowering in Young, Vigorous Sweet Cherry Trees. **HortScience**, v. 38, p. 293-298, 2003.

GUAK, S.; NEILSEN, D.; LOONEY, N. E. Growth, allocation of N and carbohydrates, and stomatal conductance of grrenhouse grown apple treated with prohexadione-Ca and gibberellins. **Journal of Horticultural Science & Biotechnology**, v.76, p. 746-752, 2001.

GREENE, D.; COSTA, G. Fruit Thinning in Pome and Stone Fruit: State of the Art. **Acta Horticulturae**, v. 998, 2013.

GONZÁLEZ-ROSSIA, D.; JUAN, M.; REIG, C.; AGUSTÍ, M. The inhibition of flowering by means of gibberellic acid application reduces the cost of hand thinning in Japanese Plums (*Prunus salicina* Lindl). **Scientia Horticulturae,** v.100, p.319-323, 2006.

IBM Corp. Released 2012. IBM SPSS Statistics for Windows, Version 21.0. Armonk, USA.

JOHNSON, R. S.; PHENE, B.; SLAUGHTER, D.; DEJONG, T.; DAY, K.; DUNCAN, R.; NORTON M.; HASEY, J. Mechanical Blossom Thinning Using Darwin String Thinner 2010 CTFA Annual Research Report. University of California – Fruit Report. Available at: <http://ucanr.edu/sites/fruireport/files/101631.pdf>.

MEIER, U. et al. The BBCH system to coding the phonological growth stages of plants – history and publications. **Journal Für Kulturflanzen**, v. 61, n.2, p. 41-52, 2009.

MELAND, M. Efficacy of chemical bloom thinning agents of European plums. **Acta Agriculturae,** Scandinavica, Sec. B, v. 57, p.235-242, 2007.

MILLER, S. S.; SCHUPP, J. R.; BAUGHER, T. A.; WOLFORD, S.D. Performance of mechanical thinners for bloom or green fruit thinning in peach. **HortScience**, v. 46, p. 43-51, 2011.

NAKAYAMA, I.; MIYAZAWA, T.; KOBATASHI, M.; KAMIYA, Y.; SAKURAI, A. Effects of a new plant growth regulator prohexadione calcium (BX-112) on shoot elongation caused by exogenously applied gibberellins in rice (*Oryza sativa* L.) seedlings. **Plant Cell Physiology,** v. 31. p. 195-200, 1990.

OLMSTEAD, J.W.; LEZZONI, A.; WHITING, M.D. Genotypic differences in sweet cherry fruit size result from differences in fruit cell number. **Journal of the American Society Horticultural Science**, v. 132, p. 697-703, 2007.

PAVANELLO, A. P.; AYUB, R. A. Aplicação de Ethephon no Raleio Químico de Ameixeira e seu Efeito Sobre a Produtividade. **Revista Brasileira de Fruticultura**, Jaboticabal – SP, v.34, n.1, p.309-316, mar, 2012.

PAVANELLO, A. P.; AYUB, R. A. Raleio Químico de Frutos de Ameixeira com Ethephon. **Ciência Rural**, Santa Maria, v.44, n.10, p. 1766-1769, out, 2014.

SAUERTEIG, K. A.; CLINE, J. A. Mechanical blossom thinning of 'Allstar' peaches influences yield and quality. **Scientia Horticulturae,** v. 160, p. 243-250, 2013.

SCHUPP, J. R.; BAUGHER, A. Peach Blossom Thinner Performance Improved with Selective Pruning. **HortScience**, v. 46, p.1486-1492, 2011.

SOLOMAKHIN, A. A.; BLANKE, M. Mechanical Flower Thinning Improve the Fruit Quality of Apples. **Journal of the Science of Food and Agriculture,** v. 90, p.735-740, 2010.

SEEHUBER, C. L.; DAMEROW, L.; BLANKE, M. M. Concepts of Selective Mechanical Thinning in Fruit Tree Crops. **Acta Horticulturae,** v. 998, 2013.

SEEHUBER, C. L.; DAMEROW, L.; BLANKE, M. M. Regulation of Source: Sink Relationship, Fruit Set, Fruit Growth and Fruit Quality in European Plum (*Prunus domestica* L.) – Using Thinning for Crop Load Management. **Plant Growth Regulation,** v.65, p.335-341, 2011.

TAHERI, A.; CLINE, J. A.; JAYASANKAR, S.; PAULS, P. K. Ethephon-Induced Abscission of ''Redhaven'' Peach. **American Journal of Plant Sciences**, v.3, p. 295-301, 2012.

UNTIEDT, R; BLANKE, M. Effect of thinning agents on whole apple tree canopy photosynthesis. **Plant Growth Regulation**, v.35, 2001.

WEBER, H. J. Chemical and Mechanical Thinning of Plums. **Acta Horticulturae,** v. 998, p.51-59, 2013.

WEBSTER, A.D.; Spencer, J.E.; Fruit thinning plums and apricots. **Plant Growth Regulation**, v. 31, p. 101-112, 2000.

ZANG, C.; WHITING, M. Pre-harvest foliar application of Prohexadione-Ca and Gibberellins modify canopy source-sink relations and improve quality and self-life of 'Bing' sweet cherry. **Plant Growth Regulation**, v.65, p.145-156, 2011.

ZOTH, M. Untersuchung zur abgestuften Ausdünnungswirkung der 'DARWIN' Fadenmashine mittels Staffelung der kinetischen Rotationsenergie. **DGG-Proceedings**, v.1, n.17, p.1-5, 2011.

CAPÍTULO II

DIFFERENT METHODS OF THINNING INFLUENCED BY VARIETY AND HAIL NETS IN APPLE ORCHARDS

ABSTRACT

Looking at the effects of thinning on apple quality, the purpose of this study was to investigate the effects of different methods of thinning in different varieties and under hail nets. The experiment was developed in Bavendorf, South Germany. The ‘Pinova‘ and ‘Braeburn‘ apple trees were covered with two types of hail net: white, black and without net. The following thinners were tested: Mechanical thinning (MT) with the ‘Darwin machine’; chemical thinning with Metamitron (CT-Metamitron) or 6-benzyladenine (CT-BA) and hand thinning (HT). The evaluations were: fruit set, time taken for HT, photosynthesis measurements, fruit retention, yield, fruit quality and thinning efficacy value. The CT-BA treatment required the highest number of hours to perform HT for both varieties and hail nets. Comparing the varieties, the Pinova demonstrated less efficiency for thinning treatments, hence more hours were needed to thin by hand. For the photosynthesis measurements there were clear differences between CT-Metamitron versus CT-BA and MT curves, where CT-Metamitron remained in effect for 11 days after the treatment. The HT treatment had the highest value for thinning efficacy with 93% and the MT treatment achieved 74% followed by CT-Metamitron with 64% and CT-BA with 54%. Overall the Braeburn variety is easier to thin than the Pinova variety and the black hail nets showed negative effects on colour value.

Keywords: *Malus domestica*. Thinning efficacy value. Crop load.

INTRODUCTION

Apple trees (*Malus domestica*) naturally produce an excess of fruitlets that negatively affect the commercial value of fruit. A prerequisite for an annual crop is an adequate number of flowers per tree, thus sufficient flower-bud formation in the preceding year. This can only be achieved when there is not too much fruit per tree (WERTHEIM, 2000). Only 7% of flowers per tree are necessary to achieve a satisfactory yield (UNTIEDT; BLANKE, 2001).

Fruit thinning has been practiced for many years, and serves a variety of purposes. An excess of fruit per tree can result in small fruit size and poor quality, broken limbs, exhaustion of tree reserves, and reduced alternate fruit bearing (DENNIS, 2000). Nevertheless, uncertainties regarding the cost and availability of agricultural labour for hand-thinning in the future has provided focus for renewed efforts to find alternative thinning materials for apples (MCARTNEY; OBERMILLER, 2012a).

Chemical thinning is one of the most important cultural practices in apple production. Chemical thinners are applied during flowering and or during the early post-bloom periods (BOUND, 2006). The chemical thinners used for apples are NAA (Naphthaleneacetic Acid), Ammoniumthiosulfate (ATS), Carbaryl, Benzyladenine (BA), Ethephon (Ethrel) and more recently, Metamitron.

Chemical stimulation of young fruit abscission during the first three weeks after bloom is an important management consideration in modern apple production systems. Sequential applications of chemical thinners with different modes of action are generally made during this period to reduce fruit set to commercially acceptable levels that eliminate the necessity for hand thinning, increase fruit size at harvest, and increase the probability of adequate return bloom in the following year (MCARTNEY; OBERMILLER, 2012b).

Young apple fruit generally become insensitive to thinning chemicals after they reach a diameter of around 16mm, coinciding with increasing carbohydrate reserves within the tree. Studies observed the effects of shade treatments on fruit set in apples, which should alter the gene expression after the imposition of abscission stimuli including shade and naphathaleneacetic acid (ZHU et al., 2011) and benzyladenine (BOTTON et., 2011). This provides the hypothesis that a carbohydrate deficit in the fruit is one of the earliest responses to chemical or environmental stimuli that trigger abscission in apple fruit (MCARTNEY; OBERMILLER, 2012a).

Benzyladenine is a chemical belonging to the cytokinin group that, when applied to thinning apple, increases fruit size by acting on cell division and the effect is proportional to application time and concentration used (GREENE et al., 1992). According to Greene

(2005), BA can increase fruit size even without the thinning effect. It has been considered a good thinner because it shows low toxicity and low residual plant growth and has been shown to imitate the biological action of plant-synthetized cytokinin (YUAN; GREENE, 2000).

A new chemical, metamitron, has been reported to encourage thinning activity in apples. It consists of the active ingredient metamitron, a systematic, xylem-translocate photosystem inhibitor, which influences the non-cyclic electron transport of H_2O to plastichinon (ECCHER et al., 2013).

The inhibitor metamitron exhibited thinning activity when applied to apple fruitlets at the 10 to 12mm diameter stage (LAFER, 2010). Metamitron disrupts the photosynthesis apparatus for 7 to 10 days post-application, reducing electron transport rates by as much as 60% (MCARTNEY; OBERMILLER, 2012a).

In principle, metamitron acts similarly to shading. This strengthens the competition between different sinks and induces abscission in weaker fruit (DORIGONI; LEZZER, 2007). Both shading and the application of chemicals that inhibit photosynthesis encourage apple fruitlet abscission. This suggests that thinning chemicals may interfere with photosynthesis, resulting in a deficiency of carbohydrates (DENNIS, 2000).

Zhu et al., (2011) noted that shading or NAA induced the expression of genes involved in ethylene biosynthesis and repressed the expression of genes involved in auxin transportation in the fruit abscission zone. Botton et al., (2011) suggested that the generation of a carbohydrate deficit in the fruit cortex provides the primary stimulus for fruit abscission, and that ethylene is not only a critical part of downstream signaling pathways, but also that increased ethylene levels provide the stimulus that ultimately triggers the abscission zone in the fruit pedicel.

The availability and efficiency of chemical thinning depends on crop, orchard, weather conditions, phenological stage, variety, flowering dynamics and tree age. This means that hand thinning is often required to adapt crop load for expected fruit size and quality (PAVANELLO; AYUB, 2014).

In recent years, chemical thinning has been adversely affected by legislation and the limited number of registered compounds. An alternative to standard chemical thinning is mechanical flower thinning.

Numerous mechanical approaches have been attempted including limb and trunk shakers, rotating arms in the canopy and manually hitting limbs. The new ‘’Darwin machine’’ recently made available, appears to show real promise for more widespread commercial use (BAUGHER et al., 2010; MILLER et al., 2011; SCHUPP et al., 2011).

The “Darwin machine’’ is consisted of a tractor-mounted frame with a 2.0m tall vertical spindle in the center of the frame (Figure 01). Attached to the spindle are 24 bars with 9 strings on each one, securing a total of 216 plastic injection strings measuring 60cm long. The speed of the clockwise rotating spindle is adjusted with a hydraulic motor and the height and angle of the frame is adjustable to conform to the vertical inclination of the tree canopy, and the intensity of thinning is adjustable by tractor speed and rotation speed of the spindle (JOHNSON et al., 2010; Fruit Tec® Company, Germany, 2016).

Figure 01. Darwin machine, Fruit Tec® (Ravensburg, 2014).

The advantages of mechanical thinning include not being influenced by environmental conditions (weather) and that it is suitable for both integrated as well as organic fruit cultivation. Mechanical thinning offers a lengthy period for application during flowering. It provides a 2-3 week temporal lapse of time without limitations due to cold weather as with chemical thinning. A disadvantage is that the training system must be tailored to the machine (COSTA et al., 2013).

The mechanical thinning strategy showed a potential for greater predictability than chemical thinning. The effects of physical removal are immediately visible, the level of crop removal can be estimated by comparing pre and post-thinning flower counts. The grower can assess the level of crop removal and adjust the machinery to increase or reduce thinning as required. The total economic impact of mechanical thinning versus hand thinning alone ranged from $175 to $1966 per hectare (BAUGHER et al., 2009).

Mechanical thinning saves labour costs, otherwise required for hand thinning in the order of 15-30 hours per hectare, equivalent to €100-150/ha, i.e., in the same order as the mechanical thinning of approximately 120 €/ha, assuming 20 ha and 10 years of depreciation (SEEHUBER et al., 2013).

The thinning intensity is dependent on driving speed, rotation speed and number of strings. The mechanical thinner offers a choice of rotor versus tractor speed, where optimum rotor speeds range from 200 to 450 rpm, while optimum tractor speeds range between 2.5 and 7.5 $km.h^{-1}$. Increase in rotor speed and increase in tractor speed have opposing effects; while an increase in rotor speed enhances the thinning efficiency, increases in tractor speed reduce this effect (SEEHUBER et al., 2013).

The increased occurrence of hail storms during the growing period, likely due to global climate change, resulted in the installation of either black or white protective hail nets in many fruit growing regions of the world used to protect apple fruit against hail storms and hail damage (BIAMONETE et al., 2015).

However, covering the trees with anti-hail nets can modify the orchard microclimate and reduce the interception of light, thus potentially causing negative consequences on the organoleptic quality of apple fruits. These include less (red) colouration, less firm fruit flesh, less sugar and therefore less taste, and possibly delayed ripening and harvest, particularly in terms of coloration (BLANKE, 2008; BIAMONETE et al., 2015). But in accordance with AMARANTE et al., (2009), that studied the effects of hail nets, the results depend on the colour and aperture size of the net, variety, rootstock, density, tree vigor, management (pruning and crop load) and climate in the production region.

It is known that a close relationship exists between apple orchard light interception and productivity. Intercepted light is the light that is taken in by plants, mainly by leaves, and provides the energy to drive the process of photosynthesis, which is fundamental to the growth and fruiting of all plants, including apple trees. In recent years coloured hail nets have become available with their possible positive effects on phytochrome, photosynthesis, yield and fruit quality (SOLOMAKHIN; BLANKE, 2011).

The aim of the present study was to evaluate the effects and properties of different thinning techniques on the quality and production of apple fruit (Braeburn and Pinova varieties) in South Germany. Additionally, different colour hail nets were also evaluated for their effects on apple fruit production, as well as for their interaction with different thinning methods.

MATERIALS AND METHODS

Field Conditions

The experiment was carried out in a experimental orchard at Competence Centre For Fruit Growing at Lake Constance (KOB) in Bavendorf, South Germany. The twelve-year-old ‘Pinova‘ and ‘Braeburn‘ apple trees (*Malus domestica* L.) were grafted on M.9, spaced in 3.0m x 0.8m and conducted in a spindle system, covered with two types of hail net: white/transparent net, black net and without net (uncovered). The hail net mesh size was 3x7 mm. The shading effect of the white hail net was up to 15% and of the black net up to 25%.

Treatments

The following thinners were tested: hand thinning, mechanical thinning with the ‘Darwin machine’ (Fruit Tec®, Germany); Chemical thinning with: 6-benzyladenine (BA) (19g/L - Maxcel® - Valent BioSciences) and Metamitron (15g/L - Brevis® - Adama), all sprayed with 1000 litres of water per hectare applied with a turbo atomizer.

A complete randomized block design was used, with four replications (four trees per replication), the treatments (Hand thinning (HT), mechanical thinning (MT) and two chemical thinners (CT)), three different hail nets (without, white and black), and two apple varieties (Braeburn and Pinova) organized as triple factorial (4x3x2).

The treatments were applied as follows:

1. Mechanical thinning;
2. Hand thinning;
3. Chemical treatment with 6-BA (Maxcel®) at 7,5 $L.ha^{-1}$ (150 $mg.L^{-1}$);
4. Chemical treatment with Metamitron (Brevis®) at 2,2 $kg.ha^{-1}$ (333 $mg.L^{-1}$);

Mechanical thinning was performed with a tractor at 9 $km.h^{-1}$ speed and 270 rpm with fifty percent strings, a total of 216 strings (meaning strong, ZOTH (2011)) were used in full bloom (FB) (BBCH Scale 65, MEIER, 2009) on April 23, 2014. HT was peformed when the fruit had reached around 25mm. When the fruit had reached around of 12mm diameter the chemical products were sprayed with a tractor machine/turbo atomizer on May 17, 2014.

Evaluations

1) **Fruit set (%):** all flower clusters were counted per tree. In the end total numbers of fruit per tree were counted, and the percentage of fruit set was estimated.

2) **Time taken for HT:** measured and calculated as average per tree, then calculated as hours per hectare. The aim of HT was to keep around 75 fruits per tree with an average 150g per fruit, yielding 40 to 50 tons per hectare.
3) **Production per Trunk Cross Sectional Area (TCSA):** Tree trunk diameter was measured twenty centimeters above graft point and the number and weight of fruit per trunk cross sectional area was calculated.
4) **Photosynthesis measurements (loss of fluorescence):** was estimated one day before chemical thinning was applied to get the information for zero day and during the 27 following days. It was measured with the Agrofirm – Chlrophyll Fluorometer. Metamitron is an herbicide, which is used in sugar beet. The PSI-meter machine has been used for the MLHD method (minimum lethal herbicide dose) which is a new concept for optimizing chemical weed control in the herbicide strategy. Using a PSI-meter, it is possible to observe whether there is an effect on plants through the use of herbicides. The effect of inhibiting photosynthesis can be accurately observed 2-3 days after the treatment.

   For the measurement, the leaf is placed between a clip and the measuring window. The abaxial side of the leaf is measured but the device is not able to save values. The PSI-meter shows the measured data on a display. The scale goes from 0 (no damage to photosystem I, completely healthy) to 100 (all photosystem I are blocked, no photosynthesis at all) (KEMPENAAR, 2004). The data is expressed in percentage of damage. A large value means that the herbicide has had a large effect.
5) **Fruit retention:** All fruit on the trees were harvested in Autumn – harvest dates had been: Pinova: first picking - September 24 and second picking October 6. Braerburn: first picking – October 9 and second picking October 30, 2014.
6) **Yield :** Each plant was totally harvested and all the fruit was weighed and counted.
7) **Fruit quality:** average fruit weight, diameter and colour were measured. The GREEFA MSE 2000 grading machine was used. The fruitmass was measured by weighing each fruit. The diameter was taken with an optical camera system while turning each single fruit. Maximum and minimum diameter was measured next to the height of each fruit while turning the fruit round and using ´fixpoints` set by the camera-software. Next to this surface the fruit can be measured where the green/yellow ground-colour can be separeted from the red/redish skin parts. Then the surface is calculated as red coloured in (%) and ground coloured in (%).

8) **Thinning efficacy value (TEV):** with this calculation it was possible to find thinning efficacy. The formula was developed by the Swiss entomologist Ph.D. Otto Scheneider-Orelli (1880-1965, Zurich, Switzerland) which usually describe the efficacy within plant protection trials. The formula was adapted for thinning calculation and based on the different numbers of flower clusters/blossoms per used tree.

TARGET = (FL – X);
FL = Total flowers per tree.
X= Desired number of fruit per tree.

REAL = (FL – Y);
Y= Actual number of fruits per tree.

$$GAP = \frac{REAL}{TARGET} * 100$$

$$TEV = \frac{(GAP - NF)}{100 - NF} * 100$$

NF - Natural fruit set

The TCSA was calculated, flower clusters/blossoms were counted and the number of fruits that were necessary per tree to have the expected yield was estimated. After the harvest it was possible to know the number of fruit and weight that there were in the tree and it is possible to correlate with expected yield. Then it was possible to calculate 100% thinning efficacy value when the optimal number of wanted fruit per tree is reached and sometimes a value of over 100% can mean overthinning.

The natural fruit fall of the Braeburn variety was then subtracted – without net (100-90); white net (100-80) and black net (100-70); and Pinova variety – without and white net (100-70) and black net (100-80). This natural fruit fall was calculated in recent years (This data is not shown).

Results were statistically processed using analysis of variance, t test and factorial analysis methods in the Sisvar 5.6 statistical package (FERREIRA, 2014). Meaningful comparisons were generated using Tukey’s test at the (5% level).

RESULTS

1. Fruit set

In relation to the fruit set, there was interaction between thinning methods and different hail nets (Table 1). For the thinning treatment with CT–Metamitron, it was observed that the white and black hail nets reduced as much as 28-15% of fruit set, respectively, when compared to without the hail net. No interactions were verified for other treatments.

Regarding the effects of hail nets in the thinning methods, it was observed that in the treatment without a hail net the HT and MT were the most effective treatments with a reduction in fruit set near to 50% and 25%, respectively, compared to treatments with chemicals thinning (Table 1).

For white hail nets, the treatments with CT and MT showed highest numbers of fruit set, statistically differing from HT, which had a smaller fruit set. The HT showed a fruit set of 32.6%, reducing around 45% compared to the other treatments (Table 1).

For black nets, the HT treatment presented the smallest fruit set, followed by MT and CT-Metamitron which did not differ statistically. The CT-BA showed the highest number of fruit set. The HT treatment significantly decreased fruit set by 50% compared with CT-BA and 37% compared with CT–Metramitron and MT (Table 1).

Table 1 - Effects of different types of thinning (Benzyladenine (BA), Metamitron Chemical thinning (CT), Mechanical (MT), Hand thinning (HT)) and different hail nets (without, white and black) on fruit (%) set in apple trees (Bavendorf, Germany, 2014).

Thinners	Hail Nets		
	Without	White	Black
CT – BA	62.8 C a	59.8 B a	58.9 C a[1]
CT – Metamitron	67.7 C a	56.8 B b	48.4 B b
MT - Darwin®	47.1 B a	50.9 B a	46.9 B a
HT – Hand	30.1 A a	32.6 A a	29.9 A a
LSD	9,49[x]	10,41[y]	
F – p-value	0.01**		

[1]Measurements followed by lower-case[x] letters in the same row and measurements followed by upper-case[y] letters in the column do not differ at the 5% level by Tukey's test. **Significant at 0.05, *Significant at 0.1, [ns] = not statistically significant.

There was interaction between thinning methods and the different tree varieties on variable fruit set (Table 2). For thinners, it was observed that the Braeburn variety showed smaller fruit set numbers compared to the Pinova variety, reducing around 35% in fruit set.

Observing the effects of different varieties on thinning methods, it was found that in the Braeburn variety, HT obtained the smallest fruit set number reducing 50% compared to the CT-BA, followed by MT reducing by 27% and lastly CT-Metamitron reducing by 4% (Table 2).

For the Pinova variety, it was found that HT obtained the smallest fruit set number reducing 50% compared to the CT-BA, followed by MT reducing by 16% and lastly CT-Metamitron reducing by 5% (Table 2).

Table 2 - Effects of different types of thinning (Benzyladenine (BA), Metamitron Chemical thinning (CT), Mechanical (MT), Hand thinning (HT)) and two varieties (Braeburn and Pinova) on fruit set (%) in apple trees (Bavendorf, Germany, 2014).

	Varieties	
Thinners	Braeburn	Pinova
CT – BA	47.6 C b	73.5 C a[1]
CT – Metamitron	45.8 C b	69.5 BC a
MT - Darwin®	34.7 B b	61.9 B a
HT – Hand	24.7 A b	37.1 A a
LSD	6,47[x]	8,50[y]
F - p-value	0.006**	

[1]Measurements followed by lower-case[x] letters in the same row and measurements followed by upper-case[y] letters in the column do not differ at the 5% level by Tukey's test. **Significant at 0.05, *Significant at 0.1, [ns] = not statistically significant.

There was no relationship between the hail nets and the varieties for variable fruit set as shown by F test .

2. Hand Thinning

It was observed that the CT-BA treatment required the highest number of hours to perform HT for both varieties and hail nets (Figure 02).

For the Braeburn variety, the treatment without hail nets with CT-BA showed 40% and 55% higher numbers of hours to perform HT than with white and black hail nets, respectively. For the treatments with white and black hail nets the number of hours required to thin by hand was not very different. For treatment without hail nets, the number of hours to perform HT treatments was greater.

It was observed that for the CT-Metamitron treatments in the Braeburn variety that the black hail nets showed 62% and white hail nets 36% less hours to perform HT than without any hail nets. It was noted that with the MT, the number of hours to thin by hand was similarly independent of which hail net was used.

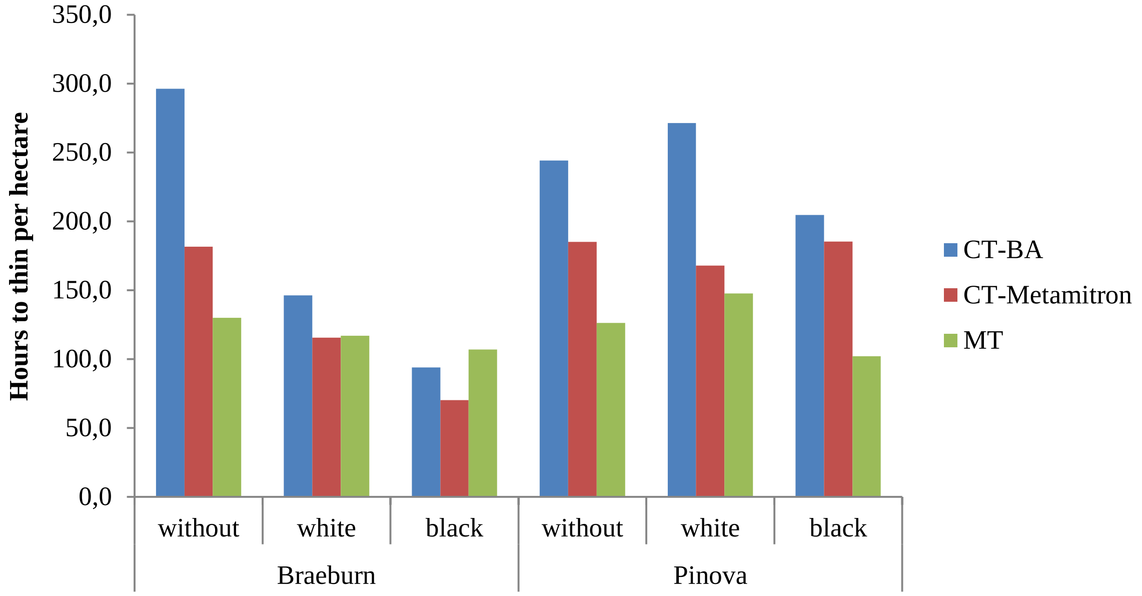
For the Pinova variety, the CT-BA treatment with white net showed the highest number of hours to perform HT 25% and 10% less hours were required to thin by hand for black nets and without nets, respectively, compared to thinning with white nets.

For the Pinova variety with CT-Metamitron, the number of hours to perform HT was similar for all hail nets. For MT treatment, the black nets showed 30% less hours and without nets 15% less hours to thin by hand than white nets.

Comparing the varieties, the Pinova demonstrated less efficiency for thinning treatments, hence more hours were needed to thin by hand than the Braeburn variety.

It could be seen that Braeburn with white and black hail nets showed to be more sensitive to the CT-Metamitron and CT-BA treatments than the Pinova variety, where less hours were required to perform HT for the Braeburn variety. For the treatments without hail nets, for both varieties, the number of hours to thin by hand was nearly the same.

Figure 02 - Hours per hectare to perform hand thinning on Braeburn and Pinova apple varieties using different hail nets (without, white and black) after thinning treatments (Benzyladenine (BA) and Metamitron Chemical thinning (CT) and Mechanical (MT) were performed, (Bavendorf, Germany, 2014).



3. **Number of fruit per TCSA**

In relation to number of fruit per TCSA, there was an interaction between thinning methods and different hail nets (Table 3). For the CT treatments, it was observed that the black hail nets reduced around 18% of the number of fruit per TCSA, when compared to without and white hail nets. No interactions were verified for MT and HT.

Looking at the effects of hail nets in the thinning methods, it was observed that without the hail net, the HT reached the lowest number of fruit per TCSA, reducing by 63% when compared with CT-BA. The HT statistically differed from MT reduction by 27%, compared with CT-BA, followed per CT-Metamitron and CT-BA with the highest number of fruit per TCSA (Table 3).

For the treatment with white hail nets, the HT reached the lowest number of fruits per TCSA reducing around 54% compared with CT-BA. This was followed by MT reduction of 25% and CT-Metamitron reduction of 2.5%, compared with CT-BA. The MT statistically differed from CT-BA and CT-Metamitron (Table 3).

For the black hail nets, the HT showed the lowest number of fruit per TCSA reducing around 48% compared to CT-Metamitron. The HT statistically differed from MT reduction by 21% and CT-BA reduction by 6%. The MT statistically differed from CT-Metamitron, however, it did not differ from CT-BA (Table 3).

Table 3 - Effects of different types of thinning (Benzyladenine (BA), Metamitron Chemical thinning (CT), Mechanical (MT), Hand thinning (HT)) and different hail nets (without, white and black) on number of fruit per TCSA in apple trees (Bavendorf, Germany, 2014).

Thinners	Hail Nets		
	Without	White	Black
CT – BA	8.4 C a	7.6 C a	6.3 BC b[1]
CT – Metamitron	8.3 C a	7.4 C ab	6.7 C b
MT - Darwin®	6.1 B a	5.7 B a	5.3 B a
HT – Hand	3.1 A a	3.5 A a	3.5 A a
LSD	1.13[x]	0.65[y]	
F - p-value	0.003**		

[1]Measurements followed by lower-case[x] letters in the same row and measurements followed by upper-case[y] letters in the column do not differ at the 5% level by Tukey's test. **Significant at 0.05, *Significant at 0.1, [ns] = not statistically significant.

There was an interaction between thinning methods and the different tree varieties on the variable number of fruit per TCSA (Table 4). For CT-thinners, it was observed that the Braeburn variety showed a smaller number of fruits per TCSA, reducing around 26% compared to the Pinova variety. No interactions were verified for MT and HT.

Observing the effects of different varieties on thinning methods, it was found that in the Braeburn variety the lowest number of fruit per tree was for HT, reducing 50% compared to CT-BA. This was followed by MT, which showed a reduction of 14% and CT-Metamitron reduction of 5%, which did not statistically differ from each other. The CT-BA treatment had the highest number of fruit per TCSA with 6.4 apples (Table 4).

For the Pinova variety, the lowest number of fruit per tree was observed for HT, reducing 60% compared to CT-BA. The MT showed a reduction of 33% and CT-Metamitron a reduction of 7%, therefore CT-Metamitron did not statistically differ from CT-BA, which had the highest number of fruit per TCSA, with 8.9 apples (Table 4).

Table 4 - Effects of different types of thinning (Benzyladenine (BA), Metamitron Chemical thinning (CT), Mechanical (MT), Hand thinning (HT)) and two varieties (Braeburn and Pinova) on number of fruit per TCSA in apple trees (Bavendorf, Germany, 2014).

	Varieties	
Thinners	Braeburn	Pinova
CT – BA	6.4 B b	8.9 C a[1]
CT – Metamitron	6.1 B b	8.4 C a
MT - Darwin®	5.5 B a	5.9 B a
HT – Hand	3.2 A a	3.5 A a
LSD	0.70[x]	0.92[y]
F - p-value	0.000**	

[1]Measurements followed by lower-case[x] letters in the same row and measurements followed by upper-case[y] letters in the column do not differ at the 5% level by Tukey's test. **Significant at 0.05, *Significant at 0.1, [ns] = not statistically significant.

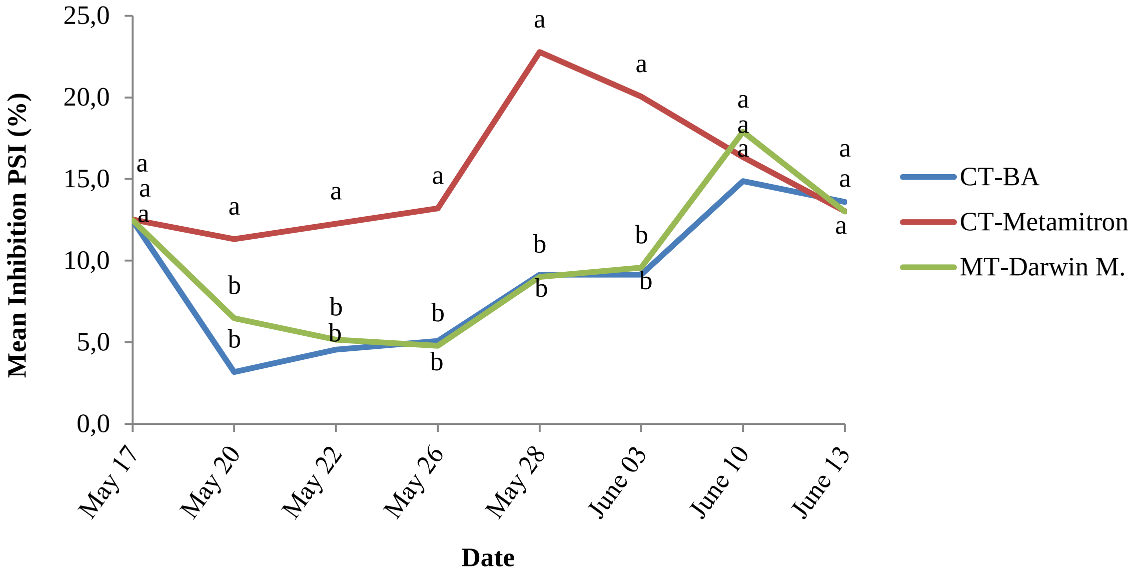
There was no interaction between the hail nets and the varieties for variable number of fruit per TCSA as shown by F test.

4. Photossynthesis measurements (loss of fluorescence):

From May 20 until June 03 statistical differences were observed between CT-Metamitron and others treatments (Figure 03). There were clear differences between CT-Metamitron versus CT-BA and MT curves. The following development of the values is mostly rate dependent of the Metamitron application.

The CT-Metamitron started high but had a great increase on May 28, eleven days after spraying. The CT-BA and MT treatments showed constant values throughout. At the end of the measurement, the curves of all treatments joined at the same level.

Figure 03 - Inhibition of photosystem I (PSI) (%) of each thinning treatment, measured May 17 – June 13, 2014. On May 17 photosynthesis was measured before treatment was applied. Measurements marked with the same letter on the same day do not differ at the 5% level by Tukey's test.



5. Yield per tree

In relation to the yield per tree, there was interaction between thinning methods and different hail nets (Table 5). For the CT treatments, it was observed that the black hail nets reduced around 22% of yield per tree, when compared to without and white hail nets. No interactions were verified for MT and HT.

Looking at the effects of hail nets in the thinning methods, it was observed that without hail nets, the HT reached the lowest yield per tree reducing 40%, compared with CT-BA, which did not statistically differ from MT reduction by 30%, followed per CT-Metamitron and CT-BA with the biggest yield per tree (Table 5).

For the treatment with white hail nets HT reached the lowest yield per tree reducing around 40% compared with CT-BA. Followed by MT and both chemicals thinners, respectively. MT differed statistically from CT-BA, however, it did not differ from the CT-Metamitron (Table 5).

For the black hail nets, the HT showed the lowest yield per tree reducing around 23% compared to CT-BA. The HT did not statically differ from MT and CT-Metamitron (Table 5).

Table 5 - Effects of different types of thinning (Benzyladenine (BA), Metamitron Chemical thinning (CT), Mechanical (MT), Hand thinning (HT)) and different hail nets (Without, white and black) on apple tree yield (kg/tree) (Bavendorf, Germany, 2014).

Thinners	Hail nets		
	Without	White	Black
CT – BA	30.7 B a	29.5 C a	23.8 B b[1]
CT – Metamitron	28.4 B a	26.9 BC a	20.7 AB b
MT - Darwin®	21.3 A a	23.5 B a	21.5 AB a
HT – Hand	17.9 A a	17.5 A a	18.3 A a
LSD	3.44[x]	3.78[y]	
F - p-value	0.0001**		

[1]Measurements followed by lower-case[x] letters in the same row and measurements followed by upper-case[y] letters in the column do not differ at the 5% level by Tukey’s test. **Significant at 0.05, *Significant at 0.1, [ns] = not statistically significant.

There was no interaction between thinning methods and the different tree varieties on variable yield per tree as shown by F test.

6. Fruit Number

In relation to the number of fruit per tree, there was interaction between thinning methods and different hail nets (Table 6). For the CT treatments, it was observed that the black hail nets reduced around 26% of the number of fruit per tree, when compared to without and white hail nets. No interactions were verified for MT and HT.

Looking at the effects of hail nets in the thinning methods, it was observed that without hail nets, the HT reached the lowest number of fruit per tree reducing by 60%, when compared with CT-BA. The HT statistically differed from MT reduction by 37%, compared with CT-BA, followed by CT-Metamitron and CT-BA with the highest number of fruit per tree (Table 6).

For the treatment with white hail nets, the HT reached the lowest number of fruit per tree, reducing around 56% compared with CT-BA. This was followed by MT reduction by 28% and CT-Metamitron reduction by 11%, compared with CT-BA (Table 6).

For the black hail nets, the HT showed the lowest number of fruit per tree reducing around 39% compared to CT-BA. The HT statistically differed from MT reduction by 12% and CT-Metamitron reduction by 9%, compared with CT-BA (Table 6).

Table 6 - Effects of different types of thinning (Benzyladenine (BA), Metamitron Chemical thinning (CT), Mechanical (MT), Hand thinning (HT)) and different hail nets (without, white and black) on number of fruit in apple tree (Bavendorf, Germany, 2014).

Thinners	Hail nets		
	Without	White	Black
CT – BA	219.0 D a	209.4 C a	156.4 B b
CT – Metamitron	189.2 C a	187.8 C a	143.9 B b
MT - Darwin®	138.7 B a	152.2 B a	137.7 B a
HT – Hand	87.7 A a	91.8 A a	95.8 A a
LSD	27.01[x]	29,63[y]	
F - p-value	0.000**		

[1]Measurements followed by lower-case letters[x] in the same row and measurements followed by upper-case[y] letters in the column do not differ at the 5% level by Tukey's test. **Significant at 0.05, *Significant at 0.1, [ns] = not statistically significant.

There was interaction between thinning methods and the different tree varieties on the variable number of fruit (Table 7). For thinners, it was observed that the Braeburn variety showed a smaller number of fruit per tree, reducing around 25% compared to the Pinova variety, with the exception of HT, which did not differ statistically.

Observing the effects of different varieties on thinning methods, it was found that in the Braeburn variety the lowest number of fruit per tree was for HT, reducing by 48% compared to CT-BA. This was followed by MT, which should a reduction of 23% and CT-Metamitron reduction of 12%, compared with CT-BA. The CT-Metamitron did not statistically differ from CT-BA which had the highest number of fruit per tree with 167 apples (Table 7).

For Pinova variety, the lowest number of fruit per tree was for HT, reducing by 56% compared to CT-BA. Followed by MT reduction by 29% and CT-Metamitron reduction by 10% compared to CT-BA, however, CT-Metamitron did not statistically differ from CT-BA which had the highest number of fruit per tree with 222 apples (Table 7).

Table 7 - Effects of different types of thinning (Benzyladenine (BA), Metamitron Chemical thinning (CT), Mechanical (MT), Hand thinning (HT)) and two varieties (Braeburn and Pinova) on number of fruit in apple tree (Bavendorf, Germany, 2014).

Thinners	Varieties	
	Braeburn	Pinova
CT – BA	167.0 C b	222.9 C a[1]
CT – Metamitron	147.1 BC b	200.2 C a
MT - Darwin®	127.8 B b	158.0 B a
HT – Hand	86.3 A a	97.3 A a
LSD	18.42[x]	24,19[y]
F - p-value	0.001**	

[1]Measurements followed by lower-case[x] letters in the same row and measurements followed by upper-case[y] letters in the column do not differ at the 5% level by Tukey's test. **Significant at 0.05, *Significant at 0.1, [ns] = not statistically significant.

There was an interaction between the hail nets and the varieties on the variable number of fruits (Table 8). It was observed that for the white and black hail net treatments, the number of fruit was 36% and 18% less, respectively, for the Braeburn variety, than for the Pinova variety.

Upon verifying the effects of hail nets on the different varieties, it was found that for the Braeburn variety, the number of fruit was inferior with the white and black hail nets compared to without hail nets. However, it was found that without hail nets, the number of fruit was 20% higher. For the Pinova variety, the number of fruit was 25% and 15% inferior with the black and without hail nets, respectively, compared to white hail nets (Table 8).

Table 8 - Effects of different hail nets (without, white and black) and two varieties (Braeburn and Pinova) on number of fruit in apple trees (Bavendorf, Germany, 2014).

Hail Nets	Varieties	
	Braeburn	Pinova
Without	151.2 A a	166.1 B a[1]
White	124.7 B b	195.8 A a
Black	120.1 B b	146.7 C a
LSD	24.91[x]	19,10[y]
F - p-value	0.004**	

[1]Measurements followed by lower-case letters[x] in the same row and measurements followed by upper-case[y] letters in the column do not differ at the 5% level by Tukey's test. **Significant at 0.05, *Significant at 0.1, [ns] = not statistically significant.

7. Fruit weight

In relation to fruit weight, there was an interaction between thinning methods and the different hail nets (Table 9). For the CT-BA, it was observed that the black hail nets increased around 9% of fruit weight and decreased 6% for HT, when compared to without hail nets. No interactions were verified for MT and CT-Metamitron.

Looking at the effects of hail nets in the thinning methods, it was observed that without hail nets, the HT reached the highest fruit weight, which increased 31%, when compared with CT-BA. The HT statistically differed from MT reduction by 11%, followed by CT-Metamitron reduction by 7%, compared with CT-BA. The CT-BA had the lowest average, with 141.5 grams per fruit (Table 9).

For the treatment with white hail nets, the HT reached the highest fruit weight, increasing around 24% compared with CT-BA. The HT statistically differed from MT reduction by 5% and CT-Metamitron reduction by 1%, compared to CT-BA, with 149.0 grams per fruit (Table 9).

For the black hail nets, the HT showed the highest fruit weight, increasing 23% compared to CT-Metamitron. The HT statistically differed from MT reduction by 7.5% and CT-BA reduction by 5%, compared with CT-Metamitron. The MT statistically differed from CT-Metamitron, however, it did not differ from CT-BA (Table 9).

Table 9 - Effects of different types of thinning (Benzyladenine (BA), Metamitron Chemical thinning (CT), Mechanical (MT), Hand thinning (HT)) and different hail nets (without, white and black) on weight (g) in apple trees (Bavendorf, Germany, 2014).

	Hail Nets		
Thinners	Without	White	Black
CT - BA	141.5 C b	149.0 B ab	155.1 BC a[1]
CT - Metamitron	152.1 BC a	150.8 B a	147.3 C a
MT - Darwin®	159.2 B a	157.2 B a	159.3 B a
HT - Hand	204.4 A a	197.3 A ab	191.7 A b
LSD	10.7[x]	11.8[y]	
F - p-value	0.007**		

[1]Measurements followed by lower-case[x] letters in the same row and measurements followed by upper-case[y] letters in the column do not differ at the 5% level by Tukey's test. **Significant at 0.05, *Significant at 0.1, [ns] = not statistically significant.

There was an interaction between thinning methods and the different tree varieties on variable fruit weight (Table 10). For thinners, it was observed that the Braeburn variety showed the highest fruit weight, increasing around 12% compared to the Pinova variety. No interactions were verified for HT.

Observing the effects of different varieties on thinning methods, it was found that in the Braeburn variety the highest fruit weight was achieved with HT, which increased by around 20% compared to other treatments. The HT treatment had the highest fruit weight with 201.3 grams per fruit. The other treatments did not show statistical differences from each other (Table 10).

For the Pinova variety, the highest fruit weight was for HT, which was around 28% higher than with CT-BA and CT-Metamitron and 22% greater compared to MT. The HT treatment had the highest fruit weight with 194.3 grams per fruit (Table 10).

Table 10 - Effects of different types of thinning (Benzyladenine (BA), Metamitron Chemical thinning (CT), Mechanical (MT), Hand thinning (HT)) and two varieties (Braeburn and Pinova) on fruit weight (g) in apple trees (Bavendorf, Germany, 2014).

Thinners	Varieties	
	Braeburn	Pinova
CT – BA	156.8 B a	140.4 C b[1]
CT – Metamitron	163.9 B a	136.1 C b
MT - Darwin®	165.7 B a	151.4 B b
HT – Hand	201.3 A a	194.3 A a
LSD	7.33[x]	9,63[y]
F - p-value	0.001**	

[1]Measurements followed by lower-case[x] letters in the same row and measurements followed by upper-case[y] letters in the column do not differ at the 5% level by Tukey's test. ** Significant at 0.01, [ns] = not statistically significant.

There was an interaction between the hail nets and the varieties for variable fruit weight (Table 11). It was observed that for the white and black hail net treatments, fruit weights were 17% and 9% higher, respectively, for the Braeburn variety compared to the Pinova variety.

Upon verifying the effects of hail nets on the different varieties, it was found that for the Braeburn variety, the fruit weights were 4% and 8% higher with black and white nets, respectively, compared to without hail nets (Table 11).

On the contrary to the Braeburn variety, the Pinova variety, showed 10% and 5% lower fruit weights with the white and black nets, respectively, compared to without hail nets (Table 11).

Table 11 - Effects of different types of hail nets (Without, white and black) and two varieties (Braeburn and Pinova) on fruit weight (g) in apple trees (Bavendorf, Germany, 2014).

Hail Nets	Varieties	
	Braeburn	Pinova
Without	165.1 B a	163.5 A a[1]
White	179.2 A a	147.9 B b
Black	171.5 B a	155.1 B b
LSD	10.92[x]	7.60[y]
F - p-value	0.000**	

[1]Measurements followed by lower-case letters in the same row and measurements followed by upper-case letters in the column do not differ at the 5% level by Tukey's test. **Significant at 0.05, *Significant at 0.1, ^{ns} = not statistically significant.

8. Diameter

In relation to the diameter of fruit, there was an interaction between thinning methods and the different hail nets (Table 12). For the CT-BA, it was observed that the black hail nets increased the diameter of fruits by 3.3%, when compared to without hail nets. No interactions were verified for CT-Metamitron, MT and HT.

Looking at the effects of hail nets in the thinning methods, it was observed that without hail nets, HT reached the highest diameter per fruit, which increased by 12%, when compared with CT-BA. The HT statistically differed from MT, decreasing by 5%, compared with CT-BA, followed by CT-Metamitron and CT-BA with the lowest diameter per fruit (Table 12).

For the treatment with white hail nets, the HT reached the highest diameter per fruit, increasing 11% compared with CT-Metamitron. Followed by MT and CT-BA, increasing around 9% compared with CT-Metamitron (Table 12).

For the black hail nets, the HT showed the highest diameter per fruit, increasing around 8% compared to other treatments. The HT statistically differed from other treatments and these did not differ between each other (Table 12).

Table 12 - Effects of different types of thinning (Benzyladenine (BA), Metamitron Chemical thinning (CT), Mechanical (MT), Hand thinning (HT)) and different hail nets (without, white and black) on diameter (mm) in apple trees (Bavendorf, Germany, 2014).

Thinners	Hail Nets		
	Without	White	Black
CT – BA	70.2 C b	71.6 C ab	72.6 B a[1]
CT – Metamitron	72.1 BC a	70.3 BC a	71.6 B a
MT - Darwin®	73.5 B a	72.8 B a	73.5 B a
HT – Hand	79.6 A a	79.1 A a	78.2 A a
LSD	2.30[x]	2.53[y]	
F - p-value	0.09*		

[1]Measurements followed by lower-case[x] letters in the same row and measurements followed by upper-case[y] letters in the column do not differ at the 5% level by Tukey's test. ** Significant at 0.05, * Significant at 0.1, [ns] = not statistically significant.

There was an interaction between thinning methods and the different tree varieties on the variable diameter of fruit (Table 13). For CT-Metamitron, it was observed that the Braeburn variety showed the highest diameter, increasing 5.5% compared to the Pinova variety. No interactions were verified for others treatments.

Observing the effects of different varieties on thinning methods, it was found that in the Braeburn variety the highest diameter was achieved with HT, increasing around 8% compared to other treatments. The HT treatment had the highest diameter with 79.4mm per fruit. The other treatments were not statistically different from each other (Table 13).

For the Pinova variety, the highest diameter was for HT, increasing around 11% compared to CT-BA and CT-Metamitron and 7% compared to MT. The HT treatment had the highest diameter with 78.6mm per fruit (Table 13).

Table 13 - Effects of different types of thinning (Benzyladenine (BA), Metamitron Chemical thinning (CT), Mechanical (MT), Hand thinning (HT)) and two varieties (Braeburn and Pinova) on diameter (mm) in apple trees (Bavendorf, Germany, 2014).

Thinners	Varieties	
	Braeburn	Pinova
CT – BA	72.1 B a	70.1 C a[1]
CT – Metamitron	73.3 B a	69.3 C b
MT - Darwin®	73.5 B a	73.1 B a
HT – Hand	79.4 A a	78.6 A a
LSD	1.57[x]	1.63[y]
F - p-value	0.008**	

[1]Measurements followed by lower-case[x] letters in the same row and measurements followed by upper-case[y] letters in the column do not differ at the 5% level by Tukey's test. **Significant at 0.05, *Significant at 0.1, [ns] = not statistically significant.

There was an interaction between the hail nets and the varieties for variable diameter of fruit (Table 14). It was observed that for the white hail net treatment, the effects of hail nets in fruit diameter were 6.5% less for the Pinova variety compared to the Braeburn variety.

Upon verifying the effects of hail nets on the different varieties, it was found that for the Braeburn variety, the diameter of fruit was 3.3% less without nets, compared to white hail nets, however these did not statistically differ from black hail nets (Table 14).

Table 14 - Effects of different types of hail net (without, white and black) and two varieties (Braeburn and Pinova) on diameter (mm) in apple trees (Bavendorf, Germany, 2014).

Hail Nets	Varieties	
	Braeburn	Pinova
Without	73.5 B a	74.2 A a[1]
White	76.0 A a	71.0 B b
Black	74.3 AB a	73.5 A a
LSD	1.90[x]	1.63[y]
F - p-value	0.000**	

[1]Measurements followed by lower-case[x] letters in the same row and measurements followed by upper-case[y] letters in the column do not differ at the 5% level by Tukey's test. **Significant at 0.05, *Significant at 0.1, [ns] = not statistically significant.

9. Colour value

In relation to the colour value, there was an interaction between thinning methods and the different hail nets (Table 15). For the CT-Metamitron and MT-Darwin, utilizing black hail nets, around 19% less colour value was observed, when compared to white hail nets and 30%

compared to without hail nets. For the HT, for black hail nets, 19% and 7.6% less colour value was observed, compared to white and without hail nets, respectively. No interactions were verified for CT-BA.

Looking at the effects of hail nets in the thinning methods, it was observed that without hail nets, the HT achieved the highest colour value, which increased by 36%, when compared with CT-BA. The HT statistically differed from MT, decreasing by 17%, comparing with CT-BA, followed by CT-Metamitron and CT-BA with the lowest colour value (Table 15).

For the treatment with white hail nets, the HT reached the highest diameter per fruit, increasing around 23% compared to others treatments. For the black hail nets, the HT showed the highest colour value, increasing around 30% compared to CT-Metamitron and MT and 20% compared to CT-BA (Table 15).

Table 15 - Effects of different types of thinning (Benzyladenine (BA), Metamitron Chemical thinning (CT), Mechanical (MT), Hand thinning (HT)) and different hail nets (without, white and black) on colour value in apple trees (Bavendorf, Germany, 2014).

	Hail Nets		
Thinners	Without	White	Black
CT – BA	55.6 C a	59.8 B a	55.6 B a[1]
CT – Metamitron	65.3 B a	57.0 B b	46.2 C c
MT - Darwin®	67.1 B a	59.8 B b	49.5 BC b
HT – Hand	86.0 A a	75.5 A b	69.7 A b
LSD	7.43[x]	8.15[y]	
F - p-value	0.000**		

[1]Measurements followed by lower-case[x] letters in the same row and measurements followed by upper-case[y] letters in the column do not differ at the 5% level by Tukey’s test. **Significant at 0.05, *Significant at 0.1, [ns] = not statistically significant.

There was interaction between thinning methods and the different tree varieties on the variable colour value (Table 16). For CT-thinners, it was observed that the Pinova variety showed smaller numbers for colour value, reducing around 15% compared to the Braeburn variety. No interactions were verified for MT and HT.

Observing the effects of different varieties on thinning methods, it was found that in the Braeburn variety the highest colour value was for HT, increasing around 20% compared to other treatments (Table 16).

For the Pinova variety, the results were similar to the Braeburn variety. The highest colour value was observed for HT, increasing 32% compared to others treatments (Table 16).

Table 16 - Effects of different types of thinning (Benzyladenine (BA), Metamitron Chemical thinning (CT), Mechanical (MT), Hand thinning (HT)) and two varieties (Braeburn and Pinova) on colour value in apple trees (Bavendorf, Germany, 2014).

Thinners	Varieties	
	Braeburn	Pinova
CT – BA	60.0 B a	49.6 B b[1]
CT – Metamitron	62.9 B a	54.1 B b
MT - Darwin®	58.6 B a	56.1 B a
HT – Hand	75.3 A a	78.9 A a
LSD	5.06[x]	6.65[y]
F - p-value	0.000**	

[1]Measurements followed by lower-case[x] letters in the same row and measurements followed by upper-case[y] letters in the column do not differ at the 5% level by Tukey's test. **Significant at 0.05, *Significant at 0.1, [ns] = not statistically significant.

There was an interaction between the hail nets and the varieties for variable colour value (Table 17). It was observed that for the white hail net treatment, the colour value was 17% less for the Pinova variety compared to the Braeburn variety.

Upon verifying the effects of hail nets on the different varieties, it was found that for the Braeburn variety, the colour value was around 13% less with black nets, compared to without and white hail nets (Table 17).

For the Pinova variety, the colour value was 24.5% less with the black nets, compared to without hail nets. The white hail nets did not statistically differ from black hail nets (Table 17).

Table 17 - Effects of different types of hail nets (without, white and black) and two varieties (Braeburn and Pinova) on colour value in apple trees (Bavendorf, Germany, 2014).

Hail Nets	Varieties	
	Braeburn	Pinova
Without	67.1 A a	70.0 A a[1]
White	67.6 A a	56.3 B b
Black	57.8 B a	52.8 B a
LSD	6.33[x]	5.25[y]
F - p-value	0.000**	

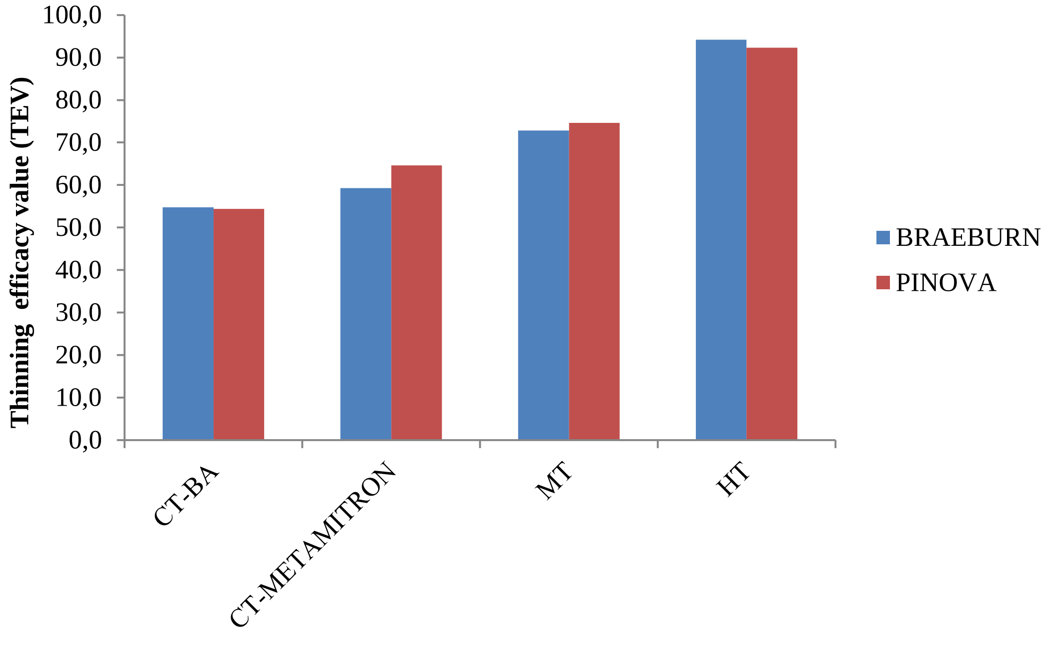
[1]Measurements followed by lower-case letters in the same row and measurements followed by upper-case letters in the column do not differ at the 5% level by Tukey's test. **Significant at 0.05, *Significant at 0.1, [ns] = not statistically significant.

10. Thinning efficacy value (TEV)

It was observed that the HT treatment had the highest value of thinning efficacy for both varieties (Figure 04). The MT treatment had 22% less thinning efficacy than HT and 15% more thinning efficacy than CT-Metamitron. Comparing the CT-Metamitron and CT-BA, the difference observed was 12%.

It could be seen that MT was closer to HT. What is important to take into account is that in 2014 there was a very high natural fruit set compared to other years. It was noted that both varieties showed similar thinning efficacy values for the same treatment.

Figure 04 – Thinning efficacy value (TEV) for Braeburn and Pinova apple varieties once thinning treatments (Benzyladenine (BA), Metamitron Chemical thinning (CT) and Mechanical (MT) were performed (Bavendorf, Germany, 2014).



DISCUSSION

In general MT was the most efficient treatment, followed by CT-Metamitron and the CT-BA showed the mildest thinning results. According to Solomakhin and Blanke (2010), the percentage of removed flowers increased linearly proportional to the MT intensity in apple trees removing 57-85% of flowers relative to 93% in the control indicates effective MT as a prerequisite for sufficient fruit size, coloration and fruit quality at harvest. This was achieved with 420 rpm at both 5.0 km.h^{-1} and 7.5 km.h^{-1} in ‘Gala’ apple trees using MT equipment called the ‘Bonner machine’.

Kon et al., (2013) determined that fruit set decreased linearly proportional to the MT intensity in Buckeye Gala apple trees using a 'Darwin machine'. It was observed that the fruit weight did not have statistical differences between the six spindle speeds tested. The explanation was that high spindle speed removed fruiting spurs in the middle and encouraged development of fruit on the periphery of the canopy, which often produce inferior fruit, remained after thinning treatment.

In contrast with our findings, Hehnen et al., (2007) reported no statistical difference between CT with BA (57% of fruit set) and MT with 360 rpm at 2.5 km.h^{-1} (62% of fruit set), but they used a different MT device called the 'Bonner machine'. However, similarly to our results, they found statistical differences between HT, CT and MT.

In relation to HT, as was expected, positive effects were found for most characteristics tested, confirming the findings reported in the literature that HT is labour intensive, takes a long time and requires expensive management. It was observed that some treatments like CT-BA required around 300 hours or more per hectare of hand thinning to achieve a satisfactory thinning efficacy. The thinning efficacy value for HT was 93%.

In previous string studies, treatment generally removed less than one blossom on average from each of the blossom clusters in the recommended range of treatments (SOLOMAKHIN; BLANKE, 2010). It was observed by Kon et al., 2013, that using spindle speeds of 180 and 210 rpm provided the best overall thinning response and minimized injury to spur leaves, but crop load reduction was insufficient in years of heavy fruit set. In the present study, 210 rpm with 9 km.h^{-1} was used and Kon et al., 2013 used 4.8 km.h^{-1}, meaning heavy thinning. In the present study, the majority of the results showed that MT did not differ from CT-Metamitron, but differed from CT-BA.

In a trial with CT in 'SunCrisp' apple trees, McArtney and Obermiller (2012a), reported reduction in fruit set and of total yield with the application of Metamitron 300 mg.L^{-1}, where fruit diameter was 18.8mm. Similar results were observed in 'Gala' apple trees by the application of Metamitron 350 mg.L^{-1} where fruit diameter was 18mm (MCARTNEY; OBEMILLER, 2012b).

Similarly to the present results, McArtney and Obermiller (2012a) observed declined photosynthesis measurements 2 days after the foliar application of metamitron to 'SunCrisp' apple trees and the values on sprayed trees remained suppressed 11 days after treatment when applied at 300 mg.L^{-1}. Schuller (2014) demonstrated a significant effect of Metamitron on photosynthesis measurements in comparison to the control, lasting from 10 days in the lowest concentration to 17 days in the highest concentration after the application. In the present trials, it was observed that Metamitron remained in effect for 11 days after the treatment.

In trials with CT in ‘Galaxy’ and ‘Braeburn’ apple trees, Schuller (2014) noted that Metamitron was an effective apple fruit thinner, which had advantages in comparison to the BA, like high thinning efficacy and less weather dependency. In years with low temperatures the Metamitron showed a big advantage over BA. The rate of the first application at the 8-10mm diameter stage was related to variety, vitality and blooming of the trees. Metamitron had an advantage over BA in that it was possible to take fluorescence measurements and if necessary perform a second application at the 12-14mm diameter stage. The remaining Metamitron stress for fruit abscission depends on the concentration and weather conditions. The second application rate can be decided depending on to photosynthesis measurements and tree conditions.

According to Lafer (2010) the thinning efficacy of Metamitron depended upon the time of application and the year of trials. ‘Elstar’ apple trees were used with early applications of Metamitron 350 $mg.L^{-1}$ at the fruitlet 6-8mm diameter stage, which caused a strong overthinning in 2006 while no thinning effect was observed in 2007. Metamitron 350 $mg.L^{-1}$ was not effective when applied at 12-14 mm diameter in 2006 and 2008, however, it was very effective in 2007. The conclusion was an adaptation of dosage on the fruitlet diameter and/or light intensity seems to be necessary for optimizing the thinning efficacy of Metamitron.

In a trial with CT in ‘Fuji’, ‘Maxi Gala’ and ‘Fred Hough’ apple trees using Metamitron isolated or in combination with BA showed great efficacy in reducing fruit production to an optimal level when performed at 5-15mm fruit size for the three varieties tested. Metamitron 768 $mg.L^{-1}$, Metamitron 384 $mg.L^{-1}$ + BA 40 $mg.L^{-1}$ and Metamitron 768 $mg.L^{-1}$ + BA 40 $mg.L^{-1}$ were used. The effect of reducing fruit production provided a great increase in fruit size and all chemical thinners significantly increased fruit weight from 26.2% to 40.3% compared to HT. There was an overthinning plus leaf phytotoxicity in the ‘MaxiGala’ variety with 768 $mg.L^{-1}$ of Metamitron. Results prove that Metamitron might be an important alternative among chemical thinners for apples, and furthermore, substitute Carbaryl. One application of Metamitron plus BA would be sufficient for thinning, even in hard thinning varieties. However, Gabardo (2015) concluded that further studies on concentration and application time would be necessary. In this present result, Metamitron 333 $mg.L^{-1}$ and BA 150 $mg.L^{-1}$ were used, and performed at the 12mm stage, where the fruit size and weight significantly decreased compared to HT.

The MT was an effective apple fruit thinner. It could be possible to use HT or MT with any type of hail nets without differences in crop load, however some differences in colour value should occur with white and black nets. The use of MT with black and without hail nets did not give differing variable yields when compare to HT. The thinning efficacy value for MT was 74%.

Similar to the present results, the use of black hail nets reduced the potential photosynthesis, leading to a reduction in yield and red colour of the fruit. These authors concluded that the white hail net is recommended to protect against hail in 'Fuji' apple trees, because it permitted better quality and intensity light for photosynthesis than black hail nets (AMARANTE et al., 2009). The reduction of red colour when the black hail nets were used was registered by others authors (AMARANTE et al., 2007; STAMPAR et al., 2002).

The use of CT with black hail nets showed statistical differences for some variables measured, when it was compared with white and without hail nets. The CT-Metamitron with black nets showed lower fruit set and colour value. The CT-BA with black nets showed an increase of fruit weight and diameter. However, if compared to the CT-Metamitron and CT-BA for each type of hail net, the efficacy observed for CT-BA were lower than CT-Metamitron, where the thinning efficacy value of CT-Metamitron was 62% and 54% for CT-BA.

According to Solomakhin and Blanke (2008), the fruit growth was greater with coloured hail nets, without effect on yield, however fruit colouration was hampered under the hail nets depending on net colour. Similarly to the present results, they observed differences in results, likely influenced by different varieties. Overall, tree growth under coloured hail nets was genetically influenced, with the 'Fuji' variety being more prone and sensitive to the adverse effects of coloured hail nets than the 'Pinova' variety, but was also influenced by the environment.

For the thinning treatments for the Braeburn variety, most variables measured did not have statistical differences between MT, CT-Metamitron and CT-BA. However, it was observed in trials without nets that the number of hours to thin was different between the treatments. On the other hand, for the Pinova variety the majority of the results showed that MT differed from CT-Metamitron and CT-BA. Overall the Braeburn variety is easier to thin than the Pinova variety.

The Braeburn variety showed lower fruit set than the Pinova variety in all hail net experiments. For the Braeburn variety lower values were observed for most variables measured for white and black hail nets. In contrast, the Pinova variety was only influenced when black hail nets were used.

In 2014, a very high natural fruit set was noted. Despite this, the trials performed showed effective thinning efficacy. It appears that it is necessary to continue development of optimal values for chemical concentrations and application times for CT-Metamitron and CT-BA, as well as for MT intensity. Further study should be carried out on different varieties, types of hail net and weather conditions. For fruit growers, a good thinning strategy has to be developed.

CONCLUSION

- The CT-BA treatment required highest number of hours to perform HT for both varieties and hail nets.
- Comparing the varieties, the Pinova demonstrated less efficiency for the treatments, hence more hours were need to thin by hand.
- Overall the Braeburn variety is easier to thin than the Pinova variety and the black hail nets showed negative effects on colour value.
- In general MT was the most efficient treatment, followed by CT-Metamitron and the CT-BA showed the mildest thinning results.
- The trials performed showed effective thinning efficacy.
- I appears that it is necessary to continue development of optimal values for chemical concentrations and application, as well as for MT intensity.
- Further study should be carried out on different varieties, types of hail net and weather conditions.
- For fruit growers, a good thinning strategy has to be developed.

REFERENCES

AMARANTE, C.V.T.; STEFFENS, C.A.; MOTA, C.S.; SANTOS, H.P. Radiação, fotossíntese, rendimento e qualidade de frutos em macieiras ‘Royal Gala’ cobertas com tela antigranizo. **Pesquisa Agropecuária Brasileira**, Brasília, v.42, n.7, p.925-931, 2007.

AMARANTE, C.V.T.; STEFFENS, C.A.; MIQUELOTO, A.; ZANARDI, O.Z.; SANTOS, H.P. Disponibilidade de luz em macieiras ‘Fuji’ cobertas com telas antigranizo e seus efeitos sobre a fotossíntese, o rendimento e qualidade dos frutos. **Revista Brasileira de Fruticultura**, Jaboticabal, v.31, n.3, p.664-670, 2009.

BAIAMONTE, I.; RAFFO, A.; NARDO, N.; MONETA, E.; PEPARAIO, M.; ALOISE, A.; KELDERER, M.; CASERA, C.; PAOLETTI, F. Effect of the use of anti-hail nets on codling moth (*Cydia pomonella*) and organoleptic quality of apple (cv. Braeburn) grown in Alto Adige Region (northern Italy). **Journal Science Food Agriculture,** v.96, p.2025-2032, 2015.

BAUGHER, T. A.; SCHUPP, J.R.; LESSER, K.M.; HESS-REICHARD, K. Horizontal String Blossom Thinner Reduces Labor Input and Increases Fruit Size in Peach Trees Trained to Open-center Systems. **Hortechnology**, v.19, 2009.

BLANKE, M. M. Alternatives to reflective mulch cloth (Extenday^{TM}) for apple under hail net. **Scientia Horticulturae**, v.116, p.223-226, 2008.

BOUND, S. A. Comparison of two 6-benzyladenine formulations and Carbaryl for post-bloom thinning of apples. **Scientia Horticulturae**, v.111, p.30-37, 2006.

BOTTON, A.; ECCHER, G.; FORCATO, C.; FERRARINI, A; BEGHELDO, M.; ZERMIANI, M.; MOSCATELLO, S.; BATISTELLI, R.; VELASCO, R.; RUPERTI, B.; RAMINA, A. Signaling pathways mediating the induction of apple fruitlet abscission. **Plant Physiology,** v.155, p.14-19, 2011.

COSTA, G.; BLANKE, M. M.; WIDMER, A. Principles of Thinning in Fruit Tree Crops – Needs and Novelties. **Acta Horticulturae**, v.998, 2013.

DENNIS, F. G. The history of fruit thinning. **Plant Growth Regulation**, v.31, p.1-16, 2000.

DORIGONI, A.; LEXXER, P. Chemical thinning of apple with new compounds. **Erwerbs-Obstbau**, v.49, p.93-96, 2007.

ECCHER, G.; BOTTON, A.; DIMAURO, M.; BOSCHETTI, A.; RUPERTI, B. Early induction of apple fruit let abscission is characterized by an increase of both isoprene emission and abscisic acid content. **Plant Physiology**, v.161, p.1952-1969, 2013.

FERREIRA, D. F. Sisvar: a Guide for its Bootstrap procedures in multiple comparisons. **Ciência Agrotecnologia**, v.38, n.2, p. 109-112, 2014.

GABARDO, G. **Metamitron como alternativa no raleio químico de pós-florada da macieira.** 2015. 90f. Dissertação (Mestrado em Produção Vegetal), Universidade Estadual de Santa Catarina, Lages, 2015.

GREENE, D.W. Effects of repeated yearly application of chemical thinners on ‘McIntosh’ Apples. **HortScience**, v.40, n.2, p.401-403, 2005.

GREENE, D.W.; AUTIO, W.R.; ERF, J.A.; ZHONGYUAN, Y.M. Mode of action of benzyladenine when used as a chemical thinner. **Journal of the American Society Horticultural Science**, v.117, p.775-779, 1992.

KEMPENAAR, A. C. MHDL online English version 3, 2004. Available at: <http://www.optoscience.com/marker/ears/pdf/MLHD_manual.pdf>.

KON, T. M.; SCHUPP, J. R.; WINZELER, E.; MARINI, R. P. Influence of Mechanical String Thinning Treatments on Vegetative and Reproductive Tissues, Fruit Set, Yield, and Fruit Quality of 'Gala' Apple. **Hortscience,** v.48, n.1, p.40-46, 2013.

LAFER, G. Effects of chemical thinning with metamitron on fruit set, yield and fruit quality of 'Elstar'. **Acta Horticulturae,** v.884, p.531-536. 2010.

LINK, H. Significance of flower and fruit thinning on fruit quality. **Plant Growth Regulation,** v.31, p.17-26, 2000.

MCARTNEY, S. J.; OBERMILLER, J. D. Comparison of the Effects of Metamitron on Chlorophyll Fluorescence and Fruit Set in Apple and Peach. **HortScience,** v.47, n.14, p.509-514, 2012a.

MCARTNEY, S. J.; OBERMILLER, J. D. Use of 1-Aminocyclopropane Carboxylic Acid and Metamitron for Delayed Thinning of Apple Fruit. **HortScience,** v.47, n.11. p.1612-1616, 2012b.

PAVANELLO, A. P.; AYUB, R. A. Raleio Químico de Frutos de Ameixeira com Ethephon. **Ciência Rural**, Santa Maria, v.44, n.10, p.1766-1769, 2014.

SEEHUBER, C. L.; DAMEROW, L.; BLANKE, M. M. Concepts of Selective Mechanical Thinning in Fruit Tree Crops. **Acta Horticulturae,** v.998, 2013.

SOLOMAKHIN, A. A.; BLANKE, M. M. Coloured hail nets alter light transmission, spectra and phytochrome, as well as vegetative growth, leaf chlorophyll and photosynthesis and reduce flower induction of apple. **Plant Growth Regulation,** v.56, p.211-218, 2008.

SOLOMAKHIN, A. A.; BLANKE, M. M. Mechanical flower thinning improves the fruit quality of apples. **Journal Science Food Agriculturae**, v.90, p.735-741, 2010.

SCHULLER, P. **Thinning in apple trees using a photosynthesis inhibitor-optimizing the application with PSI and PSII measurements.** 2014. 75f. Master thesis (Agricultural) – Bonn University, 2014.

STAMPAR, F.; VEBERIC, R.; ZADRAVEC, P.; HUDINA, M.; USENIK, V.; SOLAR, A.; OSTERC, G. Yield and fruit quality of apples cv. 'Jonagold' under hail protection nets. **Gartenbauwissenschaft,** Sttugart, v.67, p.205-210, 2002.

WERTHEIM, S. J. Developments in the chemical thinning of apple and pear. **Plant Growth Regulation,** v.31, p.85-100, 2000.

UNTIEDT R; BLANKE M. Effect of thinning agents on whole apple tree canopy photosynthesis. **Plant Growth Regulation**, v.35, n.19, 2001.

YUAN, R.; GREENE, D.W. Benzyladenine as a chemical thinner for McIntosh apples. I. Fruit thinning effects and associated relationships with photosynthesis, assimilate translocation, and nonstructural carbohydrates. **Journal of the American Society for Horticultural Science**, v.125, p. 169–176, 2000.

ZHU, H., DARDICK, C.D, BEERS, E.P, CALLANHAN, A.M, XIA, R., YUAN, R. Transcriptomics of shading-induced and NAA-induced abscission in apple (*Malus domestica*) reveals a shared pathway involving reduced photosynthesis, alterations in carbohydrate transport and signaling and hormone crosstalk. **BMC Plant Biology**, v.11, p.138, 2011. Available at: <http: www.biomedcentral.com/1471-2229/11/138>.

CONSIDERAÇÕES FINAIS

O raleio mecânico apresentou resultados positivos para a cultura da ameixeira e macieira. Para a cultura da ameixeira a opção do raleio mecânico é excelente, visto que não há produtos registrados e eficientes para o raleio químico. Para cultura da macieira, há opção do raleio químico com produtos já registrados e produtos a serem registrados. Entretanto, para o raleio químico, verificamos que o resultado depende muito das condições climáticas, de manejo, e o resultado é diferente entre cultivares. Como vimos, nenhum dos métodos testados obtiveram 100% de eficácia no raleio. Com isso, o raleio manual deve ser utilizado para complementar os demais métodos.

Na Alemanha e no Brasil, os novos pomares estão sendo implantados em sistema adensado. Com isso, a utilização de ferramentas como raleio e poda mecânica podem ser implantados. No Brasil, alguns pomares estão situados em regiões com relevo acidentado, prejudicando a utilização da mecanização, entretanto, ajustes no sistema podem ser realizados, tais como, velocidade do trator e da rotação da máquina de raleio.

Atualmente, um dos principais problemas no Brasil é o Cancro Europeu (*Nectria galligena*). O raleio mecânico sendo empregado, medidas preventivas de controle deverão ser adotadas. Na Alemanha, as principais doenças em macieiras são: Cancro Europeu e Sarna da Macieira (*Venturia ineaqualis spp*). O Cancro Europeu está presente nas regiões úmidas e as variedades 'Gala', 'Elstar' e 'Kanzi' são mais susceptíveis a esta doença bacteriana. A doença mais importante é a Sarna da macieira. Quase todas as regiões têm realizado controle com fungicida durante e depois da floração até o meio do verão. As pulverizações são realizadas com os fungicidas Dodine, Captan, Dithianon, Enxofre entre outros. Há problemas com *Erwinia amilovora* spp e os fruticultores tem utilizado Alumínio potássio tiossulfato para o controle desta doença.

No Brasil em muitas regiões produtoras há um baixo acúmulo em horas de frio, ocasionando uma floração desuniforme, baixa viabilidade do pólen, poucas gemas floríferas e um excessivo crescimento vegetativo. Mesmo com a utilização de produtos para quebra de dormência, como por exemplo, na variedade Eva, a floração é desuniforme devido à diferença na maturação das gemas. No instituto KOB, na Alemanha, local o qual realizei parte deste trabalho, a equipe de pesquisa coordenada por Michael Zoth e Daniel Neuwald, estão desenvolvendo um sensor para controlar a velocidade da máquina de raleio de acordo com o número de flores que há na planta a ser raleada.

Na Alemanha, cerca de 15% da produção de maçã é orgânica e 40 a 50% dos pomares estão utilizando telas para cobertura antigranizo. O governo oferece subsídios para produção orgânica e para compra de telas antigranizo.

A pesquisa direcionada a cultivares de macieiras está adiantada comparada ao Brasil. Eles possuem cerca de 13 variedades comerciais (Elstar, Gala, Topaz, Jonagold, Golden Delicious, Pinova, Braeburn, Fuji entre outras). A colheita dos frutos inicia-se geralmente na primeira de setembro com a variedade 'Elstar' e finaliza no mês de outubro com a variedade 'Fuji'.

Em relação às condições climáticas, na Alemanha há um maior acúmulo em horas de frio e a temperatura média é 10 °C, mais baixa comparada ao Brasil. A precipitação média na região Sul da Alemanha é de 954 mm/ano. No sul do Brasil, a precipitação média é 1200 mm/ano e a temperatura média é 22 °C. Por este motivo, todos os anos os fruticultores brasileiros tem problemas com doenças e muita dificuldade para controlar o crescimento dos ramos.

Outro fator importante sobre o controle no crescimento de ramos é o porta-enxerto. Na Alemanha, 95% dos porta-enxertos são M9. No Brasil os mais utilizados são Maruba e Maruba com filtro M9. O porta-enxerto Maruba é muito vigoroso.

Em relação às pragas, no Brasil as mais importantes são: a mariposa (*Grapholita molesta)* e a mosca das frutas (*Ceratitis capitata* e *Anastrepha fraterculus*). Na Alemanha, a praga mais importante é a (*Cydia pomonella*). Para mariposa, em ambos os países, tem sido utilizado à confusão sexual com utilização de feromônios para controlar a população de insetos e adicionalmente utilizado inseticida se necessário.

Na Alemanha, os pomares estão próximos aos locais de classificação e armazenamento. As estradas e os veículos de transporte apresentam excelentes condições de uso, facilitando à logística e minimizando problemas pós-colheita. O governo e os produtores rurais subsidiam parte do financiamento para a pesquisa e para o marketing voltado ao consumo de frutas.

No armazenamento pós-colheita, o Brasil apresenta tecnologias similares às utilizadas pelos alemães. A disponibilidade de mão-de-obra está mais escassa e onerosa na Alemanha. O custo de produção é superior comparado ao Brasil. Entretanto, o valor agregado na venda e os subsídios oferecidos pelo governo, podem tornar a fruticultura na Alemanha mais lucrativa.

ANEXOS