Growth Responses of Three New Zealand Northern Highbush Blueberry Cultivars
*(Vaccinium corymbosum)* to Nutrient Availability

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Summary

Responsiveness of three New Zealand northern highbush blueberry cultivars *(Vaccinium corymbosum)* L., 'Nui', 'Pura' and 'Reka' to three degrees of regulated nutrient availability was examined: 1) in the control treatment, no nutrient was added, 2) in the solid fertilizer treatment, a standard commercial fertilizer was applied at the start of the experiment, the release of nutrients being dependent on the properties of the fertilizer and environmental conditions, and 3) in the fertigation treatment, a dilute solution of readily available nutrients was supplied daily. Treatments were applied from mid-May 2001 up until plants were destructively harvested in mid-September 2001. For all three cultivars, accumulated dry matter in the fertigation treatment was 2 to 3 times that in the solid fertilizer treatment, whereas that in the control treatment was the least. 'Nui' had the lowest total dry matter levels, they were significantly higher in the fertigation treatment though because of increases in aboveground growth. The root system was unresponsive to the varying nutrient levels applied. 'Reka', the fastest growing cultivar, had the most responsive root system, its dry weight increasing 2.9 fold in the fertigation compared to the solid fertilizer treatment, that of 'Pura' was intermediate. We concluded that there is potential to apply a finely regulated fertigation system to commercial blueberry production.

Key Words: dry matter allocation, fertigation, nutrient availability, Vaccinium corymbosum.

Introduction

Blueberry production is on the increase in many parts of the world, including Japan, accentuating the trend to plant and cultivate blueberries in non-traditional soil types and climates (Darnell and Williamson, 1997; Patterson, 1996). In a number of these non-traditional sites, lack of vigor and poor yields, particularly for northern highbush cultivars have hindered progress. This poor performance has been primarily related to the root environment in which the plants were grown. In response, there have been numerous attempts to amend the soil, to use artificial media to grow the blueberries in, and/or to use differing fertilizer regimes to increase vigor and yield (Reeder et al., 1998). Our aim in this experiment is to determine the responsiveness of northern highbush blueberry to nutrient availability in two different growth substrates.

Four factors of the root environment are said to influence plant growth rates in northern highbush blueberries; pH, well-aerated soils, moisture and nutrient levels. The first two factors influence the level of nutrient uptake capability of the plant. Northern highbush cultivars grown in soils with a pH level above 6.0 are often associated with poor growth, reduced yields and chlorosis due to reduced uptake of iron, even in the presence of adequate nutrients (Brown and Draper, 1980; Katakura and Yokomizo, 1995; Wolfe et al., 1986). In well-compacted or saturated soils (conditions associated with low aeration levels in the soil) these cultivars also show signs of reduced vigour and dieback because of reduced root growth and consequently, reduced nutrient uptake (Abbott and Gough, 1987; Gough, 1994). Thus, a root environment conducive to nutrient uptake is vital for optimal growth.

Recent research and commercial practices associated with a number of crops such as tomatoes, cucumbers, and even apples and citrus, though not yet as far as the authors know to commercial blueberry production, have advanced the use of finely controlled fertigation as a means of providing plants with the right mix of readily available nutrients at the time when and where they are needed by the plant (Bar-Yosef, 1999; Liebig and Lippert, 1999; Neilsen et al., 2000). In so doing, growth and yield were significantly increased, fertilizer usage decreased, and consequent environmental damage from run-off or salt build-up reduced. This system emphasizes fine regulation of liquid fertilizer application, sometimes on an hourly basis, to meet the needs of the plant for optimal growth (dependent on the current phenological stage of the plant and [external] environmental conditions). With the current practice of solid
fertilizer applications, even with slow release fertilizers, such a fine control over the release and availability of nutrients in the soil is not possible either on a hourly-daily or monthly basis.

In this experiment, such a fertilization system was applied to northern highbush blueberries potted in a peatmoss-pumice mix, a media thought to provide a root environment conducive to nutrient uptake, i.e., a well aerated media with a relatively high water holding capacity, free draining and a low pH. This fertilization system provides a treatment with a consistent high nutrient availability throughout the experimental period. The aim was to characterize the potential of such a fertilization system to be applied to blueberry production in non-traditional areas and how cultivars with different growth habits respond to such a system. In addition, a new medium called aquafoam, an inert phenolic-based foam that provides a well aerated medium with good water holding capacity, is currently being proposed as a potential medium for blueberry production in Japan (Shimamoto, 2001) was tried in conjunction with the fertilization treatment.

Materials and Methods

Three New Zealand bred northern highbush cultivars, Nui, Puru and Reka derived from closely related parentage (Patel and Douglas, 1989), have different growth habits in the nursery and field. Nui is the least vigorous with a prostrate growth habit, whereas Reka is the most vigorous with an upright growth habit; Puru is intermediate.

One-year old cuttings of all three cultivars were repotted (10-liter pots) in mid-May 2001, and the treatments were immediately applied. All plants except those repotted into aquafoam were repotted with a potting mixture of Canadian peatmoss and a fine to medium grade of pumice (1:1, v/v). For the aquafoam trial, the randomly selected, slow growing ‘Nui’ cuttings were repotted into chipped aquafoam after the loose medium was washed away.

Five plants of each cultivar were randomly allocated into three blocks, a control, a solid fertilizer and a fertilization treatment. Five more plants were repotted in chipped aquafoam and were allotted to the block receiving the fertilization treatment, making a total of four treatment blocks. All blocks were hand-watered daily during the experimental period. In the control block no further treatment was applied. In the block receiving the solid fertilizer treatment, approximately 10 g of a commercial fertilizer MagAmp (6-6-6, soluble N-P₂O₅-K₂O) was sprinkled around the base of each plant at the start of the experiment, an amount equivalent to that in current standard practice in Japan for this size pot.

Preliminary trials with liquid fertilization had shown that a commercial nutrient solution (Hyponex 6-6-6, soluble N-P₂O₅-K₂O liquid fertilizer solution) diluted to 1:1500 and the pH adjusted to 4.5 with 1 N HNO₃, gave good growth results. In the fertilization treatment each plant in the block received approximately 20 ml of this diluted solution each morning for the duration of the experiment through a drip irrigation system with a timer. Cultivars within each block were randomly arranged and plants grown for 4 months until mid-September 2001 in a plastic covered greenhouse located at the University of Tsukuba, Agricultural and Forestry Research Center.

The control, solid fertilizer and fertilization treatments impose increasing degrees of nutrient availability. At harvest, the plants were dug up, leaf number and area measured for each plant. After the medium was removed from the roots, the fresh and dry weights of the roots, aboveground stems, and leaves were determined. The dry weight was determined by keeping the samples in an oven set at 65 °C until their weights became constant.

Results

Marked differences between treatments in dry matter production were apparent at harvest in September. Dry matter for all 3 cultivars in the control treatment was 25–35% of that in the fertilization treatment; that in the solid fertilizer treatment was intermediate between these two treatments (Table 1). Whether potted in a peat: pumice mix or in aquafoam, the dry matter level in ‘Nui’ receiving fertilization did not differ significantly (Table 1). Of the 3 cultivars, ‘Nui’ consistently had the lowest accumulated dry matter, whereas ‘Reka’ had the highest amount. On a percentage basis, ‘Nui’ plants partitioned

| Table 1. Dry weights of the roots, stems, and leaves of northern highbush blueberry cultivars receiving different nutrient treatments: none (Control), solid fertilizer, and fertilization. One year old cuttings were potted in 1:1 peat: pumice (Peat) or an aquafoam medium. |
|-----------------|-----------------|-----------------|-----------------|-----------------|
| Nutrients       | Medium          | Nui             | Puru            | Reke            |
|                 | Roots Stem Leaves | Roots Stem Leaves | Roots Stem Leaves | Roots Stem Leaves |
| Control         | Peat            | 4.4 1.8a 1.6a   | 6.5a 2.1a 1.7a  | 12.3ab 5.1a 3.0a |
| Solid Fertilizer| Peat            | 4.7 3.0a 3.3a   | 6.7a 5.1b 4.4b  | 7.9a 5.7a 4.6a  |
| Fertilization   | Peat            | 4.9 9.3b 9.0b   | 11.8b 16.8c 13.3c | 23.1b 21.8b 12.6b |
|                 | Aquafom         | 4.7 9.0b 8.9b   |                  |                  |

Statistical analysis by single factor ANOVA, different letters show significant difference for each cultivar at P<0.05 (n=5)
much less dry matter to roots than the other two cultivars, particularly in the fertigation treatment. Whereas, 'Reka' plants in this treatment had the highest dry matter in the roots compared to the stems or leaves (Table 1).

The allocation pattern in 'Nui' is primarily attributed to the unresponsiveness of the roots of this cultivar to the varying nutrient availabilities imposed in the treatments. Root dry matter only varied from 4.4 to 4.9 g between treatments for 'Nui' (Table 1). In contrast 'Reka' root dry matter varied from 7.9 to 23.1 g between treatments, a 2.9 fold increase in root dry matter from the control to the fertigation treatment, consistent with the higher nutrient availability in the latter treatment. 'Puru' had a 1.8 fold increase. The one exception to this trend is the higher accumulated root dry matter in the control treatment of 'Reka' compared to that in the solid fertilizer treatment. The dry matter accumulated by the aboveground portion of the plants tended to increase with increasing nutrient availability (Fig. 1).

This unresponsiveness of the root system of 'Nui' (little increase in root dry matter with increasing nutrient availability) significantly impacts its shoot/root ratio (ratio of stem and leaf dry weight to root dry weight), it is 1.8 times greater in 'Nui' than that for 'Reka' in the fertigation treatment (Fig. 2). In 'Reka', the root system was most responsive to increasing nutrient availability (Table 1); the shoot/root ratio in this cultivar increased the least with increasing nutrient availability. 'Puru' had a similar increase as 'Nui' with increasing nutrient availability, but the absolute value of the shoot/root ratio was smaller than that in 'Nui' (Fig. 2).

Resource allocation to the aerial portion of the plant varied the most between cultivars in the fertigation treatment. In the 3 cultivars there was a relatively even distribution of dry matter between leaves and stems in the control and solid fertilizer treatments (Fig. 1), with absolute levels being highest in 'Reka', the accumulated dry matter was slightly more in the stem portion than roots. In the fertigation treatment this trend was extended significantly in the 'Puru' and 'Reka' but not in 'Nui', the stem/leaf ratio was approximately 1.3:1 and 1.7:1 in 'Puru' and 'Reka' respectively. As a consequence the absolute differences in leaf dry matter were not as large between cultivars in this treatment as that of stem dry weight.

Relative differences in canopy leaf area between cultivars decreased from the control to the solid fertilizer to the fertigation treatment (Fig. 3). Relative differences in canopy leaf area between cultivars in the fertigation treatment were even less than those observed for stem dry matter. This is attributed to differences in plasticity in specific leaf area (SLA; on a dry weight basis) between cultivars. 'Nui' which had the lowest level of dry matter accumulated in the leaves, had the highest SLA, 161 cm².g⁻¹ compared to 120 cm².g⁻¹ for 'Reka' (Fig. 4). In all three cultivars leaf size consistently
increased in order from the control, solid fertilizer to fertigation, except for ‘Reka’ in the solid fertilizer treatment. Leaf size in descending order was ‘Nui’, ‘Puru’ and ‘Reka’ in all three treatments (Fig. 5).

Discussion

No attempt has been made to optimise the fertigation treatment in this experiment. Fertigation systems that have been optimized for commercial production of other crops with much finer manipulation regimes of the root environment. For example more frequent fertigation (4 to 5 times a day), varying macro nutrient ratios, volume and concentrations of liquid fertilizer depending upon growth stage of the plant with the intent to promote vegetative or reproductive growth (Aoki et al., 2001). Nevertheless, the results from this experiment demonstrate the potential of northern highbush blueberry to respond positively to intensive management of the root environment, irrespective of the growth habit of the cultivars.

During the 4-month experimental period, the dry matter accumulated in the fertigation treatment was 2 to 3 times that in the solid fertilizer treatment, whether the medium was peat:pumice or aquafoam. That the inert aquafoam medium had similar results to the peat:pumice results for ‘Nui’ plants lend further credence to the importance of a moist, free draining, well-aerated root medium with a soil solution pH between 4 and 5 for blueberries. These results also indicate that a system that intensively manages the root environment has the potential to be applicable to commercial blueberry production, particularly in non-traditional sites.

Nurserymen and blueberry growers rank the vigour of the above cultivars in the following increasing order: ‘Nui’, ‘Puru’, and ‘Reka’, which was confirmed by our results. This order is attributed to the resource allocation patterns and adaptability of the cultivars to differing nutrient availabilities. The ‘Nui’ root system has very little flexibility in adapting to variations in nutrient availability, compared to that of ‘Puru’ and ‘Reka’. Such inflexibility to changing nutrient conditions was not apparent in the aboveground growth of ‘Nui’.

Changes in aboveground dry matter, leaf size and specific leaf area indicate that the aboveground portion of ‘Nui’ has a similar level of adaptability to resource availability to that of the other cultivars. The reduced dry matter accumulation by the aboveground portion of ‘Nui’ may be blamed on the relatively poor root growth and/or nutrient absorption capacity resulting in poorer shoot growth. This interpretation is consistent with field observations of ‘Nui’ scions grafted onto vigorous rootstocks, such as ‘Homebell’ (Vaccinium ashei). The scions of this graft combination are very vigorous, compared to self-rooted ones, while still retaining the morphological and fruiting characteristics of self-rooted ‘Nui’ (Piller et al., 2002).

‘Reka’, like the other two cultivars, allocates a relatively higher proportion of dry matter to roots under conditions of poor nutrient availability as typified in the control treatment. Where it differs from the other two cultivars is in its ability to extend root growth to keep abreast of the aboveground development in favourable nutrient availability conditions, e.g., fertigation treatment. Root biomass in ‘Reka’ in this treatment was 2.0 times that for ‘Puru’ and 4.7 times that of ‘Nui’. ‘Reka’ also allocates a significantly larger portion of aboveground dry matter to the stems than leaves in this favourable environment, compared to the other two cultivars. This relates well to ‘Reka’ with its more upright growth habit.

Results from these cultivars in the juvenile stage of growth indicate that the performance of the plants is closely correlated to the growth of the root system. By providing the roots with an environment where nutrient availability closely matches the daily absorption capacity, growth of the plant is significantly improved over the more conventional cultivation method. Finely controlled fertigation, thus, has the potential to be successfully applied to commercial blueberry production, particularly in non-traditional sites.

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Literature Cited


ニュージーランド産の北部ハイブッシュブルーベリー品種Nui, Puru, Rekaの栄養生長に及ぼす肥料形態の影響

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摘 要

ニュージーランドで育成した北部ハイブッシュブルーベリーの品種Nui, Puru, Rekaについて、肥料形態と施設方法の異なる条件下での栄養生長を比較した。無肥料区を对照区とし、市販の合成肥料を施腐する図形肥料区、植物に吸収できる状態に酸化した施設液を点滴方式で毎日灌水する液体区の3処理を設けた。処理は2001年5月中旬から2001年9月中旬までを行い、処理終了後に植物を部位別に解体して生長量を測定した。乾物重は各品種の全てについて、