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PHYSICAL AND CHEMICAL METHODS TO AVOID FRUIT CRACKING IN CHERRY

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Abstract

Rain-induced fruit cracking in sweet cherries can cause heavy losses in yields and returns. Several advances in the use of different cultural practices, which reduce the incidence of fruit cracking have been made. These practices range from exclusion of water from the fruit surface during growth and maturation of the fruit, to reducing osmotic potential across the fruit skins during rainfall events, to coating the fruit with elastic hydrophobic rain exclusion biofilms. Physical exclusion of rainwater may also be achieved by covering the trees with protective plastic rain covers. Two systems have been researched in Norway; retractable plastic rain covers and multi-bay polyethylene “high tunnels”. The supporting framework of the former is built entirely of wood and overhead polyethylene curtains slide back and forth on three wires per row to open or close depending on the prevailing weather. Retractable covers must be drawn over the trees manually before rainfall events and is extremely labour intensive. The system is highly susceptible to heavy winds. High tunnels, which are accessible to tractors, are constructed of steel bows, attached to metal posts and covered with greenhouse–grade polyethylene. Tunnels may be fully ventilated on hot, humid days or completely closed for extending the growing season. The plastic covering is completely removed during winter. Cherries may be covered from bloom until harvest or only during the time when fruit are susceptible to cracking. A high density planting (1250 trees per ha) of ‘Sweetheart’/‘Colt’ in Norway grown in high tunnels yielded 9 kg per tree on average in the 4th leaf and 19 kg per tree on average in the 5th leaf. Fruit size measurements found that on average, more than half the fruit were larger than 32 mm in diameter by the 4th leaf. GA_3 treatment at yellow straw colour delayed harvest by one week, and significantly improved fruit size and fruit firmness.But soil moisture management is critical inside the tunnels as excess soil moisture can induce significant percentages of fruit cracking even inside the tunnels. In the United States, Pacific Northwest, Parka (powered by SureSeal®), a novel biofilm comprised of palm oil and cellulose, patented by Oregon State University, resulted in 50% less fruit cracking on average, higher total soluble solids and increased retention force between the pedicel and fruit than untreated control fruit.

Keywords: *Luminance THB film, Visqueen clear UV, rain covers, Parka, SureSeal®, fruit quality, yield*

INTRODUCTION

Rain-induced fruit cracking in cherries remains a problem at an international level and can cause heavy losses in yields and returns (Pennell & Webster, 1996; Vittrup Christensen, 1996; Lang & Flore, 1999; Sekse, 2005). Fruit cracking is the result of morphological, physiological, environmental and genetic factors. Unfortunately, a lack of understanding of several of the fundamental mechanisms involved in these phenomena persists. Several advances in the use of different cultural practices, which reduce fruit cracking have however, been made. These practices include exclusion of water from the fruit surface during growth and maturation of the fruit using plastic rain covers (Meland & Skjervheim, 1998; Børve et al. 2003) and reducing osmotic potential across the fruit skins during rainfall events using calcium products (Lang et al. 1997). Some cherry scion cultivars crack more easily than others (Ystaas & Frøynes, 1998; Cline et al., 1995) but why susceptible cultivars are more predisposed to cracking than resistant ones has not been explained satisfactorily.

Indeed, investigations have found that genetic differences in skin morphology (Belmans &

Keulemans, 1996), variable cuticle thickness, differences in stomatal density (Beyer & Knoche, 2002), cutin content (Schreiber et al., 1996; Knoche et al., 2000) and exocarp polar pathways are all implicated. However, all cherry fruit cuticles consist of both cutin and wax. Cutin is the largest constituent (90-99%) but only plays a minor role in water exclusion. The wax component (1-10%) however, accounts for most hydrophobicity of the cuticle. Hovland and Sekse (2004) found that water loss from the fruit skin under low air humidity was linear with time, whereas fruit at high air humidity accumulated water for 4-6 hours and this explains why in some cases, fruit cracking can take place following harvest. This also has major implications for both harvest, when prevailing conditions are cool and overcast, resulting in high relative humidity and postharvest hydrocooling. Cuticular fractures increased the conductance for water uptake (Beyer & Knoche, 2002). Knoche et al. (2002) found an 8% increase of the total conductance for water loss of the cuticle due to fractures. The number of cuticular fractures on the fruit surface influenced water loss significantly. Indeed, more cuticular fractures resulted in more water loss under low air humidity (Hovland & Sekse, 2004). This means that these fractures represent pathways for water transport through the sweet cherry surface.

Cherry fruit has a double sigmoid growth pattern (Coombe, 1976), which may contribute to fracture development during the last part of fruit growth and maturation resulting in rapid weight and volume increases, probably leading to significant mechanical stress in the cuticle (Considine & Brown, 1981). Irregular water supply to cherry trees during this period (Sekse, 1995) increased the number of cuticular fractures. Consequently, fruit volume expansion caused by water uptake through the fruit pedicel probably occurs faster than the fruit cuticle can correspondingly stretch. Consequently fractures developed. Børve et al. (2000) found that cuticular fractures acted as infection sites for and promoted post harvest fruit rot in sweet cherries; the more cuticular fractures the more rot was observed. Cuticular fractures in the sweet cherry fruit promotes fruit cracking, and are influenced by water uptake to the tree by its roots. Control of such water uptake will improve the reduction or avoidance of fruit cracking in sweet cherries. Water relations in sweet cherry fruit play a pivotal role in fruit cracking. Internal water potential of the fruit is affected mainly by sap import through the fruit pedicel but external water uptake through the fruit surface has also been implicated.

Cherry fruit cracking may also occur as a result of free surface water or an imbalance in internal water relations of the fruit. Cherry fruit will crack when water remains in contact with the fruit surface for a certain period of time. However, fruit have been known to crack even under cover, when the fruit surface is not wet. The traditional opinion is that that water uptake through the fruit surface during and after a rainfall event increases turgor pressure, thus inducing cracking. The water penetrates the wetted fruit cuticle by osmosis due to the difference in osmotic potential between the rainwater and the fruit sap (Glenn & Poovaiah, 1989). Two hydrophobic products are available commercially the first, Raingard® is a carnauba wax based product developed by Washington State University. Due to the rigid nature of carnauba, the coating must be reapplied up to 5 times during stage III of fruit growth. The second product, Parka™, powered by SureSeal® is an elastic co-polymer of cellulose and palm oil and was developed by two of the authors at Oregon State University. Due to the elasticity of the product, Parka only requires two applications for optimal coverage.

In this report we document the use of physical methods to prevent fruit cracking i.e. retractable plastic rain covers and multi-bay polyethylene high tunnels as well as the use of Parka to prevent fruit cracking based on a wax-based biofilm, which seal off the cuticular fractures, retain elasticity and allows for normal shrink-swell processes during fruit growth.

MATERIALS AND METHODS

Physical exclusion of rainwater utilizes protective plastic rain covers, which take many different forms. Two systems that have been researched in Norway include retractable plastic rain covers and multibay polyethylene high tunnels.

Bioforsk three-wires system

It consists of a main frame with wooden poles supporting three overhead wires running the length of each tree row. Within the rows, 5 m long wooden poles (100-120 mm in diameter) are spaced 12 m apart (Figure 1).

Figure 1. The Norwegian three-wires-system

In order to stabilise the poles, they are buried 1-1.2 m in the ground by machinery or hand. This results in a maximum above ground height of 4 m. At the ends of the tree rows thicker poles of 140 mm diameter are recommended. Leaning and securing the end poles outwards strengthens the main frame. Poles are connected to each other with transverse woodwork (4''x 4''at the anchor poles and 2''x 4'' in the rows) 997). Overhead curtains slide back and forth to open and close on three wires down the row. The top wire is positioned about 4 m above the ground and not more than 0.5 m higher than the side wires. The polyethylene cover is therefore gabled around the centre axis. Horizontal distance between the two side wires is row width minus 0.1 m. A maximum tree height of about 3.5 m in the beginning of the season is appropriate.

Cross-laminated or woven polyethylene sheets are used as curtains. Curtain length is similar to the pole spacing in the row. When sheets with eyelets are used, width should be the row spacing minus 0.5 m. Recommended eyelets distance along the sheet side is 1 m. Through each eyelet an elastic rubber band is treaded and equipped with a snap hook. These hooks are connected to the side wires and slide back and forth on these wires when the curtain operates. If birds are a problem, bird-netting may be installed over the plastic on extra wires connected to the top of the poles.

Multibay polyethylene tunnels

Here we wish to take appropriate green house technology to field scale at a low cost for high value crops like top and soft fruits for summer and fall production. These tunnels are comprised of galvanized metal arches spaced 2m apart, attached to galvanized metal posts, which are driven 0.7 m into the soil. For cherries a bay width of up to 8.5 m is most appropriate. In May 2005, a tractor-accessible 4 bay Haygrove® tunnel with open kit strut, was installed at the experimental farm at Bioforsk, Ullensvang, Norway (Figure 2).

Figure 2. Multibay polyethylene tunnels for sweet for prevention of fruit cracking cherry production in Norway.

Each bay was 8.5 m width and 70 m long, with legs 2.5 m in height. Bays were covered with one layer of greenhouse–grade polyethylene. The sides and doors were also covered with polyethylene, but if left open allow for ventilation. Closing allows for growing season extension. Plastic coverings are completely removed during winter and stored in the gutter area between bays and protected using black plastic. There is no permanent heating system, nor electrical connection. Tunnels are however, fed by an external trickle irrigation system that may provide nutrients through fertigation. Each tunnel was divided in half and each half was covered with either Luminance THB film (absorbing infrared light) or traditional Visqueen clear UV polythene film. These overs have different light spectral transmittance.

In each tunnel, two rows of feathered 1-year old 'Sweetheart'/'Colt' cherry trees were planted 2x4m apart, in four-tree plots with a 'Lapins' guard tree in between. All trees were trained as free spindles. Tunnels were covered before bloom (before the end of April) and covers were only removed after harvest was completed. Subplots consisted of 1) treating with 20ppm gibberellin at yellow straw colour and 2) of reflective ground covers. Records of environmental modifications, evaluation of tree growth, and yield performance were kept.

Organic biofilm

A unique formulation of complex carbohydrates and phospholipids was formulated in the College of Pharmacy, Oregon State University in late 2006. The formulation was tested for elasticity by coating a semi-flaccid balloon followed by repeated inflating and deflating of the balloon. No cracking or flaking of the Biofilm was observed. The base formulation has however, been further refinement as a result of several *in vivo* field tests beginning in May 2007. An international patent was applied for in April, 2009 and the Organic Biofilm has tentatively been named SureSeal®.

- *In Vivo* Field Testing

A 5X5 completely randomized block design was laid out at Ullensvang Research Center in 2008. There were four different treatments and an untreated control. Treatments included a) two applications of 1% Biofilm (one at straw color and another 10 days later); b) two applications of Biofilm plus fungicide fenhexamid; c) two applications of Biofilm plus plastic ground covers; d) two applications of Biofilm plus fenhexamid plus plastic ground covers. Fruit were harvested according to industry standards. On the day of harvest, the number of cracked fruit per tree was recorded. In addition, a sample of 50 fruit was harvested from each of the trees and analyzed for fruit firmness ($g.mm^{-1}$), average fruit weight (g) and TSS (% Brix).

RESULTS AND DISCUSION

Multibay polyethylene tunnels

Norway has a rather cool growing season accompanied by heavy rainfall. These tunnels protect the cherry fruit from being exposed to water on the fruit surface. However, it is important have a regular water supply to the roots as fruit can still crack due to rapid fruit volume expansion caused by water uptake through the fruit pedicel. Average temperature from May to mid-September were 14.3°C in 2008 season (data not shown). On only a few days did maximum temperatures rise above 30°C and it was necessary to ventilate the tunnels. On average, there were small differences between daily temperatures between the two different tunnel coverings and the outside temperature in the open land. However, on sunny days, maximum temperatures were 2°C higher inside the tunnels. In 2008, control trees were first harvest on September 15. In 2009, control trees were harvested on September 1. Trees treated with GA_3 trees were first harvested one week later in both years.

In contrast to similar trees grown in the open, all trees grown in the tunnels were extremely precocious and average yield per tree was 9 kg in the fourth leaf and double that in the fifth leaf (Table 1).

Within the tunnels however, there were no differences in yield between the different tunnel coverings, nor different ground covers in either year. Fruit size from trees grown under tunnels was favorable in the fourth leaf, with more than 60% of fruit being >32 mm in diameter. When yields doubled the following year, average fruit size was significant smaller. Only about 20 % of the fruit were >32 mm in diameter and the majority of the yield were in the fruit size between 28-32 mm (data on shown) suggesting over-cropping of the trees. Fruit weight increases with fruit maturity (Table 2) and neither GA_3 treatments, tunnel coverings nor different ground coverings had any negative effect on this compared to untreated control trees. In contrast however, all fruit treated with GA_3 were significantly firmer at four successive selective pick harvest dates.

Table 1. The effects of the bioregulator GA_3 and two tunnel covers (Luminance and clear plastic) on total yield of the sweet cherry cultivar 'Sweetheart' in the fourth (2008) and fifth growing season (2009).

Treatment	Kg per tree 2008	Tons per ha 2008	Kg per tree 2009	Tons per ha 2009
Gibberellin				
Control	8.9	11.1	19.3	24.1
20 ppm	8.7	10.8	18.4	23.0
Significance	NS	NS	NS	NS
Film				
Luminance	8.7	10.9	19.1	23.8
Clear film	8.9	11.1	18.5	23.2
Significance	NS	NS	NS	NS

Table 2. The effects of the bioregulator GA_3 and two tunnel covers (Luminance and clear plastic) on fruit weight and fruit firmness at four different harvest windows of the sweet cherry cultivar 'Sweetheart' in 2008

Treatment	Fruit weight, g – four harvest windows				Fruit firmness – four harvest windows [1)]			
	12.Aug.	15.Aug.	18.Aug.	21.Aug.	12.Aug.	15.Aug.	18.Aug.	21.Aug.
Gibberellin								
Control	12.4	13.0	12.4	13.0	74	70	69	74
20 ppm	14.0	14.7	14.7	14.6	81	79	77	73
F-test	**	*	***	**	***	***	***	IS
Film								
Luminance	13.6	14.1	13.9	14.3	79	74	73	69
Clear film	12.8	13.6	13.1	13.3	76	75	73	77
F-test	NS	NS	*	*	NS	NS	NS	NS
Gibberellin x cover	NS	NS	NS	NS	NS	NS	NS	NS

1) Durofel. Highest readings are the firmest fruit

Surface colour development of fruits was delayed by a week when GA_3 treated compared to untreated control trees (data not shown). In general, average total soluble solid content was high but no significant differences were found between different treatments (17-18 % Brix).

Organic Biofilm.

In Vivo Field Testing

In 2008, fruit cracking in the untreated control averaged 24.6% (Figure 3).

Two applications of 1% Biofilm reduced the average fruit cracking to 17% and further inclusion of a preharvest fungicide (fenhexamid) in combination with plastic ground covers reduced fruit cracking even more significantly to 9.8%.

Utilization of plastic ground covers is essential under heavy rainfall conditions, as the use of 1% Biofilm and fungicide only (18.2%) did not result in an improvement over the use of 1% Biofilm alone.

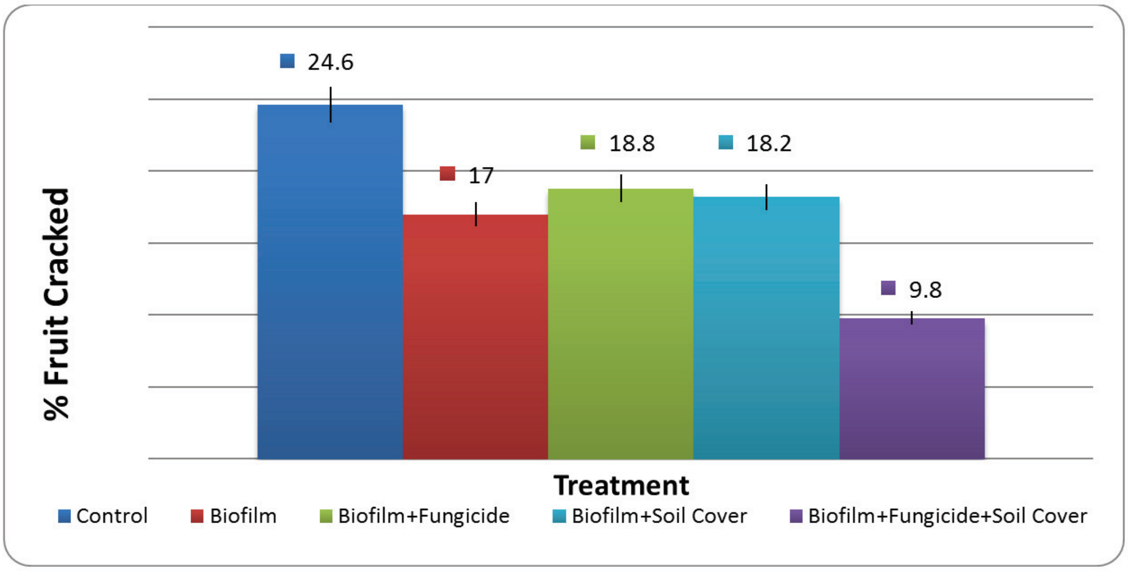

Figure 3. Average percentage fruit cracking of 'Sweetheart'cherries in Loftus, Norway sprayed twice with 1% Biofilm in 2008 in combination with or without a preharvest fungicide (fenhexamid) and plastic ground covers, compared to untreated control trees on the day of harvest.

Consequently, since exclusion of soil water in combination with the Biofilm plus fungicide reduced fruit cracking from 17% to 9.8%, we conclude that almost half the fruit cracking in Norway was the result of internal (soil-plant) water relations. Under the Norwegian conditions, fruit firmness was improved with the use of 1% Biofilm however, this was not significant. In contrast, total soluble solid concentrations were significantly higher in all treatments (ranging from 20.4% to 21.4% Brix) that included 1% Biofilm compared to the untreated control (18.6% Brix). Average fruit weight was however, only affected by the use of Biofilm in combination with ground covers but in the absence of a fungicide (8.9g) compared to the untreated control (10.6 g). Average fruit weight of the control fruit was however, not significantly different from those fruit treated with 1% Biofilm and fungicide in combination with plastic ground covers (10.2g). It is possible that exclusion of rain during the early part of the growing season may have affected fruit size and a drip irrigation system under the plastic covers is implicated. In any event, careful monitoring of the soil moisture content is imperative if fruit cracking as a result of internal water relations is to be avoided. This has major implications for irrigation of cherries especially where they are grown under dry conditions and further research should look at clarifying this aspect. Indeed evidence for this can be found where cherry fruit still crack in the Pacific Northwest even in the absence of rainfall during the three weeks preceding harvest.

CONCLUSIONS

Clearly, cherry fruit cracking may be prevented by excluding water from the surface of the fruit. This may be achieved by erecting physical barriers such as Haygrove® multi-bay tunnels and utilizing organic biofilms such as SureSeal. The choice of covering for the tunnels influences fruit quality, yield and maturity. Indeed, these tunnels allow for season extension too when used in conjunction with GA_3 treatments. The latter also results in firmer fruit. However, these tunnels have their limitations as subsequent research has found significant fruit cracking inside the tunnels under conditions of extremely high rainfall and internal soil water relations are implicated. In the current study where fruit cracking was less than 25% under natural conditions, SureSeal®, the hydrophobic elastic biofilm patented by OSU, was found to reduce fruit cracking significantly when used in conjunction with fungicides and soil covers. SureSeal® also increased fruit size, total soluble solids and the force needed to remove the pedicels from the fruit. Subsequent research (not presented here) is finding however, that limitations also exist for SureSeal®, when rainfall is excessive and natural fruit cracking exceeds 50%. Again, internal soil water relations are implicated and this only serves to demonstrate the importance of soil water management for the prevention of cherry fruit cracking both in the open and under protective covers. Gibberellic acid also has a major effect on cherry fruit cracking in combination with the soil moisture and additional research is aimed at identifying these effects.

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