THE EFFECT OF PRUNING AND TRAINING ON MACHINE HARVEST EFFICIENCY OF 'MEEKER' RED RASPBERRY

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Abstract

Cane density (5, 10 or 15 canes/hill) in a hill system with canes topped at 2 m or the entire cane length retained and looped was compared to a 15 cm and 30 cm wide hedgerow (canes topped at 2 m) in 'Meeker' red raspberry from 1995-97. Plots were harvested with a Littau rotary machine. Looped canes had 0.9 m longer canes on average than those topped. Within the hill system, total yield increased with cane density in all years. Looped treatments produced a higher yield/plot than topped treatments in all years except 1996 when looped canes had greater winter injury than topped canes resulting in a nonsignificant yield difference. Berry mass was from 5.4 to 9.7% smaller on looped than on topped canes. Hedgerow systems had a lower yield than hill systems in 1996, but a higher yield in 1997. Losses to machine harvest were not affected by pruning (cane density or topping) or production system (hill system or hedgerow). Losses were 16.2% of total yield in 1997 with 35% of the losses occurring between harvests that were on 2-day intervals.

1. Introduction

The Pacific Northwest (Oregon and Washington) is the leading producer of red raspberries in the United States with 25.2 million kilograms produced from 4,050 hectares in 1996. Over 80% of the red raspberries produced in this region are machine harvested. With increased labour costs and shortages of available labour, the amount of machine harvest is expected to increase. Various types of self-propelled, over-the-row machines are used, however, the rotary shaker machine is becoming more common than the horizontal "slapper" types.

Cormack and Waister (1976) reported 25% losses in mechanical harvested berries grown in hedgerows in Scotland. Kingston and O'Donoghue (1987) found 24% machine harvest fruit loss in 'Skeena' raspberry grown in hedgerows in New Zealand. Simpson *et al.* (1987) when testing 3 different machines in 5 commercial fields in Washington State reported losses of 21% in the hill system (stools). Martin and Nelson (1987) reported a machine harvest fruit loss of 22% in 'Meeker' using a "slapper" machine.

Machine harvest fruit loss is affected by the operator (machine speed, beater speed, centering the machine on the row), the type of machine, and the cultural practices. Hedgerow plantings, where the catcher plates remain open at a constant distance and fit tightly against the canes, may reduce fruit loss to the ground compared to hill systems; however, this has not been studied.

Essentially all red raspberries in the Pacific Northwest are produced in a hill system. Plants are set 60 to 75 cm apart in rows spaced 3 m to accommodate machine harvesters. Growers often thin out canes in the hills at pruning time. The method by which growers train the canes on the trellis is either a bundle with the canes topped at about 2 m or looped bundles with the canes either slightly topped or their entire length retained.

Mason (1981), in Scotland, found that cane density was greater in a hedgerow than in a hill system. However, the hedgerow had a greater yield than the hill system in only two out of five years (both systems topped at 1.5 m). In the hill system, fruit mass tended to be greater and there were more fruit per lateral (Mason, 1981). In North America, Crandall *et al.* (1974) obtained maximum yield with 12 canes/hill, the highest cane densities imposed. Below this, yield was found proportional to cane number (Crandall *et al.*, 1974). When cane density increased, yield per cane decreased, as canes had fewer laterals and fewer fuit per lateral (Crandall *et al.*, 1974). Increased cane density has been found to either reduce fruit mass (Terrettaz and Carron, 1980) or have little effect (Buszard, 1986).

In many production regions, the fruiting cane is topped to either remove weak or dead sections or to make the cane more manageable for hand harvest. Most research has shown that untopped canes or those topped longer than conventional, produced greater yields than those topped normally (Crandall *et al.*, 1974; Wood *et al.*, 1961). However, Martin and Nelson (1987) found no effect of training system (topped compared to retaining the entire cane) on machine harvested yield of 'Meeker'. Fruits, on average, had less mass on untopped canes than on topped ones (Crandall *et al.*, 1974; Martin and Nelson, 1987), because more, smaller fruit were harvested from the tips of canes (Braun and Garth, 1984). Many growers in the Pacific Northwest, top canes to increase fruit size; the gain in fruit size and loss in yield with this practice has not been well documented. Also, the loss in fruit mass may not be significant for machine harvested fruit for processing.

The objectives of our study were to compare the hill and hedgerow systems at various cane densities and training and pruning systems with regards to total yield, fruit mass and machine harvest efficiency.

2. Methods

'Meeker', the most widely planted commercial red raspberry in the Pacific Northwest, was studied. A field trial was established at the North Willamette Research and Extention Centre, Aurora, Ore. in spring, 1993.

The experiment consisted of 8 treatments and 4 replicates arranged in a completely randomized design. The treatments were a hill system with canes topped at 2 m with either 5, 10 or 15 canes per hill (2.2, 4.4, or 6.6 canes/m^2); a hill system with the entire cane length retained and looped trained at 5, 10 or 15 canes/hill; and a hedgerow with canes topped at 2 m and maintained to either a 15 cm (densities ranged from 3.3 to 7.7 canes/m^2, 1995-97) or 30 cm width (from 4.4 to 9.9 canes/m^2). The hill systems were established with "traditional" nursery plants set at 75 cm in the row. The hedgerows were established with root cuttings at a spacing of 60 cm in the row. Row spacing was 3 m to accommodate machine harvest.

Each plot was 6 m in length followed by a 3 m un-planted section so that the machine could be stopped and "cleared" of all fruit before moving to the next plot.

From 1995-1997, fruit were harvested by a Littau machine (Littau Harvesters Inc., Stayton, Ore.) equipped with a rotary shaker. In 1995 and 1996, fruit were harvested by machine every 5 days. Yield loss on the ground was evaluated by collecting and weighing fruit from a 1.2 m section of row in each plot. In 1997, machine harvest was every 2 to 3 days. Machine harvest efficiency was evaluated by separating fruit loss on the ground into pre-harvest (fruit yield lost between harvests) and during harvest losses. Data on berry mass (average of 25 fruit) were collected at each harvest and a weighted average calculated. Cull weight included non-marketable fruit. Postharvest yield component data were collected from 5 canes in each plot (fruit number per lateral was subsampled from one apical, middle and basal lateral on each cane). Cane diameter was measured at a 30 cm height. Primocane number per plot was counted after fruit harvest (before pruning and training) and floricane number in March.

Data were analysed by analysis of variance for the independent factors of year, training (looped or topped) and cane density (5, 10, or 15 canes/hill). In a full analysis of treatment effects, a contrast was used to compare the hedgerows to the hill systems for yield and other components. Yield and yield/cane were regressed on cane density calculated for all treatments in each year.

3. Results

Year had a significant effect on all variables measured. Within the hill systems, density (canes/hill) had a significant effect on yield/plot and yield/cane in all three years, berry mass in 1996, percent cull in 1995 and percent bud break in 1995 and 1996. Training (topped or entire cane looped) had a significant effect on yield per plot in 1995 and 1997, yield/cane in 1997, berry mass from 1995-97 and percent bud break in 1996 and 1997. There were no training by cane density interactions, except for percent bud break in 1997.

Within the hill system, total yield increased with cane density in all years (Fig.1). Cane length for the entire cane, looped treatments averaged 2.4, 3.2 and 3.2 m for 1995-97, respectively. Looped treatments had a higher yield/plot than topped treatments (2 m) in 1995 and 1997. However, in 1996 there was no difference in yield between topped and looped treatments (Fig.1).

Fruit mass was greater on topped canes than on looped canes in all years - from 5.4 to 9.7% smaller on looped (these had a average mass of 2.72 g over all years - Fig.2). There was no effect of training on fruit number per lateral in 1995 or 1996. However, in 1997, topped canes had an average of 16 fruit/lateral compared to 12 in looped canes (Table 1). Topped canes had a higher percent bud break than looped canes in 1996 and 1997. Percent bud break also declined with increasing cane density in all years except 1997 (Table 1).

The hedgerow systems had a significantly lower yield than the hill systems in 1996, but a higher yield in 1997. The hedgerow treatments had a fruit mass between that of the looped and topped hill system treatments in all years (Table 1).

In general, percent cull and percent drop were not affected by cane density, training or production system. Percent cull was greatest when the planting was young in 1995, averaging 10.7% compared to 8.7% and 3.6% in 1996 and 1997, respectively. Although there was a significant treatment effect on percent cull in 1997, it is probably not biologically significant (Table 1). Losses to machine harvest were not affected by training system or cane density. Percent drop averaged 8.3% in 1995 when the planting was young, 29.5% in 1996 and 16.2% in 1997 (Table 1). In 1997, pre-harvest drop averaged 5.6% with the remaining 10.6% of total yield falling to the ground during machine harvest.

4. Discussion

In this study, yield increased with cane density when 'Meeker' was grown in the hill system (Fig.1). In 1995, we had not yet established 15 canes/hill in our high density treatment, but in 1997 it appeared that higher yields would have been possible with a higher cane density than 15 canes/hill (6.6 canes/m^2). These findings are similar to those of Crandall *et al.* (1974) who found the greatest yield at the highest cane density imposed (12 canes/hill). Unlike Martin and Nelson (1987) who found no effect of training system on yield of 'Meeker', we found that looped canes had a significantly higher yield than topped canes in all years except 1996 (Fig.1). In 1996, the looped canes suffered more winter injury than the topped canes (this has also been observed in growers' fields after a severe winter). Greater cold damage was evidenced by the fact that yield/cane did not differ between topped and looped canes in 1996 (data not shown) and that topped canes had a higher percent bud break than looped canes in 1996 (Table 1).

Fruit mass was significantly lower on looped canes than topped canes in all years, as has been found by others (Crandall *et al.*, 1974; Martin and Nelson, 1987). However, the increased yield from retaining the entire cane when training in some years (24% greater yield in 1997, amounting to the equivalent of 3.2 t/ha, for example) needs to be considered when the end market is processing. Growers and processors should determine whether a 5 to 10% (0.14 to 0.27 g) reduction in mass is a disadvantage when processing.

Cane densities were higher in the hedgerows than in the hill systems in all years. The 30 cm wide hedgerow tended to have fewer fruit/lateral than the 15 cm wide hedgerow and the topped hill system treatments (Table 1). However, fruit mass was not significantly affected by plants being grown in a hill system or hedgerow (data not shown).

Percent cull (unmarketable fruit from machine harvest) was highest in the early years of the study, probably because the longer harvest interval adversely affected fruit quality.

Increasing machine harvest interval has been shown to increase loss in 'Skeena' red raspberry in New Zealand (Kingston and O'Donoghue, 1987). In their study, percent of total yield lost to the ground was 24, 30, and 32% for a 2-, 4-, and 6-day harvest interval, respectively. In our study, losses to machine harvest were only 8.3% when the planting was young in 1995 despite machine harvesting every 5 days. Percent drop increased to 29.5% in 1996, as planting vigor increased and the harvest interval remained long (5 days). In 1997, drop was reduced to 16.2% by harvesting every 2 to 3 days (1 out of every 3 harvests was a 3-day interval), as is done commercially. The losses to machine harvest in the last year of this study were lower than those reported by others in the Pacific Northwest, 21% by Simpson *et al.* (1987) and 22% by Martin and Nelson (1987). We found that 5.6% of the fruit loss in 1997 occurred between harvests. This is lower than the 14% reported by Kingston and O'Donoghue (1987) for both hand and machine harvested plots. We did not show an effect of cane density, training system (topping or looping) or production system (hill system or hedgerow) on machine harvest efficiency. It appears that although machine type and operation may greatly impact machine harvest efficiency, production system and pruning and training appear to have little impact on losses to machine harvest.

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Table 1 - Effect of cane density and pruning/training on yield and its components of 'Meeker' 1995-1997

Treatment	Marketable Yield (kg/plot)	Nodes/cane	Bud break (%)	Average fruit/lateral	Drop (% total yield)
1995					
5 T	11.2 d[y]	38.9 b	49.6 ab	13.2	7.1
10 T	13.7 bcd	37.8 b	39.2 c	10.5	8.2
15 T	14.7 abcd	42.3 b	34.7 c	9.0	8.6
5 L	11.5 cd	64.3 a	50.9 a	9.1	8.9
10 L	18.2 a	60.1 a	37.1 c	9.4	7.9
15 L	15.4 ab	63.3 a	42.1 abc	9.1	7.1
15 cm HR	13.2 bcd	38.0 b	48.8 ab	12.4	9.4
30 cm HR	14.9 abc	39.9 b	41.2 bc	11.9	9.1
1996					
5 T	11.2 bc	29.1 b	61.1 a	16.6	31.1
10 T	13.9 ab	28.2 b	49.9 bc	15.3	25.5
15 T	15.1 a	27.6 b	54.6 ab	16.2	28.9
5 L	11.5 bc	60.1 a	42.7 cd	15.0	28.4
10 L	16.4 a	55.4 a	40.3 d	16.2	26.5
15 L	16.6 a	56.4 a	31.0 e	12.6	30.2
15 cm HR	8.9 c	26.2 b	47.8 bcd	13.5	35.2
30 cm HR	9.0 c	28.1 b	45.9 bcd	10.5	29.9
1997					
5 T	15.2 e	23.2 c	67.0 a	14.7 abc	17.9
10 T	17.2 cde	22.5 c	57.6 ab	16.1 ab	13.1
15 T	19.9 cd	19.3 c	58.8 ab	16.8 a	16.6
5 L	16.4 de	59.8 a	46.1 cd	12.2 cd	16.4
10 L	20.9 bc	52.8 b	52.9 bc	12.2 cd	18.2
15 L	24.6 ab	57.8 ab	40.7 d	11.3 cd	16.9
15 cm HR	24.4 ab	22.8 c	51.0 bc	13.2 bcd	14.9
30 cm HR	25.2 a	24.1 c	63.2 a	11.0 d	15.8

T = canes topped at 2 m; L = canes unpruned and looped trained at number of cane/hill indicated; HR = hedgerow at width indicated
[y] Means followed by the same letter are not significantly different at P = 0.05

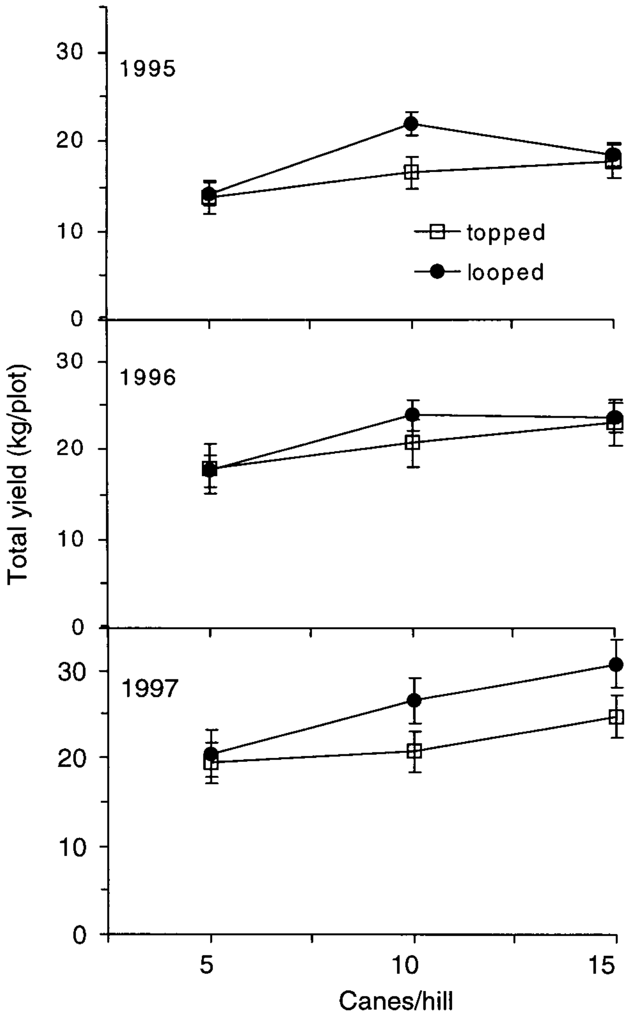

Figure 1. Effect of cane density per hill on the total yield of 'Meeker' either topped at 2m or the entire cane retained and looped, 1995-97

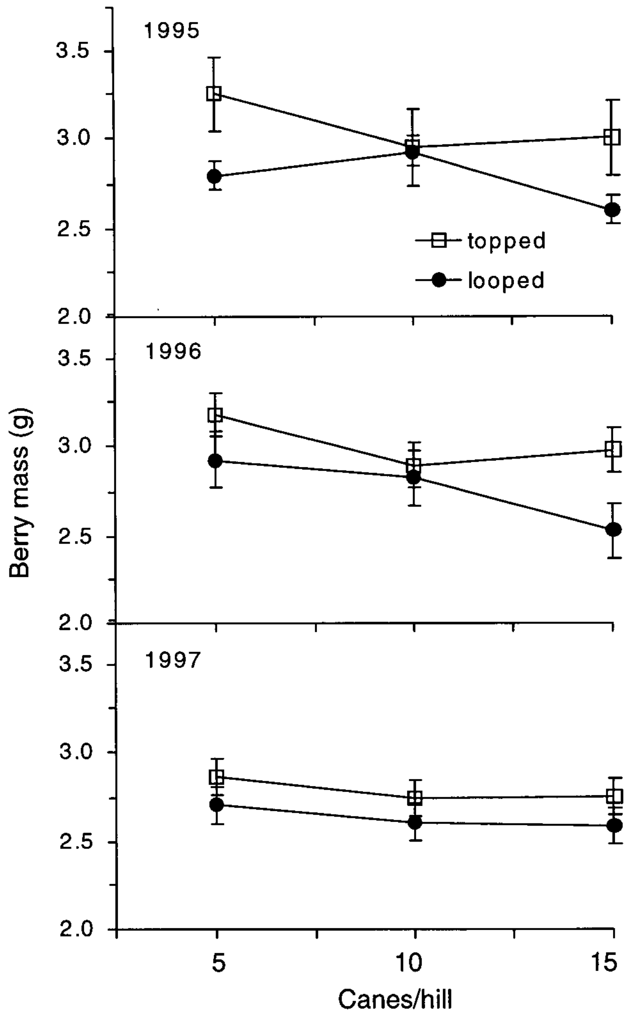

Figure 2. Effect of cane density per hill on the fruit mass of 'Meeker' either topped at 2m or the entire cane retained and looped, 1995-97