Text pages: 10
Words: 3,414
Characters:
Tables and figures:

Electrical conductivity of the nutrient solution: Implications for flowering and yield in day-neutral cultivars.

Corresponding author:	Ms. Nicole Gallace
Coauthor:	Dr. Miet Boonen
Coauthor:	Mr. Philip Lieten
Coauthor:	Prof. Dany Bylemans

Proef Centrum Fruit
Department of Field Research, Berryfruit
Fruittuinweg 1
B-3800 Sint-Truiden, Belgium.

Ph:	+32 (0)11 69 7080
GSM:	+32 (0)488 10 73 60
Fax:	+32 (0)11 69 71 10
Website address:	www.pcfruit.be
E-mail corresponding author:	nicole.gallace@pcfruit.be

Electrical conductivity of the nutrient solution: Implications for flowering and yield in day-neutral cultivars.

N. Gallace[1,a], M. Boonen[1,], P. Lieten[2] and D. Bylemans[1,3]

[1]pcfruit, Dept of Field Research Berryfruit, Sint-Truiden, Belgium; [2]Fragaria Holland, Horst, The Netherlands, [3]KU Leuven, Dept of Biosystems, Leuven, Belgium.

ABSTRACT

The influence of EC on the developmental behavior of June-bearing cultivars, particularly during flower bud initiation and differentiation has been well documented. The influence of nutrient solution EC on the growth and behavior of day-neutral cultivars however is less well established. In this trial three commercial day-neutral cultivars 'Portola', 'Murano' and 'Verity' were grown under tunnels on raised substrate beds. Plants were given nutrient solutions with either a high (1.6 mS cm^{-1}), standard (1.2 mS cm^{-1}) or low (0.7 mS cm^{-1}) EC. Assigned nutrient solutions were given continuously from planting until the end of harvest. Total yield, fruit number, fruit size and truss number were assessed.

At high EC none of the varieties displayed a difference in the number of trusses per plant, however truss architecture was more complex. Truss development at high EC led to more quaternary and quinary fruits. The resulting percentage of class one fruit (>31mm diameter) compared with class two (<31mm diameter) decreased. In the case of 'Murano' and 'Portola', the shift in production towards smaller fruit led to an increase in total yield but a total net decline in marketable fruit.

Truss development in 'Verity' at high EC like 'Murano' and 'Portola' also resulted in more complex trusses. Despite the similar shift in production towards smaller fruit, 'Verity' had an inherent ability to more evenly distribute fruit weight across its truss compared to 'Murano' and 'Portola'. This coupled with a significantly greater number of fruit per plant resulted in maximized yields of class one fruit in 'Verity' grown at EC 1.6 mS cm^{-1} (indicating potential financial gains).

These results suggest that day-neutral cultivars have varying sensitivity to high and low EC and thus differ in their EC optimum. It is also suggests that EC plays an important role in regulating the frequency and complexity inflorescence architecture in day-neutral cultivars and thus the total number of fruit. It might also be concluded that the ability of a cultivar to evenly distribute fruit weight across all berries on a truss is an important characteristic for establishing a suitable EC regime.

Keywords: *Fragaria* x *ananassa*, nutrition, plant performance, substrate, truss architecture.

[a] E-mail: nicole.gallace@pcfruit.be

INTRODUCTION

Strawberry cultivars each exhibit differences in the number of inflorescences, the type of branching and the number of flowers initiated on each inflorescence. Irrespective of genetic differences, nutrition has been shown to play a role in regulating the flowering behavior of strawberries, particularly during periods of flower initiation and flower differentiation.

In previous trials, with June-bearing types, restricted nutrition during flower differentiation led to a reduced number of inflorescences and a reduction in tertiary, quaternary and quinary fruits per inflorescence (Lieten, 2002). In the same study, it was also observed that average fruit size was larger as fruit numbers decreased. Similarly, Breen and Martin (1981) observed a reduction in truss size when nutrition was low. In other reports restricted nutrition leading up to and during flower initiation promoted flower induction (Guttridge, 1985) although in this case the final number of inflorescences was dependent on the number of developed crowns, a direct result of enhanced nutrition.

In all previous trials June-bearing cultivars have been the focus of research efforts. Flower initiation and flower differentiation in all June-bearers occurs at a discreet moment in autumn when temperature and day length conditions become favorable. At this point in time it is possible to establish a set of EC conditions conducive to flower bud initiation and/or differentiation. A separate set of EC conditions can be applied the following year during flower development and fruit growth. Day-neutral plant types however do not afford such luxury and necessitate that the requirements for flower initiation, differentiation, development and fruit growth all occur simultaneously when temperatures become favorable. Day-neutrals thus cause much confusion among substrate growers accustomed to growing short day cultivars who wish to manipulate their crop. There is significant knowledge available with regard to manipulating the flowering behavior of short day plant types, however equivalent knowledge regarding the manipulation of day-neutral flowering types is in practice largely assumed.

Typically in Central Europe EC levels advised for substrate strawberry production in june-bearers range between 1-1.45 mS cm^{-1} for optimum fruit growth and quality (Lieten, 2003). To date there has been little need to question the widely accepted rate since one cultivar 'Elsanta' has been the dominant variety for substrate production over the last thirty years, upon which most research is conducted. In recent times, interest in day-neutral plant types has gained momentum. The cropping of day-neutrals offers several benefits although there is currently no one particular cultivar which is considered mainstream. Many new cultivars present themselves annually and then quickly disappear. Nevertheless day-neutral production on substrate appears to be increasing.

Whilst the advised EC rate devised for 'Elsanta' appears to work also for most day-neutral cultivars, it is not known with any certainty if these conditions actually optimize production or not. There is thus a level of assumed knowledge that is applied in practice on day-neutrals in substrate. It is therefore the purpose of this study to confirm or reject this widely accepted EC rate as being also optimal for the production of day-neutral cultivars. It is also the purpose to examine the flowering and subsequent yield response to varying EC levels and establish if the effects are equivalent across cultivars.

MATERIALS AND METHODS

Cold stored bare rooted frigo plants of commercial cultivars ‘Verity’, ‘Murano’ and ‘Portola’ (sourced from commercial plant nurseries near Breda in Holland) were used in this trial. Plants of each variety were planted in raised substrate beds in plastic tunnels. The raised substrate bed (a semi-permanent bed) was formed in soil with a gutter along the center. A drainage pipe extended along the base of the gutter and the entire bed was covered with black weed mat. The gutter was filled with 100% blonde peat. On the 12th of March 2015, all three tunnels were planted. Each tunnel became a treatment block where all plants within a tunnel were given the same nutrient solution with a specific concentration. Each of the three cultivars was replicated six times in each tunnel. Each replicate was comprised of eighteen plants. All plants were spaced in two rows down the bed at six plants per running meter and replicate plots of all varieties were completely randomized within the tunnel. Each tunnel was comprised of three substrate beds, each fifty meters long. The nutrient solution was fed via a pressure compensated drip tube with drippers spaced every 25cm. Designated feed solutions were given from the first moment after planting in March until the end of harvest in October. An EC rate of 1.2 mS cm^{-1} was used as the standard control typical of an EC given during a crop of 'Elsanta'. An EC both lower and higher than the control rate was applied. An EC rate of 0.7mS cm^{-1} comprised the low EC solution and the high concentration nutrient solution had an EC of 1.6 mS cm^{-1}.

At the end of June 2015 flower trusses formed in the previous autumn (in 2014) were removed. First trusses were not considered relevant to the trial since they were initiated and differentiated under different EC conditions in the nursery the previous year. All plants were harvested twice a week. At each harvest total yield was recorded, the size grading determined and total number of fruits counted. At the end of the harvest season the average number of flower trusses per plant and the number of fruits per truss was recorded.

After testing for 'homogeneity of variance', data for total yield, average fruit per plant, average truss per plant and average fruit per truss was analyzed using either Duncans General Linear Model or Friedmans two-way ANOVA.

RESULTS

Plants fed at the high EC level were dark green and had large vigorous foliage with visibly longer petioles and more leaves than the standard and low EC treatments. Conversely plants fed the low EC rate of 0.7 mS cm^{-1} gave visibly less leaves, were lighter in color, and had a smaller leaf area. Petioles and flower trusses were also visibly shorter than the other treatments (data not shown).

In all cultivars, plants fed a high EC resulted in a slightly later harvest season whilst those fed at the lower rate tended to have an earlier middle harvest date. There were no noticeable differences in the production pattern of plants fed varying EC. The production pattern of all plants fed under the different EC regimes appeared to follow the same pattern with no visible variation (data not shown).

High EC (1.6 mS cm^{-1}) consistently gave the highest total yield (g per plant) across all day-neutral cultivars tested. Cultivar 'Verity' gave the greatest total yield increase at high EC yielding 13% more than plants fed the standard rate (1.2 mS cm^{-1}) (table 1). The total yield increase of both Murano and Portola at high EC was 6% and 1% more respectively (table 2,3).

At low EC (0.7 mS cm^{-1}) all cultivars gave a much reduced total yield per plant compared with the standard EC. As with high EC, each cultivar varied in its relative sensitivity to reduced EC. The cultivar 'Portola' appeared most sensitive giving 30% less total yield per plant when EC was low. Cultivars 'Murano' and 'Verity' also experienced yield decline at low EC giving 18% and 11% less total production respectively.

At high EC all cultivars generated the greatest number of fruits per plant although only 'Verity' and 'Murano' had a total fruit number that was significantly higher than the standard (with 90% confidence). At high EC 'Verity' produced on average 16 more fruits per plant, 'Murano' gave an extra 10 fruits per plant compared with plants fed at the standard rate.

At low EC all cultivars generated significantly less (95% confidence) fruit per plant compared to the standard. 'Verity' at low EC generated on average 17 fruit less than those fed with the standard, the cost in fruit number per plant for 'Portola' was 32 fruit and for 'Murano' 28.

Average fruit weight across all cultivars was also influenced by EC. In general reducing the EC gave rise to fruit with an increased average berry weight whilst increasing the EC led to fruit with a lower average fruit weight.

Relative size grading and hence the resulting volume of class one (<31mm diameter, marketable) fruit was therefore also affected. Again the level of sensitivity varied among cultivars. In all cases plants fed a high EC produced a lower percentage of class one fruit (>31mm diameter) compared with the standard. Conversely plants fed a low EC produced an equivalent or higher percentage of class one fruit compared with the standard rate. Generally, the resulting percentage of class two fruit (diameter <20mm) increased at high EC and was consistently lowest at low EC.

Truss architecture also varied across the different EC treatments. As EC increased all cultivars generated trusses that were more complex with a greater number of tertiary, quaternary and quinary fruit and a higher average fruit number per truss. Similarly, plants raised at low EC typically produced trusses with significantly less fruits per truss.

The number of trusses generated per plant also varied across EC treatments. For all cultivars truss number was significantly lower at EC 0.7 mS cm^{-1} compared to EC 1.2. For cultivars 'Murano' and 'Portola' truss number was greatest at the standard EC (1.2 mS cm^{-1}) although there was no significant difference compared with the number of trusses formed at high EC. Unlike 'Portola' and 'Murano', 'Verity' at high EC produced more trusses (5% more) per plant although the increase was not significant.

When the net yield of class one fruit is exclusively considered then the different cultivars begin to suggest different EC optimums. In the case of 'Portola' and 'Murano' the total net yield (table 2,3) of class one fruit is optimized at the standard EC. Conversely class one fruit was lowest at EC 0.7 mS cm^{-1}. 'Verity' on the other hand had a total net yield of class one fruit that was greatest at high EC compared to the standard (table1). At low EC total net yield of class one fruit was considerably less.

DISCUSSION

Although the current trial is based on day-neutral cultivars, results here can in part be supported by results in previous studies. In 2002, Lieten reported that withholding nutrition during flower initiation and differentiation in June- bearers led to reduced flower number, reduced total yield and improved average fruit weight. Breen and Martin (1981) reported reduced truss size with poor nutrition. It is therefore not surprising that during the harvest season of day-neutral cultivars during which flower induction and differentiation must also takes place, that similar observations were made.

Previous studies on Junebearers however have focused heavily on the timing of nutrient application especially leading up to flower bud initiation and following flower differentiation (Yoshida, 1992, and Lieten 2002). Research on june bearers suggests that reduced nutrition just prior to initiation promotes earlier flower initiation, however if continued during the flower differentiation period then flower number per inflorescence is reduced. Results of the current trial do not aim to verify if low EC leads to early flower bud initiation in day-neutrals. According to the current results, any promotion of flower bud initiation during the main harvest period due to withheld nutrition or low EC 0.7 mS cm^{-1} would occur at the expense of truss number and fruit number per plant, thus significantly reducing total yield.

It is perhaps worthwhile in future trials to consider the timing of application of the nutrient solution following planting in the lead up to flower bud initiation in the new season, locally termed 'second trusses'. 'First trusses' are considered those initiated in the previous autumn in the nursery. A typical gap in production separates the two flushes and is preferably avoided since it upsets the continuity of supply and potentially also impedes yield potential. If withholding nutrition in early spring were to promote early onset of flower initiation and consequent development of second trusses assisting to bridge the typical gap in production then the timing of EC application in day-neutrals would be warranted. General harvest patterns for each of the treatments in this trial however did not provide any evidence of earlier onset of spring flower initiation (data not shown). It was also beyond the scope of this study.

Few papers have reported effects of EC on resulting inflorescence structure and consequences for marketable yield. While total yield gives some idea about productivity, it is the portion of class one fruit that is considered a more interesting measure for growers. The generation of small and misshaped fruit contributes to excess costs that are unlikely to be adequately remunerated by local markets. In the case of 'Elsanta', truss architecture is typically complex and prone to producing an abundance of lower order, small fruits. It is therefore the purpose of research efforts to maintain fruit size through reducing inflorescence size and also inflorescence number.

Despite increased total yields and total fruit number at high EC, the relative shift towards smaller, less marketable fruit in both 'Portola' and 'Murano' means that at high EC total marketable yield is in fact reduced rather than optimized. 'Verity' on the other hand has a total marketable yield that is optimized at high EC. Verity has a higher average fruit number per truss compared with the other two cultivars. Therefore one would expect a higher number of smaller lower order fruit. However for 'Verity' this is not the case. This begs the question 'why'? All cultivars show similar flowering responses to EC. What is inherently different about the cultivar 'Verity' that gives rise to optimized marketable yields at high EC? Quite probably it has to do with 'Verity's' inherent truss morphology. In all EC treatments Verity maintained the highest percentage of class one fruits compared to the other cultivars. It is thus reasonable to suggest that the inherent ability of 'Verity' to distribute fruit weight more evenly across each truss compared with the other cultivars make it possible to better exploit the benefits of high EC (ie increased fruit number and total yield) without compromising total marketable yield. Looking at the results it is also reasonable to suggest that increasing the high EC rate could even lead to further yield improvement in 'Verity' without compromising the marketable portion of the total harvest. It will be the task of future trials for this to be verified.

The results of this study indicate that the widely advised standard EC rate (in this case 1.2 mS cm^{-1}) for the production of June-bearing cultivar 'Elsanta' on substrate, is not necessarily the best rate for optimizing marketable yield in all day-neutral cultivars. It would appear that there exists inherent cultivar differences in truss morphology leading to differing EC optimums especially in terms of resulting class 1 fruit. Consequently the widespread adoption of a standard EC for optimizing day-neutral strawberry production on substrate is unrealistic.

Undoubtedly plants fed at high EC give more fruits per plant, more fruits per truss, more trusses per plant and the highest total yield. It is however the combination of truss number per plant and the inherent distribution of fruit weight over its entire truss that ultimately determines the resulting yields of class one (marketable) fruit of each day-neutral cultivar and thus its optimum EC.

Literature cited

Breen, P.J; and Martin, L.W., (1981). Vegetative and reproductive growth responses of three strawberry cultivars to nitrogen. J.Am.Soc.Hort.Sci., 106:266-272.

Guttridge, C.G., 1985. Fragaria x anannassa. In The CRC Handbook of Flowering. Volume III, pp. 16-33.Ed. A.H.Halevy. (Boca Raton, Florida : CRC Press).

Lieten, P. (2002). The effect of nutrition prior to and during flower differentiation on phyllody and plant performance of short day strawberry Elsanta. Acta Hortic.567, 345-348.

Lieten, P. (2003). Nutrition of protected strawberries. Paper presented at : International Fertiliser Society (Izmir, Turkey).

Yoshida, Y., (1992). Studies on Flower and Fruit Development in Strawberry with special Reference to Fruit Malformation in 'Ai-berry'. Memoirs of Faculty of Agriculture. (Kagawa University), 57, pp. 94.

Table 1. Yield and Flowering Results of Cultivar 'Verity'.

Cultivar/EC level	Production			Quality Grading				
	Total (g/plant)	(%)	(kg m^{-2})	First class g/plant (%) (>31mm)	Second class (g/plant) (%) (<31mm)	Average fruit weight (g/plant)	Average fruit per plant	Ave trusse pla
Verity/EC 0.7	820	89	3.28	599 (73)	131 (16)	14.1	58a	14
Verity/EC 1.2	920	100	3.68	672 (73)	156 (17)	12.3	75b	18
Verity/EC 1.6	1050	114	4.20	704 (67)	210 (20)	11.5	91c	18

*Results sharing similar letters are not significantly different

Table 2. Yield and Flowering Results of Cultivar 'Portola'.

Cultivar/EC level	Production			Quality Grading				
	Total (g/plant)	(%)	(kg m^{-2})	First class g/plant (%) (>31mm)	Second class (g/plant) (%) (<31mm)	Average fruit weight (g/plant)	Average fruit per plant	Av tr per
Portola/EC 0.7	800	70	3.19	496 (62)	521 (19)	19	65a	1
Portola/EC 1.2	1140	100	4.58	718 (63)	251 (22)	15	97b	2
Portola/EC 1.6	1160	101	4.64	673 (58)	243 (21)	21	96b	2

*not enough repetitions

**Results sharing similar letters are not significantly different

Table 3. Yield and Flowering Results of Cultivar 'Murano'.

Cultivar/EC level	Production			Quality Grading			
	Total (g/plant)	(%)	(kg m^{-2})	First class g/plant (%) (>31mm)	Second class (g/plant) (%) (<31mm)	Average fruit weight (g/plant)	Average fruit per plant
Murano/EC 0.7	970	82	3.86	572 (59)	213 (22)	19	70a
Murano/EC 1.2	1180	100	4.72	614 (52)	271 (23)	25	98b
Murano/EC 1.6	1.250	106	5.01	588 (47)	313 (25)	28	108c

*not enough repetitions

**Results sharing similar letters are not significantly different