Effects of spawn control practices on yield and fruit quality in raspberry.

T. Miller (Washington State University),
D. Jarret, R. Brennan, and R. Hancock (James Hutton Institute)

Two herbicides and manual spawn control were tested for their effects on polytunnel-grown raspberry yield and fruit quality during 2012. The trial was conducted at West Jordanstone Farm (Peter Marshall, grower cooperator) near Alyth (Perth and Kinross), Scotland.

Materials and Methods

Three-year-old raspberry ('Glen Ample') was used for the trial. Plots included four raspberry plants in 4-L pots and grown in a poly-tunnel. Shark (carfentrazone) and Harvest (glufosinate) were applied one, two, or three times to control spawn, as contrasted with hand-removed primocanes and nontreated raspberry canes. Herbicides were applied as a directed spray to the base of the canes when primocanes were 10-cm tall (22 March, 17 April, and 11 May) using an air-pressurized backpack sprayer; hand primocane control was conducted on the same days.

Plots were hand-harvested daily from 15 June to 31 July by the grower's picking crew. Berries were scored as First or Second Class fruit, and each class was weighed. Additionally, four berries from each plot were collected on 28 June and 6 and 18 July for fruit quality analyses; these samples were weighed then frozen at -80 C until used for fruit quality analysis. Frozen fruit were gently broken into separate drupelets from which 3-g subsamples were extracted for organic acid and sugar identification and quantification on 16-20 August. Total fruit polyphenols were measured on 7 September and total anthocyanin on 18 September using a spectrophotometer. Sugars were identified and quantified on 29-30 August and organic acids were identified and quantified on 12-14 September, both using HPLC. Fruit remaining following extraction were processed for juice ºBrix score and pH on 3-5 October.

The experimental design was a randomized complete block with four replicates. Data were analyzed using SAS, and means were separated using Fisher's Protected LSD ($P = 0.05$).

Results

Berry Yield. Few significant differences in yield were noted as compared to the nontreated check. The interaction of herbicide x removal was not statistically significant for any total yield measurement (Table 1). There was a consistent trend toward larger fruit depending on how many times primocanes were removed, with three removals resulting in numerically larger fruit. Shark, Harvest, and hand control all tended to result in more and larger fruit than on nontreated raspberry plants, although these increases were not statistically significant (Table 2). Berry weight was increased significantly with two or three primocane removals compared to berries from nontreated or once-treated raspberry plants, regardless of method of primocane removal.

Average daily yield was increased in two cases: when primocanes were removed three times by hand, and when primocanes were removed twice using Harvest (Table 3). This pattern was true also for average daily production of First Class fruit. The percentage of first class fruit production was significantly higher when raspberry was treated with Shark two times as compared to nontreated raspberry; percent of First Class fruit on plants treated with Shark twice was statistically equal to Harvest applied two or three times or with three hand-removals of primocanes. Herbicide selection alone did not affect daily berry yield measurements, although the trend was for higher daily yield with primocane removal (Table 4). Primocane removal two

or three times increased daily yield and First Class fruit yield as compared to no treatment or once-treated raspberry plants, regardless of method of primocane removal. Percentage of First Class fruit was also greater with two or three removals than with only one removal. There did not appear to be any influence of these treatments on ripe berry production timing (data not shown).

There are at least two other factors to consider regarding berry yield data. First, all raspberry plots were irrigated the same in this trial regardless of primocane management treatments. In an actual production situation, these different treatments would have likely been irrigated differently due to differences in raspberry canopy. Nontreated plants tended to yield less than plants with thinner canopies due to active primocane management; this tendency could potentially have been eliminated had those plants received more water. In a more typical (warmer) year, this factor alone may have accounted for a more statistically significant result. Growers should also keep in mind that different canopy densities may also require differential disease and insect management strategies. Second, the low level of Second Class fruit production was fairly consistent across the primocane management treatments, and was particularly noticeable in daily berry yield. Treatments resulting in lower daily berry yield were therefore mostly due to losses in First Class yield, which represents the highest potential economic impact. Thus, removing canes at least twice provided the greatest yield of First Class fruit every day, based on these single season numbers.

Berry Quality. There was a significant interaction of herbicide x removal for several factors measured in this trial. The most sweeping was that all primocane management programs resulted in reduced °Brix as compared to nontreated raspberry (Table 5). Sampling timing was apparently the single most important factor in this difference, with fruit picked 18 July registering a °Brix of 10.1, significantly higher than fruit picked either 28 June or 6 July (°Brix of 8.2 and 7.8, respectively) (Table 6). Juice pH did not vary much, although fruit from hand-pruned raspberries was slightly less acidic than juice from berries borne on nontreated raspberry plants. Sugar content did not closely follow juice °Brix and pH, with fruit from nontreated plants lower in glucose than from six herbicide x removal treatments, and higher in fructose and sucrose in plants whose primocanes were hand-removed twice (Table 5). Fruit from raspberry plants whose primocanes were removed once with either Harvest or by hand contained more sugar than nontreated plants. Most treatments resulted in berries containing more total organic acids than fruit from nontreated raspberry, approximately 85% of which consisted of citrate. Either Harvest or hand primocane control applied twice resulted in a similar level of organic acids as in berries from nontreated plants. Total polyphenol content did not differ by treatment, although anthocyanin content in fruit from Shark applied three times or Harvest or hand primocane programs applied one time exceeded anthocyanin content of fruit from nontreated raspberry plants.

Most fruit quality parameters differed by sampling date (Table 6). Sugar content, including fructose and sucrose, and °Brix generally decreased from 28 June to 6 July and then significantly increased by 18 July. Juice yield decreased from the first two sampling dates (averaging about 650 L/tonne) to 18 July (602 L/tonne), while juice pH decreased from 2.70 on 28 June to about 2.67 in the July samplings. Polyphenol and anthocyanin content was lowest on 28 June, highest on 6 July, and moderate on 18 July. Organic acids were only slightly affected by sampling date, with malate content highest in June, decreasing by 6 July and then increasing by 18 July.

All methods of primocane management increased total organic acid content of berries compared to fruit from nontreated raspberry, citrate in particular (Table 6). Herbicide choice did not affect any other measurement of fruit quality. The number of primocane removals increased organic acid and glucose content of berries compared to fruit from nontreated raspberry, although fruit from plants whose primocanes were removed twice were lower in citrate, glucose, and total organic acid content than in plants with primocanes removed either one or three times.

While most fruit quality measurements differed significantly depending on herbicide choice and number of times the canes were removed, there were few clear patterns in the data. These results indicate that spawn control programs generally increase the content of most of the measured constituents of fruit quality while decreasing °Brix, although most of these increases were not statistically significant. Organic acid content was most directly related to primocane management program, with fruit from managed raspberry plants producing more organic acids than non-managed plants. Fruit quality constituents differed widely based on sampling time, perhaps indicating that day-to-day ripening may be the largest contributor to production of the fruit constituents measured in this trial.

Raspberry in poly-tunnel production.

From top to bottom, herbicide-treated plot, hand controlled plot, nontreated plot.

Table 1. Total berry yield[z] parameters for 'Glen Ample' raspberry grown in poly-tunnel and treated with spawn control herbicides (2012).

Treatment[y]	Total berry yield	Mean berry weight	First class fruit	Second class fruit	Percent first class fruit
	kg/plant	g/berry	kg/plant	kg/plant	%
Shark, 1 time	1.97	4.3	1.48	0.49	75
Shark, 2 times	1.95	4.8	1.60	0.35	83
Shark, 3 times	1.97	5.1	1.57	0.41	79
Harvest, 1 time	1.75	4.6	1.37	0.38	78
Harvest, 2 times	2.23	5.0	1.81	0.42	81
Harvest, 3 times	1.98	5.1	1.59	0.39	80
Hand, 1 time	1.70	4.9	1.31	0.39	77
Hand, 2 times	2.03	5.0	1.53	0.49	76
Hand, 3 times	2.28	5.0	1.88	0.40	82
Nontreated	1.85	4.3	1.45	0.40	79
Pr > F	0.15	0.16	0.18	0.96	0.89

Means within a column and followed by the same letter, or not followed by a letter, are not significantly different ($P < 0.05$). Pr > F values must be < 0.05 for the means in the column to be considered significantly different.

[z]Berries were harvested daily from 15 June through 31 July 2012.

[y]"Shark" is carfentrazone; "Harvest" is glufosinate. Herbicides and hand control were applied 22 March, 17 April, and 11 May 2012 when primocanes were approximately 10 cm tall.

Table 2. Total berry yield[z] parameters for 'Glen Ample' raspberry grown in poly-tunnel and treated with spawn control herbicides (2012).

Treatment[y]	Total berry yield	Mean berry weight	First class fruit	Second class fruit	Percent first class fruit
	kg/plant	g/berry	kg/plant	kg/plant	%
Herbicide					
Shark	1963	4.8	1557	407	79
Harvest	1988	4.9	1591	398	80
Hand	2001	4.8	1575	427	78
None	1849	4.3	1446	403	79
Pr > F	0.86	0.20	0.88	0.95	0.96
Cane removal					
One time	1792	4.5 bc	1380	412	77
Two times	2069	4.9 ab	1648	420	80
Three times	2078	5.1 a	1679	399	80
None	1849	4.3 c	1446	403	79
Pr > F	0.19	0.006	0.18	0.98	0.68

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Table 3. Average daily raspberry yield[z] for 'Glen Ample' raspberry grown in poly-tunnel and treated with spawn control herbicides (2012).

Treatment[y]	Daily berry yield	First class fruit	Second class fruit	Percent first class fruit
	g/plant	g/plant	g/plant	%
Shark, 1 time	44 cd	32 cde	11	76 d
Shark, 2 times	43 cde	36 bc	8	83 a
Shark, 3 times	44 cd	35 cd	9	79 bcd
Harvest, 1 time	39 de	30 de	8	79 bcd
Harvest, 2 times	50 ab	40 ab	9	81 ab
Harvest, 3 times	44 bcd	35 cd	9	80 abc
Hand, 1 time	38 e	29 e	9	76 d
Hand, 2 times	45 abc	34 cde	11	77 cd
Hand, 3 times	51 a	42 a	9	82 ab
Nontreated	41 cde	32 cde	9	79 bcd
Pr > F	0.0001	0.0001	0.08	0.002

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[y]"Shark" is carfentrazone; "Harvest" is glufosinate. Herbicides and hand control were applied 22 March, 17 April, and 11 May 2012 when primocanes were approximately 10 cm tall.

Table 4. Average daily raspberry yield[z] for 'Glen Ample' raspberry grown in poly-tunnel and treated with spawn control herbicides (2012).

Treatment[y]	Daily berry yield	First class fruit	Second class fruit	Percent first class fruit
	g/plant	g/plant	g/plant	%
Herbicide				
Shark	44	35	9	80
Harvest	44	35	9	80
Hand	44	35	9	79
None	41	32	9	79
Pr > F	0.52	0.47	0.63	0.46
Cane removal				
One time	40 b	31 b	9	77 b
Two times	46 a	37 a	9	80 a
Three times	46 a	37 a	9	80 a
None	41 b	32 b	9	79 ab
Pr > F	0.0001	0.0001	0.85	0.02

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[z]Berries were harvested daily from 15 June through 31 July 2012.

[y]"Shark" is carfentrazone; "Harvest" is glufosinate. Herbicides and hand control were applied 22 March, 17 April, and 11 May 2012 when primocanes were approximately 10 cm tall.

Table 5. Fruit quality parameters from 'Glen Ample' raspberry[z] grown in poly-tunnel and treated with spawn control herbicides (2012).

Treatment[y]	Juice yield	°Brix	pH	Total polyphenols	Total anthocyanin	Glucose	Fructose	Sucrose	Total sugars	Malate	Citrate	Total organic acids
	L/tonne	%		mg/100ml	mg/500ml	g/L	g/L	g/L	g/L	g/50ml	g/50ml	g/50ml
Shark, 1 time	617	8.8 b	2.67 bc	3371	7287 d	89 bcd	142 cd	102 ab	332 bcd	5.3 cd	35.7 bcd	41.0 bcd
Shark, 2 times	647	8.7 bc	2.68 bc	3431	8551 abc	96 abc	152 abc	110 a	358 abc	5.9 bcd	38.4 abc	44.3 abc
Shark, 3 times	643	8.7 bc	2.67 bc	3364	8667 ab	103 ab	155 ab	105 ab	363 ab	6.7 ab	40.9 ab	47.6 ab
Harvest, 1 time	636	8.8 b	2.68 bc	3487	9208 a	107 a	153 abc	109 a	368 a	6.7 ab	42.8 a	49.5 a
Harvest, 2 times	644	8.7 bc	2.67 bc	3258	7334 d	80 cd	148 a-d	101 abc	328 cd	5.5 bcd	31.8 cd	37.3 cd
Harvest, 3 times	638	8.5 bc	2.69 abc	3371	8070 a-d	91 abc	143 bcd	95 bc	329 cd	6.0 bc	36.4 abc	42.4 abc
Hand, 1 time	627	8.8 b	2.66 bc	3348	8636 ab	105 ab	159 a	103 ab	368 a	7.5 a	42.1 ab	49.6 a
Hand, 2 times	639	8.4 c	2.69 ab	3320	8018 bcd	82 cd	137 d	88 c	307 d	5.3 cd	32.7 cd	38.0 cd
Hand, 3 times	641	8.5 bc	2.71 a	3414	8544 abc	105 ab	147 a-d	102 ab	353 abc	5.6 bcd	41.7 ab	47.3 ab
Nontreated	617	9.2 a	2.66 c	3301	7475 cd	72 d	153 abc	108 ab	332 bcd	4.5 d	28.8 d	33.3 d
Pr > F	0.46	0.001	0.01	0.20	0.02	0.0005	0.02	0.03	0.002	0.001	0.0003	0.0003

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[z]Berries were sampled three times for fruit quality analyses: 28 June and 6 and 18 July 2012.

[y]"Shark" is carfentrazone; "Harvest" is glufosinate. Herbicides and hand control were applied 22 March, 17 April, and 11 May 2012 when primocanes were approximately 10 cm tall.

Table 6. Fruit quality parameters from 'Glen Ample' raspberry[z] grown in poly-tunnel and treated with spawn control herbicides (2012).

Treatment[y]	Juice yield	°Brix	pH	Total polyphenols	Total anthocyanin	Glucose	Fructose	Sucrose	Total sugars	Malate	Citrate	Total organic acids
	L/tonne	%		mg/100ml	mg/500ml	g/L	g/L	g/L	g/L	g/50ml	g/50ml	g/50ml
Sampling												
First	645 a	8.2 b	2.70 a	3,068 c	6,182 c	91	151 b	84 b	326 b	8.3 a	35.7	44.0
Second	659 a	7.8 c	2.67 b	3,578 a	10,273 a	90	123 c	78 b	291 c	4.0 c	36.7	40.7
Third	602 b	10.1 a	2.66 b	3,453 b	8,151 b	98	173 a	144 a	416 a	5.5 b	39.1	44.6
Pr > F	0.0001	0.0001	0.0001	0.0001	0.0001	0.26	0.0001	0.0001	0.0001	0.0001	0.20	0.18
Herbicide												
Shark	638	8.7	2.67	3,390	8,248	97	150	106	353	6.0	38.6 a	44.6 a
Harvest	639	8.6	2.68	3,372	8,204	93	148	101	342	6.0	37.0 a	43.0 a
Hand	636	8.6	2.69	3,361	8,399	97	148	98	343	6.1	38.8 a	45.0 a
None	617	9.2	2.66	3,301	7,475	72	152	108	332	4.5	28.8 b	33.3 b
Pr > F	0.44	0.43	0.14	0.87	0.67	0.06	0.94	0.79	0.88	0.26	0.04	0.04
Cane removal												
One time	627	8.8	2.67	3,405	8,476	101 a	152	105	358	6.6	40.6 a	47.2 a
Two times	644	8.6	2.68	3,337	7,968	86 b	146	100	331	5.5	34.3 b	39.9 b
Three times	641	8.6	2.69	3,383	8,427	100 a	148	101	349	6.1	39.7 a	45.8 a
None	617	9.2	2.66	3,301	7,475	72 c	152	108	332	4.5	28.8 c	33.3 c
Pr > F	0.17	0.38	0.07	0.69	0.45	0.0002	0.79	0.89	0.44	0.06	0.0002	0.0002

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