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Growth habit of primocane raspberry cultivars grown as long canes for summer cropping

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Abstract

Primocane raspberries require a long growing season and many of them are too late for cropping in the Northern climate, even when grown in a high tunnel. If the primocanes are not cut down in the fall, lateral shoots in lower parts of the cane produce summer crop in the second year of the cane's growth cycle. The aim of our study was to examine the growth habit of seven primocane raspberry cultivars during the second year of the cane's growth cycle and thus evaluate their suitability for the production of a summer crop. Long cane plants of 'Autumn Bliss', 'Autumn Treasure', 'Joan J', 'Imara', 'Kwanza', 'Kweli', and 'Polka' were raised, and grown in a high tunnel after overwintering. Different types of broken buds (from primary, secondary or tertiary buds) on the canes were recorded and lateral length and berry number of each node was measured during summer cropping. Of the cultivars studied here, the growth habit of 'Imara' and 'Kwanza' seemed to be most suitable for summer crop production as long cane plants during their second year of growth. 'Kwanza' plants were sturdy with a high number of laterals and no need for trellising. 'Imara' plants were more trailing with the fruiting laterals concentrated in the middle regions of the canes, and therefore needed trellising.

Keywords: *Rubus idaeus*, lateral shoot, long cane, primary bud, secondary bud, tertiary bud

INTRODUCTION

Raspberry (*Rubus idaeus* L.) cultivars are divided into primocane (annual) and floricane (biennial) types according to their growth cycle (Carew et al., 2000). The distinction between these two groups, however, is not absolute. In fact some floricane cultivars (such as 'Glen Moy', for example) are intermediate, between primocane and floricane types, as they initiate flowers early and produce a small amount of crop during the first year (so called 'tip fruiting') (Ourecky, 1976; Carew et al., 2000). Further, if the canes of the primocane cultivar are not cut down in the fall, lateral shoots in lower parts of the cane produce a summer crop in the second year of the cane's growth cycle, thus performing like a floricane cultivar. As the second crop comes from buds on the lower part of the cane that have failed to produce in the first year, ample fall cropping reduces the amount of summer crop the following year. The proportion of buds that fruit and flower during the first year is genotype dependent, but also affected by environmental conditions (Carew et al., 2003; Sønsteby & Heide, 2010). The time of fruiting in a primocane may also be manipulated by cultural treatments so that only negligible yield is produced in the first year (Oliveira et al., 1996).

A lot of breeding effort in raspberries now focuses on primocane varieties because of the possibilities they provide for season extension, and a growing interest for cultivation in high tunnels. Primocane raspberries require a long growing season, and most of them are too late for cropping in Finland, even when grown in a high tunnel. Growing primocane cultivars as long cane plants for summer crop production is one possibility for expanding the selection of cultivars available for growers in the Northern climates. While growth and development of primocane varieties during their first year have been studied extensively (see Carew et al., 2000 and Heide & Sønsteby, 2011, and the references therein), less is known about how these varieties perform during the second year of growth and when grown for summer cropping.

The goal of our study was to examine the growth habit of seven primocane raspberry cultivars during the second year of the cane's growth cycle with the aim to evaluate their suitability for the production of a summer crop.

MATERIAL AND METHODS

Plant material and growing conditions

Primocane raspberry cultivars 'Autumn Bliss', 'Autumn Treasure', 'Imara', 'Joan J', 'Kwanza', 'Kweli', and 'Polka' were received from commercial nurseries and grown in a high tunnel at the University of Helsinki research site in Viikki (60°13' N; 25°1' E) during the growing seasons 2015 and 2016. The tunnel (8 m W × 35 m L × 4 m H) was covered with clear polyethylene (Folitec UV M 42, Folitec, Westerburg, Germany), and the tunnel floor with white woven polypropylene fabric (MyPex®).

The plants were planted in 10-L pots filled with peat (OPM 630 W, Kekkilä Oy, Vantaa, Finland) in spring 2015 and pruned to two primocanes per pot. Three rows in the tunnel were 2.4 m apart, and the plant spacing within a row was 0.4 m. The plants were fertigated through drip irrigation three times a day with a 0.01% compound fertilizer, Taimi-Superex (NPK 19–4.4–20.2) (Kekkilä Oy, Vantaa, Finland), from 16 May through 5 June, and with a mixture of Taimi-Superex and Turve-Superex (NPK 12–4.7–27.1) (0.08%) from 6 June through 19 August.

After primocane cropping, the number of lateral shoots that had produced a fall crop was recorded, and on 2 December the primocanes were tipped at about 150 cm height. The plants were laid down on the MyPex® fabric, and covered with several layers of acryl cover to protect against frost during winter.

Plants were placed in the high tunnel again on April 29, 2016. Five to 12 plants of each cultivar were included in the experiment. The spacing of the three rows in the high tunnel was 2.4 m, and the plant spacing was 0.5 m within a row. The plants were pruned to one long cane (floricane) per pot. During the growing season, one new primocane per pot was allowed to grow. A bumblebee hive (Minipol, Koppert Biological Systems, Romulus, MI, USA) was placed in the tunnel to ensure pollination on 1 June, 2016.

Plants were fertigated through drip irrigation three times daily for 10 min with a compound fertilizer Taimi-Superex (NPK 19-4.4-20.2) (Kekkilä Oy, Vantaa, Finland) from 17 May through 31 May, with a mixture (1:1) of Taimi-Superex and Turve-Superex (NPK 12-4.7-27.1) from 1 June through 31 July, and with Flower-Superex (NPK 11-3-26) from 1 August through 16 August. The conductivity of the fertigation solution was 1.02 mS/cm. In May, 9 × 1 g of YaraLiva™ Calcinit™ (N 15.5, Ca 19) (Yara, Oslo, Norway) per plant and 4 × 1 g Taimi-Superex per plant was given as additional fertilization.

Soap (Mäntysuopa, Henkel Norden Oy, Stockholm, Sweden) in 2 % solution was used to control small raspberry aphid (*Aphis ideaei*). Biological pest control included *Neoseiulus cucumeris* to control thrips, *Neoseiulus californicus* and *Phytoseiulus persimilis* to control spider mites, and BerryProtect tubes containing different species (*Aphidius ervi*, *A. matricariae*, *A.colemani*, *Ephedrus cerasicola*, *Praon volucre*, *Aphelinus abdominalis*) were used to control aphids (Biotus Oy, Forssa, Finland).

Measurements

The number of buds that had produced a fall crop was recorded on 2 December, 2015. In spring 2016, the diameter of the long canes was measured above the soil level and at 80 cm in height. The number of different types of broken buds (primary, secondary, and tertiary) on the canes were recorded. During the harvest season, raspberry fruits were harvested and counted three times a week. In addition, for three plants per cultivar, fruit yield was harvested and measured for each node separately, and the length of the longest lateral shoot in each node was measured. After the harvest season, the dry weight of the plants, for the canes and the lateral shoots separately, was determined at 80 °C for 7 d.

The data were analyzed with ANOVA using the GLM procedure of the SAS 9.4 software (SAS 9.4, SAS Institute Inc.). Tukey's test with a significance level of $P < 0.05$ was used for pairwise comparisons of the cultivar means.

RESULTS AND DISCUSSION

With the aim to evaluate the growth habit of the primocane raspberry cultivars during their second year of growth, the number of different types of broken buds on the canes were recorded, and lateral lengths and berry number of each node measured. Raspberry canes may have several buds at a node (Jennings, 1979). This characteristic is genetically determined; some genotypes only have one primary bud in each node, while others may have secondary and even tertiary buds present at each node (Jennings, 1988). Total number of living nodes included all the nodes, where at least one type of a bud, either primary, secondary, or tertiary had broken (Table 1). 'Kwanza' had the highest number of living nodes per cane, 21.3, on an average, and 'Imara' had the lowest, 12.6, on an average. Some of these nodes may have produced a lateral shoot already during the previous year.

The number of nodes that had produced a fall crop in the previous year was highest in 'Polka' and lowest in 'Kwanza' (Table 1). The proportion of flowering and fruiting nodes in a primocane is a measure of the primocane fruiting strength and varies greatly between cultivars (Sønsteby and Heide, 2010). Ample fall cropping reduces the amount of summer crop the following year. In the study of Svensson (2016) on organic production of raspberry in high tunnels, summer crops of primocane cultivars were very small, because majority of the buds had broken during the previous fall.

The development of different types of buds into laterals is also affected by environmental conditions. Growth of a secondary bud is usually suppressed by a primary bud, but it may replace the primary bud, if this is damaged e.g. by frost or mechanically, and compensate for yield (Moore, 1994). Even without damage to the primary bud, multiple buds in a node may break. According to Jennings (1979), high cane diameter is related to production of multiple laterals per node, but reduces the proportion of nodes producing a lateral.

The total number of summer crop producing laterals per cane may be estimated as a sum of the laterals from primary buds and secondary buds, as these laterals produce the majority of the yield, and it was highest in 'Kwanza' and lowest in 'Polka' (Table 1). Although 'Kwanza' canes had a high number of nodes, as well as plenty of fruiting laterals, the yield per node was relatively low in this cultivar (Table 2). The number of laterals per cane that emerged from the primary buds was highest in 'Kwanza' and lowest in 'Imara', 'Joan J', and 'Polka'. The highest number of secondary buds producing a lateral was observed in 'Autumn Bliss', where equal numbers of laterals were from primary and secondary buds. In 'Autumn Bliss' even some of the nodes that had produced a fruiting lateral the previous year, had a lateral shoot originating from a secondary or a tertiary bud. Secondary bud break was low in 'Joan J', 'Kweli', and 'Polka'. In 'Kweli', only 18% of the fruiting laterals were from secondary buds.

Table 1. Cane diameter, total number of nodes, number of nodes that produced fall crop, and the number of different types of lateral shoots in primocane raspberry cultivars during the second year of growth. Values marked with the same letter are not significantly different at $P < 0.05$ by Tukey's test (n = 5-12).

Cultivar	Cane diameter (cm)	Total living nodes	Fall cropping nodes	Laterals from primary buds	Laterals from secondary buds	Laterals from tertiary buds
'Autumn Bliss'	1.6 c	20.1 d	4.6 abc	11.5 ab	11.3 b	6.0 ab
'AutumnTreasure'	1.1 a	17.8 cd	3.6 ab	13.4 abc	7.4 ab	1.9 a
'Imara'	1.2 ab	12.6 a	2.8 ab	9.2 a	7.2 ab	3.5 ab
'Joan J'	1.3 abc	14.4 abc	6.7 bc	8.9 a	5.1 a	6.5 b
'Kwanza'	1.5 bc	21.3 d	1.8 a	18.1 c	8.0 ab	5.3 ab
'Kweli'	1.3 abc	17.7 bcd	3.8 abc	14.7 bc	3.2 a	2.5 ab
'Polka'	1.3 abc	12.8 ab	8.3 c	8.8 a	3.5 a	6.1 ab
P	0.001	< 0.001	0.001	< 0.001	0.001	0.004

Table 2. Marketable yield per cane (n = 5-12) and per node (n = 3) in primocane raspberry cultivars grown as long cane plants for summer cropping. Values marked with the same letter are not significantly different at $P < 0.05$ by Tukey's test.

Cultivar	Yield (kg/cane)	Yield (g/node)
'Autumn Bliss'	2.38 b	136
'Autumn Treasure'	0.62 a	50
'Imara'	1.92 b	164
'Joan J'	1.64 ab	94
'Kwanza'	1.66 ab	101
'Kweli'	1.80 b	134
'Polka'	1.65 ab	141
P	< 0.001	ns.

The growth habit of the cultivars is presented in Figure 1. In 'Autumn Bliss', the lateral shoot length and the berry number on the lateral shoots was relatively even along the whole length of the long cane. 'Autumn Bliss' had sturdy canes, which, however, needed support because also the lateral shoots were long and heavy. Total plant dry weight was highest in this cultivar, followed by 'Kwanza' (Figure 2). The number of berries per lateral shoot in 'Autumn Bliss' was high compared to the other cultivars, but this was compromised by small berry size (data not shown).

The lateral shoots of 'Autumn Treasure' were relatively short, and the crop, although modest in quantity, was evenly distributed along the cane. The overall performance of this cultivar was quite poor in our experiment. 'Joan J' did not perform very well, either. For some reason, in part of the 'Joan J' plants, the lowest third of the canes only produced vegetative laterals. 'Joan J' canes were trailing and needed trellising in cultivation.

The growth habit of 'Imara' seemed to be optimal for summer crop production. The fruit yield was concentrated in the middle region of the canes, except the long fruiting laterals originating from the lowest buds that needed trellising during cultivation.

In 'Kwanza', the lateral shoot length and the berry number on the lateral shoots was relatively even along the whole length of the long cane. The average length of the internodes, 4.6 cm, was shortest of all the studied cultivars, and the node number was high. 'Kwanza' had sturdy spineless canes that did not need trellising. The highest cane dry weight and the largest cane diameter were observed in 'Kwanza' and 'Autumn Bliss' (Table 1, Figure 2). The lateral shoots in 'Kwanza' were also relatively thick, and the number of lateral shoots originating from primary buds was highest among the cultivars studied (Table 1). Relatively few new primocanes emerged during the growing season.

In 'Kweli', the most productive lateral shoots were situated at the base of the canes and therefore needed trellising during cultivation, making the growing of this cultivar laborious. Of the newly released Dutch cultivars, 'Imara' and 'Kweli' showed much less vigorous vegetative growth than 'Kwanza'. Their canes were trailing, and needed trellising during cultivation. Both of them to some extent, but especially 'Kweli' had a few long lateral shoots in the lower parts of the cane that also needed trellising.

As 'Polka' is a very early primocane cultivar (Danek, 2002; Sønsteby and Heide, 2010), several buds in the upper parts of its canes had broken during the primocane cropping in previous year, and consequently, summer crop was concentrated in the middle and lower parts of the long canes. 'Polka' was the earliest fall cropper in our study, as well, while the latest fall cropping season was observed in 'Kweli' and 'Kwanza' (data not shown). Internode length in 'Polka' was relatively long, 6.7 cm, on an average.

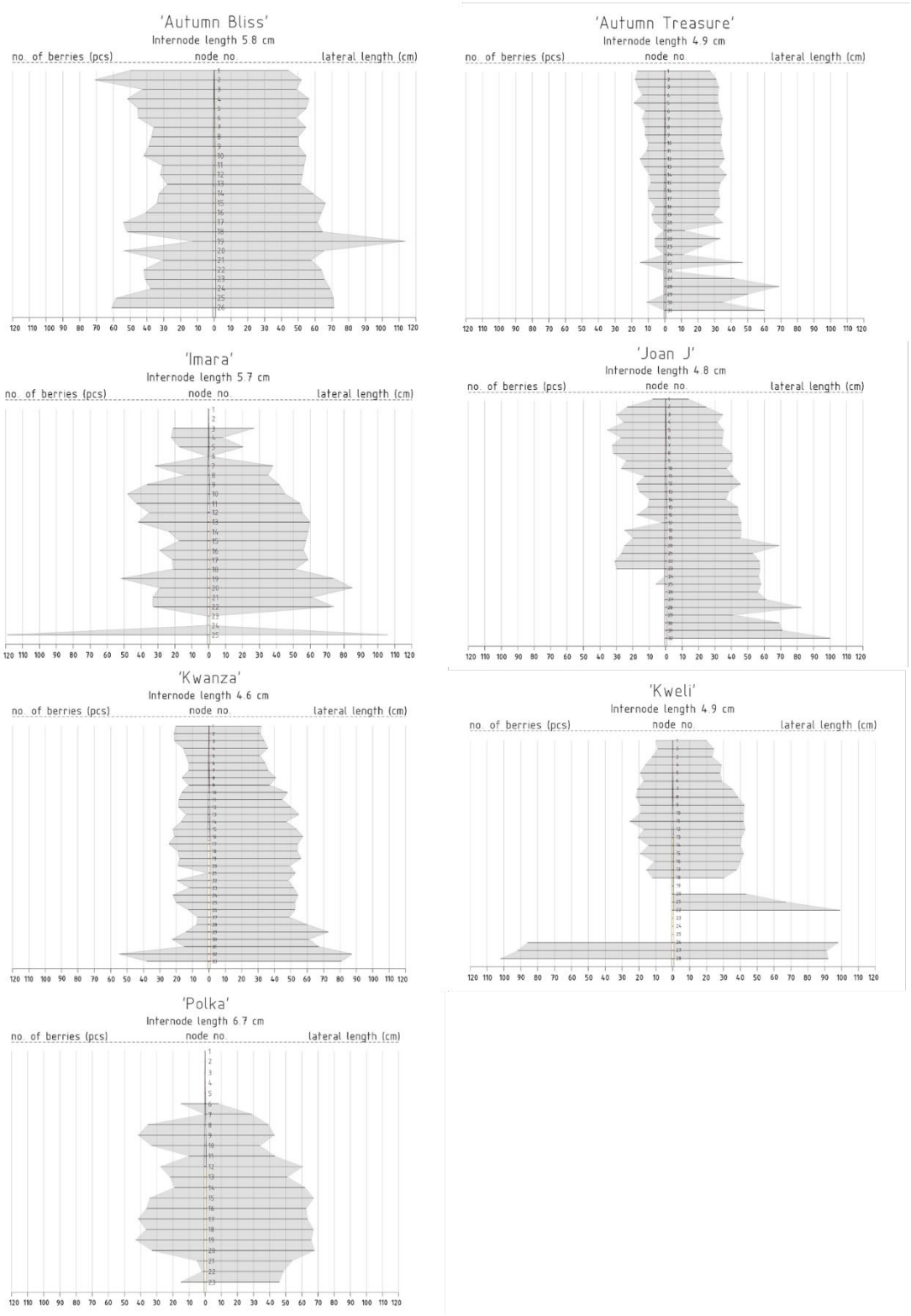

Figure 1. Growth habit of primocane raspberry cultivars during the second year of growth. Lateral buds on the cane are numbered on the vertical axis starting from the top of the cane. Number of berries (pcs) per lateral shoot is presented on the left side of the horizontal axis (n = 3), and the average length (cm) of the longest lateral shoot in each node on the right side of the horizontal axis (n = 5-12).

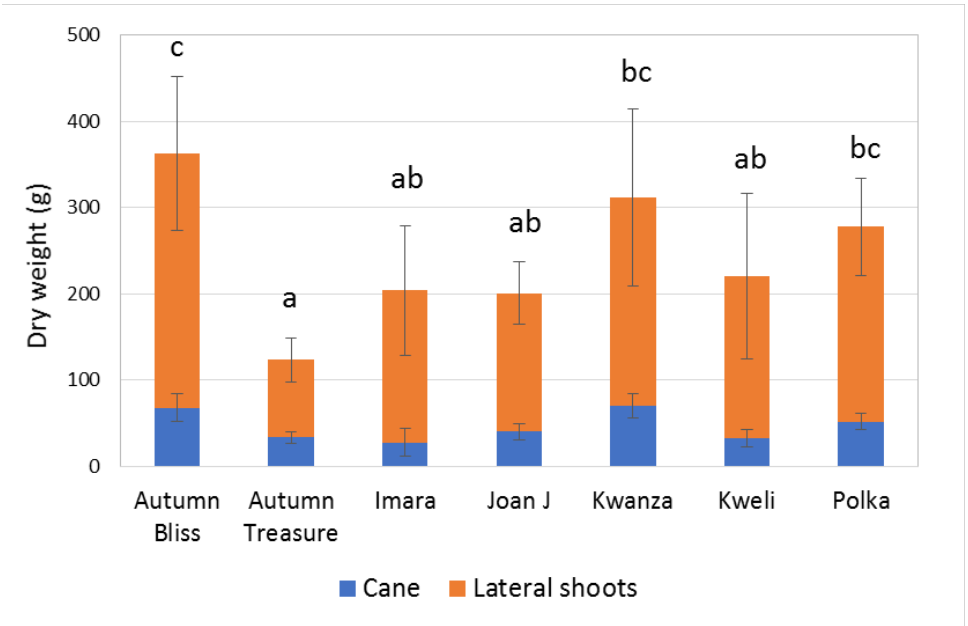

Figure 2. Dry weight of the cane and the lateral shoots in primocane raspberry cultivars during the second year of growth. The vertical bars represent ± SD, n = 5-12. Total plant dry weight values marked with the same letter are not significantly different at $P < 0.05$ by Tukey's test.

When primocane cultivars are grown for summer cropping, the aim is to have as many buds as possible that do not produce a primocane crop, but rather enter dormancy at the end of the growing season. The proportion of buds fruiting the first year may be affected by growing conditions. Generally, long day and increasing growth temperature enhance flowering and increase the number of buds further down the cane that grow out and produce fruiting laterals during the first year (Sønsteby and Heide, 2009). However, in the study of six primocane varieties, 'Autumn Bliss' and 'Polka' were different from the other genotypes in that the proportion of fruiting and dormant buds were less affected by raising temperature (in the range 20 to 26 °C), and in 'Autumn Treasure', flowering was actually suppressed at temperatures above +20 °C (Sønsteby and Heide, 2010). 'Imara', 'Kwanza', and 'Kweli' are relatively new varieties and little published knowledge is available on their behaviour and response to temperature and other environmental conditions.

CONCLUSIONS

Of the cultivars studied here, the growth habit of 'Imara' and 'Kwanza' seemed to be most suitable for summer crop production as long cane plants during their second year of growth. 'Kwanza' plants were sturdy with a high number of laterals and no need for trellising. 'Imara' plants were more trailing with the fruiting laterals concentrated in the middle regions of the canes and needed trellising. In 'Kweli', the most productive lateral shoots were very long and situated in the base of the canes, which made trellising a challenge. 'Autumn Bliss' had very vigorous vegetative growth and a small berry size. The overall performance of 'Autumn Treasure' and 'Joan J' was poor in our experiment. As 'Polka' is a very early primocane cultivar, many of its buds had produced fall crop, making it less suitable for growing as a long cane plant for summer cropping.

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