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High productivity of soilless strawberry cultivation under rain shelters

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ABSTRACT

The effect of rain shelters on the performance of the day-neutral strawberry (*Fragaria* × *ananassa*) Monterey cultivar was studied in northern Québec in trials extending over 2 years. The main objective of the study was to evaluate the benefits of growing strawberry crops under plastic rain shelters in terms of yield, fruit quality, disease incidence and economical returns for soilless strawberry production. Five treatments were carried out and these included four − under rain shelters cultivation (T1 to T4) and one under open-air conditions (the Control, C). Under rain shelters conditions, plants were grown in either peat (PE; T1 treatment) or peat-sawdust (PS25; T2 treatment) substrates. Early forcing of bare-root plants (T3) in combination with a rain shelter cover was also carried out in an attempt to generate consistent early yields by the end of July as such would allow producers to capture a niche market for strawberries in Québec. Finally in T4, the PE substrate was laid onto a capillary mat to determine the potential of sub-surface water retention technology to minimize water use. In comparison to the Control treatment, protected cultivation led to a significantly lower incidence of strawberry mildew [*Sphaerotheca macularis* (Wall. ex Fries)] and consistently higher marketable yields which largely compensated for the initial costs associated with the rain shelters. When grown under greenhouse conditions, forced plants had a significant production peak earlier, coinciding with the period of high prices for fresh strawberries in 2013. However, the economical analysis revealed that this method was not always profitable. Balancing economical and environmental considerations, the conditions of the T4 treatment were found to be best for generating both consistent water savings and profits (CAD $ 724–1356 per 0.1 ha) compared to the Control. Taken together, our results highlight the potential for rain shelters for soilless strawberry production, and should be a more profitable and environmentally friendly cultivation method for strawberry producers.

1. Introduction

From 22 to 27 thousand metric tons of fresh strawberries (*Fragaria* × *ananassa*) are produced each year in Canada (2012–2016 period; Statistical overview of the Canadian fruit industry, 2016). Quebec is the top producing province in Canada (274,822 metric tons), representing 28.8% of commercial strawberry production (Statistical overview of the Canadian fruit industry, 2016). Strawberries are generally produced in open-field systems on raised beds. However, soil-born strawberry diseases are currently a major limiting factor that severely impacts the plant agronomic performance and generates economic losses in conventional production fields (Koike et al., 2010). Recently, and in response to increasing regulatory constraints on all fumigants, soilless culture has dramatically increased in Europe (Neri et al., 2012). While many studies have shown that soilless strawberry production may be a suitable alternative growing system in North America (Kempler, 2002; Paranjpe et al., 2008), there is still a need to expand this crop production system to a commercial scale.

For decades, peat has been widely marketed in due to its great productivity potential and its lower price than alternative inorganic substrates (Parent and Ilnicki, 2002). In spite of its high availability in North America, northern Asia and Europe, peat is not readily renewable, which is a problem in a long-term perspective of sustainable production (Joosten and Clarke, 2002). With respect to peatland conservation, researchers are trying to develop a rational use of this resource by developing and testing horticultural mixes made of peat and

Abbreviations: AFP, air-filled porosity; K_{sat}, saturated hydraulic conductivity; K(θ), unsaturated hydraulic conductivity; BD, bulk density; EC, electrical conductivity; ET, evapotranspiration; PS25, peat-sawdust; θ, volumetric water content; θ_e, estimated water content; WHC, water holding capacity; WP, water productivity; WRC, water retention curves

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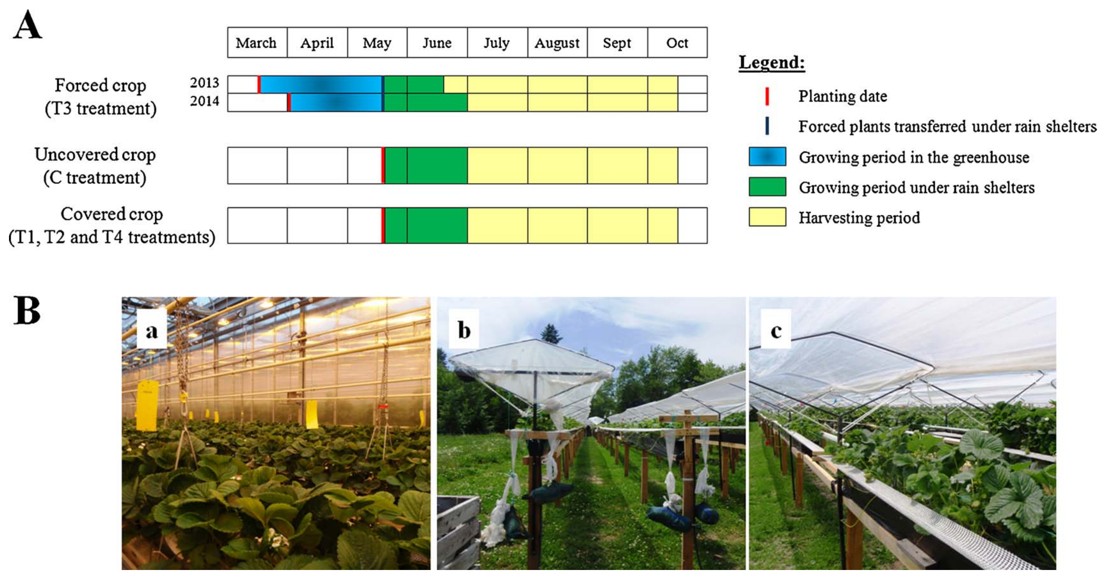

Fig. 1. Experimental design used during the two-year trial. (A) Schematic representation of the experimental design used for the forced plants (T3), the unprotected (Control, C) and protected (T1, T2 and T4) cultivation of strawberries. For T3, the two different strategies adopted for the two years are represented. (B) Photos of soilless strawberry cultivation for forced crop under greenhouse (a), under rain shelter conditions (b, left line) or unprotected (b, right line) with 1.5 m spacing within rows and a final pole density of 243 poles.ha^{-1}. Growing strawberries under rain shelter covers (c). Nets were placed horizontally on either side of the troughs to sustain the flowering stems and facilitate fruit ripening.

wood industry by-products such as bark and sawdust (Clarke and Rieley, 2010; Aubé et al., 2015). Improved performances using bark-based substrates and peat-bark mixes have been previously demonstrated for soilless strawberry production (Jarosz and Konopinska, 2010; Depardieu et al., 2016). In contrast, even when added in small proportions to peat-based growing media, sawdust can affect strawberry plant growth (Jarosz and Konopinska, 2010). Previous studies showed that specific, precise irrigation and fertigation strategies need to be defined to reach the full productivity potential of peat-sawdust substrates (Lemay et al., 2012). Although the suitability of such mixes has been demonstrated for protected (high tunnel) strawberry culture (Depardieu et al., 2016), their performance needs to be further confirmed in a context of open-air rain shelter fruit production.

In northern areas where the season for strawberry production is especially short, expanding the berry production season is particularly important and can be achieved by day-neutral varietal innovation (Taghavi et al., 2016), forcing an early spring crop (Demchak, 2009; Kadir et al., 2006), or using tunnels (Ballington et al., 2008; Medina et al., 2009; Janke et al., 2017). Although several studies have reported attempts to force strawberries in greenhouses, until now a successful summer commercial production has never been reported (Deyton et al., 2009; Neri et al., 2012; Paparozzi, 2013; Takeda, 2000). At present, most marketed cultivars are not adapted to winter climate (Khanizadeh, 2002) and-or highly susceptible to the most destructive and economically important pathogens of strawberry worldwide, including *Botrytis cinerea*, *Phytophthora sp.*, *Sphaerotheca spp.* and *Verticillium spp.* (Elmhirst, 2005; Barboza et al., 2017; Hancock et al., 2008).

Protected culture systems such as greenhouses and tunnels are becoming more popular for frost protection (Neri et al., 2012; Maughan, 2013), extension of the harvesting period, increased yields (Lieten and Baetes, 1991; Grijalba et al., 2015), and fruit quality improvement (Kadir et al., 2006; Xiao et al., 2001) as well as the control of several major plant diseases (Evenhuis and Wanten, 2006; Kennedy et al., 2013). However, warm and dry conditions and the absence of rainfall in these production systems favor the development of strawberry mildew [*Sphaerotheca macularis* (Wall. ex Fries)] (Amsalem et al., 2006; Xiao et al., 2001). Until now, protected strawberry production has remained highly dependent on the intensive use of chemicals to control this plant disease (Pertot et al., 2007). Numerous trials have shown that mildew was persistent under tunnels (Daugaard, 2008; Prémont, 2015) and has had significant adverse economic impact on soilless strawberry production. Botrytis fruit rot caused by *Botrytis cinerea* is another major limiting factor in berry production under high-tunnel environment (Grijalba et al., 2015). Even with weekly applications of fungicides, up to 15% of fruit loss has been observed for cultivars susceptible to *Botrytis cinerea* (Legard and Chandler, 1998). Alternatively, crop cultivation under rain shelters has the potential to achieve economic benefits due to the low cost of these structures combined with the better fruiting performance of crops than in open-field production (Latifah et al., 2014; Xu et al., 2013). These protected structures effectively reduce fruit damage due to rain, frost and disease occurrence, while creating a more favorable microclimate in terms of ventilation and relative humidity than do greenhouses and tunnels (Inada et al., 2005). Furthermore, such growing system appears to be a viable alternative cultivation system in northern America where significant rainfalls occur during the production season.

The main purpose of this study was to evaluate the benefits of growing strawberry plants in substrate under rain shelters in terms of yield, fruit quality and disease incidence. By protecting strawberries from rain while reducing infection risks associated to the *Sphaerotheca macularis* and *Botrytis cinerea* pathogens, we hypothesized that this growing system would increase marketable yields. We further aimed to optimize the seasonal fruit yields and water use under the rain shelter and soilless production conditions by using (1) greenhouse-forced plants, (2) a low cost and locally produced peat-sawdust mixture and (3) a capillary mat under the peat substrate.

2. Methodology

2.1. Treatments

The five treatments consisted of one group of strawberry plants cultivated under open-field conditions (C, control treatment) and four different cultivation systems/conditions with strawberry plants grown using the rain-shelter cultivation technology (T1, T2, T3, T4; see Fig. 1 for details). T1 and T2 corresponded to plants grown in PE and PS25, respectively. Under T4 conditions, the PE substrate was laid on a capillary mat (AQUAMAT®, Soleno Textiles, Laval, QC, Canada) to minimize water use (Caron et al., 2005a). The T3 treatment involved bare root plants that were forced in the greenhouse during spring and then