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ANNALES AGRICULTURAE FENNIAE, VOL. 30: 415—439 (1991)

Seria HORTICULTURA N. 70 — Sarja PUUTARHAVILJELY n:o 70

THE EFFECT OF NEW CULTIVATION PRACTICES ON THE YIELD, CANE GROWTH AND HEALTH STATUS OF RED RASPBERRY (*RUBUS IDAEUS* L.) IN FINLAND

Selostus: Uusien viljelymenetelmien vaikutus vadelman satoon, versojen kasvuun ja terveyteen Suomessa

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Academic dissertation
To be presented, with the permission of
the Faculty of Agriculture and Forestry
of the University of Helsinki for public
criticism in the Main Building
of the University, Auditorium XII,
on April 8th, 1992, at
12 o'clock a.m.

PREFACE

This study was carried out at the South Savo Research Station of the Agricultural Research Centre in 1980—1991. I want to express my deep gratitude to my teacher, Professor Erkki Kaukovirta, Head of the Department of Horticulture, University of Helsinki, for his support and guidance over the years.

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Mikkeli, January 1992

Pirjo Dalman

LIST OF ORIGINAL ARTICLES

The original articles summarized here are:

I DALMAN, P. 1991. Yield and cane growth of red raspberry in annual, biennial and semi-biennial cropping. Ann. Agric. Fenn. 30: 441—446.

II DALMAN, P. 1991. The effect of the first-flush primocane removal and additional nitrogen fertilization on the yield, cane growth and cane diseases of red raspberry. Ann. Agric. Fenn. 30: 447—462.

III DALMAN, P. 1991. The effect of vegetative cane removal on the yield at different cane heights of red raspberry. Ann. Agric. Fenn. 30: 463—475.

IV DALMAN, P. 1991. The effect of the first-flush primocane removal on the yield of red raspberry harvested by the Joonas Harvester. Ann. Agric. Fenn. 30: 477—483.

V DALMAN, P. & MALKKI, S. 1986. Experiments on chemical and cultural control of the raspberry cane midge (*Resseliella theobaldi*) and midge blight. Ann. Agric. Fenn. 25: 233—241.

Reference to these articles is made in the text by citing the appropriate Roman numeral.

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THE EFFECT OF NEW CULTIVATION PRACTICES ON THE YIELD, CANE GROWTH AND HEALTH STATUS OF RED RASPBERRY (*RUBUS IDAEUS* L.) IN FINLAND

Dalman, P. 1992. **The effect of new cultivation practices on the yield, cane growth and health status of red raspberry (*Rubus idaeus* L.) in Finland.** Ann. Agric. Fenn. 30: 415—439. (Agric. Res. Centre, South Savo Res. Sta., SF-50600 Mikkeli, Finland.)

The primocane removal, biennial cropping, semi-biennial cropping and machine harvest of red raspberry cvs. Ottawa and Muskoka were investigated in six field experiments in 1980—1987. Competition between fruiting canes and vegetative canes was discussed on the basis of the results of field experiments.

The experiments show that it is possible to achieve significant yield increases when vegetative canes are removed at the beginning of the growing season or totally during the season, but there is a risk that the vigour of plants decreases during the course of years. In the first year, removal of the first flush of vegetative canes at a height of 15 cm increased the yield of cv. Muskoka by 40 % and that of cv. Ottawa by 18 % when picked by hand. When harvested by the Joonas Raspberry Harvester, primocane removal increased the yield of cv. Muskoka by 31 %, but did not increase the yield of cv. Ottawa. In the first cropping year the yield of cv. Ottawa was 32 % higher in the biennial system than in the annual system. When the vegetative canes were removed once at the beginning of flowering, the yield of cv. Ottawa was 55 % higher than without the removal.

The yield increase was due to the increase in yield per fruting cane. The berry number per fruiting lateral was higher when the primocanes were removed, but the number of laterals was not affected. The yield increased in all portions of the fruiting cane. The removal of vegetative canes increased the berry size of cv. Ottawa, but not that of cv. Muskoka.

After the first year the yield did not increase and the plant vigour decreased with decreasing cane length and node number. Additional nitrogen fertilization of 25 kg/ha during flowering failed to increase plant vigour.

Primocane removal tended to decrease the incidence of fungal cane diseases, mainly *Didymella applanata,* of cv. Muskoka. The primocane removal of cv. Ottawa resulted in good control of the raspberry cane midge, *Resseliella theobaldi,* and midge blight. When both the first flush and the second flush of canes were removed, the control of midge larvae was better, but cane growth was excessively weakened.

In the semi-biennial cropping, the vegetative canes developed without competition from fruiting canes, but in the fruiting years, vegetative canes were not removed; the yield did not increase, and cane growth was as poor as in the biennial system. This indicates that in the biennial cropping a prerequisite for an increase in yield is the removal of vegetative canes in the harvest year, not the removal of fruiting canes in the non-cropping year.

The yield increases after the removal of vegetative canes show that the removal reduces competition between vegetative canes and fruiting canes for light, and probably for water and mineral nutrients, too. The results indicate that competition for assimilates and reserve carbohydrates increases, however, because after the removal the raspberry plant always produces a new flush of vegetative canes.

Index words: red raspberry, primocane removal, cropping system, machine harvest, cultivar, nitrogen fertilization, cane diseases, *Didymella applanata, Resseliella theobaldi,* midge blight, competition

The new cultivation practices which are investigated in the present study are based on the theory of competition between the raspberry canes. In the absence of competition from fruiting canes (biennial and semi-biennial cropping systems) the growth of vegetative canes increases. On the other hand, when the vegetative canes are removed totally during the growing season (biennial cropping system), or when only the first flush of canes is removed (primocane removal technique), the yield production of fruiting canes increases.

CRANDALL et al. (1980) believe that primocane removal increases the yield by reducing the competition for storage compounds, photosynthates, nutrients, and light. According to WAISTER and WRIGHT (1989), the increase in yield is primarily an effect of removal of shading of fruiting laterals, rather than an effect of removal of competing sink of assimilates, or reduction in competition for water or mineral nutrients.

1. Review of the literature

1.1. Growth and carbohydrate economy of red raspberry

1.1.1. Vegetative canes and fruiting canes

The red raspberry (*Rubus idaeus* L.) is an unusual species in that it bears woody biennial shoots on a perennial root system. The natural habit of raspberry is to form dense colonies of shoots, which arise as stem suckers from basal axillary buds, or as root suckers from buds on roots (HUDSON 1959). At a raspberry plantation, where the growth is confined within long narrow rows, the tallest and thickest shoots arise from basal buds (LAWSON 1980). The emergence of the first-flush suckers in the spring is completed by the time the tallest have reached a height of about 15 cm. If this flush is left undisturbed, no further emergence occurs. If, however, sucker vegetation is removed at any time during spring or early summer, a second flush of suckers appears, and repeated treatments stimulate the development of further flushes (LAWSON 1980).

The shoots grow vigorously and may attain a height of 3 m or more. As they elongate, adventitious roots form freely on their subterranean part. Shortening days and falling temperatures cause the shoots to cease elongation at the end of the growing season. At the same time most of the axillary meristems initiate flower primordia. Leaves become senescent and fall (HUDSON 1959, WILLIAMS 1959). During the first growing season, the vegetative shoot may be referred to as primocane, young cane, first-year cane, and vegetative cane (HUDSON 1959, WAISTER et al. 1977, WILLIAMSON et al. 1979).

Raspberry flower buds have a cold requirement for breaking of dormancy. In the spring, axillary buds develop into fruiting laterals, which bear both leaves and flowers. Towards ground level there are a few buds which normally fail to elongate. At the same time with the lateral growth, one or more of the basal buds below soil level start to elongate vigorously into a vegetative replacement shoot, which repeats the biennial cycle described above. After fruiting, the whole shoot dies back to the position from which a replacement shoot has grown (HUDSON 1959). The terms fruiting cane, old cane, second-year cane, and floricane are used for the raspberry shoot which is fruiting in its second season (HUDSON 1959, WAISTER et al. 1977, WILLIAMSON et al. 1979).

1.1.2. Light interception and partitioning of dry matter

As with any crop, the productivity of raspberry is a function of four factors: seasonal interception of light, efficiency of its conversion to dry matter, the partitioning of the dry matter to the usable organs, and the water content of these organs (WAISTER and WRIGHT 1989). Partitioning within the whole plant involves production of carbohydrates in photosynthetic organs (sources), phloem loading, and subsequent translocation and unloading at regions of growth or storages (sinks) (DAIE 1985).

In the spring the floricanes of raspberry leaf out rapidly, build up a large leaf biomass early in the season, transfer their photosynthate to the developing fruits, initiate leaf senescence, and fade away gradually. The decreasing floriance leaf area index (LAI) is, however, balanced by the developing primocane LAI. The frost-hardy primocanes maintain a high LAI well into October (WHITNEY 1982). According to the measurements made by WRIGHT (1979), the post harvest growth may account for as much as 25 % of the total primocane dry weight at the end of the season.

Studies of BRAUN et al. (1989) showed that the primocane leaf area increased fivefold between anthesis and preharvest, but between preharvest and postharvest only a slight further increase of the canopy volume was observed. The volume of the floriance canopy was nearly constant during the two and a half months between anthesis and postharvest. The distribution of flowers at anthesis and fruit at preharvest correlated highly with leaf area.

Between the beginning of flowering and the end of fruiting, the increment of dry weight in the fruiting cane is almost exclusively attributable to fruit growth (WAISTER and WRIGHT 1989). WHITNEY (1978) demonstrated a direct relationship between floriance leaf production and fruit production. According to CRANDALL et al. (1974), the number of fruits is closely related to the supply of food materials, principally carbohydrates, available to the developing fruit laterals. Part of this carbohydrate is produced by the new leaves, but most of it must come from storage reserves.

By the end of raspberry fruiting, approximately 0.60 of the current year's dry matter increment in the fruiting cane is allocated to fruit growth (WAISTER and WRIGHT 1989). Expressed on a whole plant basis including primocanes, the fraction of dry matter in the fruit is 0.32 at the end of harvest. Allowing for an estimated 25 % increase in growth of the primocanes between then and the end of the season, the fraction falls to 0.29. This represents the Harvest Increment as defined by CANNELL (1985), but does not take account of the dry matter distribution to roots (WAISTER and WRIGHT 1989).

1.1.3. Production and deployment of reserve carbohydrates

The production and deployment of reserve carbohydrates are not easily linked to any single source of reserves. Studies of WHITNEY (1982) indicated that in Canada during May, the drop in reserve carbohydrates in overwintering canes wast most probably attributed to the production of fruiting laterals. The lateral leaves produced the photosynthate that initially was utilized to replenish the reserve supply of carbohydrates in the floricane stem. Eventually the photosynthate was transferred to the developing fruit.

The development of the primocanes early in the growing season was dependent upon a different source of reserve carbohydrates. Primocanes used probably the reserves stored in the root system. However, the root system rapidly replenished its store of reserve carbohydrates once the functional primocane leaf biomass was developed (WHITNEY 1982).

1.2. Competition between fruiting and vegetative growth

1.2.1. *Intra plant competition between sinks*

A plant can be considered a collection of individual sinks which compete with each other. During plant growth these sinks will change in competitive ability leading to diversion of assimilates towards the stronger sinks. As far as carbohydrate allocation is concerned, CANNELL (1985) suggests an order of priority between sinks where developing seeds would appear to have priority for assimilates with roots, and storage coming last. It is also apparent that developing flower initials are generally weak sinks (WRIGHT 1989).

Order of priority by CANNELL (1985)

High ——————————————> Low

Seeds > Fleshy fruit parts = Shoot apices and leaves > Cambium > Roots > Storage

A sink's competitive ability is a function of its activity, size, and proximity to source (DAIE 1985). The usual explanation for the poor ability of roots to attract assimilates is that they are farthest away from the leaves, and over long distances there is resistance to assimilate flow (WRIGHT 1989). The sink growth rate plays a role in the regulation of sink activity since rapidly growing sinks must create a steeper gradient of assimilates than slower growing ones (WRIGHT 1989). Hormones play a role in the regulation, but it is generally accepted that hormones are not the sole control mechanism. Further, low water potential attracts water with associated mineral nutrients towards developing fruits. Since developing seeds are generally recognized to be a source of plant hormones, and many fruits are known to develop low water potentials during their growth, this could account for their high sink strength (WRIGHT 1989).

1.2.2. *Competition between vegetative canes and fruiting canes of raspberry*

According to WHITNEY (1982), under natural conditions, the competition for the available light and assimilates between the primocane and the floricane of raspberry is minimized by the temporal and spatial separation of their activities. In commercial production systems, however, competition between the two phases has been demonstrated either by complete removal of one cane phase (WAISTER et al. 1977, WRIGHT and WAISTER 1982 a and b), or by the removal of the first flush of primocane growth (WILLIAMSON et al. 1979, CRANDALL et al. 1980, LAWSON and WISEMAN 1983). Both techniques have been shown to give substantial yield increases when fruiting takes place.

WRIGHT and WAISTER (1982 a) compared the growth of primocanes in raspberry stools with normal complement of fruiting canes (annual system) with that in stools from which all fruiting canes had been removed prior to the start of the growing season (biennial system). The latter treatment led to the production of more primocanes, but their average height was lower, largely because of reduced internode length. The total weight of primocane material produced in the biennial system was c. 30 % higher than that from the annual. The biennial primocanes produced a significantly greater leaf area which retained for a longer period. The authors concluded that these were probably light effects, with fruiting cane shading in the annual system causing greater primocane internode extension, and also promoting leaf abscission.

The yield of the biennial system was higher than that of the annual system because of increased number of fruits, arising from the greater number of canes and nodes per cane. Fruit size was not affected. Biennial treatment showed an increase in leaf area and duration and this, together with the better light conditions enjoyed by the biennial system, probably accounted for the increase in yield (WRIGHT and WAISTER 1982 b). The annual system reached its maximum light interception level by the end of May, while the biennial did not do so until the end of August. Although the annual system was overall more efficient in light interception, self-shading led to loss of potential yield. Shading and leaf abscission in the lower laterals led to arrested development of some fruits, and reduced expansion of others (WRIGHT and WAISTER 1984).

When only the first flush of primocanes was removed, the yield increased as a result of higher number of berries per fruiting lateral, and often as a result of greater berries as well (CRANDALL et al. 1980, LAWSON and WISEMAN 1983, BUSZARD 1986, FREEMAN et al. 1989 a). CRANDALL et al. (1980) believed that removal increased yield by reducing the competition of rapidly growing primocanes for storage compounds, photosynthates, nutrients, and light during the critical stages of blossom development. According to WAISTER and WRIGHT (1989), the increase in yield was primarily an effect of removal of shading of fruiting laterals, rather than an effect of removal of a competing sink of assimilates, or reduction in competition for water or mineral nutrients.

2. Background and objective of the present study

In Finland, the cultivation area of red raspberry was only 134 ha in 1990, whereas black currant covered an area of 1245 ha and strawberry 3423 ha (ANON. 1991). However, the demand for raspberry was great, and the whole Finnish production, about 200 tons, went onto the fresh market, where the grower price was satisfactory. In 1989, frozen raspberries were imported for the berry processing industry altogether 2140 tons (ANON. 1990). The reasons for the low production of raspberry are mainly weak winterhardiness, and high production costs. More than half of the costs consist of hand harvesting; and pruning and supporting of the canes is expensive, too. Locally there has been shortage of pickers. In addition, pests and diseases occasionally cause yield losses.

During the last decades, new cultivation practices of raspberry have been developed in the Pacific Northwest and in Scotland, where raspberries are grown on thousands of hectares (TURNER 1980, SCHEER and GARREN 1987). Machine harvesting and biennial production system reduce the costs of harvesting, pruning and supporting. Removal of the first primocanes increases fruit yield and controls excessive cane vigour. The removal improves also the health status of a plantation infested by raspberry cane midge (*Resseliella theobaldi* (Barnes)) and fungal cane diseases (*Leptosphaeria coniothyrium* (Fckl.) Sacc., *Botrytis cinerea* Pers. ex Fr., *Didymella applanata* (Niessl) Sacc.) (WILLIAMSON et al. 1979).

Responses to the new management vary between climatic conditions and between cultivars. Muskoka and Ottawa are the most widely used cultivars in Finland, but elsewhere they are seldom cultivated. They winter reasonably well, but the yields are relatively low (SÄKÖ and HIIRSALMI 1980). Both cv. Ottawa (Viking × (Loganberry × St. Regis)) and cv. Muskoka (Newman 23 × Herbert) originate in Ontario, Canada (BLAIR 1950). The fruits of cv. Ottawa are larger than those of cv. Muskoka. Cultivar

Ottawa produces fewer canes, and the canes are thicker and sturdier. Cv. Muskoka is more susceptible to spur blight (*Didymella applanata*) (Säkö et al. 1980), but less susceptible to cane midge than cv. Ottawa (Dalman 1986).

The aim of the present study was to investigate the responses of cvs. Ottawa and Muskoka to new cultivation practices: primocane removal, machine harvest, as well as biennial and semi-biennial cropping. Yield components, cane growth, and the incidence of both fungal cane diseases and raspberry cane midge were examined. Competition between fruiting canes and vegetative canes is discussed on the basis of the results of field experiments.

MATERIAL AND METHODS

1. General description of the experiments

The materials and methods used in the experiments are described in detail in each individual paper. Only the general features are described here. Field experiments were carried out in Mikkeli (II, III, V), in Puumala (I), or in Kitee (IV) in 1980—1987. The vegetative canes were removed mechanically, either pulling by hand or using secateurs, because the use of dinoseb, the most effective herbicide for the treatment, is prohibited in Finland. In accordance with normal practice, the canes were supported between wires, and the fruiting canes were topped to a height of 170 cm in the spring. Fertilizer applications, as well as pest and weed control complied with the recommendations of the Agricultural Advisory Centres.

Yield and cane growth of cv. Ottawa were investigated in conventional annual cropping, biennial cropping and semi-biennial cropping during four years (I). Under the annual cropping system, both the fruiting canes and the vegetative canes were allowed to grow every year. In the biennial and the semi-biennial cropping systems, the vegetative canes developed without competition from fruiting canes. In the biennial system, the fruiting canes also grew without vegetative canes; the canes were removed three or four times during the growing season when they reached a height of 20—40 cm. In the semi-biennial system, the vegetative canes were not removed during the summer; all the canes were removed after harvest.

The effect of the first-flush primocane removal on the yield, cane growth, and fungal cane diseases of cvs. Ottawa and Muskoka, and the ability to increase plant vigour by additional nitrogen were studied during three years (II). The first flush of primocanes was removed every year when the canes reached a height of 15 cm. Nitrogen fertilization consisted of (a) nitrogen 25 kg/ha in spring with no additional nitrogen, or (b) nitrogen 25 kg/ha in spring and 25 kg/ha during flowering.

The effect of timing of vegetative cane removal on the yield of cv. Ottawa was studied in plants where only one fruiting cane competed with vegetative canes, and competition between the fruiting canes was prevented (III). Yield components were examined in different portions of the fruiting cane at heights of 0—43 cm, 43—85 cm, 85—128 cm, and 128—170 cm. The cane removal treatments consisted of (a) no cane removal, (b) removal once at a cane height of 15 cm, (c) removal once at the beginning of flowering, (d) removal once at the beginning of harvesting, or (e) removal four times throughout the growing season at a cane height of 15 cm.

The need of the first-flush primocane removal in machine harvest was studied with both cultivars (IV). Harvesting with the prototype of the Joonas Raspberry Harvester when the primocanes were removed was compared with harvesting without primocane removal. The first flush of primocanes was removed when canes reached a height of 15—20 cm.

The effect of cultural and chemical control measures, including primocane removal, on the incidence of raspberry cane midge and fungal cane diseases was studied when the severe cane midge infestation of cv. Ottawa was observed in the autumn of 1979 (V). The primocanes were removed when the canes were 10—20 cm high. In 1980, the first flush and the second flush of canes were removed; in 1981 and 1982, only the first flush of canes was removed.

2. Measurement of cane growth

The effect of experimental treatments on cane growth was studied by recording the number of vegetative canes (I, II, III), the height of the canes (I, II, III, V), and the diameter and node number of the canes (II). In addition, the need of pruning in autumn was estimated when the number of vegetative canes which were cut out was counted, and their fresh weight was weighed (II).

The number of vegetative canes was usually recorded at the end of the growing season at the end of September or beginning of October (II, III). When the vegetative canes were thinned at the beginning of July (I), the number of canes was recorded before thinning.

The height of vegetative canes was measured at the end of the growing season (I, II, III, V). Three vegetative canes per plot were sampled, and the mean of three canes was used for the analysis of the results. In one experiment (III), the cane height was measured also at the beginning of the harvest. Cane diameter at a height of 90 cm and node number were recorded on three vegetative canes per plot at the end of the growing season (II).

3. Estimation of the incidence of fungal cane diseases and raspberry cane midge

When the incidence of fungal lesions and midge larvae was estimated, one vegetative cane per metre was sampled and cut out (II, V). Midge blight was assessed at the start of harvesting by counting the dead, wilted fruiting canes (V).

In 1980—1981 (V), when plants were infested by the raspberry cane midge, the canes were sampled after harvesting at the end of August; at this time third-instar larvae were abundant on the canes. The lowest parts of the canes, 0—30 cm, were examined. The number of midge larvae under the outer cortex was estimated on a scale of 0—3, where 0 = no larvae, 1 = one to three larvae, 2 = four to ten larvae and 3 = more than ten larvae per cane. The area of skin covered by fungal lesions was estimated on a scale of 1—5, where 1 = 0—2.5 %, 2 = 2.5—10 %, 3 = 10—20 %, 4 = 20—40 %, and 5 = more than 40 % of the skin was covered by lesions. Fungal species in the vegetative canes were investigated at the Department of Plant Pathology of the University of Helsinki. These results have been published by RUOKOLA (1982).

In 1985—1987 (II), when no cane midge was found, the canes were sampled after pruning at the end of September or at the beginning of October. The lower part of the cane, 0—100 cm, was examined. The area of skin covered by lesions was estimated on a scale of 0—3, where 0 = no lesions, 1 = less than 25 %, 2 = 25—50 %, and 3 = more than 50 % of the skin area was covered by lesions. The violet-brown discoloured lesions were caused mainly by the spur blight (*Didymella applanata*).

4. Harvesting and yield components

The effect of experimental treatments on yield was studied by weighing the marketable yield (I, II, III, IV, V) and the yield which was not marketable (II, IV), by counting the number of berries (III) and by measuring the weight of 100 berries to estimate the berry size (I, II). The number of fruiting canes (I, II, V) and that of fruiting laterals (III) were also recorded.

Berries were usually picked by hand twice a week (I, II, V). The weight of 100 berries was measured when each plot was picked on the third occasion (I, II). In one experiment (III), the berries were counted and weighed on each picking occasion at intervals of 2—4 days. The berries which were not marketable (II) included mouldy berries, and berries damaged by the raspberry beetle (*Byturus tomentosus* Fabr.).

In the machine harvest trial (IV) the yield was harvested by a prototype of the Joonas Raspberry Harvester. Harvesting took place on six occasions at intervals of two, three or four days. The crew consisted of an operator and four sorters beside two inspection belts. Harvested samples were collected into shallow plastic containers. Sorters removed by hand fruit contaminants from the inspection belts. The contaminants, which were weighed, contained mostly unripe berries, but also included some mouldy, crushed or soft berries, as well as fruits damaged by the raspberry beetle. The extraneous material which was lighter than the berry was removed by air-cleaning devices.

The number of fruiting canes was recorded in spring after the injuried canes had been cut out (II) or at the beginning of harvest (I, V). The number of fruiting laterals was recorded at the beginning of harvesting (III).

5. Weather conditions

During the course of the experiments, in 1980—1987 (Table 1), there were two hard winters that damaged raspberry canes (II). In the winter of 1984/1985, the lowest temperature was —34.7 °C, and in the winter of 1986/1987, it was —42.1 °C. The effective day-degrees of the growing seasons of 1980, 1983, 1984, and 1986 were high; the seasons of 1981, 1985, and 1987 were rainy. The growing season of 1987 was exceptionally cold and rainy; effective day-degrees was lower than ever measured in Mikkeli.

Weather conditions were unfavourable to the cane growth in 1986 and 1987 (II). In the growing season of 1986, June was warm and dry, and at the end of July and beginning of August it was much warmer than normally. In June, the precipitation was only one fifth of the long-term average. During the machine harvest period in 1986 (IV) there was only one rainy day, on August 11, and the next day the plants were wet when harvested.

Table 1. Temperature and precipitation in Mikkeli in 1980—1987 and the long-term averages.

	Mean monthly temperature °C								
	1980	1981	1982	1983	1984	1985	1986	1987	1931—1960
January	—10.9	—5.9	—14.3	—4.5	—7.0	—19.3	—11.0	—20.9	—9.1
February	—10.0	—8.8	—8.2	—10.6	—7.5	—17.5	—13.5	—9.2	—9.2
March	—6.4	—7.6	—1.3	—3.6	—4.9	—2.8	—1.0	—6.3	—5.3
April	3.3	0.5	2.0	4.6	4.2	—0.2	1.9	1.6	1.8
May	7.0	10.8	8.5	11.4	13.0	8.3	10.6	7.7	8.6
June	17.2	13.2	10.3	13.6	13.6	13.2	17.1	13.0	13.9
July	16.2	16.9	16.7	17.3	15.4	15.4	16.8	14.8	16.7
August	14.0	13.2	14.7	14.2	13.7	15.7	12.7	11.0	14.6
September	9.5	9.0	9.0	10.6	8.8	8.8	5.9	7.8	9.4
October	3.7	5.1	3.0	4.2	5.5	5.4	4.3	5.5	3.6
November	—5.0	—1.6	2.0	—4.7	—0.9	—3.2	2.2	—3.4	—1.1
December	—6.1	—8.5	—2.7	—5.7	—4.7	—8.9	—11.6	—8.2	—5.4
	Effective day-degrees of the growing season								
	1233	1185	1069	1294	1231	1195	1223	910	
	Total monthly precipitation mm								
	1980	1981	1982	1983	1984	1985	1986	1987	1931—1960
January	32	45	33	75	97	34	52	23	42
February	25	27	11	12	35	11	14	33	30
March	15	47	20	43	35	39	20	23	28
April	17	25	35	55	14	47	41	8	33
May	54	29	55	63	50	68	38	40	40
June	65	96	72	64	66	43	11	149	57
July	49	134	34	38	91	115	78	52	69
August	157	94	97	65	47	74	93	119	73
September	34	43	38	93	117	80	61	90	61
October	101	112	32	88	108	75	59	17	61
November	96	83	84	65	42	52	58	74	48
December	78	98	77	80	39	63	66	52	43
	Total of the growing season								
	358	395	297	324	371	381	281	449	300

RESULTS AND DISCUSSION

1. Growth responses

1.1. The effect of biennial and semi-biennial cropping systems

In annual, biennial and semi-biennial cropping (I) the vegetative canes of cv. Ottawa reached almost the same height in the first autumn, but in the third year the height was strongly reduced both in biennial and in semi-biennial cropping. The cropping systems did not affect significantly the number of canes. A decrease in cane height and an increase in cane number in biennial cropping have been reported previously (WAISTER et al. 1977, WRIGHT and WAISTER 1982 a, TERRETTAZ 1983, BUSZARD 1986, CORMACK and WAISTER 1989).

According to WRIGHT and WAISTER (1982 a), the internode length of vegetative canes shortened in biennial cropping when not shaded by the fruiting canes. CORMACK and WAISTER (1989) reported that although the cane height decreased, the total number of nodes and, after topping, the number of cropping nodes increased. In the present experiment (I), also in annual cropping the need for topping was small, as only some canes reached a height of two metres.

1.2. The effect of primocane removal and additional nitrogen fertilization

When the first flush of primocanes was removed each year in 1985—1987, the plant vigour of cvs. Ottawa and Muskoka also decreased strongly (II). The growth responses of the cultivars were similar. In the first year, the number of vegetative canes in autumn and the need of pruning decreased. However, the plants produced a sufficient number of strong canes for fruiting in the following year. During the second and the third year, the number of strong canes decreased as the removal reduced the cane length, cane diameter and node number, and increased the internode length. When both the first flush and the second flush of the canes of cv. Ottawa were removed in 1980 (V), the cane height remained far below the topping height of 170 cm as early as in the first year.

The purpose of primocane removal is to control the excessive vigour or raspberry canes; when the canes of vigorous cultivars are shorter, the node number below the topping height usually increases. The removal decreases also the diameter and the number of replacement canes (WILLIAMSON et al. 1979, CRANDALL et al. 1980, NORTON 1980, REBANDEL and PRZYSIECKA 1981, LAWSON and WISEMAN 1983, FREEMAN and DAUBENY 1986, FREEMAN et al. 1989 b, SULLIVAN and DALE 1989).

In vigorous plantations the correct timing of cane removal allows replacement canes to produce sufficient fruiting cane length for the following year. However, weak plantings or non-vigorous cultivars can be permanently damaged by the treatment, as cane production may prove inadequate (NORTON 1980, CRANDALL et al. 1980, LAWSON 1986, SULLIVAN and DALE 1989). This was seen in 1987, when the primocane removal of cvs. Ottawa and Muskoka was investigated in a non-vigorous plantation (II). In the previous year drought had affected adversely the cane height, and the growing season in 1987 was exceptionally cold and rainy; in autumn the height of replacement canes was less than one metre.

The increased nitrogen fertilization failed to increase the vigour of cvs. Ottawa and Muskoka (II). The lower quantity of nitrogen, 25 kg per hectare, complied with the Finnish recommendation (ANON. 1989), and the higher quantity was twice as high. Anyhow, additional nitrogen had no consistent effect on the cane height, cane diameter, node number, or on the cane number. CRANDALL et al. (1980) reported similar results when they used greater amounts of nitrogen, 78.5—156.9 kg/ha; the additional nitrogen had no effect on the cane growth after primocane removal.

When the first flush of primocanes is removed at a heigh of 15 cm, in Finnish conditions at the end of May or in the beginning of June, the growing season of replacement canes is three to four weeks shorter than that of first-flush canes. The canes miss the period of rapid growth in May when the days are long in Finland. In addition, the time available for the production of photosynthates and the regeneration of the overwintering carbohydrate reserves is shorter. CRANDALL et al. (1980) showed that the amount of carbohydrates per bud in dormant canes was reduced by primocane removal during the previous growing season.

According to WHITNEY's (1982) theories, when primocanes are removed at a height of 15 cm, their photosynthates are not able to correct the resultant decrease in root reserves; the storage compounds in roots are used once more to produce the replacement canes. After the primocane removal, the cane number decreases and the size of canes, as well as their leaf area, decrease. As a result, the carbohydrate reserves are reduced, and the plant vigour declines during the course of years.

2. The effect of primocane removal on cane health

Removal of the first-flush primocanes tended to reduce the fungal cane diseases, mainly spur blight, of the susceptible cv. Muskoka (II). Reduced incidence of *Leptosphaeria coniothyrium* infecting either physical wounds (cane blight) or midge feeding wounds (midge blight), *Botrytis cinerea* (cane botrytis), or *Didymella applanata* (spur blight), after primocane removal has been reported earlier (WILLIAMSON et al. 1979, REBANDEL and PRZYSIECKA 1981, FREEMAN and DAUBENY 1986). WILLIAMSON et al. (1979) showed that the later the canes were removed, the lower was the incidence of diseases. The apparent resistance of replacement canes to the diseases may be due to their being physiologically younger. According to BURCHILL and BEEVER (1975), the key factor predisposing canes to infection by *D. applanata* seems to be senescence of their cortical tissue, leaves and petioles.

In 1985—1987 (II), when no raspberry cane midge was found, the incidence of fungal lesions in the vegetative canes of cv. Ottawa was low. The cultivar is not susceptible to spur blight, but the cane midge can cause severe fungal infestion (V). In 1980—1981 there was a significant positive correlation between the numbers of midge larvae and fungal lesions. The most common of the isolated fungi was *D. applanata* (RUOKOLA 1982). Other weak wound pathogens were *Fusarium avenaceum* (Cda. ex Fr.) Sacc. and *F. culmorum* (W. G. Sm.) Sacc. *Leptosphaeria coniothyrium*, the most strong of the pathogens, was rare in the samples.

The raspberry cane midge lays eggs in the splits which develop in the bottom 40 cm of vegetative canes (PITCHER 1952). Replacement canes growing after the removal of the first-flush primocanes avoid serious midge infestation because their splits develop late (NIJVELDT et al. 1963, SEEMULLER 1976, WILLIAMSON et al. 1979). Primocane removal of cv. Ottawa resulted in good control of midge larvae, fungal lesions and midge blight (V). When the first flush and the second flush of canes were removed, the control of larvae was better than after one removal, but the control of midge blight worsened. Cane growth was excessively weakened by two removals, and the weak canes were probably destroyed easier by midge blight.

When primocane removal improves the health status of vegetative canes, the yield may increase in the following year (WILLIAMSON et al. 1979, REBANDEL and PRZYSIECKA 1981, FREEMAN and DAUBENY 1986). In the present study (II), the incidence of cane diseases in cv. Muskoka was high in the autumn of 1985. The yield was, however, good in 1986, and the removal did not increase it. DALMAN (1986) reported also earlier that the high incidence of fungal lesions on the canes of cv. Muskoka did not cause any serious yield losses. WILLIAMSON (1980) concluded that in Scotland spur blight alone rarely reduces yield seriously, because lesions and infected buds predominate in the relatively infertile part of canes below 45 cm. In addition, infections by *D. applanta* are usually superficial and do not normally penetrate the vascular tissues.

Midge blight is a more serious problem than spur blight; 35 % of the fruiting canes of cv. Ottawa were destroyed by midge blight before harvesting in 1981, and 26 % in 1982 (V). When the feeding sites of midge larvae are invaded by pathogenic fungi, lesions which block part of the vascular cylinder may develop. Midge blight is defined as the death, bud failure, and lateral wilt of fruiting canes which follow midge injury to vegetative canes (PITCHER 1952, NIJVELDT et al. 1963, SEEMULLER 1976, WILLIAMSON et al. 1979). In addition to the primocane removal the control of midge blight is possible in Finland by cultivating cv. Muskoka which is less susceptible to the cane midge than is cv. Ottawa (DALMAN 1986).

3. Yield responses

3.1. The effect of biennial and semi-biennial cropping system

In the first cropping year, the yield of cv. Ottawa was 32 % higher in the biennial cropping system than in the annual system (I). After three years the plant vigour was strongly diminished in biennial cropping, and in the second harvest year the yield was not higher than in annual cropping. Greater yields have been obtained for a range of cultivars, and under varying conditions after the introduction of the biennial culture (WAISTER et al. 1977, WRIGHT and WAISTER 1982 b, TERRETTAZ 1983, CLARK 1984, BUSZARD 1986, CORMACK and WAISTER 1989). However, the long-term effects have been reported on rare occasions. The experiments of WAISTER et al. (1977) included three and those of CORMACK and WAISTER (1989) two cropping years; they observed no decline in plant vigour.

The semi-biennial cropping system did not result in any yield enhancement (I). On the contrary, in the second harvest year the yield was lower than in annual and in biennial cropping. This indicates that one of the important conditions for the yield increase in biennial cropping was the removal of vegetative canes in the harvest year, not the removal of fruiting canes in the non-cropping year. When the non-cropping years are taken into account, the biennial system yielded 60 %, and the semi-biennial cropping yielded 40 % of the yield in annual cropping.

3.2. The effect of vegetative cane removal

Removal of the first-flush primocanes increased the yield of cv. Muskoka by 40 % and that of cv. Ottawa by 18 % in the first year of treatment (II). Later the yield did not increase, as the plant vigour of both cultivars was reduced. The cane growth was badly reduced when the first and the second flush of canes of cv. Ottawa were removed, but in the following years the yield did not decrease, because the control of midge blight was good (V).

In machine harvest, the primocane removal did not increase the yield of cv. Ottawa, and the 31 % yield increase of cv. Muskoka was equal to, or even less than that in hand harvesting (IV). Primocane removal obviously did not improve the operation of the Joonas Harvester, even though after removal the vegetative canes were shorter during the harvesting (III). According to BARRITT (1976) and MARTIN (1985), reduced growth allows the fruit-catching device of harvesters to work more effectively. The device of the Littau and the BEI harvesters consists of spring-loaded overlapping plates, but Joonas has flexible rubber catching trays. In the Pacific Northwest the main cultivars are more vigorous than cvs. Ottawa and Muskoka, and the need of vigour control is also greater. In this trial (IV), the row width at the cane base was carefully restricted by pruning and supporting, which also made the operation of the harvester easy.

Removing the canes once when they reached a height of 15 cm, or four times during the growing season at a height of 15 cm, like in the biennial system, did not increase significantly the yield of cv. Ottawa when only one fruiting cane competed with vegetative canes (III). It was more beneficial for fruit production to remove canes at the beginning of flowering or at the beginning of harvesting. When the removal was done at the beginning of flowering, in the first year of the treatment the yield was 55 % higher than without cane removal; the long-term effects were not studied (III).

Removal of the first-flush canes was not observed to affect fruit quality, or the amount of extraneous material on the inspection belts in machine harvest (IV). According to SCHEER and GARREN (1987), cane removal may decrease *Botrytis* fruit rot, as the vegetative canes are shorter, and the fruiting laterals dry faster after rain. The harvesting season in 1986 was dry, and only a small amount of fruits was infested by rot. In the rainy seasons of 1985 and 1987, the amount of rejected berries was high (II); primocane removal improved in hand harvesting the fruit quality of cvs. Ottawa and Muskoka in 1987, but not in 1985.

3.3. Yield components

In biennial cropping, the yield increase of cv. Ottawa was due to the increase in berry size and yield per cane, but the number of fruiting canes was not affected (I). In earlier studies (WAISTER et al. 1977, WRIGHT and WAISTER 1982 b, TERRETTAZ 1983, CLARK 1984, BUSZARD 1986, CORMACK and WAISTER 1989), the yield increased, because the number of canes per metre and the number of nodes per cane were higher than in annual cropping. In contrast to the present experiment, berry size did not increase in earlier studies.

Removal of the first-flush primocanes increased also the berry size of cv. Ottawa but not that of cv. Muskoka (II). Cane removal increased the berry number per fruiting lateral, but the number of fruiting laterals was not affected (III). Many previous studies have shown that the primocane removal increases yield as a result of higher number of berries per cane and often as a result of increased berry size as well (NORTON 1973 and 1980, WILLIAMSON et al. 1979, CRANDALL et al. 1980, REBANDEL and PRZYSIECKA 1981, LAWSON and WISEMAN 1983, SIDOROVICH 1985, BUSZARD 1986, FREEMAN and DAUBENY 1986, FREEMAN et al. 1989 a).

It was possible to affect the number of berries by a treatment as late as at the beginning of flowering, although flower initiation takes place in the autumn and winter (MATHERS 1952, WILLIAMS 1959). According to WAISTER et al. (1977), any change in berry number must be a consequence of differences in the number of aborted flowers or flower initials. Under conditions of conventional cane growth, many of the late developing and smaller blossom buds apparently fail to reach anthesis and set fruit (CRANDALL et al. 1980).

CRANDALL et al. (1980) reported that cane removal has no effect on the number of berries on the upper laterals, but greatly increases the numbers on laterals of the middle and lower portions of the canes. When the canes of cv. Ottawa were removed at the beginning of flowering, the yield per lateral increased particularly in the lowest portion of the cane (III). This did not have any significant bearing on the total yield, however, as this portion provided only 7 % of the total yield. The increase in the quantity and size of berries on all the fruiting laterals was of greater importance.

The yield of cv. Ottawa was distributed across the portions of the fruiting cane largely to the same extent as the laterals at the beginning of harvesting. The berry size was not affected by the height of the cane. The upper half of the cane produced 66 % of fruiting laterals, 66 % of yield, and 66 % of berry number. The fruit number per lateral was highest in the middle portion of the cane (III).

CRANDALL et al. (1980) believed that primocane removal increased yield by reducing the competition of rapidly growing primocanes for storage compounds, photosynthates, nutrients, and light during the critical stages of blossom development. According to WAISTER and WRIGHT (1989), the increase in yield was primarily an effect of removal of shading of fruiting laterals rather than an effect of removal of a competing sink of assimilates, or reduction in competition for water or mineral nutrients.

4. Competition between fruiting canes and vegetative canes

In biennial cropping (I), the cane growth of cv. Ottawa weakened, even though competition between vegetative and fruiting canes for light was prevented. The reason for reduced growth may be the removal of primocanes several times during the harvest years. This prevented the replenishment of carbohydrate root reserves as no photosynthetic vegetative canes developed. In addition, the reserves had to be used several times to produce new primocanes.

The vigour of the plants declined just as much in semi-biennial cropping (I), even though the vegetative canes were removed only after harvest. It is possible that the carbohydrate root reserves were deficient since the first cropping year, when the canes were removed at the end of August. WRIGHT (1979) and WHITNEY (1982) showed that in annual cropping the vegetative canes retained their photosynthetic leaf area until October, thus extending the time available for the regeneration of the overwintering carbohydrate root reserves.

It is also possible that the vegetative canes used the photosynthates produced by the fruiting canes in their early growth period, before their own leaf area was formed. Carbohydrate root reserves were the main source of carbohydrates, however, because vegetative canes developed also when all the fruiting canes were removed. Vegetative canes develop from the root buds, or from the basal buds of fruiting canes (HUDSON 1959), and do not become independent until their own leaf area and root system is developed. Therefore the yield was higher in the absence of vegetative canes, but the vigour of the vegetative canes declined when fruiting canes were removed (I).

When the vegetative cane removal was studied in plants where there was only one fruiting cane with a whole bush of vegetative canes (III), the results also indicate that vegetative canes may exploit the photosynthates of fruiting canes; removing the canes once when they were 15 cm long, or four times during the growing season, did not increase the yield significantly, although such an increase was recorded in normal raspberry plantations (I, II).

The competition between the fruiting canes and vegetative canes for light was prevented by removing vegetative canes along the growing season at a height of 15 cm (I, III). It was, however, more beneficial for fruit production to remove canes at the beginning of flowering or at the beginning of harvesting (III). So, competition for light was not the major factor influencing yield production.

According to CANNELL (1985) and WRIGHT (1989), developing flower initials are generally weak sinks of assimilates, and seeds and fleshy fruit parts are stronger sinks than shoot apices and leaves. So, when the canes of cv. Ottawa were removed at a height of 15 cm at the end of May (III), the replacement shoots were stronger sinks of carbohydrates than the flower initials. When the removal took place at the beginning of flowering or at the beginning of harvesting, the developing seeds and fruits were strong sinks, and the carbohydrates were allocated to fruit production.

When the vegetative canes were removed at the beginning of flowering, the photosynthates of the canes had obviously already replenished the root storage compounds, and the replacement shoots used these reserves. The removal of canes reduced the competition during the flowering and fruit ripening, and consequently the yield increased. When vegetative canes were removed several times during the course of the summer, competition with the fruiting canes for light, water and nutrients was minimized. The yield did not increase as much as expected, however, since producing a new crop of canes four times without replenishing the storage compounds put a strain on the root reserves and the fruiting cane.

In conclusion, the yield increase after the removal of vegetative canes (I, II, III, IV) showed that the removal reduced the competition between vegetative canes and fruiting canes for light, and probably for water and mineral nutrients, too. The competition for assimilates and reserve carbohydrates increased, however, because after cane removal the raspberry plant always produced a new flush of vegetative canes.

CONCLUSIONS

New cultivation practices of red raspberry in Finland

The present study shows that the vigour of plants may reduce strongly during the course of years when the vegetative canes are removed in the beginning of the growing season or totally during the summer. In Finland, the main cultivars Ottawa and Muskoka are not extremely vigorous, and the short growing season increases the risk of reduced growth. The highest yield was obtained when the vegetative canes were removed at the beginning of flowering, and raspberry cane midge was best controlled when the first and the second flush of canes were removed, but the weakening of plants precludes the use of late treatments. Because of the decline in plant vigour and the low average yield, neither the biennial cropping nor the semi-biennial cropping system is recommended for raspberry in Finland.

In some cases, however, it was possible to achieve significant yield increases when the vegetative canes of cvs. Ottawa and Muskoka were removed. Cane removal improved the health status of plants by reducing the incidence of raspberry cane midge, midge blight, and spur blight. In addition, the cane removal may reduce the fruit rot if the season is rainy. Furthermore, the removal may diminish the labour requirement in raspberry production. As a result of reduced growth of vegetative canes, harvesting, pruning, and supporting is easier. When increasing the berry size, the removal improves the results in hand picking.

The primocane removal did not increase the fruit collection of Joonas Raspberry Harvester. Joonas collected the berries effectively by the rubber catching trays without seriously damaging the vegetative canes. So, the removal is not necessary in machine harvest of cvs. Ottawa and Muskoka. However, when the removal increases the yield, the economy of machine harvest improves. The harvesting of cvs. Ottawa and Muskoka by Joonas has given promising results; especially cv. Muskoka seems to be suitable for machine harvest because of the good quality of berries. At present, machine harvesting of raspberry is not of great interest in Finland, because the demand on fresh market is great, the price is reasonable, and there is no shortage of pickers.

On the basis of the present experiments

primocane removal is recommended for cvs. Ottawa and Muskoka only when canes grow to a height of 2.5 metres or more, and vigorous growth of new canes makes harvesting, pruning, and supporting laborious. The treatment is also recommended to the less vigorous plantings of cv. Ottawa infested by the raspberry cane midge in the previous summer. Spur blight alone does not make the treatment necessary. In addition, the removal can be done always in the last year of the planting. The first flush of primocanes must be removed at a maximum height of 10 cm, i.e. during the third or fourth week in May. The canes are removed too early rather than too late. It is necessary to have irrigation systems, because drought during early summer reduces strongly the growth of replacement canes.

At present the chemical removal is the most economical practice on the large-scale use. Glufosinate-ammonium (Basta) has been registered for the weed control of raspberry in Finland in the beginning of 1990. The use of the herbicide for the primocane removal of both cultivars, Ottawa and Muskoka, should be carefully tested before large-scale use. It is important that the vegetative canes die quickly and totally, the treatment may not cause residues in berries, or injure fruiting canes or second-flush canes by translocation or root uptake. After the banning of dinoseb-in-oil since 1990 in the Pacific Northwest, and since 1988 in Scotland, alternative techniques, both chemical and mechanical, have been investigated extensively. The new promising methods should be tested also in Finland.

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SELOSTUS

Uusien viljelymenetelmien vaikutus vadelman satoon, versojen kasvuun ja terveyteen Suomessa

PIRJO DALMAN

Maatalouden tutkimuskeskus

Vadelman viljelyala oli Suomessa vuonna 1990 vain 134 ha ja tuotanto noin 200 tonnia, vaikka tuorevadelman menekki oli hyvä ja marjanjalostusteollisuus toi vadelmaa ulkomailta yli 2000 tonnia. Viljelyhalukkuutta ovat vähentäneet vadelman talvehtimisongelmat ja korkeat tuotantokustannukset. Yli puolet kustannuksista muodostaa sadonkorjuu, mutta myös leikkaus ja tuenta tulee kalliiksi. Merkittävillä vadelmantuotantoalueilla Pohjois-Amerikan länsirannikolla ja Skotlannissa on viime vuosikymmeninä kehitetty uusia, työtä säästäviä viljelymenetelmiä. Koneellinen sadonkorjuu ja vuorovuosiviljely alentavat tuotantokustannuksia. Kasvuversojen poistokäsittely lisää satoa, hillitsee voimakaskasvuisten lajikkeiden pituuskasvua sekä helpottaa leikkausta ja tuentaa. Uusi versosto, joka kehittyy versonpoiston jälkeen, saastuu versotauteihin ja varsisääskeen vähemmän kuin kasvukauden alusta asti kasvanut versosto.

Tämän tutkimuksen tavoitteena oli selvittää, voidaanko uusia viljelymenetelmiä käyttää vadelmantuotannossa Suomessa. Kenttäkokeissa tutkittiin vuosina 1980—1987 kasvuversojen poiston vaikutusta Ottawa- ja Muskoka-lajikkeiden versojen kasvuun, versotautien runsauteen ja satokomponentteihin käsin poimittaessa ja konekorjuussa. Kasvuversojen poiston vaikutusta varsisääsken esiintymiseen tutkittiin sääskelle alttiin Ottawa-lajikkeen versoissa. Vuorovuosiviljelyä ja osittaista vuorovuosiviljelyä kokeiltiin Ottawa-lajikkeella, ja samalla tutkittiin satoversojen poiston vaikutusta kasvuversojen kasvuun. Kenttäkokeiden tulosten perusteella tarkasteltiin kasvuversojen ja satoversojen välistä kilpailua, sillä kasvuversojen poistokäsittely ja vuorovuosiviljely perustuvat teoriaan, jonka mukaan käsittelyt vähentävät kasvuversojen ja satoversojen välistä kilpailua valosta, yhteyttämistuotteista, ravinteista ja vedestä.

Muskoka-lajikkeen sato suureni ensimmäisenä vuonna käsinpoiminnassa 40 % ja konekorjuussa 31 %, kun kasvuversot poistettiin keväällä noin 15 cm:n pituisina. Ottawalajikkeen sato suureni ensimmäisenä vuonna käsinpoiminnassa 18 % mutta ei suurentunut konekorjuussa. Vuorovuosiviljelyssä kasvuversot poistettiin satovuosina neljä kertaa, ja Ottawa-lajikkeen sato oli ensimmäisenä vuonna 32 % suurempi kuin tavanomaisessa viljelyssä. Kun Ottawa-lajikkeen kasvuversot poistettiin vasta kukinnan alussa, oli sato 55 % suurempi kuin ilman versojen poistoa.

Menetelmät eivät lisänneet merkitsevästi versomääriä, joten sato suureni, koska sato versoa kohti lisääntyi. Kasvuversojen poisto ei vaikuttanut satoa tuottavien sivuversojen lukumäärään. Marjamäärä sivuversoissa lisääntyi ja Ottawa-lajikkeen marjakoko suureni. Muskoka-lajikkeen marjojen kokoon kasvuversojen poisto ei vaikuttanut. Sato lisääntyi verson kaikissa sivuversoissa. Verson alimpaan neljännekseen, 0—43 cm:n korkeudelle, kehittyi vähän sivuversoja, ja alle 10 % sadosta tuli satoverson alimmasta neljänneksestä.

Kasvuversojen poistokäsittely ja vuorovuosiviljely lisäsivät satoa ensimmäisenä käsittelyvuonna, mutta myöhemmin kasvustot heikkenivät eikä sato suurentunut. Kasvuversojen poisto heikensi liikaa Muskoka- ja Ottawa- lajikkeiden versojen pituuskasvua, eikä kukinnan aikaan annettu typpilisäys, 25 kg/ha, voimistanut sitä.

Kasvuversojen poisto vähensi vatunvarsisääsken ja midge blight -taudin vioituksia Ottawa-lajikkeen versoissa ja versotautisaastuntaa Muskoka-lajikkeen versoissa. Versonpoiston jälkeen kehittyvien uusien versojen kuori halkeilee myöhemmin kuin kasvukauden alusta asti kasvaneiden versojen, ja ensimmäisen sukupolven sääskinaaraille ei ole munintapaikkoja versoissa. Midge blight -tauti aiheuttaa suuria satotappioita, sillä se tunkeutuu sääskitoukkien vioituskohdista versojen johtosolukkoon. Versotauti yksistään alentaa harvoin satoa, sillä se esiintyy versojen pintasolukoissa ja tuhoaa silmuja verson alaosista, missä sadontuotto on muutenkin vähäistä.

Osittaisessa vuorovuosiviljelyssä kasvuversoja ei poistettu kesällä satovuosina mutta välivuosina kasvuversot kehittyivät ilman satoversojen kilpailua. Sato ei suurentunut lainkaan, ja versojen pituuskasvu oli yhtä heikkoa kuin vuorovuosiviljelyssä. Ilmeisesti vuorovuosiviljelyn sato suureni siksi, että kasvuversot poistettiin useita kertoja satovuosina, eikä siksi, että välivuosina kasvuversot kehittyivät ilman satoversojen kilpailua. Kun välivuodet otetaan huomioon, oli vuorovuosiviljelyn sato 60 % ja osittaisen vuorovuosiviljelyn sato 40 % tavallisen viljelyn sadosta.

Sadon suureneminen kasvuversojen poiston seurauksena osoittaa, että poisto vähentää kasvuversojen ja satoversojen välistä kilpailua valosta, ja ilmeisesti myös vedestä ja ravinteista. Kilpailu yhteyttämistuotteista ja varastoravinnosta sen sijaan lisääntyy, koska vadelma tuottaa poistettujen kasvuversojen tilalle aina uuden versoston.

Uusien viljelymenetelmien käyttö Suomessa

Tutkimus osoitti, että on mahdollista saavuttaa huomattavia sadonlisäyksiä, kun vadelman kasvuversot poistetaan kasvukauden alkupuolella tai useita kertoja kasvukauden kuluessa. Versojen poisto vähentää myös versotauteja ja vatunvarsisääskeä. Lisäksi käsittelyillä on viljelyteknisiä etuja. Marjojen suureneminen nopeuttaa käsinpoimintaa. Poiminta helpottuu myös siksi, että sadonkorjuun aikaan kasvuversoja ei ole lainkaan tai ne ovat lyhyempiä ja hennompia kuin kasvukauden alusta asti kasvaneet versot. Ilmankierto kasvustossa tehostuu, kasvusto kuivuu nopeammin sateiden jälkeen ja marjojen homeisuus saattaa vähentyä. Myös kasvukauden lopulla kasvuversot ovat lyhyempiä kuin tavanomaisesti kehittyneet versot, joten versojen tuenta ja leikkaus on helpompaa.

Ottawa- ja Muskoka -lajikkeiden kasvuversojen poistokäsittely ei ilmeisesti ole välttämätöntä korjuukoneen toiminnan kannalta. Konekorjuun kannattavuus kuitenkin paranee, jos vadelman sato suurenee. Kasvuversojen poisto ei tehosta Joonas-vadelmankorjuukoneen toimintaa eikä marjojen talteenottoa. Joonas-koneessa talteenotto tapahtuu kasvuston alaosassa joustavilla kumireunaisilla lautasilla, jotka painuvat tiiviisti versoja vasten. Korjuuvuonna tehtyjen havaintojen mukaan lautaset eivät aiheuttaneet versoihin tuhoisia vioituksia. Vadelman korjuusta Joonas-koneella on saatu lupaavia tuloksia; marjan hyvän laadun vuoksi Muskoka-lajike sopii konekorjuuseen paremmin kuin Ottawa.

Kasvuversojen poistokäsittelyllä ja vuorovuosiviljelyllä on monia etuja, mutta vaarana on kasvustojen heikkeneminen. Suomessa kasvukauden lyhyys ja lajikkeiden keskinkertainen kasvuvoimakkuus lisäävät riskiä. Kokeissa sato suureni eniten, kun kasvuversot poistettiin vasta kukinnan alussa, ja vatunvarsisääsken torjunta oli tehokkainta, kun sekä ensimmäinen että toinen versosto poistettiin. Kasvustojen heikkenemisen takia myöhään kasvukaudella tehdyt poistot eivät kuitenkaan ole mahdollisia. Kasvuston heikkenemisen ja matalan keskisadon vuoksi vuorovuosiviljelyä ja osittaista vuorovuosiviljelyä ei suositeta Suomeen.

Kasvuversojen poistokäsittely voidaan tehdä Ottawa- ja Muskoka-lajikkeille kasvustoissa, joissa versot kehittyvät noin 2,5 metrin pituisiksi ja voimakas kasvu haittaa sadonkorjuuta, leikkausta ja tuentaa. Käsittelyä suositetaan myös heikommille Ottawa-kasvustoille, jos versoista on edellisenä syksynä löytynyt vatunvarsisääsken toukkia. Pelkkä versotautien esiintyminen ei anna aihetta käsittelyyn. Lisäksi kasvuversot voidaan poistaa aina viimeisenä viljelyvuonna. Ensimmäisenä kehittyneet kasvuversot poistetaan viimeistään 10 cm:n pituisina toukokuun kolmannella tai viimeisellä viikolla. Poisto tehdään mieluummin liian aikaisin kuin liian myöhään. Viljelmällä pitäisi olla kastelumahdollisuus, sillä alkukesän kuivuus saattaa pahasti heikentää versonkasvua.

Versojen poisto aiheuttaa kustannuksia ja on tuskin kannattavaa, jos ei ole käytettävissä kemiallista hävitettä. Vadelman versojen hävittämiseen on Suomessa käytettävissä ainoastaan glufosinaatti-ammonium (Basta). Esimerkiksi dikvatti (Reglone) ei sovi heikon tehonsa takia tähän tarkoitukeen. Glufosinaatti-ammoniumista on saatu ristiriitaisia tuloksia, joten sen käyttö nimenomaan poistokäsittelyyn satoversojen tyvellä tulisi testata sekä Ottawa- että Muskokalajikkeella. On tärkeää, että versot kuolevat nopeasti ja kokonaan. Hävitteestä ei saa jäädä jäämiä satoon, eikä se saa vioittaa satoversoja tai juuristoa. Uusia kemiallisia, mekaanisia ja fysikaalisia menetelmiä versojen poistoon tutkitaan maailmalla laajasti, ja lupaavat menetelmät pitäisi nopeasti testata myös Suomessa.

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YIELD AND CANE GROWTH OF RED RASPBERRY IN ANNUAL, BIENNIAL AND SEMI-BIENNIAL CROPPING

PIRJO DALMAN

DALMAN, P. 1991. **Yield and cane growth of red raspberry in annual, biennial and semi-biennial cropping.** Ann. Agric. Fenn. 30: 441—446. (Agric. Res. Centre of Finland, South Savo Res. Sta., 50600 Mikkeli, Finland.)

Red raspberry (*Rubus idaeus* L.) cv. Ottawa was grown under annual, semi-biennial and biennial cropping systems during four years. In the first cropping year, the yield was 32 % higher in the biennial system than in the annual system. The yield increase was due to the increases in berry size and yield per cane, but the number of fruiting canes was not affected. Later, the yield did not increase, and the cane height was strongly reduced in biennial cropping.

In the semi-biennial cropping, the vegetative canes developed without competition from fruiting canes, but in the fruiting years, vegetative canes were not removed; the yield did not increase, and cane growth was as poor as in the biennial system. This indicates that in the biennial cropping a prerequisite for an increase in yield is the removal of vegetative canes in the harvest year, not the removal of fruiting canes in the non-cropping year.

Index words: red raspberry, cropping system, cultivar.

INTRODUCTION

The biennial cropping system was developed to diminish the high production costs of raspberries. In this system, also called alternate year cropping, a raspberry block produces only one crop in two years. In the cropping year, herbicides, usually dinoseb-in-oil, are used to kill the vegetative canes, and all the canes are cut mechanically after the harvest. In the subsequent season, only vegetative canes grow in the rows, and they need minimal care. When compared to conventional annual cropping, the yield increases, and picking is easier in the absence of vegetative canes. Further, the costs of pruning and tying are lower, and the incidence of pests and diseases is reduced (SHEETS et al. 1975, WAISTER et al. 1977, TURNER 1980, LOVELIDGE 1981, GORDON and WILLIAMSON 1984, SCHEER and GARREN 1987). In mechanical harvesting, damage to vegetative canes by machines is avoided, and machines pick the fruits more effectively (WAISTER and CORMACK 1976, MULLIGAN and JENNER 1979, MARTIN 1985, RAMSAY et al. 1985).

However, the plant vigour may diminish in biennial cropping, and the average annual yield may be lower than in annual cropping. In years of high berry prices, the reduction in yield makes biennial cropping uneconomical. In addition, removal of vegetative canes in the cropping year involves extra costs (TURNER 1980, Lovelidge 1981, Olander 1983, Terrettaz 1983, Scheer and Garren 1987).

In the biennial cropping system, competition between fruiting canes and vegetative canes is minimized. According to Wright and Waister (1982 a, 1982 b, 1984), the most important factor influencing growth and yield is the competition for light.

There are differences in the response to biennial cropping between cultivars (Waister et al. 1977, Terrettaz 1983, Clark 1984, Buszard 1986, Cormack and Waister 1989). The objective of this study was to examine growth and yield responses of cv. Ottawa to biennial cropping. The semi-biennial cropping was also tested, because the use of dinoseb is prohibited in Finland. In the semi-biennial system, vegetative canes grow in the absence of fruiting canes, but in the fruiting year, the vegetative canes are not removed until after the harvest. Competition between vegetative and fruiting canes is discussed on the basis of the results of field experiments.

MATERIAL AND METHODS

The experiment was carried out at a commercial raspberry farm in Puumala (61°36′ N and 28°11′ E) in 1981—1984. A randomized block design with four replicates was used to compare conventional annual cropping, biennial cropping and semi-biennial cropping of cv. Ottawa. Planting was done in 1977, and in the spring of 1981 the vigour of the plantation was typical of cv. Ottawa.

The plots were 10 m long; the row spacing was 3.7 m, and the width of the row base was about 60 cm. The canes were supported between two pairs of wires at about 60 cm and 120 cm above ground level. In accordance with normal practice, the fruiting canes were topped to a height of 170 cm, and the fruited canes were removed after harvest. Fertilizer applications, pest and weed control complied with the recommendations of the Agricultural Advisory Centres.

Under the annual cropping system, both the fruiting canes and the vegetative canes were allowed to grow every year. The vegetative canes were thinned at the beginning of July and after harvesting. The aim was to leave for a row length of one metre seven to nine of the stoutest canes for fruiting.

Biennial cropping was started by cutting down all the canes in the spring of 1981. In 1981 and 1983, only vegetative canes were grown. The canes were not thinned, but in the autumn the damaged or weak canes, usually those shorter than 60 cm, were removed. In 1982 and 1984, the crop was harvested, and during the harvest years vegetative canes also developed. When these reached a height of 20—40 cm, they were removed pulling by hand three or four times during the growing season (9 June, 19 July, 11 August and 7 September 1982; and 14 June, 16 July and 20 August 1984).

In the semi-biennial cropping system, only vegetative canes were grown in 1981 and 1983, and they were managed like in the biennial cropping system. In the harvest years the vegetative canes were not removed during the summer; all the canes were removed after harvest (7 September 1982, and 20 August 1984).

In 1981 and 1983, the number of vegetative canes was recorded at the beginning of July before cane thinning on annual plots. At the beginning on October, the height of canes was measured on three randomly chosen canes per plot. In 1982 and 1984, the number of fruiting canes was recorded at the beginning of harvest. The berries were picked twice a week; on the third picking the weight of 100 berries was measured. The results were tested using the analysis of variance. The significances of differences between the cropping systems were assessed by the Student-Newman-Keuls test.

RESULTS

In all cropping systems, the vegetative canes reached almost the same height in the first autumn (Table 1). In the third autumn, the canes were shorter in biennial cropping and in semi-biennial cropping than in annual cropping. The number of canes developed during the non-cropping years of the biennial and semi-biennial systems was not affected significantly by the cropping systems (Table 1). In the number of fruiting canes there was a slight difference (P = 0.08) between the cropping systems only in 1984 (Table 2).

In the first harvest year, the crop yield was 32 % higher (Table 2) and the berry size was 13 % greater (Table 3) in biennial cropping than in annual cropping. The semi-biennial cropping and the annual cropping systems produced equally high yields. In the second harvest year, the yields from the biennial and the annual cropping systems were equal, but semi-biennial cropping yielded less (Table 2). The yield per fruiting cane was lower in semi-biennial cropping than in biennial cropping in 1982 and in annual cropping in 1984 (Table 3). When the non-cropping years are taken into account, the biennial system yielded 60 %, and the semi-biennial cropping yielded 40 % of the yield in annual cropping.

Table 2. Berry yield and number of fruiting canes in annual, semi-biennial and biennial cropping of red raspberry cv. Ottawa.

	Yield kg/100 m²		Number of fruiting canes/metre	
Cropping system	1982	1984	1982	1984
Annual cropping	47^{a}	46^{a}	8.5^{a}	7.0^{a}
Semi-biennial cropping	44^{a}	30^{b}	10.1^{a}	9.3^{a}
Biennial cropping	62^{b}	50^{a}	9.0^{a}	11.0^{a}

Means with a different letter within a column are significantly different ($P<0.05$).

Table 1. Number of vegetative canes and cane height in annual, semi-biennial and biennial cropping of red raspberry cv. Ottawa.

	Number of vegetative canes/metre		Cane height cm	
Cropping system	1981	1983	1981	1983
Annual cropping	11.1^{a}	17.7^{a}	164^{a}	173^{a}
Semi-biennial cropping	14.6^{a}	18.8^{a}	155^{a}	120^{b}
Biennial cropping	13.6^{a}	23.3^{a}	145^{a}	135^{b}

Means with a different letter within a column are significantly different ($P<0.05$).

Table 3. Berry yield per fruiting cane and weight of berries in annual, semi-biennial and biennial cropping of red raspberry cv. Ottawa.

	Yield/ fruiting cane g		Weight of 100 berries g	
Cropping system	1982	1984	1982	1984
Annual cropping	207^{ab}	242^{a}	279^{a}	220^{a}
Semi-biennial cropping	170^{b}	116^{b}	259^{a}	204^{a}
Biennial cropping	255^{a}	179^{ab}	316^{b}	210^{a}

Means with a different letter within a column are significantly different ($P<0.05$).

Growth responses of cv. Ottawa to biennial and semi-biennial cropping

Both in biennial and in semi-biennial cropping the vegetative canes developed without competition from fruiting canes. The number of canes did not increase significantly, and in the third year of the experiment, the height of canes remained far below the topping height. A decrease in cane height and an increase in the cane number have been reported previously (WAISTER et al. 1977, WRIGHT and WAISTER 1982 a, TERRETTAZ 1983, BUSZARD 1986, CORMACK and WAISTER 1989). According to WRIGHT and WAISTER (1982 a), the internode length of vegetative canes shortens when not shaded by the fruiting canes, and the biennial canes produce a greater leaf area which is retained for a longer period than in annual cropping.

CORMACK and WAISTER (1989) reported that although the cane height decreased in biennial cropping, the total number of nodes and, after topping, the number of cropping nodes increased. Only WRIGHT and WAISTER (1982 a) reported that the shortening of canes was partly due to a reduction in the number of nodes produced in the biennial system. After topping, the canes of vigorous cultivars retain more nodes in biennial than in annual cropping. In the present experiment, also in annual cropping the need for topping was small, as only some canes reached a height of two metres. Node numbers of cv. Ottawa were not recorded.

Yield responses of cv. Ottawa to biennial and semi-biennial cropping

The fruiting canes grew without competition from vegetative canes in the biennial cropping. When compared to the annual system, the yield was higher in the first harvest year as a result of greater berries and higher yield per cane, but not as a result of increased number of canes. Higher yields have been obtained for a range of cultivars, and under varying conditions of biennial culture (WAISTER et al. 1977, WRIGHT and WAISTER 1982 b, TERRETTAZ 1983, CLARK 1984, BUSZARD 1986, CORMACK and WAISTER 1989). In these studies the yield increased in biennial cropping, because the number of canes per metre and the number of nodes per cane were higher than in annual cropping. In addition, WRIGHT and WAISTER (1982 b, 1984) showed that when the fruiting canes grew in the absence of shade from vegetative canes, the dry weight and leaf area index were higher than in annual cropping, resulting in intensified photosynthesis.

In contrast to the present experiment, in earlier studies berry size did not increase in biennial cropping (WAISTER et al. 1977, WRIGHT and WAISTER 1982 b, TERRETTAZ 1983, CLARK 1984, BUSZARD 1986, CORMACK and WAISTER 1989). In these studies, the cane number was higher in biennial cropping than in annual cropping. Greater competition between canes and laterals on the same cane probably explains the small fruit size. In the first harvest year, the cane number of cv. Ottawa was in the biennial cropping almost the same as in the annual cropping, and reduced competition from vegetative canes resulted in increased berry size.

In the second harvest year, the yield from the biennial cropping of cv. Ottawa was not greater than that from annual cropping. The number of fruiting canes was high, but the canes were short, the yield per cane was low, and the berry size did not increase. The plant vigour of cv. Ottawa was strongly diminished after three years of biennial cropping. The experiments of WAISTER et al. (1977) included three and those of CORMACK and WAISTER (1989) two cropping years, but no decline in plant vigour was reported. The long-term effects of biennial cropping have not been studied.

In semi-biennial cropping no yield increase was observed. On the contrary, in the second harvest year the yield was lower than in annual and in biennial cropping. This indicates that one of the important conditions for the yield increase in biennial cropping was the removal of vegetative canes in the harvest year, not the removal of fruiting canes in the non-cropping year.

Because of the decline in plant vigour and the low average yield, neither the biennial cropping nor the semi-biennial cropping system is recommended for cv. Ottawa in Finland.

Competition between fruiting and vegetative canes

In biennial cropping the plants of cv. Ottawa weakened, even though competition between vegetative and fruiting canes for light, water and nutrients was prevented. The reason for reduced growth may be the removal of primocanes several times during the harvest years. According to WHITNEY (1982), this prevented the replenishment of carbohydrate root reserves as the photosynthetic vegetative canes did not develop. In addition, the reserves had to be used several times to produce new primocanes.

Why, then, did the vigour of the plants decline just as much in semi-biennial cropping, even though the vegetative canes were removed only after the harvest? It is possible that the carbohydrate root reserves were deficient since 1982, when the canes were removed at the end of August. WRIGHT (1979) and WHITNEY (1982) showed that in annual cropping the vegetative canes retain their photosynthetic leaf area until October, thus extending the time available for the regeneration of the overwintering carbohydrate root reserves.

It is also possible that the vegetative canes used the photosynthates produced by the fruiting canes in their early growth period, before their own leaf area had formed. Therefore the yield was higher in the absence of vegetative canes, but the vigour of the vegetative canes declined when fruiting canes were removed.

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SELOSTUS

Vuorovuosiviljelyn ja osittaisen vuorovuosiviljelyn vaikutus vadelman satoon ja versonkasvuun

PIRJO DALMAN

Maatalouden tutkimuskeskus

Vuorovuosiviljelyssä vadelma tuottaa satoa joka toinen vuosi. Satovuosina kasvuversot hävitetään useita kertoja kesän aikana herbisideillä. Syksyllä satoa antaneet versot leikataan pois, ja seuraavana vuonna riveissä kasvaa vain kasvuversoja. Versojen välinen kilpailu vähenee ja satovuosina sato suurenee. Menetelmä alentaa vadelman korkeita tuotantokustannuksia, sillä versojen leikkaus ja tuenta sekä marjojen poiminta helpottuu. Vuorovuosiviljelyn etuihin kuuluu myös eräiden tautien ja tuholaisten väheneminen. Konekorjuussa kasvuversot eivät vioitu ja marjojen irrotus ja talteenotto tehostuu. Vadelmalajikkeet ovat reagoineet vuorovuosiviljelyyn lähes samalla lailla, mutta reagointivoimakkuus on vaihdellut. Joissakin tapauksissa kasvustot ovat heikentyneet ja keskisadot jääneet pieniksi.

Tässä tutkimuksessa selvitettiin vuorovuosiviljelyn ja osittaisen vuorovuosiviljelyn vaikutuksia 'Ottawa'-lajikkeen satoon ja versonkasvuun neljän vuoden aikana. Osittaisessa vuorovuosiviljelyssä kasvuversot kehittyivät ilman satoversojen kilpailua, mutta satovuosina kasvuversoja ei poistettu. Tätä menetelmää tutkittiin, koska siinä tuotantokustannukset ovat pienet, ja koska tehokkaimman versohävitteen, dinosebin, käyttö on kielletty Suomessa.

Kenttäkoe järjestettiin Puumalassa vuosina 1981—1984. Kasvusto oli istuettu vuonna 1977, riviväli oli 3,7 m ja versorivin leveys noin 60 cm. Versot tuettiin kahdella lankaparilla, ja satoversot latvottiin keväällä tarvittaessa 170 cm:n korkeudelta. Tavallisessa viljelyssä kasvuversoja harvennettiin heinäkuun alussa ja sadonkorjuun jälkeen. Tavoitteena oli jättää rivimetrille 7—9 vahvinta versoa satoversoiksi. Vuorovuosiviljelyssä kasvoi vuosina 1981 ja 1983 vain kasvuversoja. Niitä ei harvennettu, mutta vioittuneet ja heikot, alle 60 cm pitkät versot poistettiin syksyllä. Satoa saatiin vuosina 1982 ja 1984. Satovuosina kasvuversot poistettiin käsin kitkien kolme tai neljä kertaa kesässä 20—40 cm:n pituisina. Osittaisessa vuorovuosiviljelyssä kasvoi kasvuversoja vuosina 1981 ja 1983. Satovuosina 1982 ja 1984 kasvuversoja ei poistettu kesän aikana, vaan vasta sadonkorjuun jälkeen, jolloin kaikki versot leikattiin pois.

Vuorovuosiviljelyn ensimmäisenä satovuonna sato oli 32 % suurempi kuin tavallisessa viljelyssä. Marjakoko ja sato versoa kohti oli suurempi kuin tavallisessa viljelyssä, mutta versomäärä oli lähes sama. Vuorovuosiviljelyn kolmantena vuonna versojen pituuskasvu heikkeni ja versot jäivät noin 135 cm pitkiksi. Seuraavana vuonna sato ei ollut tavallisen viljelyn satoa suurempi. Osittaisessa vuorovuosiviljelyssä sato ei suurentunut lainkaan, ja versojen pituuskasvu oli yhtä heikkoa kuin vuorovuosiviljelyssä. Ilmeisesti vuorovuosiviljelyn sato suureni siksi, että kasvuversot poistettiin satovuosina, eikä siksi, että välivuosina kasvuversot kehittyivät ilman satoversojen kilpailua.

Kun välivuodet otetaan huomioon, oli vuorovuosiviljelyn sato 60 % ja osittaisen vuorovuosiviljelyn sato 40 % tavallisen viljelyn sadosta. Kasvustojen nopean heikkenemisen ja heikon keskisadon vuoksi vuorovuosiviljelyä ja osittaista vuorovuosiviljelyä ei suositeta 'Ottawa'-lajikkeelle Suomessa.

ANNALES AGRICULTURAE FENNIAE, VOL. 30: 447—462 (1991)

Seria HORTICULTURA N. 72 — Sarja PUUTARHAVILJELY n:o 72

THE EFFECT OF THE FIRST-FLUSH PRIMOCANE REMOVAL AND ADDITIONAL NITROGEN FERTILIZATION ON THE YIELD, CANE GROWTH AND CANE DISEASES OF RED RASPBERRY

PIRJO DALMAN

DALMAN, P. 1991. **The effect of the first-flush primocane removal and additional nitrogen fertilization on the yield, cane growth and cane diseases of red raspberry.** Ann. Agric. Fenn. 30: 447—462. (Agric. Res. Centre of Finland, South Savo Res. Sta., SF-50600 Mikkeli, Finland.)

Removal of the first-flush primocanes and additional nitrogen fertilization of red raspberry (*Rubus idaeus* L.) cvs. Muskoka and Ottawa were studied during three years in 1985—1987. The canes were removed mechanically when they had reached a height of 15 cm, and additional nitrogen was applied 25 kg/ha during flowering.

In the first year, cane removal increased the yield of cv. Muskoka by 40 % and that of cv. Ottawa by 18 %. The yield increase was due to the increase in yield per fruiting cane. The removal increased the berry size of cv. Ottawa but not that of cv. Muskoka. After the first year the yield did not increase, and plant vigour of both cultivars reduced. The removal reduced cane length, cane diameter and node number, and increased internode length. In the third year, cane removal decreased the number of fruiting canes. Additional nitrogen failed to increase plant vigour. The incidence of fungal cane diseases of cv. Muskoka was reduced by the cane removal.

Index words: red raspberry, cultivar, cane removal, nitrogen fertilization, cane diseases

INTRODUCTION

Red raspberry primocane removal refers to the practice of spraying the basal 0.5 m portion of the cane row with a desiccant chemical, usually dinoseb-in-oil, once or several times in the spring when primocanes are 10—25 cm high (NORTON 1973). The cane removal technique, also referred to as primocane control, chemical pruning, cane burning, primocane suppression, or cane vigor control, was developed to manage excessive vigour of canes. The replacement canes that develop after the removal of the first canes are shorter, thinner and less in number than the vegetative canes grown normally from the beginning of the season. Access to the fruit at harvest improves, supporting of canes is easier, and canes are exposed to less physical injury by pickers, wind and machinery (WILLIAMSON et al. 1979, NORTON 1980, LAWSON and WISEMAN 1983, FREEMAN and DAUBENY 1986).

Many studies have shown that the primocane removal increases yield (NORTON 1973 and 1980, WILLIAMSON et al. 1979, CRANDALL et al. 1980, REBANDEL and PRZYSIECKA 1981, LAWSON and WISEMAN 1983, SIDOROVICH 1985, BUSZARD 1986, FREEMAN and DAUBENY 1986, FREEMAN et al. 1989 a and b). The greatest yield responses are obtained with the most vigorous cultivars (CRANDALL et al. 1980, FREEMAN et al. 1989 a). The removal improves also the health status of a plantation infested by raspberry cane midge (*Resseliella theobaldi* (Barnes)) and fungal cane diseases (WILLIAMSON et al. 1979, REBANDEL and PRZYSIECKA 1981, FREEMAN and DAUBENY 1986).

In vigorous plantations the correct timing of cane removal allows replacement canes to produce sufficient fruiting cane length for the following year. However, weak or young plantings, or non-vigorous cultivars can be permanently damaged by the treatment, as cane production may prove inadequate (NORTON 1980, CRANDALL et al. 1980, LAWSON and WISEMAN 1983, LAWSON 1986, FREEMAN et al. 1989 b, SULLIVAN and DALE 1989). According to CRANDALL et al. (1980), increasing nitrogen levels have failed to counteract the reduction in vigour.

The objective of the present study was to investigate the effects of the first-flush primocane removal on cultivars Ottawa and Muskoka, the most widely grown cultivars of red raspberry in Finland. The ability to increase plant vigour by additional nitrogen, applied during flowering, was studied, too. The cultivars overwinter reasonably well, but the yields are relatively low (SÄKÖ and HIIRSALMI 1980). Cultivar Muskoka produces more and thinner canes, and is more susceptible to spur blight (*Didymella applanata* (Niessl) Sacc.) (SÄKÖ et al. 1980), but less susceptible to cane midge than cv. Ottawa (DALMAN 1986). In the present study, cane growth, yield, and the incidence of cane diseases were examined.

MATERIAL AND METHODS

Field experiments were carried out separately for cv. Ottawa and Muskoka at the South Savo Research Station in Mikkeli (61° 40′ N and 27° 13′ E) in 1985—1987. The split-plot design with three replicates was used. The whole-plot treatments involved nitrogen fertilization as follows:

nitrogen 25 kg/ha in spring and
no additional nitrogen during flowering

nitrogen 25 kg/ha in spring and
25 kg/ha during flowering.

The sub-plot treatments were as follows:

no primocane removal

removal of the first-flush primocanes.

Dates of experimental treatments are shown in Table 1. In spring, NPK fertilizer (7—5—15 % with micronutrients) was applied in a 70 cm narrow band along the rows. The amount of NPK fertilizer was 36 g/m^2, and accordingly it contained nitrogen 2.52 g/m^2. During flowering, calcium nitrate (N 15.5 %) was applied. The amount of 16 g/m^2 of calcium nitrate contained nitrogen 2.48 g/m^2. The first flush of primocanes was removed every year, pulling by hand when the canes had reached a height of 15 cm (Table 1). The whole-plots were 6.0 m and the sub-plots 3.0 m long.

Planting of experiments was done in the spring of 1983; spacing was 3.5 m between rows, and 60 cm between plants. Canes were grown in hedge rows, and the width of the row base was restricted to 40 cm. The canes were supported between two pairs of wires at about

Table 1. Dates of experimental treatments.

Treatment	1985	1986	1987
NPK fertilization	16 May	19 May	19 May
Calcium nitrate application	10 July	1 July	10 July
Primocane removal	3 June	29 May	11 June

60 cm and 110—140 cm above ground level. In accordance with normal practice, the fruiting canes were topped to a height of 170 cm in the spring. Pest and weed control complied with the recommendations of the Agricultural Advisory Centres. The soil was medium fine sand. Nutrient contents of the soil samples collected from the experimental field on 30 May, 1985 are given in Table 2.

In the spring of 1985, fruiting canes were left equally in the sub-plots; the cane number of cv. Ottawa was 28 per plot, and that of cv. Muskoka 62 canes per plot. Afterwards only the fruited canes, and the weak or damaged canes were cut out; all strong canes were left.

After pruning in autumn, the number of the vegetative canes which were cut out was counted, and their fresh weight was measured. The number of the canes which were left was also counted. One vegetative cane per metre was sampled and cut out. The mean of three canes per plot was used for the analysis of the results. First, cane length and cane diameter at a height of 90 cm were measured. The node number was counted on the whole cane in 1985, but in 1986 and in 1987 the nodes were counted only to the topping height of 170 cm. Further, the lower part of the cane, 0—100 cm, was examined to estimate the incidence of fungal lesions. The area of skin covered by lesions was estimated on a scale of 0—3, where 0 = no lesions, 1 = less than 25 % of the skin area, 2 = 25 % to 50 % of the skin area, and 3 = more than 50 % of the skin area was covered by lesions. The lesions were caused mainly by the spur blight.

The number of fruiting canes was calculated in spring after the injuried canes had been cut out. Berries were picked twice a week, and on the third occasion the weight of 100 berries was

Table 2. Nutrient contents and pH of soil samples collected from the experimental field on 30 May 1985. Nutrients mg/l of soil, n = 6.

		cv. Ottawa		cv. Muskoka	
		N 25 kg/ha	N 25 + 25 kg/ha	N 25 kg/ha	N 25 + 25 kg/ha
pH	$\bar{x}$	6.45	6.75	6.85	6.50
	(min — max)	(6.00—6.80)	(6.45—7.10)	(5.93—7.10)	(6.25—6.75)
NO_3-N	$\bar{x}$	5.84	5.34	8.81	7.89
	(min — max)	(3.35—9.75)	(3.63—6.80)	(5.03—17.0)	(5.75—12.3)
NH_4-N	$\bar{x}$	7.60	8.25	7.80	7.96
	(min — max)	(5.28—9.85)	(4.83—10.9)	(5.00—11.0)	(6.13—9.18)
P	$\bar{x}$	12.2	17.3	19.2	12.7
	(min — max)	(8.5—16.8)	(12.5—27.6)	(6.8—24.8)	(9.5—20.3)
K	$\bar{x}$	135	155	175	190
	(min — max)	(110—160)	(130—190)	(110—260)	(130—300)
Ca	$\bar{x}$	1290	2190	2650	1690
	(min — max)	(750—1650)	(1300—4300)	(625—3525)	(1100—3100)
Mg	$\bar{x}$	85	115	140	105
	(min — max)	(60—100)	(90—200)	(60—190)	(80—165)
B	$\bar{x}$	0.93	0.73	0.75	0.66
	(min — max)	(0.51—1.67)	(0.46—0.99)	(0.45—1.05)	(0.38—0.97)
Cu	$\bar{x}$	2.13	2.32	2.30	2.35
	(min — max)	(1.40—2.77)	(1.55—3.19)	(1.14—4.58)	(1.15—3.35)
Mn	$\bar{x}$	49.4	54.5	60.7	44.6
	(min — max)	(23.3—90.5)	(25.2—125)	(25.1—101)	(18.5—89.5)

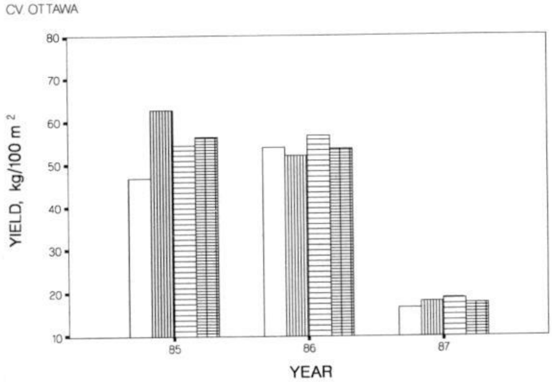
measured. The berries which were not marketable were weighed, too. These included mouldy berries, and berries damaged by the raspberry beetle (*Byturus tomentosus* Fabr.).

At a row width of 70 cm, soil samples were collected from a soil layer 20 cm deep three times during the growing seasons. In 1985, soil samples were taken at the end of May (30 May), in the middle of August (14 August) and in the middle of September (19 September). In 1986 and in 1987, the samples were taken at the beginning of flowering (16 June, 1986 and 1 July, 1987), at the beginning of harvesting (23 July, 1986 and 11 August, 1987) and at the end of harvesting (26 August, 1986 and 18 September, 1987). Soil samples were analyzed in the laboratory of the Department of Soil Science of the Agricultural Research Centre. NO_3-N and NH_4-N were analyzed by the method of LINDEN (1981). Ca, K, Mg, and P were determined by the method described by VUORINEN and MÄKITIE (1955). Further, B, Mn, and Cu were analyzed by the method of SILLANPÄÄ et al. (1975).

Leaf samples were collected from the upper part of vegetative canes after harvesting (4 September, 1985, 28 August, 1986 and 18 September, 1987). The samples were dried in room temperature and analyzed in the Central Laboratory of the Agricultural Research Centre.

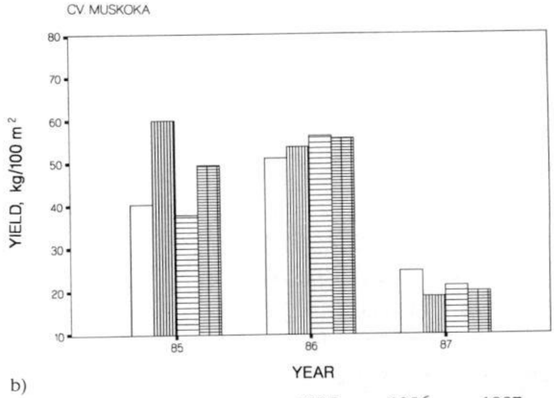
Table 3. Temperature and precipitation in Mikkeli in 1983—1987 and the long-term averages.

	Mean monthly temperature °C					
	1983	1984	1985	1986	1987	1931—1960
January	—4.5	—7.0	—19.3	—11.0	—20.9	—9.1
February	—10.6	—7.5	—17.5	—13.5	—9.2	—9.2
March	—3.6	—4.9	—2.8	—1.0	—6.3	—5.3
April	4.6	4.2	—0.2	1.9	1.6	1.8
May	11.4	13.0	8.3	10.6	7.7	8.6
June	13.6	13.6	13.2	17.1	13.0	13.9
July	17.3	15.4	15.4	16.8	14.8	16.7
August	14.2	13.7	15.7	12.7	11.0	14.6
September	10.6	8.8	8.8	5.9	7.8	9.4
October	4.2	5.5	5.4	4.3	5.5	3.6
November	—4.7	—0.9	—3.2	2.2	—3.4	—1.1
December	—5.7	—4.7	—8.9	—11.6	—8.2	—5.4
	Effective day-degrees of the growing season					
	1294	1231	1195	1223	910	
	Total monthly precipitation mm					
	1983	1984	1985	1986	1987	1931—1960
January	75	97	34	52	23	42
February	12	35	11	14	33	30
March	43	35	39	20	23	28
April	55	14	47	41	8	33
May	63	50	68	38	40	40
June	64	66	43	11	149	57
July	38	91	115	78	52	69
August	65	47	74	93	119	73
September	93	117	80	61	90	61
October	88	108	75	59	17	61
November	65	42	52	58	74	48
December	80	39	63	66	52	43
	Total of the growing season					
	324	371	381	281	449	300



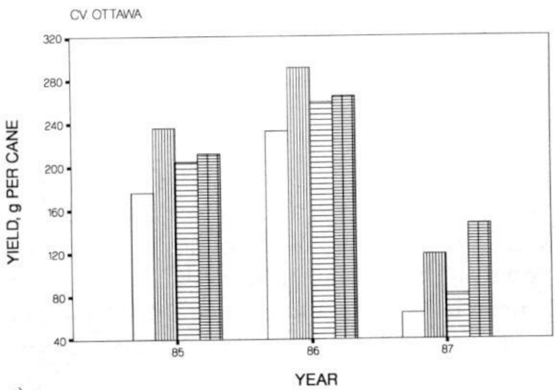
a)

F-values:		1985	1986	1987
	Fertilization	0.01	0.22	23.00*
	Cane removal	7.27	0.24	0.00
	Interaction	4.37	0.01	0.15



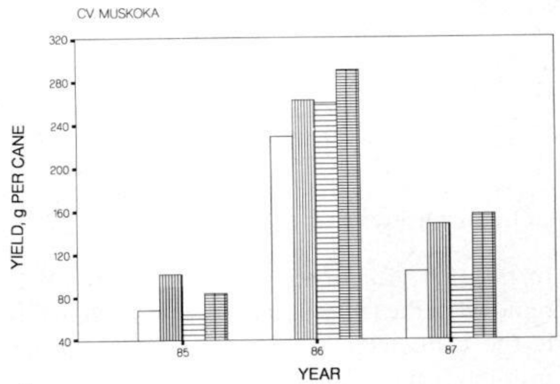
b)

F-values:		1985	1986	1987
	Fertilization	2.81	0.32	0.37
	Cane removal	18.28*	0.01	1.00
	Interaction	1.22	0.03	0.40



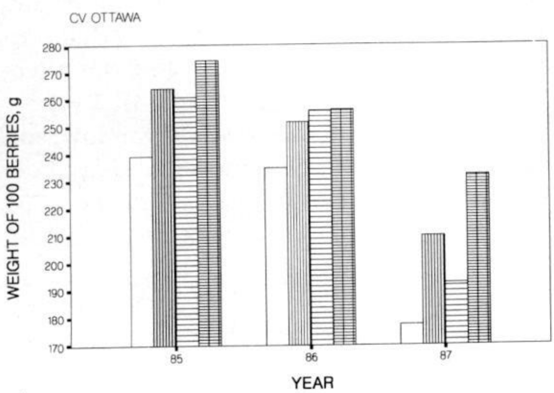
c)

F-values:		1985	1986	1987
	Fertilization	0.01	0.00	1.27
	Cane removal	7.27	1.17	75.27***
	Interaction	4.37	0.80	0.62



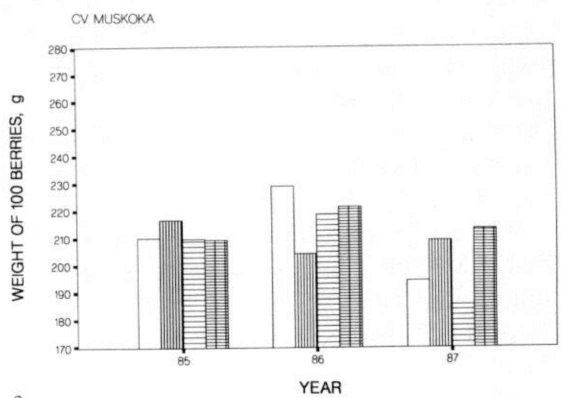
d)

F-values:		1985	1986	1987
	Fertilization	2.81	13.97	0.05
	Cane removal	18.28*	0.96	21.97**
	Interaction	1.22	0.00	0.42



e)

F-values:		1985	1986	1987
	Fertilization	1.36	1.05	3.26
	Cane removal	4.76	0.30	31.19**
	Interaction	0.41	0.28	0.32



f)

F-values:		1985	1986	1987
	Fertilization	0.10	0.38	1.25
	Cane removal	0.21	1.43	2.55
	Interaction	0.26	2.20	0.25

Figure 1. Effect of first-flush cane removal and additional nitrogen fertilization (a, b) on the marketable yield per 100 m², (c, d) on the marketable yield per fruiting cane and (e, f) on the berry weight of red raspberry cultivars Ottawa and Muskoka.

= N 25 kg/ha, no cane removal

= N 25 kg/ha, removal of canes

= N 25 + 25 kg/ha, no cane removal

= N 25 + 25 kg/ha, removal of canes

The Kjeldahl method (PEACH and TRACEY 1956) was used to determine the percentage of N in leaves.

When results were studied statistically, the analysis of variance was used, and each of the three years were analyzed separately.

When the experiments started in the spring of 1985, the vigour of plants was typical of the cultivars, or it was even higher than normally. During the course of the experiments, the vigour reduced strongly. In 1983—1987, there were two hard winters that damaged raspberry canes (Table 3). In the winter of 1984/1985, the lowest temperature was —34.7 °C, and in the winter of 1986/1987, it was —42.1 °C. Weather conditions both in 1986 and 1987 were unfavourable to the cane growth. In the growing season of 1986, June was warm and dry, and at the end of July and in the beginning of August it was much warmer than normally. In June the precipitation was only one fifth of the long-term average, but the plantation was not irrigated. The growing season of 1987 was exceptionally cold and rainy; effective day degrees was lower than ever measured in Mikkeli.

RESULTS

Cultivar Ottawa

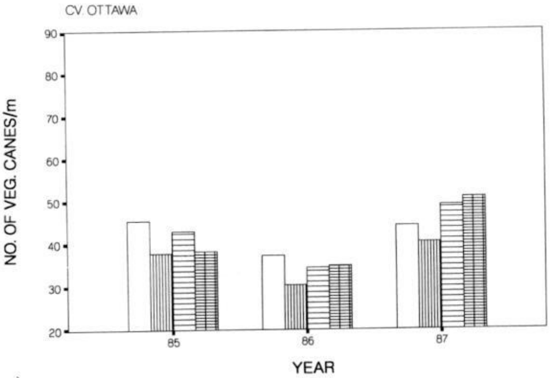
In the first year of the experiment, in 1985, removal of the first primocanes increased slightly the marketable yield ($P = 0.054$), yield per fruiting cane ($P = 0.054$) and berry size ($P = 0.095$) (Fig. 1). When the primocanes were removed, the yield was 17.7 % higher than without the removal. In the second year, the removal did not affect the yield. In the third year, the removal increased significantly the yield per fruiting cane and the berry size, but did not increase the yield per area. The primocane removal reduced the amount of berries damaged by the raspberry beetle or by fungus only in 1987 ($P = 0.020$).

When additional nitrogen was applied, the marketable yield increased by 5.3 % in 1987, but did not increase in 1985, or in 1986 (Fig. 1). Additional nitrogen did not affect yield per cane or berry size. In 1987, the higher quantity of nitrogen reduced the amount of damaged berries ($P = 0.040$).

In the first year, the primocane removal reduced slightly ($P = 0.057$) the number of vegetative canes in autumn (Fig. 2), and significantly the weight of pruned canes (Fig. 3). In the second year, the primocane removal reduced the weight of pruned canes, cane diameter and cane length (Fig. 3), as well as node number (Fig. 2). In the third year of the experiment, the primocane removal decreased the number of fruiting canes (Fig. 2), and reduced the cane diameter and cane length, as well as node number. The removal increased the internode length slightly ($P = 0.054$) in 1986 and significantly ($P = 0.009$) in 1987. Additional nitrogen fertilization had no significant effect on the cane growth (Figs. 2 and 3).

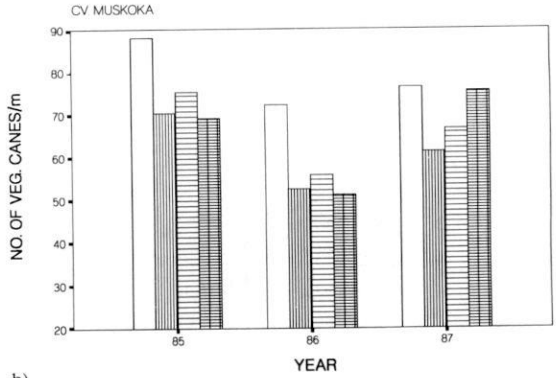
The incidence of cane diseases was low, and only in 1987 the cane removal tended to decrease fungal lesions of vegetative canes (Fig. 4). Nitrogen fertilization did not affect cane diseases.

Neither removal of the first primocanes nor nitrogen application affected the nitrogen content of leaves (Fig. 5), or the content of mineral nitrogen in soil during the growing seasons (Fig. 6). When the soil samples were collected before blossom in 1986, the content of NO_3-N in soil was after cane removal slightly higher ($P = 0.054$) than without removal.



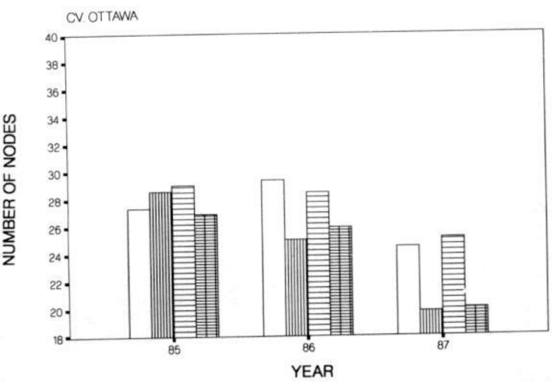
a)

F-values:		1985	1986	1987
	Fertilization	0.18	0.05	2.00
	Cane removal	7.00	1.48	0.09
	Interaction	0.44	1.95	0.69



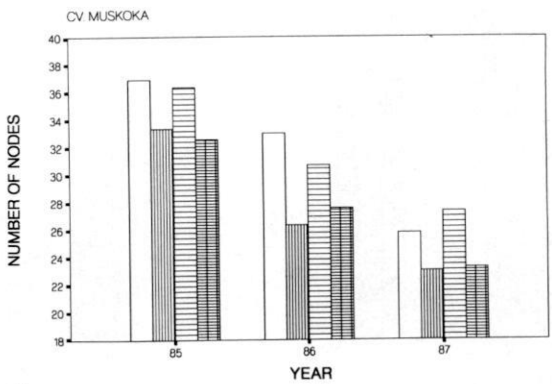
b)

F-values:		1985	1986	1987
	Fertilization	1.61	2.91	0.14
	Cane removal	9.35*	11.75*	0.15
	Interaction	2.16	4.56	2.13



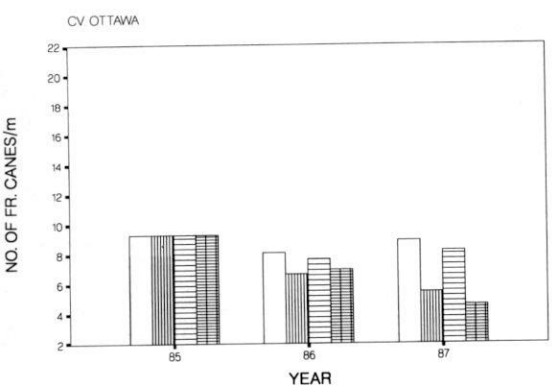
c)

F-values:		1985	1986	1987
	Fertilization	0.00	0.00	4.00
	Cane removal	0.10	8.25*	25.47**
	Interaction	1.40	0.55	0.05



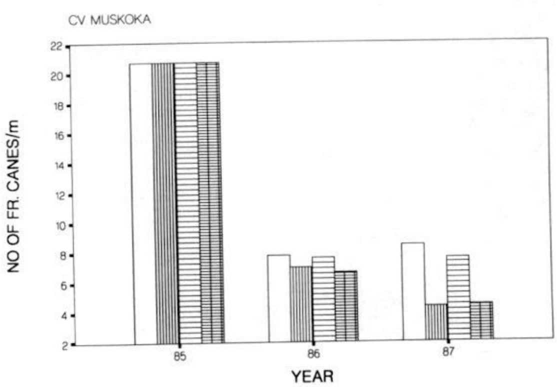
d)

F-values:		1985	1986	1987
	Fertilization	1.92	0.89	3.82
	Cane removal	5.08	10.88*	20.78**
	Interaction	0.00	1.44	0.78



e)

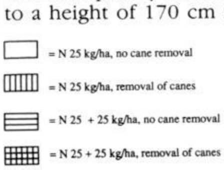
F-values:		1986	1987
	Fertilization	0.01	2.01
	Cane removal	2.23	17.84*
	Interaction	0.26	0.01

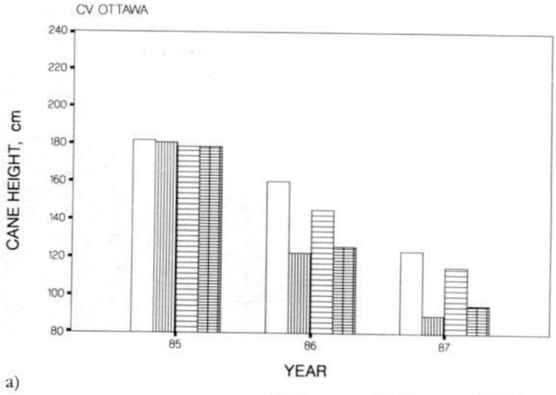


f)

F-values:		1986	1987
	Fertilization	0.09	0.16
	Cane removal	2.56	78.94***
	Interaction	0.02	1.50

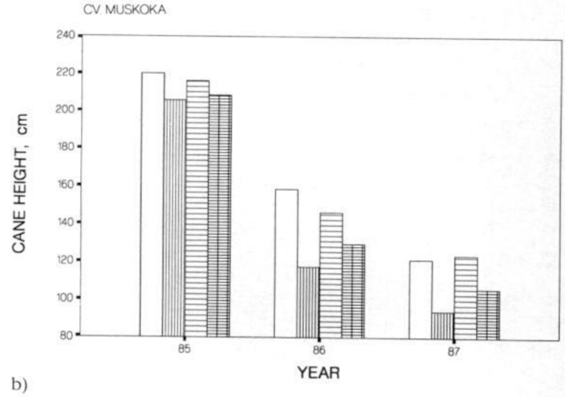
Figure 2. Effect of first-flush cane removal and additional nitrogen fertilization (a, b) on the number of vegetative canes before pruning in autumn, (c, d) on the node number on vegetative canes and (e, f) on the number of fruiting canes of red raspberry cultivars Ottawa and Muskoka. Node number was counted on the whole canes in autumn 1985 and to a height of 170 cm in 1986 and 1987.





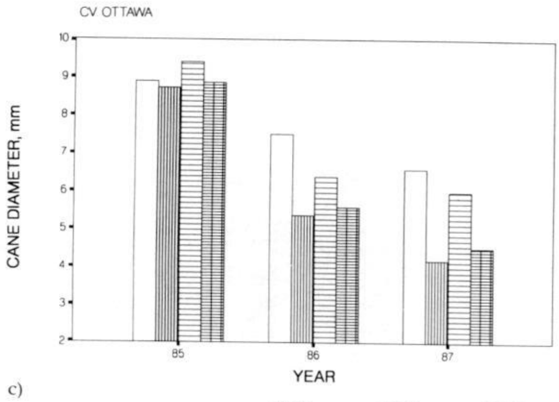
a)

F-values:		1985	1986	1987
	Fertilization	1.32	0.52	0.04
	Cane removal	0.01	14.34*	9.91*
	Interaction	0.01	1.47	0.66



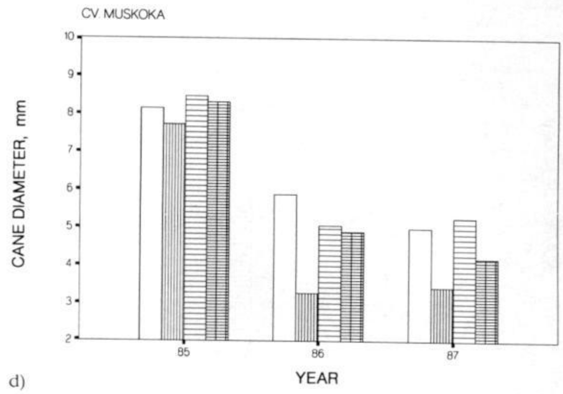
b)

F-values:		1985	1986	1987
	Fertilization	0.01	0.00	1.17
	Cane removal	3.22	21.55**	6.65
	Interaction	0.29	3.86	0.29



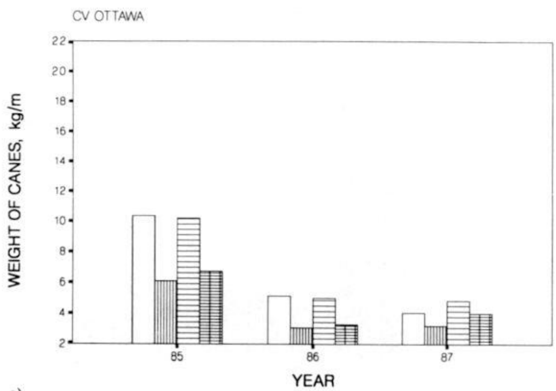
c)

F-values:		1985	1986	1987
	Fertilization	6.43	1.00	0.06
	Cane removal	0.52	7.93*	8.52*
	Interaction	0.15	1.65	0.49



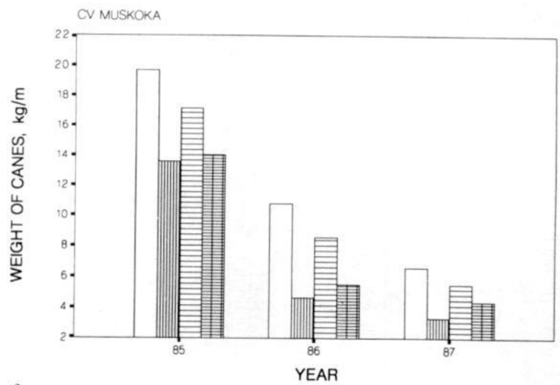
d)

F-values:		1985	1986	1987
	Fertilization	23.03*	0.58	1.38
	Cane removal	0.50	10.86*	5.22
	Interaction	0.11	8.42*	0.19



e)

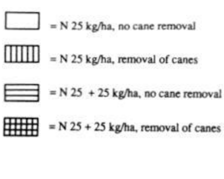
F-values:		1985	1986	1987
	Fertilization	0.02	0.00	5.36
	Cane removal	456.76***	10.80*	4.44
	Interaction	4.84	0.10	0.00



f)

F-values:		1985	1986	1987
	Fertilization	0.43	0.30	0.00
	Cane removal	10.87*	52.61**	16.13*
	Interaction	1.15	5.98	3.86

Figure 3. Effect of first-flush cane removal and additional nitrogen fertilization (a, b) on the length of vegetative canes in autumn, (c, d) on the diameter of the vegetative canes at a height of 90 cm and (e, f) on the weight of the vegetative canes that were cut out in autumn. Red raspberry cultivars Ottawa and Muskoka.



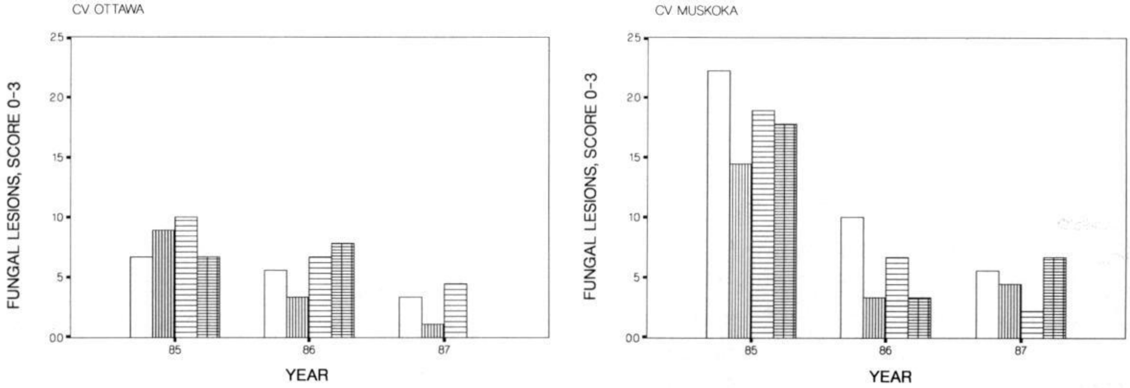


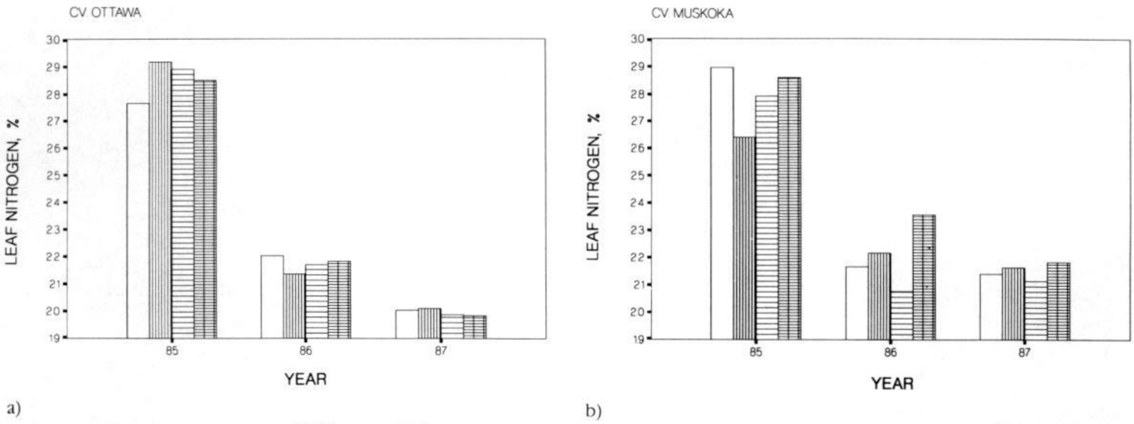
Figure 4. Effect of first-flush cane removal and additional nitrogen fertilization on the incidence of cane diseases on red raspberry cv. Ottawa and Muskoka. Fungal lesions on vegetative canes to a height of 100 cm were estimated in autumn on a scale of 0—3. 0 = no lesions, 1 = less than 25 % of the skin area, 2 = 25 % to 50 % of the skin area, and 3 = more than 50 % of the skin area is covered by lesions.

= N 25 kg/ha, no cane removal
= N 25 kg/ha, removal of canes
= N 25 + 25 kg/ha, no cane removal
= N 25 + 25 kg/ha, removal of canes

Cultivar Muskoka

In the first year of experiment, removal of the first primocanes increased the marketable yield per area and that per fruiting cane; the yield was 40.2 % higher than without cane removal (Fig. 1). In the second year, the primocane removal did not affect the yield. In the third year, the removal increased only the yield per fruiting cane. The berry weight of cv. Muskoka was not affected by the primocane removal (Fig. 1). The amount of berries damaged by the raspberry beetle or by fungus was reduced by the cane removal slightly (P = 0.054) in 1987.

Additional nitrogen did not affect the yield per area or berry weight (Fig. 1). The higher quantity of nitrogen increased the yield per



a)

F-values:		1985	1986	1987
	Fertilization	2.17	0.01	0.22
	Cane removal	0.78	0.15	0.00
	Interaction	2.32	0.33	0.01

b)

F-values:		1985	1986	1987
	Fertilization	39.52*	0.09	0.00
	Cane removal	1.41	2.79	0.24
	Interaction	4.08	1.36	0.06

Figure 5. Effect of first-flush cane removal and additional nitrogen fertilization on the nitrogen content in leaves' dry matter of red raspberry cv. (a) Ottawa and (b) Muskoka.

= N 25 kg/ha, no cane removal
= N 25 kg/ha, removal of canes
= N 25 + 25 kg/ha, no cane removal
= N 25 + 25 kg/ha, removal of canes

fruiting cane slightly (P = 0.065) in 1986, and the amount of damaged berries significantly (P = 0.027) in 1985.

In the first year, the primocane removal decreased significantly the number of vegetative canes in autumn and slightly (P = 0.087) the node number of the canes (Fig. 2). The removal reduced the weight of pruned canes (Fig. 3) and increased the internode length of vegetative canes every year (in 1985 P = 0.042; in 1986 P = 0.032; in 1987 P = 0.014). In the second year, the removal decreased the number of vegetative canes, cane length (Fig. 3) and node number. In 1986, the primocane removal decreased the cane diameter significantly when no additional nitrogen was applied (Fig. 3). In the third year, the primocane removal decreased the number of fruiting canes (Fig. 2) and the node number of vegetative canes. In addition, the removal decreased slightly the

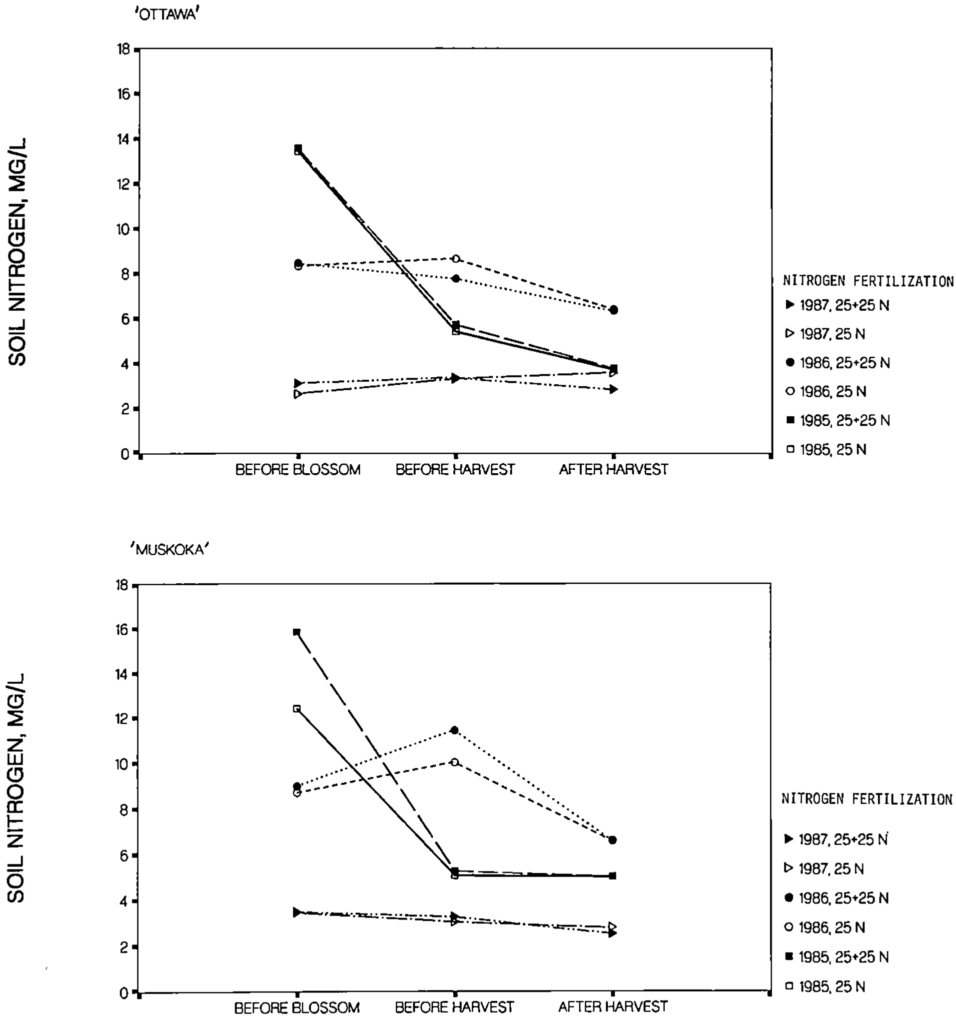


Figure 6. Effect of additional nitrogen fertilization on the development of nitrogen content in soil, red raspberry cv. Ottawa and Muskoka. Soil nitrogen includes NH_4-N and NO_3-N. The cane removal treatments are combined.

cane diameter (P = 0.084) and the cane length (P = 0.061).

Additional nitrogen increased the cane diameter in 1985 (Fig. 3), but otherwise nitrogen fertilization had no effect on the cane growth (Figs. 2 and 3).

Removal of the first-flush canes tended to decrease the incidence of fungal lesions both in 1985 and in 1986, but not in 1987 (Fig. 4). Nitrogen fertilization did not affect cane diseases.

Additional nitrogen fertilization increased the nitrogen content of leaves in 1985 (P = 0.024) when the first-flush canes were removed; the interaction was not significant (P = 0.114), however (Fig. 5). Removal of the first-flush canes did not affect significantly the leaf nitrogen content. The content of mineral nitrogen in soil samples during the growing seasons was not affected by the fertilization treatments (Fig. 6). When the soil samples were collected before blossom in 1986, the content of NO_3-N in soil was after cane removal higher than without removal, P = 0.050.

DISCUSSION

Growth responses

The number of canes produced by cv. Muskoka was almost twice that produced by cv. Ottawa, and the need of pruning was greater. The canes of cv. Ottawa were slightly thicker and had fewer nodes than the canes of cv. Muskoka. Despite these differences, the growth responses of the cultivars to the primocane removal were nearly similar.

In the first year, the number of vegetative canes in autumn reduced after primocane removal. However, the plants produced a sufficient number of strong canes for fruiting in the following year. During the second and the third year, the cane removal reduced the vigour of both cultivars: cane number was not much affected, but the number of strong canes decreased. The canes were thinner and shorter, and the node number below the topping height was lower than without cane removal.

The primocane removal technique was developed to control the excessive vigour of raspberry canes; the vigour declines as the height and the diameter of canes decrease (WILLIAMSON et al. 1979, CRANDALL et al. 1980, FREEMAN and DAUBENY 1986). When the canes of vigorous cultivars are shorter, the node number below the topping height usually increases (CRANDALL et al. 1980, LAWSON and WISEMAN 1983). The removal has also decreased the number of replacement canes (WILLIAMSON et al. 1979, CRANDALL et al. 1980, NORTON 1980, REBANDEL and PRZYSIECKA 1981, LAWSON and WISEMAN 1983, FREEMAN and DAUBENY 1986, FREEMAN et al. 1989 b, SULLIVAN and DALE 1989).

The primocanes of the cultivars Ottawa and Muskoka were removed in a non-vigorous plantation in the spring of 1987, and the removal reduced plant vigour strongly. Also in earlier experiments with poor plantations or non-vigorous cultivars, cane production has proved inadequate after as little as one season of treatment, and the adverse effect on cane quality has been cumulative (NORTON 1980, CRANDALL et al. 1980, LAWSON 1986, SULLIVAN and DALE 1989). In addition, drought has affected adversely the second-flush cane height (CRANDALL et al. 1980, LAWSON and WISEMAN 1985, LAWSON 1986). With well-managed plantations of vigorous cultivars where canes are about 3 m high, cane production can be maintained at an adequate level for at least four years (NORTON 1980, CRANDALL et al. 1980, LAWSON and WISEMAN 1983, FREEMAN and DAUBENY 1986).

When the first flush of primocanes is removed at a height of 15 cm, in Finnish conditions at the end of May or in the beginning of June, the growing season of replacement canes is from three to four weeks shorter than that of first-flush canes. The time available for the production of photosynthates and the regeneration of the overwintering carbohydrate reserves is shorter, too. CRANDALL et al. (1980) showed that the amount of carbohydrates per bud in dormant canes was reduced by primocane removal during the previous growing season. According to WHITNEY's (1982) theories, when primocanes are removed at a height of 15 cm, their photosynthates are not able to correct the resultant decrease in root reserves; the storage compounds in roots are used once more to produce the replacement canes. After the primocane removal, the cane number decreases and the size of canes, as well as their leaf area, reduces. As a result, the carbohydrate reserves reduce, and the plant vigour declines during the course of years.

In the present experiments, primocane removal was done mechanically by hand pulling, because the use of dinoseb was prohibited in Finland. When the removal is done chemically, the effect is slower, and the growing season of replacement canes is shorter than after mechanical removal. However, at present the chemical removal is the most economical practice in large-scale use.

Replacement canes not only have shorter growing season than the first-flush canes, but they also have to compete with the fruiting phase of the crop (LAWSON and WISEMAN 1983). In the present experiments, the internodes of replacement canes were longer than those of the first-flush canes which implies increased competition for light between the fruiting canes and the replacement canes.

Yield responses

Yields of cultivars Ottawa and Muskoka were almost equal, including the season 1985 when the fruiting canes of cv. Muskoka numbered twice those of cv. Ottawa. During the previous winter, cv. Muskoka had more injuries, and the yield per cane was lower than that of cv. Ottawa. Berries of cv. Ottawa were larger than those of cv. Muskoka.

Many studies have shown that the primocane removal increases yield as a result of higher number of berries per cane and often as a result of greater berries as well (NORTON 1983 and 1980, WILLIAMSON et al. 1979, CRANDALL et al. 1980, REBANDEL and PRZYSIECKA 1981, LAWSON and WISEMAN 1983, SIDOROVICH 1985, BUSZARD 1986, FREEMAN and DAUBENY 1986, FREEMAN et al. 1989 a). In the first year of the present study, primocane removal increased the yield of both cultivars, and the effect was greater on cv. Muskoka than on cv. Ottawa. The yield per fruiting cane increased, but berry size was not much affected. In the second year, the removal did not increase yield, although after the primocane removal in 1985 the number of strong canes was not significantly lower, and their size was not significantly smaller than without removal. However, according to CRANDALL et al. (1980), the amount of carbohydrates in canes might be lower after cane removal during the previous growing season.

In the third year, the number of fruiting canes was lower and the length, diameter and node number were smaller than without primocane removal. The removal did not increase yield, but neither did the yield decrease, because the yield per cane, as well as the berry size increased as a result of the removal. During the hard winter of 1986/1987, the strongest canes of raspberries were usually more injuried. The damage showed in the middle portion of canes when the fruiting laterals failed to develop. The less vigorous canes which developed after the cane removal survived better. BUSZARD (1986) has reported that in Eastern Canada, the primocane removal has improved winter survival of canes.

CRANDALL et al. (1980) believed that primocane removal increases yield by reducing the competition of rapidly growing primocanes for storage compounds, photosynthates, nutrients, and light during the critical stages of blossom development. According to WAISTER and WRIGHT (1989), the increase in yield is primarily an effect of removal of shading of fruiting laterals rather than removal of a competing sink of assimilates, or reduction in competition for water or mineral nutrients.

In the present experiments, removal of the first-flush canes improved the fruit quality of both cultivars in 1987, but not in 1985. Both seasons were rainy, and the amount of rejected berries was high. According to SCHEER and GARREN (1987), cane removal may decrease *Botrytis* fruit rot, as the vegetative canes are shorter, and the fruiting laterals dry faster if rain occurs.

Cane diseases

In 1985, when the incidence of fungal cane disease was high, cv. Muskoka was more susceptible to the diseases than cv. Ottawa. Primocane removal tended to reduce the cane diseases of cv. Muskoka. Reduced incidence of fungal cane diseases after primocane removal has been reported earlier by WILLIAMSON et al. (1979), by REBANDEL and PRZYSIECKA (1981), and by FREEMAN and DAUBENY (1986). In addition, the replacement canes growing after the removal have avoided serious infestation by raspberry cane midge and midge blight (NIJVELDT et al. 1963, SEEMULLER 1976, WILLIAMSON et al. 1979, DALMAN and MALKKI 1986).

Studies of WILLIAMSON et al. (1979) showed that replacement canes had a much lower incidence of lesions attributed to *Leptosphaeria coniothyrium* (Fckl.) Sacc. infecting either physical wounds (cane blight) or feeding wounds (midge blight) affected by raspberry cane midge. Cane botrytis (*Botrytis cinerea* Pers. ex Fr.) and spur blight were also less common in treated than in untreated plots. The later the canes were removed, the lower was the incidence of diseases. The apparent resistance of replacement canes to the diseases may be due to their being physiologically more juvenile (WILLIAMSON et al. 1979). The key factor predisposing canes to infection by *D. applanata* seems to be senescence of their cortical tissue, leaves and petioles (BURCHILL and BEEVER 1975).

When primocane removal improves the health status of vegetative canes, the yield may increase in the following year (WILLIAMSON et al. 1979, REBANDEL and PRZYSIECKA 1981, FREEMAN and DAUBENY 1986). In the present experiment, the incidence of cane diseases, mainly spur blight, in the canes of cv. Muskoka was high in the autumn of 1985. Anyhow, the yield was good in 1986, and the removal did not increase it. DALMAN (1986) reported also earlier that the high incidence of fungal lesions on the canes of cv. Muskoka did not cause serious yield losses. WILLIAMSON (1980) has concluded that in Scotland spur blight alone rarely reduces yield seriously, because lesions and infected buds predominate in the relatively infertile part of canes below 45 cm. Infections by *D. applanata* are usually superficial and do not normally penetrate the vascular tissues.

Primocane removal and additional nitrogen fertilization

The contents of NH_4-N and NO_3-N in soil samples were not increased by the additional nitrogen. During 1986, the nitrogen content in soil was higher than in 1985 or in 1987. However, in August of 1986, the nitrogen content of leaves was lower than in 1985. Obviously, the drought in 1986 disturbed the nitrogen uptake by plants. During the cold and rainy season of 1987, the mobilization of nitrogen might be low which resulted in low nitrogen content both in soil and in leaves. The nitrogen level in soil was in the spring of 1985 higher than in 1986 and in 1987, because the soil samples were collected earlier.

When raspberry is grown in medium-fine sand soil, where the nitrate-nitrogen content is below 10 mg per litre of soil, the recommendation of annual nitrogen fertilization in Finland is 25 kg N per hectare (ANON. 1989). In the present experiments, the lower quantity of nitrogen was equivalent to the recommendation, and the higher quantity was twice that. Anyhow, additional nitrogen had no consistent effect on the growth, yield, incidence of fungal cane diseases, or on the nitrogen content in the leaves of cultivars Ottawa and Muskoka.

The increased nitrogen fertilization failed to increase the vigour of cultivars Ottawa and Muskoka. CRANDALL et al. (1980) also studied the effects of greater nitrogen amounts on the plant vigour after the primocane removal. Treatments included one, two or three cane removal sprays, and nitrogen applications of 78.5 kg/ha, 112 kg/ha, 156.9 kg/ha, or 156.9 kg/ha as a split application 78.5 kg + 78.5 kg. The additional nitrogen had no effect on the cane diameter, cane height, node number, or on the cane number in the sprayed plots.

CONCLUSIONS

On the basis of the present experiments, for cultivars Ottawa and Muskoka primocane removal is recommended only to plantings where canes grow to a height of 2.5 metres or more, and vigorous growth of new canes makes harvesting, pruning and supporting laborious. DALMAN and MALKKI (1986) recommended the treatment also to plantings of cv. Ottawa infested by the raspberry cane midge in the previous summer. In addition, the removal can be done always in the last year of the planting. The first flush of primocanes must be removed at a maximum height of 10 cm, i.e. during the third or fourth week in May. The canes are removed too early rather than too late. It is necessary to have irrigation systems, because drought during the early summer reduces strongly the growth of replacement canes.

Glufosinate-ammonium (Basta) has been registered for the weed control of raspberry in Finland in the beginning of 1990. TUOMINEN (1990) tested the effect of the herbicide on weeds and on the primocanes of cv. Ottawa, and recommended one spraying of glufosinate-ammonium when the primocanes are about 15 cm high. However, LAWSON and WISEMAN (1985) did not consider glufosinate-ammonium suitable for cane desiccation, because the effect was too slow, and there was evidence of translocation up the fruiting cane and into the stool. SEIPP (1989) achieved good results when glufosinate-ammonium was applied together with ammonium sulfate, but the pure chemical was not as effective. The use of glufosinate-ammonium for the primocane removal of both cultivars, Ottawa and Muskoka, should be carefully tested before large-scale use. Also the new promising methods introduced by HOWARD et al. (1989) and LAWSON and WISEMAN (1989) should be tested in Finland.

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SELOSTUS

Kasvuversojen poistokäsittelyn ja typpilisälannoituksen vaikutus vadelman satoon, versonkasvuun ja versotauteihin

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Kasvuversojen poistokäsittelyllä tarkoitetan ensimmäisinä keväällä kehittyvien kasvuversojen poistoa kokonaan 10—25 cm:n mittaisina. Poisto tehdään yleensä kemiallisesti dinosebilla. Poistettujen versojen tilalle kehittyy uusi versosto, joka on heikompi kuin kasvukauden alusta asti kehittynyt versosto. Käsittelyn seurauksena erityisesti voimakaskasvuisten lajikkeiden sato on suurentunut ja sadonkorjuu, versojen leikkaus ja tuenta ovat helpottuneet. Käsittely on myös vähentänyt versotautien ja vatunvarsisääsken esiintymistä vadelman versoissa. Joissakin tapauksissa versojen poistokäsittely on heikentänyt kasvua liikaa ja seuraavina vuosina sato on jäänyt heikoksi.

Tämän tutkimuksen tavoitteena oli selvittää kasvuversojen poistokäsittelyn vaikutuksia 'Ottawa'- ja 'Muskoka'-lajikkeiden satoon, versojen kasvuun ja versotauteihin. Lisäksi tutkittiin, voidaanko versojen kasvua voimistaa typpilannoituksella poistokäsittelyn jälkeen. Kasvuversot poistettiin käsin kitkien touko-kesäkuun vaihteessa noin 15 cm:n pituisina. Poisto tehtiin käsin, koska dinosebin käyttö oli kielletty Suomessa ja esimerkiksi dikvatti ja parakvatti eivät sovellu versojen poistoon. Toukokuun puolivälissä koko koe lannoitettiin puutarhan Y-lannoksella, joka sisälsi typpeä 25 kg/ha. Puolet kokeesta sai kalsiumnitraatissa lisätyppeä 25 kg/ha kukinnan aikaan heinäkuun alkupuolella. Maalaji oli karkea hieta, ja maan nitraattityppipitoisuus alle 10 mg/l. Kenttäkokeet istutettiin keväällä 1983, ja koekäsittelyt tehtiin v 1985—1987.

Ensimmäisenä vuonna kasvuversojen poisto lisäsi 'Muskoka'-lajikkeen satoa 40 % ja 'Ottawa'-lajikkeen satoa 18 %. 'Ottawa'-lajikkeen marjakoko suureni, mutta käsittely ei vaikuttanut 'Muskoka'-lajikkeen marjakokoon. Ensimmäisen vuoden jälkeen poistokäsittely ei lisännyt satoa, sillä lajikkeiden kasvu heikkeni. Käsittelyn jälkeen versot jäivät lyhyiksi ja ohuiksi, silmuja kehittyi vähän ja nivelvälit olivat pitkät. Kolmantena koevuonna käsittely vähensi satoversojen lukumäärää. Lisätyppilannoitus ei voimistanut versojen kasvua. Typpilannoitus ei vaikuttanut johdonmukaisesti versojen kasvuun, satoon, versotauteihin eikä maan ja lehtien typpipitoisuuteen, vaikka 50 kg typpeä hehtaarille oli kaksinkertaisesti vadelmalle suositettu typpimäärä.

'Ottawa'-lajikkeen kasvuversoja kehittyi puolet 'Muskoka'-lajikkeen versomäärästä. Versotauteja esiintyi runsaasti syksyllä 1985 ja 'Muskoka' oli taudeille alttiimpi kuin 'Ottawa'. Kasvuversojen poistokäsittely vähensi versotautisaastuntaa 'Muskoka'-lajikkeen versoissa.

Tutkimuksen perusteella kasvuversojen poistokäsittelyä suositetaan 'Ottawa'- ja 'Muskoka'-lajikkeille vain kasvustoissa, joissa versot kehittyvät 2,5 metrin pituisiksi ja voimakas kasvu haittaa sadonkorjuuta, tuentaa ja leikkausta. Aiemmin Dalman ja Malkki (1986) ovat suosittaneet käsittelyä 'Ottawa'-lajikkeelle, jos kasvustosta on edellisenä syksynä löytynyt vatunvarsisääsken toukkia. Lisäksi poistokäsittelyn voi tehdä kaikilla viljelmillä viimeisenä viljelyvuonna. Ensimmäisinä kehittyneet kasvuversot poistetaan, kun ne ovat noin 10 cm pitkiä eli toukokuun kolmannella tai neljännellä viikolla. Versot poistetaan mieluummin liian aikaisin kuin liian myöhään eikä missään tapauksessa enää kesäkuussa, jotta uusille versoille jäisi riittävästi kasvuaikaa. Kastelulaitteet varmistavat uuden versoston kehittymistä, sillä kokeissa huomattiin alkukesän kuivuuden heikentävän kasvua voimakkaasti.

Kokeissa versot poistettiin käsin, mutta käytännön viljelyksillä poisto on kannattavaa vain kemiallisesti. Glufosinaatti-ammoniumin (Basta) käyttö vadelman rikkakasvien torjuntaan on ollut sallittua Suomessa vuoden 1990 alusta. Kasvuversojen poistossa on siitä saatu ulkomailla ristiriitaisia tuloksia, joten sopivuus 'Ottawa'- ja 'Muskoka'-lajikkeille pitäisi tutkia ennen laajempaa käyttöä. Dinosebi on nykyisin kielletty lähes kaikkialla ja uusia versohävitteitä testataan intensiivisesti. Uudet lupaavat menetelmät, sekä kemialliset että mekaaniset, pitäisi saada nopeasti kokeisiin Suomeen.

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THE EFFECT OF VEGETATIVE CANE REMOVAL ON THE YIELD AT DIFFERENT CANE HEIGHTS OF RED RASPBERRY

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Vegetative cane removal of red raspberry (*Rubus idaeus* L.) cv. Ottawa was studied in plants where only one fruiting cane competed with vegetative canes, and competition between the fruiting canes was prevented. The effect of timing of cane removal was evaluated, and yield components were examined at fruiting cane heights of 0—43 cm, 43—85 cm, 85—128 cm and 128—170 cm.

Removing the canes once when they had reached a height of 15 cm, or four times during the growing season at a height of 15 cm, did not increase the yield significantly. When the canes were removed at the beginning of flowering, the yield was 55 % higher and the berries ripened earlier than without cane removal. The higher yield resulted from the higher berry number per fruiting lateral and from the heavier berries; the number of fruiting laterals was not affected. The quantity and size of berries increased on all the fruiting laterals. The lower half of the cane produced 34 % of the total yield.

It was more beneficial for fruit production to remove vegetative canes once at the beginning of flowering or at the beginning of harvesting than four times throughout the season. The cane removal reduced the competition for light, water and mineral nutrients, but increased the competition for assimilates and reserve carbohydrates, because after removal the raspberry plant produces a new flush of vegetative canes.

Index words: red raspberry, cane removal, competition.

INTRODUCTION

Removal of vegetative canes of raspberry at the beginning of the growing season, or several times during the season, reduces competition between vegetative and fruiting canes. Usually the yield from fruiting canes increases, but there are differences between cultivars (WAISTER et al. 1977, CRANDALL et al. 1980, BUSZARD 1986, FREEMAN et al. 1989).

CRANDALL et al. (1980) showed that cane removal had no effect on the number of berries on the upper fruiting laterals, but greatly increased the berry numbers on laterals from the middle and lower portions of the canes. WRIGHT and WAISTER (1984) also observed that after cane removal the numbers of harvested berries were higher towards the base of the fruiting cane than without cane removal. Berry number correlated well with the leaf number of fruiting laterals. WRIGHT and WAISTER (1984) concluded that, when canes are not removed, shading and leaf abscission in the lower laterals lead to arrested development of some fruits, and reduced expansion of others.

However, the lower half of the fruiting cane has less potential for yield production than the upper half, because the number of nodes and fruiting laterals decreases towards the base of the cane. The yield is closely correlated with the number of laterals (CRANDALL et al. 1974, ORKNEY and MARTIN 1980). In addition, the reproductive vigor of laterals is often lower towards the base of the fruiting cane (CRANDALL et al. 1974, DALE and TOPHAM 1980, CRANDALL et al. 1980).

The objective of this study was to investigate the effect of vegetative cane removal on the yield of red raspberry cv. Ottawa, the timing of removal, and the yield components in different portions of the fruiting cane. Competition between fruiting and vegetative canes was studied in plants where only one fruiting cane competed with a whole bush of vegetative canes, and competition between the fruiting canes was prevented.

MATERIAL AND METHODS

The field experiment of red raspberry cv. Ottawa was carried out at the South Savo Research Station in Mikkeli (61°40′ N and 27°13′ E) in 1986. The split-plot design with four replicates was used, and whole units were selected randomly. The whole-unit treatments involved removal of vegetative canes as follows:

- no cane removal
- removal once at a cane height of 15 cm (27 May)
- removal once at the beginning of flowering (13 June)
- removal once at the beginning of harvesting (24 July)
- removal four times throughout the growing season at a cane height of 15 cm (27 May, 13 June, 8 July and 24 July).

The canes were removed mechanically, either pulling by hand or using secateurs. In accordance with normal practice, the fruiting canes were topped to a height of 170 cm. The sub units were four portions of the fruiting cane at heights of 0—43 cm, 43—85 cm, 85—128 cm and 128—170 cm.

Only two fruiting canes were left to a plot length of 1.5 m in the spring of 1986. At the beginning of flowering, one of the canes was removed, and the other was marked at heights of 43, 85 and 128 cm. The canes which were left for fruiting are described in Table 1. Except for the plots where vegetative canes were removed at the beginning of the harvest, the canes were equal in terms of number of nodes. In these plots the number of nodes per cane was higher after topping than in the other plots.

The field was planted in the spring of 1983, spacing was 1.8 m between rows, and the width of the row base was about 30 cm. The fruiting canes were supported by tying in a wire at a height of 140 cm. Fertilizer applications as well as pest and weed control were performed according to the recommendations of Agricultural Advisory Centres.

The number of fruiting laterals was recorded at the beginning of harvesting. At harvest, from 23 July to 22 August, the berries were counted and weighed on ten occasions at intervals of 2—4 days. The height of vegetative canes was measured at the beginning of the harvest, and again at the end of the season when the number of canes was counted. The analysis of variance of the hierarchic model and Tukey's studentized range test were used for calculation of the results.

RESULTS

When the vegetative canes were removed once at a height of 15 cm, the new canes were about 20 cm shorter than the canes grown undisturbed from the beginning of the season (Table 2), and about 50 cm shorter after cane removal at the beginning of flowering. When the cane removal had taken place at the beginning of the harvest, new canes were maximally 30 cm high in autumn. At the end of the season, the number of canes was reduced only when canes were removed four times during the growing season (Table 2).

Table 1. Height of the fruiting canes, and number of nodes per cane of red raspberry cv. Ottawa which started to grow in the spring of 1986.

	Removal of vegetative canes				
	No removal	Once at a height of 15 cm	Once at the begin. of flowering	Once at the begin. of harvesting	Four times at a height of 15 cm
Fruiting canes before topping					
Height of cane, cm					
Plot 1	220	215	230	205	220
Plot 2	210	215	215	220	215
Plot 3	200	225	220	210	215
Plot 4	220	205	205	210	220
Mean	213	215	218	211	218
		$\bar{x}$ (n = 20)	215 ± 1.7 cm		
Number of nodes/cane					
Plot 1	25	27	27	31	25
Plot 2	27	22	27	29	22
Plot 3	21	23	25	27	26
Plot 4	26	22	22	33	26
Mean	24.8	23.5	25.3	30.0	24.8
		$\bar{x}$ (n = 20)	25.8 ± 0.7		
Fruiting canes after topping					
Number of nodes/cane					
Plot 1	13	15	12	20	14
Plot 2	16	12	15	16	14
Plot 3	14	12	16	16	16
Plot 4	14	14	15	22	15
Mean	14.3	13.3	14.5	18.5	14.8
		$\bar{x}$ (n = 20)	15.0 ± 0.6		
Height of the lowest node, cm					
Plot 1	42	25	41	26	27
Plot 2	35	42	19	40	44
Plot 3	28	46	20	26	22
Plot 4	29	36	48	23	39
Mean	33.5	37.3	32.0	28.8	33.0
		$\bar{x}$ (n = 20)	32.9 ± 2.1 cm		

Cane removal did not affect the number of fruiting laterals (Table 3). On average, 7 % of laterals were situated in the lowest portion of the fruiting cane; 27 % at the height of 43—85 cm; 28 % 85—128 cm, and 38 % in the uppermost portion. At the beginning of the harvest, the percentages of dead laterals were as follows:

	mean	range
no cane removal	3.6 %	(0—14 %)
removal once at a height of 15 cm	1.9 %	(0—8 %)
removal at the beginning of flowering	1.6 %	(0—6 %)
removal at the beginning of harvesting	12.2 %	(0—18 %)
removal four times at a height of 15 cm	10.2 %	(0—19 %)

Table 2. Effect of different removal times of vegetative canes on the cane height and number of red raspberry cv. Ottawa in 1986.

Removal treatment	Cane height (cm) at the beginning of harvesting		Cane height (cm) at the end of the season		Number of canes/metre
	Mean	Maximum	Mean	Maximum	
No cane removal	114	140	134	180	29.3
Removal once at a height of 15 cm	93	125	119	155	32.3
Removal once at the beginning of flowering	56	95	78	130	31.0
Removal once at the beginning of harvesting	116	145	14	30	36.3
Removal four times at a height of 15 cm	13	20	26	45	14.3

Table 3. Effect of vegetative cane removal on the number of fruiting laterals at different cane heights of red raspberry cv. Ottawa in 1986.

Removal treatment	Number of fruiting laterals Height of fruiting cane				Sum
	170—128 cm	128—85 cm	85—43 cm	43—0 cm	
No cane removal	4.8	4.0	3.8	1.3	13.9
Removal once at a height of 15 cm	4.8	3.3	4.0	1.0	13.1
Removal once at the beginning of flowering	5.3	4.5	3.5	1.0	14.3
Removal once at the beginning of harvesting	6.5	4.8	4.0	1.0	16.3
Removal four times at a height of 15 cm	5.5	3.3	3.5	1.0	13.3
Mean	5.4	4.0	3.8	1.0	14.1

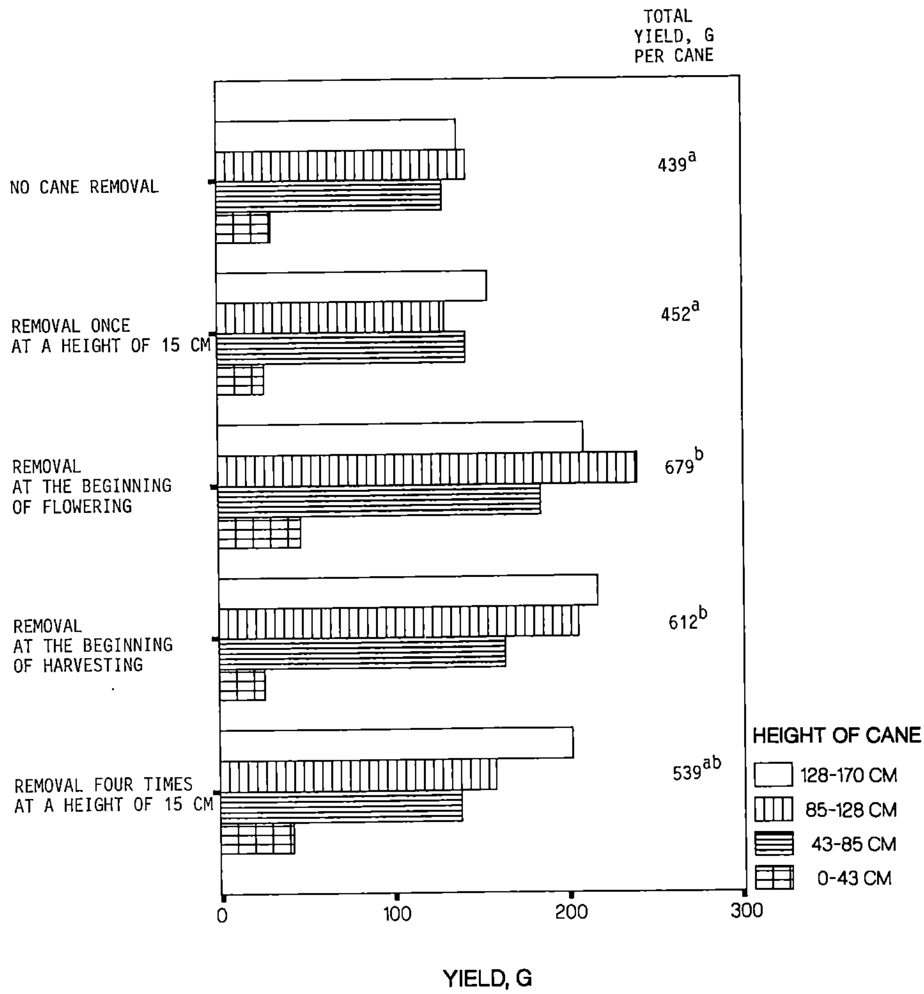

Fig. 1. Effect of vegetative cane removal on the berry yield at different cane heights of red raspberry cv. Ottawa in 1986. Means with a different letter are significantly different ($P < 0.05$).

Cane removal, $F = 7.10^{***}$

Height of fruiting cane within each removal treatment, $F = 13.89^{***}$

When the vegetative canes were removed at the beginning of flowering, the yield was 55 % higher (Fig. 1), the number of berries was 36 % greater (Fig. 2), and the berry size was 19 % greater (Fig. 3) than without cane removal. When the cane removal took place at the beginning of harvesting, the yield was 39 % higher and the number of berries was 37 % higher, than without removal, but the weight of berries was not affected. When compared to the plants where canes were not removed, the removal once or four times at the height of 15 cm did not increase significantly berry yield, number, or berry weight.

The berry weight was equal in all portions of the fruiting cane (Fig. 3). Cane removal did

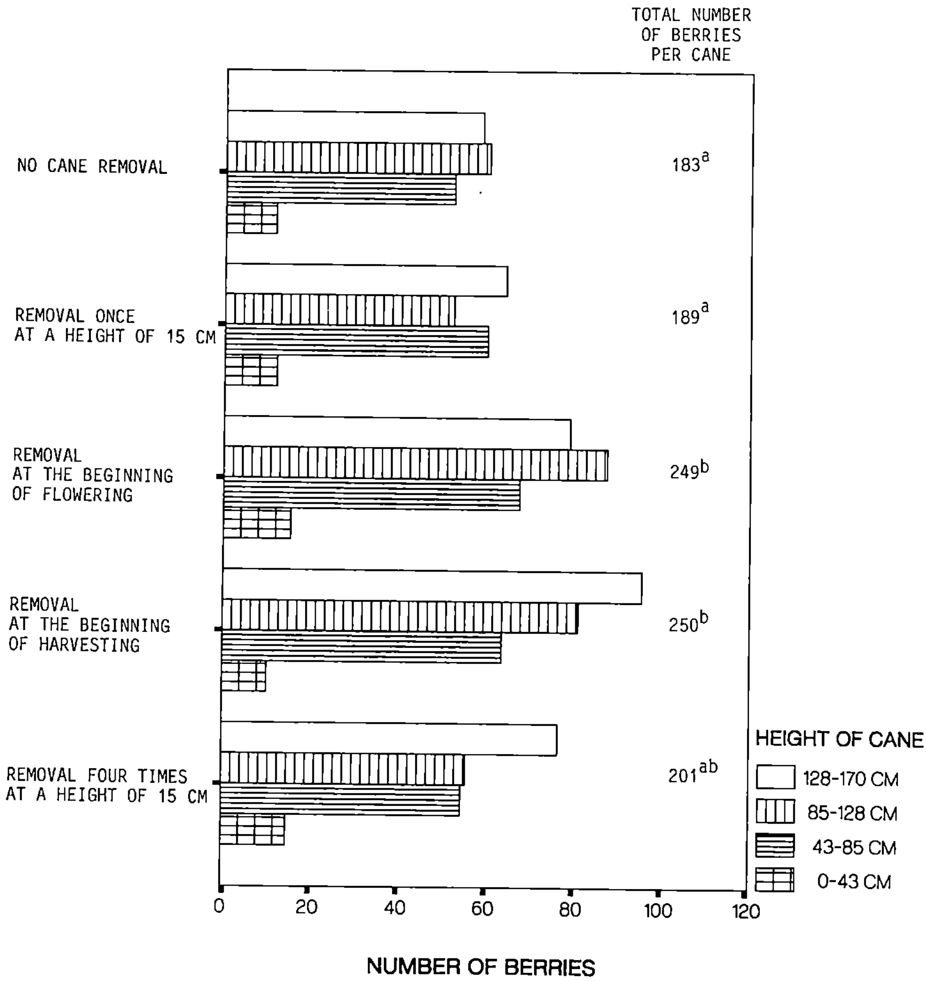

Fig. 2. Effect of vegetative cane removal on the berry number at different cane heights of red raspberry cv. Ottawa in 1986. Means with a different letter are significantly different ($P<0.05$).

Cane removal, $F = 5.62^{***}$

Height of fruiting cane within each removal treatment, $F = 17.51^{***}$

not affect the percentage of yield (Fig. 1), or the percentage of berry number (Fig. 2) distributed across the portions of the fruiting cane. So, when canes were removed at the beginning of flowering, 7 % of the yield was harvested at the height of 0—43 cm; 27 % at 43—85 cm; 35 % at 85—128 cm, and 31 % at the height of 128—170 cm. When vegetative canes were not removed at all, the corresponding percentages were 7 %, 29 %, 33 %, and 31 %.

When vegetative canes were removed at the beginning of flowering, the yield per fruiting lateral was 55 % higher than without cane removal (Table 4). The number of fruits per lateral increased by 36 % (Table 5). It seems that yield and berry number per fruiting lateral increased at the lowest part of fruiting cane when vegetative canes were removed at the beginning of flowering or four times during the season. According to the analysis of variance, there were no significant differences between the cane portions either in yield per lateral (P = 0.315) or in berry number per lateral (P = 0.139). This may be due to the presence of missing values, as in five canes there were no laterals at the height of 0—43 cm.

Table 4. Effect of vegetative cane removal on the yield per fruiting lateral at different cane heights of red raspberry cv. Ottawa in 1986. Means with a different letter within a column are significantly different ($P < 0.05$).

Removal treatment	Yield (g) per fruiting lateral Height of fruiting cane				Mean
	170—128 cm	128—85 cm	85—43 cm	43—0 cm	
No cane removal	30.4	36.7	36.2	20.8	31.0[a]
Removal once at a height of 15 cm	32.2	42.0	37.1	30.8	35.5[a]
Removal once at the beginning of flowering	42.0	53.3	50.6	46.7	48.2[b]
Removal once at the beginning of harvesting	34.2	43.7	41.6	24.7	36.1[ab]
Removal four times at a height of 15 cm	37.7	47.8	40.2	43.8	42.4[ab]
Mean	35.3	44.7	41.1	31.6	

Cane removal, F = 5.25**
Height of fruiting cane within each removal treatment, F = 1.18 ns

Table 5. Effect of vegetative cane removal on the berry number per fruiting lateral at different cane heights of red raspberry cv. Ottawa in 1986. Means with a different letter within a column are significantly different ($P < 0.05$).

Removal treatment	Number of berries per fruiting lateral Height of fruiting cane				Mean
	170—128 cm	128—85 cm	85—43 cm	43—0 cm	
No cane removal	13.0	15.2	14.4	8.5	12.8[a]
Removal once at a height of 15 cm	13.5	16.4	15.6	13.8	14.8[ab]
Removal once at the beginning of flowering	16.0	19.4	19.0	15.3	17.4[b]
Removal once at the beginning of harvesting	14.8	17.2	16.1	10.0	14.5[ab]
Removal four times at a height of 15 cm	14.2	16.9	15.8	15.3	15.6[ab]
Mean	14.3	17.0	16.2	12.1	

Cane removal, F = 3.69**
Height of fruiting cane within each removal treatment, F = 1.50 ns

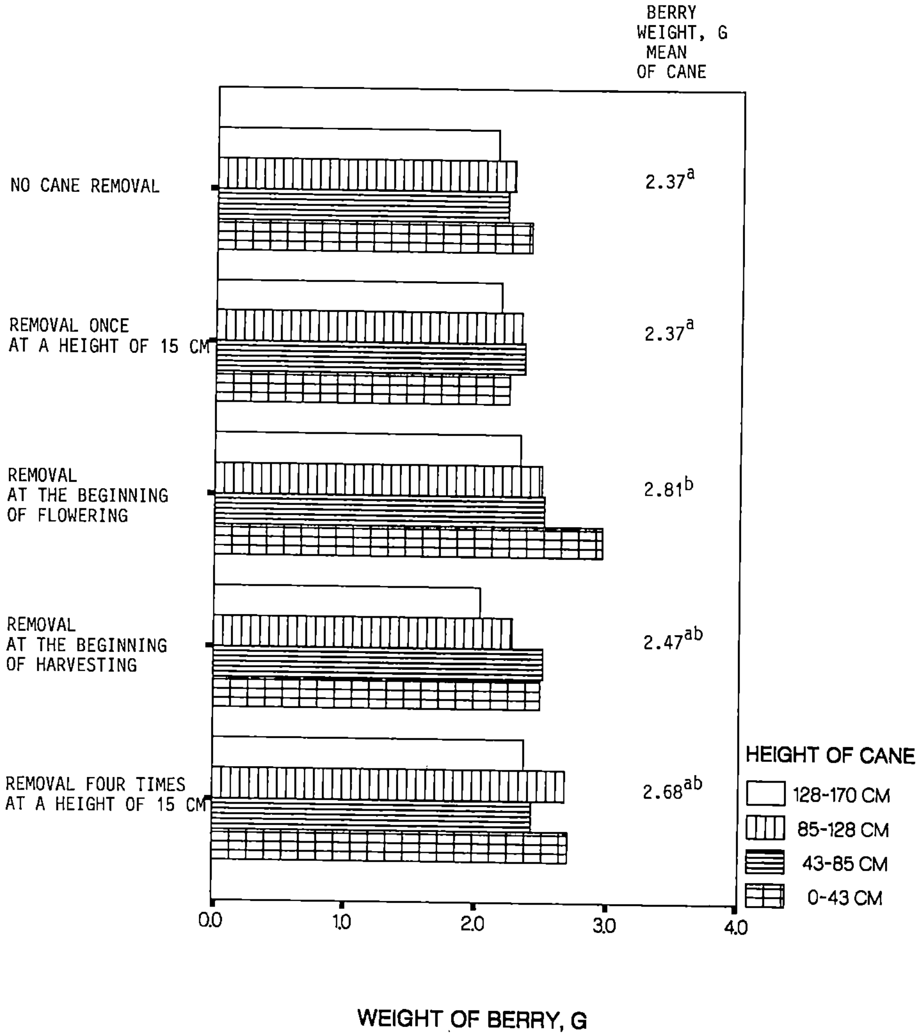

Fig. 3. Effect of vegetative cane removal on the berry weight at different cane heights of red raspberry cv. Ottawa in 1986. Means with a different letter are significantly different ($P<0.05$).

Cane removal, $F=3.88^{*}$

Height of fruiting cane within each removal treatment, $F=0.51$ ns

During the first week of harvesting, 41 % of the total yield was picked; after the second week 82 %, and after the third week 96 % (Fig. 4). When the vegetative canes were removed at the beginning of flowering, the yield of the first harvest week was 82 % higher than without cane removal. During the harvest season, the weight of berries decreased, with or without vegetative cane removal (Fig. 5).

The berries ripened first at the top of the cane. At the.height of 128—170 cm, 60 % of the yield ripened during the first week of harvesting; at 85—128 cm 46 %; at 43—85 cm 21 %, and in the lowest portion 10 % (Fig. 6).

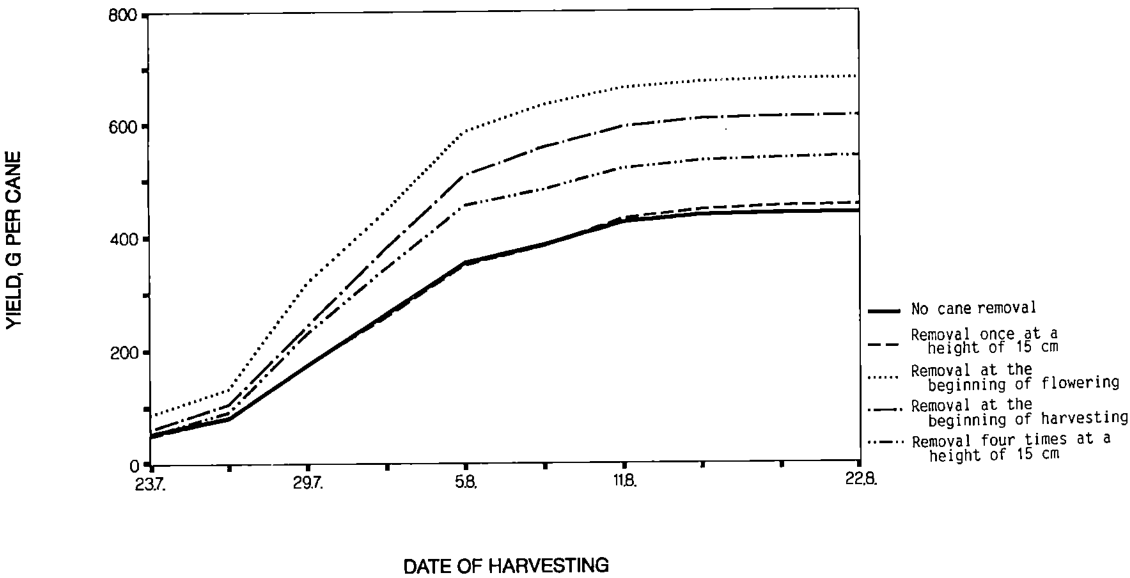

Fig. 4. Effect of vegetative cane removal on the yield ripening of red raspberry cv. Ottawa during 1986.

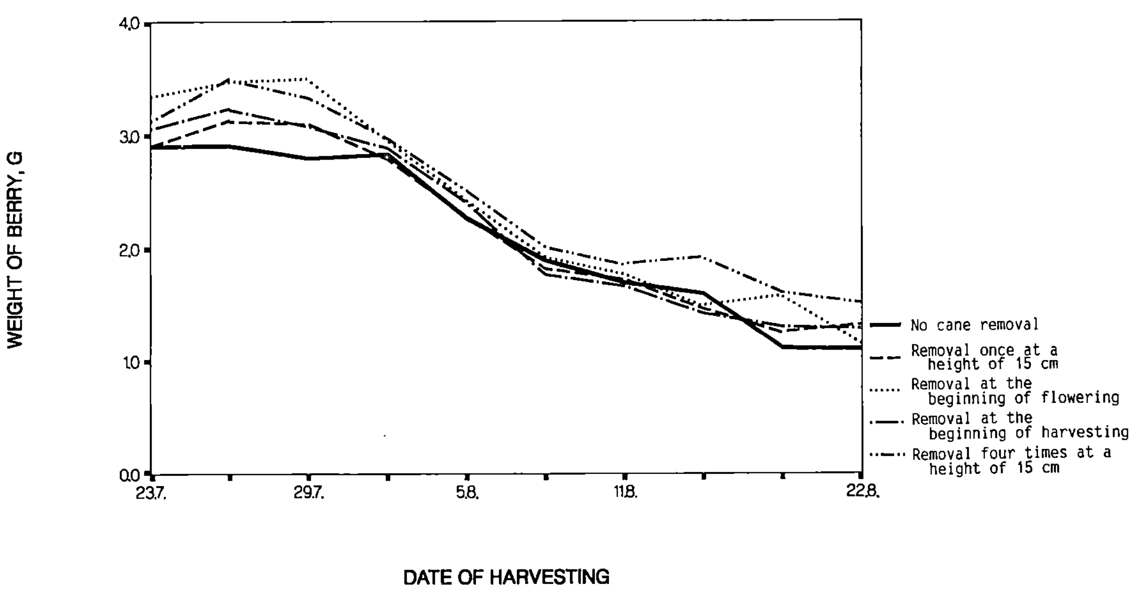

Fig. 5. Effect of vegetative cane removal on the berry weight of red raspberry cv. Ottawa in 1986.

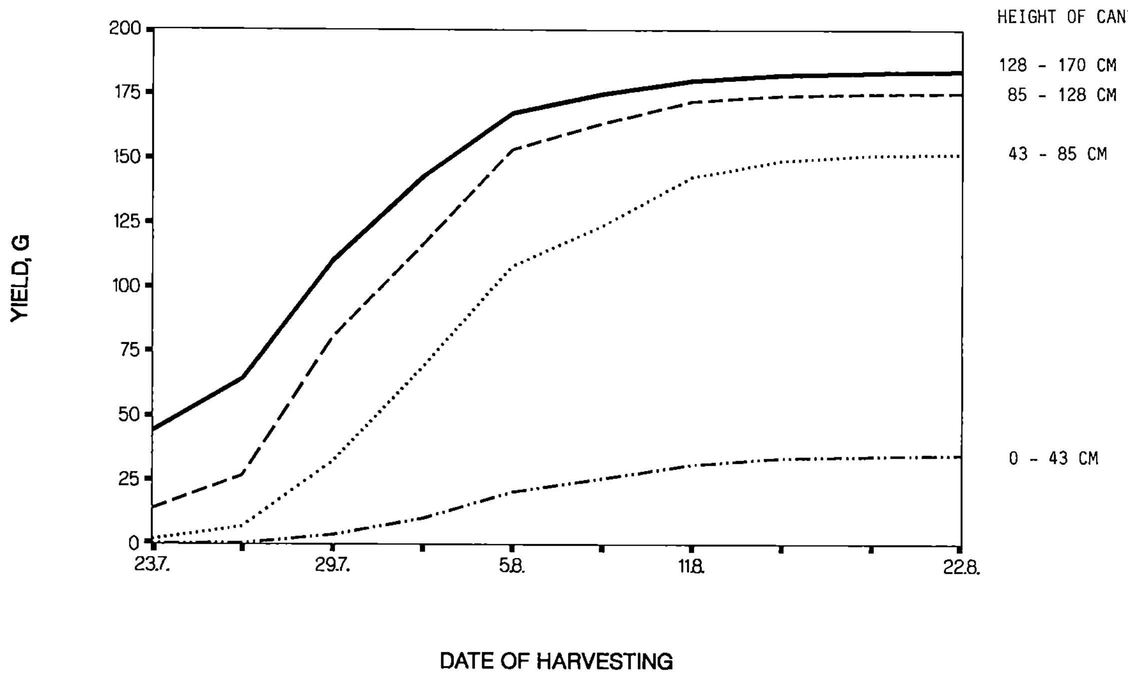

Fig. 6. Ripening of yield at different cane heights of red raspberry cv. Ottawa in 1986.

DISCUSSION

The effect of vegetative cane removal on the yield components of red raspberry cv. Ottawa

When the vegetative canes of red raspberry cv. Ottawa were removed at the beginning of flowering, the yield was higher than without cane removal. The yield increased as a result of the higher berry number per fruiting lateral and greater berries, but the number of fruiting laterals was not affected. In addition, berries ripened earleir when the canes had been removed. Several cultivars respond to the vegetative cane removal by increasing the number of fruits per lateral and the berry size (WAISTER et al. 1977, CRANDALL et al. 1980, WRIGHT and WAISTER 1982, LAWSON and WISEMAN 1983; BUSZARD 1986, FREEMAN et al. 1989).

According to WAISTER et al. (1977), any change in berry number must be a consequence of differences in the number of aborted flowers or flower initials, as flower initiation takes place in the autumn and winter (MATHERS 1952, WILLIAMS 1959), i.e., before cane removal treatments are started. Under conditions of conventional cane growth, many of the late developing and smaller blossom buds apparently fail to reach anthesis and set fruit (CRANDALL et al. 1980).

When the vegetative canes of cv. Ottawa were removed at the beginning of harvesting, the yield was 39 % higher, and the number of berries was 37 % greater than without removal. The yield per fruiting lateral and the size of berries were not affected. In this case, the high yield was, to some extent, due to the greater number of laterals in the canes before the experiment started.

The yield of cv. Ottawa was distributed across the portions of the fruiting cane largely to the same extent as the laterals at the beginning of harvesting. The berry size was not affected by the height of the cane. The upper half of the cane produced 66 % of fruiting laterals; 66 % of yield, and 66 % of berry number. Similar results were obtained by CRANDALL et al. (1974), and by ORKNEY and MARTIN (1980). The fruit number per lateral of cv. Ottawa was the highest in the middle portion of the cane. In the experiment of ORKNEY and MARTIN (1980), the reproductive vigour of laterals was quite consistent, regardless of the cane portion from which it came, but in many cultivars the vigour increases towards the top of the cane (CRANDALL et al. 1974, DALE and TOPHAM 1980, CRANDALL et al. 1980).

According to CRANDALL et al. (1980), cane removal has no effect on the number of berries on the upper laterals, but greatly increases the numbers on laterals of the middle and lower portions of the canes. When the canes of cv. Ottawa were removed at the beginning of flowering, the yield per lateral increased particularly in the lowest portion of the cane. This did not have any significant bearing on the total yield, however, as this portion provided only 7 % of the total yield. The increase in the quantity and size of berries on all the fruiting laterals was of greater importance.

Competition between fruiting and vegetative canes

WRIGHT and WAISTER (1982, 1984) concluded that competition between fruiting and vegetative canes for light was the major factor influencing yield production. In the present study, the competition for light was prevented by removing canes along the growing season at a height of 15 cm. It was, however, more beneficial for fruit production to remove canes at the beginning of flowering or at the beginning of harvesting. So, competition for light was not the major factor. CRANDALL et al. (1980) believed that cane removal increased yields by reducing the competition of rapidly growing vegetative canes also for storage compounds, photosynthates, water and nutrients, in addition to light, during the critical stages of blossom development.

According to CANNELL (1985) and WRIGHT (1989), developing flower initials are generally weak sinks of assimilates, and seeds and fleshy fruit parts are stronger sinks than shoot apices and leaves. So, when the canes of cv. Ottawa were removed at a height of 15 cm at the end of May, the replacement shoots were stronger sinks of carbohydrates than the flower initials. When the removal took place at the beginning of flowering or at the beginning of harvesting, the developing seeds and fruits were strong sinks, and the carbohydrates were allocated to fruit production.

WHITNEY (1982) demonstrated that vegetative canes first develop largely with the help of the carbohydrate root reserves. Once the functional primocane leaf biomass is developed the root system rapidly replenishes its store of reserve carbohydrates. According to WHITNEY'S (1982) theories, when the vegetative canes of cv. Ottawa were removed at a height of 15 cm, their photosynthates were not able to correct the resultant decrease in root reserves. The storage compounds had to be used once more to produce vegetative canes.

When the vegetative canes were removed at the beginning of flowering, the photosynthates of the canes had obviously already replenished the root storage compounds, and the replacement shoots used these reserves. The removal of canes reduced the competition for light, water and nutrients during the flowering and fruit ripening, and consequently the yield increased. When vegetative canes were removed several times during the course of the summer, competition with the fruiting cane for light, water and nutrients was minimized. The yield did not increase as much as expected, however, since producing a new crop of canes four times without replenishing the storage compounds put a strain on the root reserves and the fruiting cane.

Removing the canes once when they were 15 cm long, or four times during the growing season, did not increase the yield significantly, although such increases have previously been recorded in normal raspberry plantations (WAISTER et al. 1977, CRANDALL et al. (1980), LAWSON and WISEMAN 1983, FREEMAN et al. 1989), including cv. Ottawa (DALMAN 1991 a, 1991 b). In the present experiment, cane removal was studied in plants where there was only one fruiting cane with a whole bush of vegetative canes. The competition was studied in an extreme case, and the results indicate that, in addition to the carbohydrate root reserves, vegetative canes exploit the photosynthates of fruiting canes. Cane removal reduced the competition between the vegetative cane and the fruiting cane for light, water and nutrients, but when one fruiting cane's photosynthates were used to produce a whole bush of vegetative canes, the disadvantages of the method were as great as the advantages, and the yield did not increase.

In conclusion, the yield increase after the removal of vegetative canes showed that the removal reduced the competition between vegetative canes and fruiting canes for light, water, and mineral nutrients. The competition for assimilates and reserve carbohydrates increased, however, because after cane removal the raspberry plant always produces a new flush of vegetative canes.

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SELOSTUS

Kasvuversojen poiston vaikutus vadelman satoon verson eri osissa

PIRJO DALMAN

Maatalouden tutkimuskeskus

Useissa tutkimuksissa on osoitettu, että vadelman sato suurenee, jos kasvuversot poistetaan kasvukauden alkupuolella tai useita kertoja kesän kuluessa. Poisto vähentää kasvuversojen ja satoversojen välistä kilpailua, ja sato suurenee erityisesti verson keski- ja alaosassa. Tässä tutkimuksessa selvitettiin eri kehitysvaiheissa tehdyn versonpoiston vaikutuksia 'Ottawa'-lajikkeen satoon satoverson eri korkeuksilla. Kasvuversojen ja satoversojen välistä kilpailua tutkittiin kasvustossa, jossa ei ollut lainkaan satoversojen keskinäistä kilpailua, sillä 1,5 metrin koeruutuun jätettiin keväällä vain yksi satoverso.

Kenttäkokeessa vuonna 1986 tutkittiin käsittelemättömän lisäksi neljää kasvuversojen poistokäsittelyä: poisto kerran 15 cm:n pituisina (27. toukokuuta), poisto kukinnan alussa (13. kesäkuuta), poisto sadonkorjuun alussa (24. heinäkuuta) ja poisto neljä kertaa kesässä 15 cm:n pituisina (27. toukokuuta, 13. kesäkuuta, 8. heinäkuuta ja 24. heinäkuuta). Versot poistettiin käsin kitkien tai saksilla leikaten. Satoverso latvottiin keväällä 170 cm:n korkeudelta ja jaettiin merkkinauhoilla neljään yhtä pitkään osaan: 0—43 cm, 43—85 cm, 85—128 cm ja 128—170 cm.

Kun kasvuversot poistettiin kerran 15 cm:n pituisina, olivat niiden tilalle kehittyneet versot sadonkorjuun alkaessa ja kasvukauden lopulla noin 20 cm lyhyempiä kuin kasvukauden alusta asti kasvaneet versot. Kun versonpoisto tehtiin kukinnan alussa, olivat tilalle kehittyneet versot noin 50 cm lyhyepiä kuin normaalisti kehittyneet versot. Sadonkorjuun alussa tehdyn poiston jälkeen uudet versot kasvoivat talveen mennessä noin puolen metrin pituisiksi.

Sato oli suurin, kun kasvuversot poistettiin kukinnan alussa. Myös sadonkorjuun alussa tehty versonpoisto lisäsi satoa käsittelemättömään verrattuna. Versojen poisto kerran tai neljä kertaa 15 cm:n pituisina ei lisännyt satoa merkitsevästi, vaikka sato on suurentunut aiemmissa tutkimuksissa. Nyt versojen poistoa tutkittiin poikkeuksellisessa kasvustossa, sillä vain yksi satoverso kilpaili koko kasvin kasvuversojen kanssa.

Kukinnan alussa tehdyn versonpoiston jälkeen sato oli 55 % suurempi kuin ilman versojen poistoa. Marjojen lukumäärä oli 36 % ja marjakoko 19 % suurempi. Versonpoisto myös aikaisti sadon kypsymistä, sillä ensimmäisen viikon sato oli 82 % suurempi kuin ilman versojen poistoa. Versojen poisto ei vaikuttanut satoa tuottavien sivuversojen määrään. Sato suureni siksi, että marjamäärä sivuversoa kohden lisääntyi ja marjakoko suureni. Marjalukuun voitiin vaikuttaa kukinnan alussa tehdyllä käsittelyllä, vaikka vadelman kukka-aiheet erilaistuvat kukintaa edeltävänä syksynä.

'Ottawa'-lajikkeen sato jakautui satoverson eri osiin samassa suhteessa kuin sivuversot jakautuivat sadonkorjuun alkaessa. Marjat olivat samansuuruisia verson eri osissa. Verson ylemmässä puoliskossa sijaitsi 66 % sivuversoista, 66 % sadosta ja 66 % marjojen lukumäärästä. Kukinnan alussa tehdyn versonpoiston jälkeen sato suureni verson kaikissa sivuveroissa. Alaosan sivuversoissa sato suureni eniten, mutta verson alimpaan neljännekseen kehittyi niukasti sivuversoja. Alaosan sadonlisäyksellä oli vain vähän merkitystä kokonaissadon kannalta, sillä 7 % sadosta tuli satoverson alimmasta neljänneksestä.

Kasvuversojen ja satoversojen välinen kilpailu valosta, vedestä ja ravinteista estettiin lähes kokonaan, kun kasvuversot poistettiin neljä kertaa kesässä 15 cm:n pituisina. Yllättäen sato suureni kuitenkin enemmän, kun kasvuversot poistettiin kukinnan alussa tai vasta sadonkorjuun alussa. Sadon suureneminen osoittaa, että versojen poisto vähentäää kasvuversojen ja satoversojen välistä kilpailua valosta, vedestä ja ravinteista. Kilpailu yhteyttämistuotteista ja varastoravinnosta sen sijaan lisääntyy, sillä vadelma kasvattaa poistettujen kasvuversojen tilalle aina uuden versoston, jonka alkukehitys tapahtu pääosin varastohiilihydraattien avulla.

ANNALES AGRICULTURAE FENNIAE, VOL. 30: 477—483 (1991)

Seria HORTICULTURA N. 74 — Sarja PUUTARHAVILJELY n:o 74

THE EFFECT OF THE FIRST-FLUSH PRIMOCANE REMOVAL ON THE YIELD OF RED RASPBERRY HARVESTED BY THE JOONAS HARVESTER

PIRJO DALMAN

DALMAN, P. 1991. **The effect of the first-flush primocane removal on the yield of red raspberry harvested by the Joonas Harvester**. Ann. Agric. Fenn. 30: 477—483. (Agric. Res. Centre of Finland, South Savo Res. Sta., SF-50600 Mikkeli, Finland.)

Removal of the first-flush primocanes of red raspberry (*Rubus idaeus* L.) cvs. Ottawa and Muskoka was studied in machine harvest in 1986. The primocanes were removed mechanically when they reached a height of 15—20 cm. The crop was harvested by the prototype of the Joonas Raspberry Harvester the fruit-catching device of which consisted of a rubber tray system. Without primocane removal cv. Muskoka yielded 3.5 tons and cv. Ottawa 3.6 tons per hectare. Primocane removal increased the yield of cv. Muskoka by 31 %, but did not increase the yield of cv. Ottawa. The removal did not affect the amount of rejected material on the inspection belts. The fruit quality of cv. Muskoka was higher than that of cv. Ottawa.

Index words: red raspberry, cultivar, machine harvest, cane removal.

INTRODUCTION

Red raspberries are harvested by machine on commercial scale in the Pacific Northwest, where the most widely used harvester is the Littau, and the main cultivars are Willamette and Meeker. Primocane removal is a common cultivation practice; reduced vegetative growth at the time of harvest allows the harvester to work effectively, as the berry-catching plates press against the plants from both sides of the row (BARRITT 1976, MARTIN and LAWRENCE 1976, MARTIN 1985, SCHEER and GARREN 1987).

The need of primocane removal when the Joonas Raspberry Harvester is used has not been examined. Joonas (Fig. 1) is a straddle-type harvester that differs from the Littau harvester in that the berry-catching device consists of a rubber tray system (Fig. 2). In addition, Joonas has linens to abate the speed of dropping berries after the removal.

The objective of this study was to investigate the effects of the first-flush cane removal on the yield of cvs. Ottawa and Muskoka, the most widely grown cultivars of red raspberry in Finland, when harvested by the Joonas machine.

Figure 2. The fruit-catching device of Joonas consists of a rubber tray system.

Figure 1. The prototype of the Joonas Raspberry Harvester.

Figure 3. Red raspberry cultivars Ottawa (left) and Muskoka (right).

Figure 4. Harvested berries and fruit contaminants were collected into shallow plastic containers.

Photos: Ismo Ruutiainen

MATERIAL AND METHODS

The machine harvest trial was carried out in 1986 on a commercial farm in Kitee (62° 06′ N and 30° 08′ E). The harvesting of cvs. Ottawa and Muskoka (Fig. 3) with Joonas Harvester when the first flush of primocanes was removed was compared to harvesting without primocane removal. The first flush of primocanes was removed mechanically, pulling by hand, on June 3 when canes had reached a height of 15—20 cm. A randomized block design with two replicates was used. The plots of cv. Muskoka were 42 m, and those of cv. Ottawa 45 m long.

The planting dated from 1983; spacing was 3.5 m between rows, and 60 cm between plants. Canes were grown in hedge rows. Growth was vigorous as the canes attained a height of 2.5 m. In the autumn of 1985 the row width at the cane base was restricted to 20—30 cm; the cane number was 7 to 10 canes per metre. In the next spring the fruiting canes were topped to a height of 170 cm. The canes were supported between two wires which were fastened to the sides of wooden posts at a height of 110—150 cm. At the beginning of harvest the width of the row base was restricted to 40 cm, and vegetative canes were supported between two wires at about 60 cm above ground level. Fertilizer applications as well as pest and weed control were performed according to the recommendations of Agricultural Advisory Centres.

The crop yield was harvested by the prototype of the Joonas Raspberry Harvester. The first harvest took place on July 31 and the last one on August 15. On the farm, hand-picking started one week earlier, on July 25, and ended on August 26. Machine harvest took place on six occasions at intervals of two, three or four days. The crew consisted of an operator and four sorters beside two inspection belts. The harvested samples were collected into shallow plastic containers and weighed (Fig. 4).

From the inspection belts sorters removed by hand fruit contaminants which were weighed (Fig. 4). The material contained mostly raw berries, but some mouldy, crushed or soft berries, as well as fruits damaged by raspberry beetle (*Byturus tomentosus* Fabr.) were collected, too. The extraneous material which was lighter than the berry was removed by air-cleaning devices. Fruit firmness and the amount of crushed berries were observed during the harvest and about one hour later when the berries were weighed.

Damages caused by machine to fruiting and vegetative canes were observed during harvest and in autumn when canes were pruned. The aim was to examine the machine damage and the yield the next year, but because of severe winter injuries in 1987, the machine damage could not be assessed.

During the harvest period there was only one rainy day, on August 11, and the next day the plants were wet when the harvester operated. At the beginning of the harvest season the weather was sunny and warmer than normally.

RESULTS

The yield of cv. Ottawa harvested by the Joonas machine averaged 3 600 kg/ha, and the removal of the first-flush primocanes did not increase it (Table 1). The yield of cv. Muskoka was 3 500 kg/ha without cane removal, and 31 % greater when the primocanes were removed.

At the first harvest, Joonas collected 34 % of

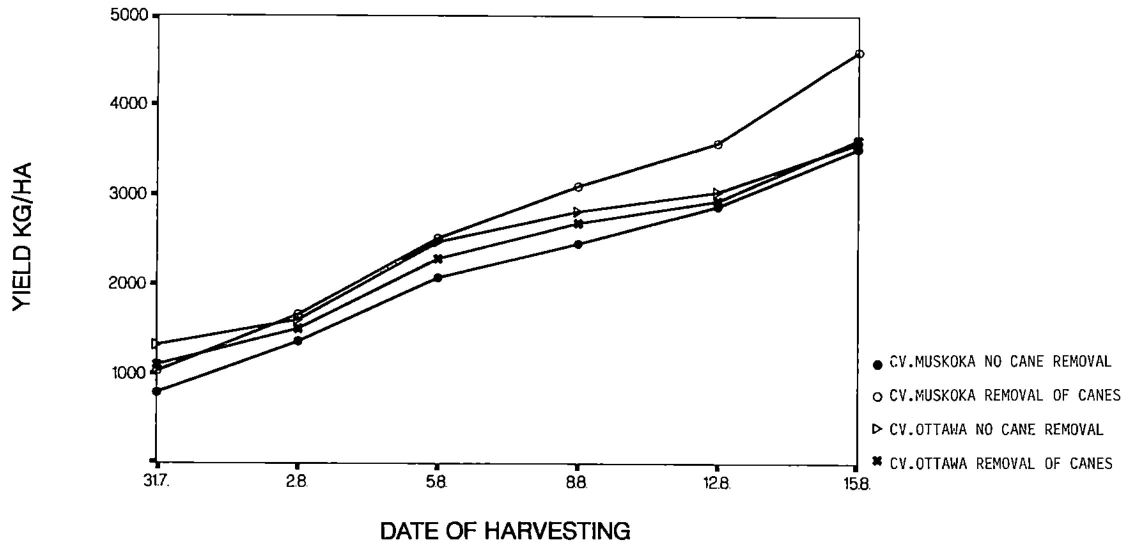

Figure 5. The effect of the first-flush primocane removal on the cumulative yield of red raspberry harvested by the Joonas machine in 1986.

the total yield of cv. Ottawa, and 22 % of the yield of cv. Muskoka (Fig. 5). Cane removal did not affect yield at the beginning of the season, but increased later the yield of cv. Muskoka.

The fruit quality of cv. Muskoka was higher than that of cv. Ottawa. There were less crushed and soft berries, and the quality remained high longer during the season. The amount of rejected material from the inspection belts was slightly smaller for cv. Muskoka than for cv. Ottawa (Table 2). Removal of the first-flush canes was not observed to affect fruit quality, or the amount of extraneous material on the inspection belts (Table 2).

When dropping into containers, the berries were usually whole and clean (Fig. 4), but about one hour later, the berries on the bottom of containers tended to be crushed and juicy. To-

Table 1. The effect of the first-flush primocane removal on the yield of red raspberry cvs. Ottawa and Muskoka harvested by the Joonas machine in 1986.

	Yield kg/hectare		
	Cv. Ottawa	Cv. Muskoka	Mean
Removal of canes			
Block one	3770	4660	4200
Block two	3460	4530	4000
Mean	3620	4600	4110
No cane removal			
Block one	3600	3580	3600
Block two	3540	3410	3500
Mean	3570	3500	3540

Table 2. The effect of the first-flush primocane removal on the amount of extraneous material collected from the inspection belts of the Joonas Raspberry Harvester in 1986.

	% of the total yield weight		
	Cv. Ottawa	Cv. Muskoka	Mean
Removal of canes			
Block one	15	14	15
Block two	14	12	13
Mean	15	13	14
No cane removal			
Block one	22	12	17
Block two	16	13	14
Mean	19	13	16

wards the end of the harvesting season the quality became lower as the amount of crushed and soft berries increased. In addition, lower quality was observed when the machine operated on a wet plantation.

The Joonas Harvester did not break fruiting laterals or leaf stalks. Shallow damages, barely detectable pressure marks on vegetative canes were caused by the shaking rods and rubber catching trays, as well as by the supporting wires. More serious damage with bruising cane surface was caused by the conveyor that collects the fruits from trays. However, deep wounds were only found when the row base was wider than 40 cm, or when the harvester was not properly driven. Cultivar and primocane removal did not affect the amount of damages.

DISCUSSION

Removal of the first-flush primocanes did not increase the yield of cv. Ottawa in machine harvest, and the yield increase of cv. Muskoka was equal to, or even less than that in hand harvesting (DALMAN 1991). The primocane removal did not improve the operation of the Joonas Harvester; the efficiency of fruit detaching and fruit catching did not increase.

According to BARRITT (1976) and MARTIN (1985), primocane removal allows the fruit-catching device to work more effectively. The device of the Littau and the BEI harvesters consists of spring-loaded overlapping plates, but Joonas has flexible rubber catching trays. In the Pacific Northwest the main cultivars Willamette and Meeker are more vigorous than cvs. Ottawa and Muskoka, and the need of vigour control in machine harvest is greater. In this trial, the row width at the cane base was carefully restricted by pruning and supporting, which also made the operation of the harvester easy.

According to DALMAN and RUUTIAINEN (1986), only a small amount of berries went to waste falling on the ground through the catching device of Joonas. The main problem was the narrow frame, the vegetation not being able to open inside the frame after shaking. When the machine passed the row, and the canes opened, lots of detached berries hiding among leaves fell on the ground. Compared to the prototype, the commercial model of Joonas has a wider and longer frame.

DAUGAARD and VANG-PETERSEN (1982) considered the berry firmness of cv. Ottawa superior to that of cv. Muskoka. However, cv. Muskoka has smaller berries, and the fully ripe fruits detach more easily than those of cv. Ottawa. Medium-size berries and easy detaching are good characteristics for mechanical harvesting (DAUGAARD and VANG-PETERSEN 1982). In the present study, fruit quality of cv. Muskoka was higher than that of cv. Ottawa. Primocane removal did not increase the yield at the beginning of the season when the fruit quality was best.

Primocane removal was not observed to affect fruit quality. According to SCHEER and GARREN (1987), if rain occurs, cane removal may decrease *Botrytis* fruit rot, as vegetative canes are shorter, and fruiting laterals dry faster. The harvesting season in 1986 was dry, and only a small amount of fruits was infested by rot. Warm and sunny weather made the machine operation easy, but when it is cooler, fruit quality is better. Harvesting at the lowest possible temperature would be advantageous for maintaining fruit quality during handling and storage (MARTIN and LAWRENCE 1976, MORRIS 1983, SCHEER and GARREN 1987).

Unfortunately, the effects of damages on the cane survival and on the yield in the following year could not be estimated. In Scotland, one of the main problems in mechanical harvesting is cane damages and diseases (RAMSAY et al. 1985). Yield reductions of up to 30 % have been recorded in plantations harvested mechanically in the previous year (CORMACK and WAISTER 1976). This loss was due mainly to infection of wounds on young canes by the cane blight fungus *Leptosphaeria coniothyrium* (Fckl.) Sacc. (WILLIAMSON and HARGREAVES 1978, HARGREAVES and WILLIAMSON 1978). In addition, WOODFORD (1976) observed that there were more larvae of the raspberry cane midge (*Resseliella theobaldi* (Barnes)) in primocanes damaged by the catch plates of a harvester than in primocanes from hand-picked rows.

WILLIAMSON and RAMSAY (1984) concluded that in the United Kingdom, or in other raspberry growing areas where conditions favour cane blight, the use of harvesters with overlapping metal fruit-catching plates is not advisable. When the Joonas Harvester was constructed, the damage problems were taken into account. ANDOR and KOLLANYI (1988) reported that less than 5 % of canes were damaged when Joonas was used in Hungary.

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SELOSTUS

Kasvuversojen poistokäsittelyn vaikutus vadelman satoon konekorjuussa

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Maatalouden tutkimuskeskus

Kasvuversojen poistokäsittely kuuluu yleisesti vadelman konekorjuuviljelmien viljelytekniikkaan Pohjois-Amerikan länsirannikolla. Poistettujen tilalle kehittyvä uusi versosto on sadonkorjuun aikaan hennompaa kuin kasvukauden alusta asti kasvanut versosto, joten marjojen irrotus ja talteenotto versorivin alaosassa tehostuu. Tässä tutkimuksessa selvitettiin kasvuversojen poistokäsittelyn vaikutusta 'Ottawa'- ja 'Muskoka'-lajikkeiden satoon, kun sato korjattiin suomalaisella Joonas vadelmankorjuukoneella. Amerikkalaisissa korjuukoneissa marjojen talteenotto tapahtuu versoja vasten painuvilla jousitetuilla levyillä, kun taas Joonaksessa marjat kootaan kumireunaisilla, jousitetuilla ja pyörivillä lautasilla.

Koe järjestettiin kesällä 1986 vadelmaviljelmällä Kiteellä. Koeruudut olivat yli 40 metriä pitkiä. Ensimmäisinä kehittyneet kasvuversot poistettiin riveistä käsin kitkien kesäkuun 3. päivänä, jolloin versot olivat 15—20 cm pitkiä. Poisto tehtiin käsin, koska Amerikassa käytetty dinosebi on kielletty Suomessa ja esimerkiksi dikvatti ja parakvatti eivät sovellu versojen poistoon. Käsittelemättömissä ruuduissa kasvuversot saivat kehittyä normaalisti. Viljelmä oli istutettu v. 1983, riviväli oli 3,5 m ja taimietäisyys istutettaessa 60 cm. Syksyllä 1985 versorivin tyvi kavennettiin 30 cm:iin ja rivimetrille jätettiin 7—10 versoa. Versosto oli noin 2,5 m korkeaa, ja keväällä 1986 versot latvottiin 170 cm:n korkeudelta. Satoversot tuettiin lankaparilla, joka kiinnitettiin 110—150 cm:n korkeudelle tukipaalun sivuille. Sadonkorjuun alussa versorivin tyvi kavennettiin leikkaamalla noin 40 cm:iin ja kasvuversot tuettiin paalauslangoilla 60 cm:n korkeudelta.

Sato korjattiin Joonas vadelmankorjuukoneen prototyypillä, jota testattiin Suomessa ensimmäistä kertaa. Ensimmäinen korjuuajo oli 31. heinäkuuta ja viimeinen 15. elokuuta. Käsinkorjuu viljelmällä alkoi viikkoa aikaisemmin ja päättyi 26. elokuuta. Satoa korjattiin koneella yhteensä kuusi kertaa kahden, kolmen tai neljän päivän välein. Kone ajoi rivillä aina samaan suuntaan. Miehistöön kuului kuljettajan lisäksi yhteensä neljä lajittelijaa molemmin puolin konetta olevilla lajitteluhihnoilla. Sato korjattiin mataliin muovilaatikoihin.

Lajitteluhihnoilta otettiin talteen myös myyntiin kelpaamaton sato, joka oli pääosin raakoja, kantoineen irronneita marjoja, mutta myös homeisia, pehmeitä ja vattumadon vioittamia marjoja oli joukossa. Lehdet ja muut kevyet roskat kone puhdisti ennen lajitteluhihnoille tuloa. Marjojen ulkoista laatua tarkkailtiin silmämääräisesti korjuun aikana ja noin tunnin kuluttua punnituksen yhteydessä. Korjuu tapahtui pääosin poutasäässä, sillä korjuukaudelle sattui vain yksi sadepäivä 11. elokuuta. Satokauden alkupuoli oli poikkeuksellisen lämmin, mikä nopeutti marjojen pehmenemistä poiminnan jälkeen.

Korjuukoneen vioituksia sato- ja kasvuversoille tarkkailtiin korjuun aikana ja syksyllä leikkauksen yhteydessä. Tavoitteena oli tutkia tarkasti koneen aiheuttamien vioitusten vaikutusta satoon seuraavana vuonna. Talvi 1986/1987 aiheutti kuitenkin viljelmällä myös käsinpoiminta-alueilla niin pahat talvivauriot, ettei konevioitusta voitu tutkia.

'Muskoka'-lajikkeen sato oli ilman kasvuversojen poistokäsittelyä 3,5 tonnia hehtaarilta ja versonpoisto lisäsi satoa 31 %. 'Ottawa'-lajikkeen sato oli 3,6 tonnia eikä poistokäsittely suurentanut sitä. 'Muskoka'-lajikkeen sadonlisäys oli samaa luokkaa tai hieman pienempi kuin käsinpoimintakokeissa, joten ilmeisesti kasvuversojen poistokäsittely ei ratkaisevasti tehostanut Joonas-korjuukoneen toimintaa.

Poistokäsittely ei vaikuttanut marjan ulkoiseen laatuun. 'Muskoka'-lajikkeen laatu oli parempi kuin 'Ottawan', sillä marjat olivat ehjempiä ja kiinteämpiä, ja laatu pysyi hyvänä myös loppusadossa. Versonpoisto ei vaikuttanut myöskään versojen vioittumiseen. Korjuukone ei katkonut satoa antavia sivuversoja eikä lehtiruoteja. Täristyssauvat ja talteenottolautaset samoin kuin tukilangat aiheuttivat pinnallisia hankaumia kasvuversoihin. Versoihin tuli syvempiä ruhjeita, jos rivin tyvi oli yli 40 cm leveä tai konetta ei ohjattu huolellisesti. Ne aiheutti kuljetin, jolle marjat putoavat talteenottolautasilta.

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EXPERIMENTS ON CHEMICAL AND CULTURAL CONTROL OF THE RASPBERRY CANE MIDGE (*RESSELIELLA THEOBALDI*) AND MIDGE BLIGHT

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The effects of cultural and chemical control measures on the number of raspberry cane midge larvae and fungal lesions in first-year canes, the wilting of second-year canes caused by midge blight and the yield of the red raspberry cv. Ottawa were studied in 1980—82. Azinphos-methyl, trichlorfon and tolylfluanid did not reduce midge blight incidence. When the second-year cane density was reduced from 10—12 canes/m to 5—6 canes/m and first-year canes were thinned respectively, the yield decreased from 52 kg/100 m^2 to 25 kg/100 m^2 but midge blight was not reduced. The mechanical removal of young canes at the height of 10—20 cm reduced the incidence of midge blight significantly. When the first and the second flush of young canes were removed the effect on cane midge larvae was better than after one removal but the growth of replacement canes was so weakened that yield did not increase.

Index words: red raspberry, *Resseliella theobaldi*, midge blight, chemical control, cultural control, cane density, young cane removal, azinphos-methyl, trichlorfon, tolylfluanid.

INTRODUCTION

The raspberry cane midge, *Resseliella theobaldi* (Barnes), lays eggs in the splits which develop in the bottom 40 cm of first-year red raspberry canes (PITCHER 1952). The larvae feed between the outer cortex and the periderm and degrade cell wall components (SEEMÜLLER and GRÜNWALD 1980). This damage is of little direct importance, but when the feeding sites are invaded by pathogenic fungi, lesions which block part of the vascular cylinder may develop.

The name midge blight describes the death, bud failure and lateral wilt of fruiting canes which follow midge injury to first-year canes. In the first year the symptoms are discrete, lobate, sunken areas concentrated towards the base of the cane (PITCHER and WEBB 1952). According to WILLIAMSON and HARGREAVES (1979a), the irregular patch lesions caused by midge blight can best be seen by scraping the cane in winter to remove all of the rind and cork. The principal fungal species from the larval feeding areas have been isolated (PITCHER and WEBB 1952, NIJVELDT et al. 1963, WILLIAMSON and HARGREAVES 1979b, SEEMÜLLER and GRÜNWALD 1980, RUOKOLA 1982).

Midge blight has been prevented more succesfully by controlling the cane midge than by application of fungicides. However, the cultural measures which are employed to control fungal cane diseases are recommended to be applied against midge blight. These include the thinning of canes, which promotes an open type of growth (NIJVELDT et al. 1963, SEEMÜLLER and KRCZAL 1980). Growers are currently advised to control cane midge by avoiding cultivation of susceptible varieties; by biennial cropping; by the removal of the first flush of young canes or by application of insecticides (SEEMÜLLER and KRCZAL 1980, GORDON and WILLIAMSON 1984). Removal of the first canes at the height of 10—20 cm can be done either by cutting or spraying with the desiccant herbicide dinoseb in oil. Replacement canes growing after the removal thus avoid serious midge infestation because their splits develop late (NIJVELDT et al. 1963, SEEMÜLLER 1976, WILLIAMSON et al. 1979).

Insecticidal control involves spraying before harvesting, to kill first-generation midges and eggs, and after harvest, to control the third generation. Direct control of the most damaging second generation is not allowed because emergence coincides with harvest. The timing of spraying is difficult because the emergence period varies considerably from year to year and from site to site, and it is not easy to observe adult midges or eggs in the field. It is more simple to spray when a certain level of natural splitting has been reached. In England, growers can contact advisers who operate a warning system in some midgeprone areas (GUNN and FOSTER 1978, WOODFORD et al. 1979, GORDON and WILLIAMSON 1984). Chlorpyrifos, gamma-HCH, fenitrothion, dimethoate or parathion, applied at high volume to the basal part of the cane and reapplied once or twice at 10—14 day intervals, should provide adequate control (WOODFORD et al. 1979, SEEMÜLLER and KRCZAL 1980, GORDON and WILLIAMSON 1984).

The importance of midge blight and the susceptibility of the most widely cultivated varieties Ottawa and Muskoka in Finland have been discussed by RUOKOLA (1982) and DALMAN (1986). The aim of this preliminary trial was to experiment with cultural and chemical treatments to control cane midge and midge blight in the susceptible variety Ottawa.

MATERIAL AND METHODS

The control trial was carried out in 1980—82 at the South Savo Research Station where the severe cane midge infestation of a five-year-old raspberry plantation of cv. Ottawa was observed in autumn 1979. The thinning of canes and tolylfluanid were applied to decrease fungal cane diseases, and the removal of young canes, azinphos-methyl and trichlorfon were employed against cane midge. The split plot design with four replicates was used, the cane densities being whole-unit treatments. Each sub-unit plot was 3 m long with 2,5 m intervals between the rows.

Eighteen first-year canes/meter were left in the high cane density plots and nine canes/meter in the low cane density plots at the end of June. In September the first-year cane densities were sixteen and eight/meter, respectively. The aim was to leave twelve second-year canes/meter in the high density plots and six/meter in the low density plots at the start of growing season. However, the canes died frequently during the winter, so that the number of living second-year canes was as follows in the middle of May:

	low cane density	high cane density
1980	5,9 canes/meter	10,2 canes/meter
1981	4,5 —"—	9,4 —"—
1982	5,6 —"—	11,4 —"—

Tolylfluanid at 0,125 % active ingredient (as Euparen M) was sprayed when first-year canes were 5—10 cm high at the end of May and again two weeks later.

The removal of young canes was done mechanically by hand cutting when the canes were 10—20 cm high. In 1980 the first flush and the second flush of canes were removed at the beginning and in mid-June. In 1981 and 1982 the first flush of canes was removed only.

The artificial splits in first-year canes were used, as by STENSETH (1977) and GUNN and FOSTER (1978), to determine the beginning of the oviposition of the cane midge in early summer 1980. The method was not useful because the previous year's splits in second-year canes were preferred by females to artificial splits. Therefore, about ten second-year canes and ten first-year canes were examined weekly until eggs or larvae were found in 1981 and 1982. Trichlorfon at 0,16 % a. i. (as Dipterex) and azinphos-methyl at 0,05 % a. i. (as Gusation) were sprayed at the basal 80 cm of the canes on June 26th, 1980 and on June 29th, 1981, when the first eggs and larvae were found, and again after harvest on August 28th, 1980 and September 3rd, 1981, when there were numerous larvae in the canes. Raspberry flowered in late June. In 1982 insecticides were not applied against the midge because the first eggs were not found until July 6th. The whole trial was sprayed with azinphos-methyl to control the raspberry beetle (*Byturus tomentosus*) every year at the beginning of June and just before the onset of flowering in the middle of June.

Three first-year canes/plot, totalling 120 canes yearly, were sampled systematically after harvesting but before the application of trichlorfon and azinphos-methyl. The basal parts of the canes, 0—30 cm, were examined to estimate the incidence of larvae and fungal lesions. At this time third-instar larvae were abundant on the canes and fungal lesions were easy to asses before cane maturation. The number of all fungal lesions on the outer cortex was estimated. The area of skin covered by lesions in the scoring classes 1, 2, 3, 4 and 5 corresponded approximately to: 0—2,5; 2,5—10; 10—20; 20—40 and >40 %, respectively. The number of midge larvae under the outer cortex was estimated on a scale of 0—3, where 0 = no larvae, 1 = one to three larvae, 2 = four to ten larvae and 3 = more than ten larvae per cane. The dead, wilted second-year canes were counted at the start of harvesting to asses midge blight. Berries were picked twice a week.

Fungal species in the first-year canes were investigated at the Department of Plant Pathology of the University of Helsinki in autumn 1980 and 1981. These results have been published by RUOKOLA (1982).

Statistical comparison of the incidence of larvae and fungal lesions was not possible. The significance of other differences between the treatments was tested with analysis of variance. Pearson correlation coefficients were used.

RESULTS

The incidence of cane midge larvae in first-year raspberry canes in autumn 1981 was almost as frequent as that in 1980 (Tables 1 and 2). In high cane density there were less canes attacked by larvae than in low cane density, and in 1980 the number of larvae was also lower in high cane density. The removal of young canes reduced the number of larvae clearly. In 1980 canes were removed twice and the effect was better than that after one removal in 1981. Trichlorfon and azinphos-methyl tended to increase the incidence of larvae compared to untreated canes.

The incidence of fungal lesions in first-year canes was much the same in autumn 1981 as that in 1980, and it was not affected by cane density (Tables 3 and 4). Fungal lesions were decreased by the removal of young canes. After two removals there were less lesions than after one removal. Tolylfluanid tended to reduce the number of lesions. In 1980—81 there was a significant positive correlation, $r = 0,52$ ($P < 0,001$, $n = 240$), between the numbers of midge larvae and fungal lesions on first-year canes.

Thirty-five percent of second-year canes were destroyed by midge blight before har-

Table 1. Effect of cultural and chemical control on the number of cane midge larvae in first-year raspberry canes in autumn 1980 and 1981. Larvae on the scale 0—3, with 0 = no larvae, 1 = one to three larvae, 2 = four to ten larvae and 3 = more than ten larvae.

	Larvae (0—3)				
	Low cane density		High cane density		
Treatment	1980	1981	1980	1981	Mean
Untreated	1,7	1,1	1,0	1,1	1,2
Young canes removed	0,3	0,5	0,2	0,7	0,4
Trichlorfon	2,3	1,5	1,7	1,0	1,6
Azinphos-methyl	1,6	1,3	1,4	1,4	1,4
Azinphos-methyl and tolylfluanid	2,2	1,4	1,7	1,7	1,7
Mean	1,6	1,1	1,2	1,2	

Table 2. Effect of cultural and chemical control on the incidence of cane midge larvae in first-year raspberry canes in autumn 1980 and 1981. % of canes examined.

	Canes attacked (%)				
	Low cane density		High cane density		
Treatment	1980	1981	1980	1981	Mean
Untreated	83	84	59	75	75
Young canes removed	17	50	8	50	31
Trichlorfon	92	100	75	67	84
Azinphos-methyl	75	100	75	84	84
Azinphos-methyl and tolylfluanid	83	84	84	100	88
Mean	70	84	60	75	

Table 3. Effect of cultural and chemical control on the number of fungal lesions on first-year raspberry canes in autumn 1980 and 1981. Lesions on the scale 0—5, classes 1, 2, 3, 4 and 5 correspond to 0—2,5, 2,5—10, 10—20, 20—40 and >40 % of the stem area, respectively.

	Fungal lesions (0—5)				
	Low cane density		High cane density		
Treatment	1980	1981	1980	1981	Mean
Untreated	2,8	3,0	2,9	3,2	3,0
Young canes removed	0,9	1,5	0,9	1,5	1,2
Trichlorfon	4,2	3,0	3,2	2,3	3,2
Azinphos-methyl	3,0	2,9	2,7	2,8	2,8
Azinphos-methyl and tolylfluanid	2,9	2,4	2,4	2,9	2,6
Mean	2,8	2,6	2,4	2,6	

Table 4. Effect of cultural and chemical control on the incidence of fungal lesions on first-year raspberry canes in autumn 1980 and 1981. % of canes examined.

	Canes attacked (%)				
	Low cane density		High cane density		
Treatment	1980	1981	1980	1981	Mean
Untreated	100	100	100	100	100
Young canes removed	67	100	84	92	86
Trichlorfon	100	100	100	92	98
Azinphos-methyl	100	100	100	100	100
Azinphos-methyl and tolylfluanid	92	92	100	100	96
Mean	92	98	97	97	

vesting in 1981 and 26 % in 1982 (Table 5). Cane density did not affect the wilting of canes significantly (P > 0,05). Removal of young canes decreased cane death significantly in low cane density in 1981 (P < 0,05) and in both cane densities in 1982 (P<0,05). Twenty-three percent of the second-year canes were destroyed by midge blight in 1981 after two cane removals in 1980, and 10 % in 1982 after one removal in 1981. Pesticide treatments did not reduce the incidence of midge blight; in low cane density they tended to increase it.

The mean yield was 45 kg/100 m^2 in 1981 and 32 kg/100 m^2 in 1982 (Table 6). The yield was affected by cane density significantly in both years (P < 0,01). For 1981—82 the average yield in high cane density was 52 kg/100 m^2 which is twice that in low cane density, 25 kg/100 m^2. The removal of young canes and the pesticide treatments did not affect the yield significantly (P > 0,05). The yield and the number of canes at the start of harvesting were correlated positively, r = 0,68 (P < 0,001, n = 77).

After the removal of young canes the replacement canes grew shorter than the canes grown normally from the beginning of season, especially after two removals in 1980 (Table 7).

Table 5. Effect of cultural and chemical control on the infestation of second-year raspberry canes by midge blight. Dead canes before harvesting in 1981 and 1982.

	Dead canes (%)				
	Low cane density		High cane density		
Treatment	1981	1982	1981	1982	Mean
Untreated	29	27	45	22	31
Young canes removed	14	9	32	11	17
Trichlorfon	42	36	37	23	35
Azinphos-methyl	45	37	34	26	36
Azinphos-methyl and tolylfluanid	40	38	32	26	34
Mean	33	30	36	21	

Component of variation	in 1981	in 1982
between cane densities	F = 0,35 ns	F = 2,53 ns
between control treatments	F = 2,66 ns	F = 3,99 x
interaction	F = 4,86 x	F = 0,23 ns

Table 6. Effect of the cultural and chemical control of raspberry cane midge and midge blight on the saleable yield in 1981 and 1982.

	Yield (kg/100 m^2)				
	Low cane density		High cane density		
Treatment	1981	1982	1981	1982	Mean
Untreated	26	25	53	42	37
Young canes removed	32	25	58	45	40
Trichlorfon	25	22	68	37	38
Azinphos-methyl	22	25	63	40	38
Azinphos-methyl and tolylfluanid	28	17	72	37	39
Mean	26	23	63	40	

Component of variation	in 1981	in 1982
between cane densities	F = 39,44 xx	F = 60,79 xx
between control treatments	F = 2,01 ns	F = 0,59 ns
interaction	F = 2,45 ns	F = 0,11 ns

Table 7. Effect of the cultural and chemical control of raspberry cane midge and midge blight on the first-year cane height in autumn 1980 and 1981.

	Cane height (cm)				
	Low cane density		High cane density		
Treatment	1980	1981	1980	1981	Mean
Untreated	175	170	185	180	180
Young canes removed	125	145	125	165	140
Trichlorfon	185	165	185	180	180
Azinphos-methyl	185	170	185	180	180
Azinphos-methyl and tolylfluanid	180	170	185	185	180
Mean	170	165	175	180	

DISCUSSION

The life cycle of the raspberry cane midge has not been investigated in Finland but according to the observations made during the control trial two generations occurred in 1980 and 1981. Larvae were first found in the last week of June, so the emergence of first-generation midges had obviously begun during the second week of June. The second-generation adults had emerged at about the start of harvesting at the end of July and during harvest as there were third-instar larvae in the canes after harvesting. The first natural splits in the first-year canes of cv. Ottawa can be observed in late June but larvae may be found in the previous year's splits of second-year canes as well (DALMAN 1986).

The correlation between the midge larvae and fungal lesions in the first-year canes of cv. Ottawa has also been observed earlier (DALMAN 1986). Cv. Ottawa is not susceptible to spur blight (*Didymella applanata*) (RUOKOLA 1982) but midge larvae can cause severe fungal infestation. The symptoms of midge blight in first-year canes described by PITCHER and WEBB (1952) can be used to asses the extent of infested plantations of cv. Ottawa in late summer.

The number of the most damaging second-generation larvae tended to increase when azinphos-methyl and trichlorfon were applied against the first generation. This might have resulted from the damage caused by spraying to the natural enemies of the midge (BOLDYREV 1971). Applications of azinphos-methyl against the raspberry beetle had no affect on the cane midge, although they were obviously performed during the emergence of the first midges. On the other hand, spraying against the cane midge might have increased the 1981 yield because insecticides do reduce the damage caused by the raspberry beetle. Tolylfluanid tended to reduce fungal lesions estimated on the cane rind, but the wilting of second-year canes was not affected by the treatment. Fungicides do not control the fungi penetrating into the cane vascular cylinder from larval feeding areas (NIJVELDT et al. 1963, SEEMÜLLER 1976, GORDON and WILLIAMSON 1984).

Fenitrothion is the most interesting of the insecticides recommended against the cane midge elsewhere (STENSETH 1977, WOODFORD et al. 1979, SEEMÜLLER and KRCZAL 1980, GORDON and WILLIAMSON 1984). The application of fenitrothion against the raspberry beetle is permitted in Finland but that of gamma-HCH, diazinon and chlorpyrifos is prohibited. Dimethoate and parathion were applied against the beetle at the South Savo Research Station prior to 1980 yet the cane midge still invaded the raspberries. In addition to the testing of insecticides, both the timing of spraying in early summer and autumn, as well as the volume of spray required should be investigated.

The thinning of canes recommended by NIJVELDT et al. (1963) did not decrease fungal cane diseases when the cane midge occurred. On the contrary, thinning may increase fungal lesions because there are more larvae/cane in lower cane density as reported by MASON (1981). The effect of cane number on yield has been reported in many papers but only MASON (1981) has discussed the results in relation to midge blight incidence. Cv. Ottawa produces canes sparingly and in the trial it was difficult to obtain more than ten fruiting canes per meter. Therefore, whenever a plantation is infested by the cane midge, all the canes long enough to be supported by wires should be allowed to grow.

The removal of young canes resulted in good control over midge larvae, cane diseases and midge blight, although reinfestation by midge from neighbouring rows reduced efficiency. Following two removals the control of larvae was better than after one removal but the control of midge blight worsened. Cane growth was excessively weakened by two removals and weak canes were destroyed by midge blight. Two removals of young canes were performed in the first year of the trial and because of weakened growth the yield was not increased although the control of midge blight was good. Removal is recommended for vigorous cultivars only (NIJVELDT et al. 1963, SEEMÜLLER 1976, WILLIAMSON et al. 1979). Cv. Ottawa is not classified as a vigorous variety, but for a plantation infested heavily by midge blight removal can be done in two years. Young canes must be removed only once when they are 15—20 cm high. Removal has other advantages, too, because the competition between first-year canes and fruiting canes is reduced. Moreover, yield and berry size increase and access to the fruit at harvest as well as overall health status improve (WILLIAMSON et al. 1979). Removal is economical only when done chemically, but application of dinoseb onto raspberry is prohibited in Finland.

In addition to the removal of young canes the control of midge blight is possible in Finland by cultivating cv. Muskoka which is less susceptible to the cane midge than is cv. Ottawa and equally winterhardy (DALMAN 1986).

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SELOSTUS

Vatunvarsisääsken ja midge blight -taudin torjunta

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Maatalouden tutkimuskeskus

Vatunvarsisääski munii vadelman versojen alaosiin kuoren luonnollisiin halkeamiin. Toukat elävät versoissa kuoren alla ja koteloituvat maahan. Kesässä kehittyy yleensä kaksi sukupolvea. Eniten vahinkoa aiheuttaa toinen sukupolvi, joka munii versoihin sadonkorjuun aikaan. Toukat imevät ravintoa ensimmäisen vuoden versoista mutta eivät juuri haittaa vadelman kasvua. Varsinaisen tuhon aiheuttavat toukkien syöntialueelle iskeytyvät sienet, jotka tunkeutuvat versojen keskustaan. Seuraavana vuonna versojen kasvu on hidasta, silmuja ja sivuversoja kuihtuu ja pahoin saastuneet versot kuolevat ennen kuin niistä saadaan satoa. Taudin nimi on englanniksi midge blight. Ensimmäisen vuoden versoihin tauti aiheuttaa lähes samanlaisia laikkuja kuin versotaudit spur blight ja cane blight.

Midge blight -taudin torjuntaan ei ole tehokkaita fungisideja, joten torjunta suunnataan varsisääskeä vastaan. Pääasialliset torjuntakeinot ovat lajikevalinta, vuorovuosiviljely, uusien versojen poisto ja ruiskutukset sääsken ensimmäistä sukupolvea vastaan. Keväällä ensimmäisinä kehittyvät uudet versot poistetaan kokonaan 10—20 cm:n pituisina, jolloin tilalle kasvavien versojen halkeilu viivästyy eikä ensimmäisen sukupolven naaraille ole munintapaikkoja. Myös lajikkeiden kestävyys riippuu kuoren halkeilun ajankohdasta ja määrästä. Torjuntaruiskutukset aloitetaan munien löydyttyä tai versojen halkeilun alettua. Yleensä ruiskutetaan 2—3 kertaa parin viikon välein.

Vatunvarsisääsken ja midge blight -taudin torjuntamahdollisuuksia sekä sääsken elintapoja torjunnan ajoittamiseksi selvitettiin vuosina 1980—82 Etelä-Savon tutkimusasemalla, missä 5 vuotta vanha 'Ottawa'-kasvusto oli pahoin saastunut midge blight -tautiin. Varsisääskeä yritettiin torjua poistamalla uudet versot tai ruiskuttamalla atsinfossimetyyliä (Gusation) ja triklorfonia (Dipterex) ensimmäisten toukkien löydyttyä ja sadonkorjuun jälkeen. Sienitautien torjumiseksi versot ruiskutettiin kahdesti tolyylifluanidilla (Euparen M) keväällä kahden viikon välein sekä harvennettiin versoja niin, että tiheään kasvustoon jäi 10—12 satoversoa/m ja harvaan kasvustoon 5—6 versoa/m.

Vuosina 1980 ja 1981 vatunvarsisääskellä oli ilmeisesti kaksi sukupolvea. Ensimmäiset toukat löydettiin versoista kesäkuun viimeisellä viikolla, ja sadonkorjuun jälkeen versoissa oli paljon täysikasvuisia toisen polven toukkia. Toukkien ja sienilaikkujen määrät olivat ensimmäisen vuoden versoissa syksyllä selvästi korreloituneita. 'Ottawa' ei ole altis versotaudille mutta varsisääski aiheuttaa voimakkaan sienisaastunnan.

Torjunta-ainekäsittelyt eivät vähentäneet midge blight -taudin aiheuttamaa satoversojen kuihtumista. Tolyylifluanidi ei vaikuttanut versojen sisäosiin tunkeutuviin sieniin, joille toukat raivasivat tietä. Atsinfossi-metyyli ja triklorfoni eivät tehonneet sääsken toukkiin ja muniin, jotka ovat suojassa kuoren alla. Vattukuoriaista vastaan tehdyt kaksi atsinfossi-metyyliruiskutusta eivät myöskään tehonneet sääskeen, vaikka sattuivat sääsken aikuistumisen aikoihin. Viime vuosina on sääsken torjunnassa saatu muualla hyviä tuloksia fenitrotionilla, jonka käyttö myös Suomessa voisi tulla kysymykseen. Ruiskutusten ajoitus ja tekniikka, esim. nestemäärä, kaipaavat lisätutkimusta.

Versomäärän vähentyessä puoleen sato aleni lähes vastaavasti eikä harventaminen vähentänyt midge blight -tautia. 'Ottawa' on niukasti versova lajike ja kokeessa oli vaikeuksia saada kehittymään 10 satoversoa metrille, joten vatunvarsisääsken esiintyessä Ottawa-lajiketta ei tarvitse harventaa.

Ensimmäisten uusien versojen poisto kokonaan oli tehokas torjuntakeino varsisääskeä ja midge blight -tautia vastaan. Kun versot poistettiin kahdesti, oli teho varsisääskeen parempi, mutta versojen pituuskasvu heikkeni liikaa.

Yleensä käsittelyä suositellaan vain voimakaskasvuisille lajikkeille. Jos varsisääskeä esiintyy, poisto voidaan tehdä myös Ottawa-lajikkeelle kahtena vuonna peräkkäin. Versot poistetaan viimeistään 20 cm pitkinä touko-kesäkuun vaihteessa. Suurilla viljelmillä poisto on kannattavaa vain, jos se voidaan tehdä kemiallisesti. Esim. Englannissa versot tuhotaan dinosebilla, mutta sitä tuskin sallitaan Suomessa. Parakvatti ja dikvatti eivät ole olleet tehokkaita; eräitä uusia herbisidejä on kokeissa.

Midge blight -tautia voidaan Suomessa estää tehokkaasti viljelemällä Muskoka-lajiketta, joka ei ole yhtä altis sääskelle kuin 'Ottawa'. Siellä, missä sääskeä ei vielä esiinny, on varottava alkusaastuntaa taimien mukana, sillä munia, vastakuoriutuneita toukkia ja mullassa kulkeutuvia koteloita on vaikea huomata.

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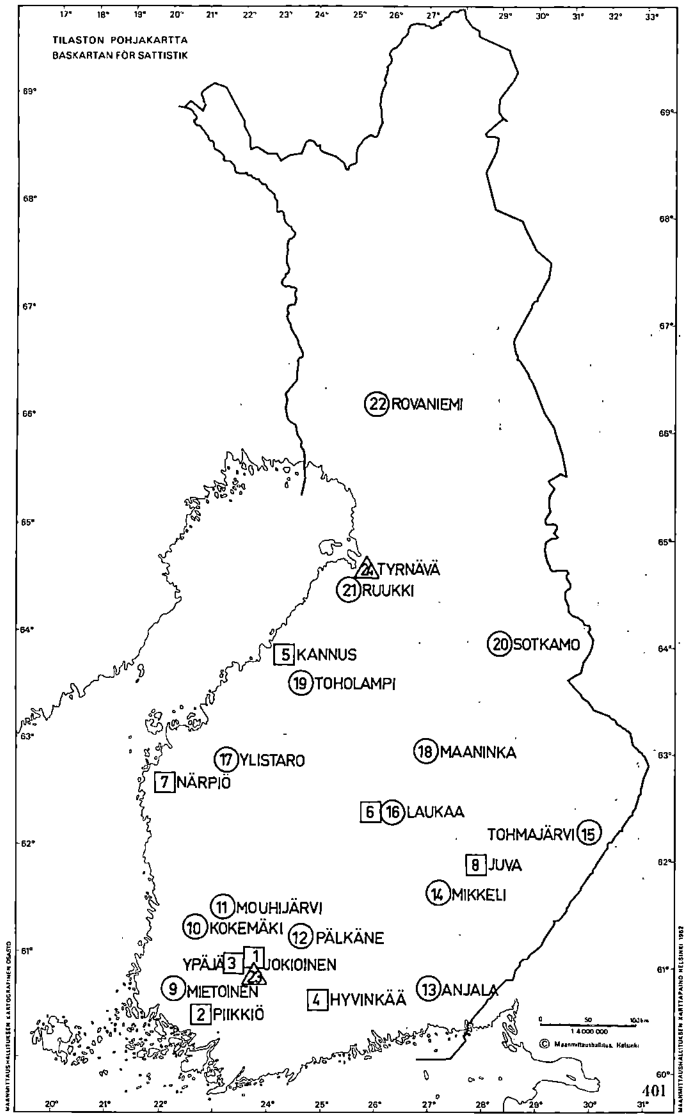

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