SEASON EXTENSION FOR STRAWBERRIES IN BRITISH COLUMBIA

By

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Abstract

The Pacific Northwest is recognized for producing high quality strawberries (*Fragaria x ananassa* Duch.). Unfortunately, these are produced over an extremely short season of no more than 4 weeks. This situation is ideal for the processing market but not the fresh market where an extended season is essential. However, the recently introduced production systems together with the introduction of the day neutral cultivars have the potential to extend the season. The purpose of the present investigations was to examine these systems and the various day neutral cultivars in southwestern British Columbia.

The production systems investigated were the waiting bed and the raised hill row. Both systems involve traditional June-bearing (short day) cultivars planted sequentially, resulting in a harvest season of at least 10 weeks. Among the cultivars tested in the waiting bed system, 'Rainier' was the most promising and 'Hood' the least; 'Totem' and 'Shuksan' gave intermediate responses. In the hill row 'Rainier' was again the most promising. However, in the second year of both systems, when production occurs in the traditional 4 week time period, 'Totem' was the most promising. Comparing the 2 systems, hill rows were more profitable than waiting beds.

Day neutral cultivars begin flowering approximately one month after planting, and fruiting occurs from June or early July until October. In these investigations, they were grown at various spacings on raised beds, covered with black plastic mulch and trickle irrigated. The most promising cultivars tested were 'Selva' and 'Tribute' and the most promising spacing was 30 cm.
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List of Abbreviations

DN  day neutral cultivar(s)
SD  short day cultivar(s)
EB  ever bearing cultivar(s)
WB  waiting bed cultural system(s)
MR  matted row cultural system(s)
HR  hill row cultural system(s)
RB  raised bed(s)
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1. Introduction

The Pacific Northwest has long been recognized as producing high quality strawberries comparable or superior to those produced anywhere in North America. Production is on short-day, June-bearing (SD) cultivars over a relatively short season of 3 to 4 weeks in the late spring or early summer. This is an ideal situation for processing which has been the main outlet for the fruit produced in the region, but it restricts the fresh market season. Moreover, in recent years there has been a considerable increase in the demand for high quality fresh fruit over a long period and, at the same time, a demand for greater self-sufficiency in strawberry production. Unfortunately the available day neutral (DN) cultivars did not have the quality or productivity to meet these demands.

The British Columbia strawberry industry has been based almost exclusively on the processing market. For this the industry has relied on matted row (MR) culture and SD cultivars. For several years now the prices for processed fruit have not been favorable and, at the same time, production costs have risen. Imports from Mexico and California have been relatively cheap. The fresh market, however, has not been favored by the industry in British Columbia. Shipping to the prairie provinces is largely undeveloped. The fruiting season is from the middle
of June into July and there is no local fruit available after that period. In recent years, there has been interest in expanding fresh market production. This market requires large, high quality fruit produced over an extended season. These requirements are not necessarily met by MR culture. Thus the purpose of the present study was to evaluate alternative cultural systems using DN, ever-bearing (EB) as well as SD cultivars.

1.1. Cultivars

There have been many changes in the last few decades as improved cultivars, with resistance to pests and diseases and increased winterhardiness have become available (Daubeny 1989). Detailed descriptions of most strawberry cultivars are available (Sjulin and Barritt 1984, Anon. 1987, Daubeny 1971, Pritts and Dale 1989, Bringhurst and Voth 1987a, Bringhurst and Voth 1987b, Bringhurst and Voth 1987c, Bringhurst and Voth 1987d, Bringhurst and Voth 1987e). Production has expanded considerably and techniques of growing have started to change in some regions (Daubeny 1989, Bringhurst and Voth 1989). DN cultivars and annual production, mainly in California are changing the picture rapidly. In the Pacific Northwest the need for virus tolerance and winter hardiness have been the more important considerations for breeding new cultivars (Lawrence 1989, Daubeny 1979). Other regions in North America have different problems and different

SD cultivars initiate flowers when daylengths are less than 13.5 hours (Hellman and Travis 1988). Flower development can be interrupted, by either cold temperature, or high temperature. Flower bud initiation of SD occurs from late August to the first frosts in British Columbia. In California, initiation of flowers takes place in the spring also and flowering can occur throughout the summer, as long as temperatures do not exceed the maximum (40°C) for initiation. Temperature seems to override the daylength effect. In B.C. flowering generally commences in late April and continues through May with fruit ripening from mid-June to the first week of July. Runnering will occur after fruiting (Durner and Poling 1988) and can be stopped by 30°C temperatures (Galletta and Brinhurst 1990). Under long days, axillary buds develop into runners, which are prostrate, 2-noded stems. Branch crown development may occur during the period between flowering and runnering, when days are too short for runner development, but not short enough for flower initiation (Durner et al. 1984).

Flower bud initiation of EB cultivars, which are long day plants, occurs during most of the growing season except the early spring, when initial fruiting takes place (Durner and Poling
1988). This time depends on latitude. Runner production will also take place during the entire growing season (Durner et al. 1984).

DN cultivars initiate flowers throughout the growing season unless temperatures exceed 30°C, when floral induction is greatly inhibited (Bringhurst and Voth 1987). There are strong and weak DN, but errors in classification can occur during the selection stage in breeding programs, for example, chilling times can influence the floral behavior of the plants (Nicoll and Galletta 1987). Runner production is sparse compared to the SD cultivars and occurs during long days (Durner and Poling 1988). Runner production is enhanced by long days (Durner and Poling 1988, Durner et al. 1984, Pritts and Dale 1989). Runnering can be promoted in some cultivars with cytokinins, but elevated levels over an extended period reduce production of runners (Pritts 1986). In other cultivars flower development is not influenced by cytokinins.

In latitudes like that of British Columbia, flower initiation takes place approximately 9 months before SD flowering (Strik 1987). Initiation takes place when daylength becomes less than 13.5 hours and would until the day length exceeds this in the spring (Strik and Proctor 1988b). Initiation halts during the dormancy period. Most crowns, except for the smallest, initiate
flowers. It is important that optimum conditions are provided during the fall to initiate enough flowers for the next season. In contrast, DN cultivars initiate flowers under any daylength and can therefore produce fruit during the entire growing season. Depending on cultivar, several flushes of fruiting occur or fruiting is continuous.

Flower trusses develop terminally and once they have formed, no further growth will occur in this axis of growth (Dana 1981, Anderson 1983). The axillary bud immediately below the truss will develop into a branch crown which will take over as the major extension growth. The trusses appear to arise laterally as they are displaced to the sides when the crowns develop. Within the truss first one primary flower is formed, then lateral growing points appear below this flower and initiate secondary flowers, usually 2. Further flower initiation takes place below these and there are 4 tertiary flowers next and then 8 quartenary flowers and so on. This varies with cultivar. Each of the described stages is separated by 2 leaves. A truss with such a branching habit is theoretically able to bear unlimited numbers of fruits, but usually flower initiation is terminated at the quartenary or quinary stages. The actual and relative length of trusses, branches and pedicels vary in response to environmental factors, such as daylength, temperature and winter chilling. Time of truss initiation determines size of it. With the
emphasis on large fruits it is desirable to not have any fruit beyond the tertiary stage. Primary fruits usually have around 400 achenes (seeds), while quartenary will have only 80. Achene number greatly influences the size of the fruit.

1.2. Mulches

Organic mulches have been in use in some growing regions for a long time while plastic mulches have become popular more recently. However, in the Fraser Valley of British Columbia organic mulches have not been used as winter rains not only rot the material used for the mulch but also cause crown rots in the plants they are supposed to protect. Also, fluctuating winter temperatures cause early emergence under the mulch and subsequent freezing of the plant and/or the flowers.

In India, clear plastic mulch improved yields by 68% and pine needles by 33 % compared to no mulch (Baldivyala and Aggarwal 1981). Pine needles increased fruit size. Plastic mulch resulted in earlier fruit. Quality of fruit was better with pine needles applied at a rate of 10 tonnes per hectare.

In Florida, biodegradable paper mulches coated with polyethylene were just as effective as black plastic mulches and lasted for the 7 month season, after which it had degraded and
did not need to be removed (Albregts and Howard 1972).

In Nova Scotia, yield in the first year of a planting was increased greatly by black plastic mulch and a double row compared to a single row. In the second year of the planting, irrigation was the most important factor increasing both fruit size and total yield (Blatt 1984). In Oregon, leaflet elongation, flower and fruit numbers and subsequently yields were increased using black plastic mulch at 2 drip irrigation levels, probably through the warming of the soil throughout the upper 20 cm (Renquist et al. 1982b). The mulched plants used water more efficiently, but vegetative growth was even more enhanced than was fruit yield. (Renquist et al. 1982a, Renquist et al. 1982c). In Minnesota, higher temperatures were found under poly foam mulches than under Sudangrass mulch or no mulch (Hertz and Stushnoff 1982). Mulch protected the plants more effectively than no mulch in the winter; however, it also advanced flowering and early frosts killed many flowers, thus eliminating the advantage. Earlier but lower yields were obtained from clear polyethylene mulched plots (Hertz 1979). Sudangrass placed under the plastic reduced fruit size and yield, but when applied on top of the plastic mulch increased yield. Non-mulched plots had about the same yield as Sudangrass mulched plots. Black polyethylene was nearly as effective as Sudangrass.
In England, larger yields on ridges were obtained with black or clear plastic mulch compared to no mulch (Anderson and Guttridge 1978). In Vermont, manmade or natural snow, used as a mulch, at 15 cm depth provided better insulation and winter protection than did straw mulch (Boyce and Linde 1986). Crowns on raised beds (RB) were colder than on flat beds, and those without plastic mulch colder than with plastic. A combination of no mulch and RB caused significant yield loss through freezing (Boyce and Reed 1983).

Temperatures were higher under clear, black and white plastic mulch and black plastic increased runner and fruit numbers in Virginia (Himmelrick 1982). The greatest yield came from clear or black plastic mulched beds. Airspace between clear plastic mulch and soil provided insulation from low temperatures. In Wisconsin, clear plastic mulch increased yield and advanced the season (Scheel 1982b).

In Iowa, DN plants with straw or white on black plastic mulch flowered and yielded more than did plants on clear or white plastic mulch (Fear and Nonnecke 1989). More crowns per plant, runners per plot and greater leaf, crown and root dry weights were associated with clear plastic than with the others. It is suggested that if DN are grown on mulches which moderate temperature there will be less vegetative but more reproductive
growth.

In Norway, tunnels of plastic over the plants and black mulch on the soil, increased yield more than just clear mulch on the beds (Nestby 1985c, Nestby 1979). Black plastic mulched plots had larger fruit, more fruit rot (Botrytis cinerea Pers. ex Fr.) and lower yields than did plots with white plastic mulch (Nestby 1985b). It was also noted, that any plastic mulch can help control weeds and fruit rot and gave a cleaner, more attractive fruit (Nestby 1985c).

In Germany, under floating clear plastic mulch with 500-800 holes per m², harvest time was advanced by as much as 8 days (Eulenstein 1983). Floating mulch was removed before pollination. Good yield was obtained with close spacing. However floating clear mulches were not recommended because of the difficulty in applying them.

1.3. Irrigation and Fertilization

Many factors can influence the uptake of nutrients from the soil by the plant (Johanson 1981). Temperature, daylength, light intensity, humidity, soil moisture content, organic matter content, pH, tillage, soil amendments, herbicides and the
presence of other nutrients can be involved. Important nutrients for strawberries are nitrogen, potassium, calcium, phosphorus and magnesium in significant amounts and in lesser amounts manganese, iron, copper, boron, zinc, sulfur and molybdenum.

The mode of fertilizer application is relevant. Where a hill system was used in Florida, soil applied, side dressed nitrogen fertilizer in increasing rates increased yield and fruit number whereas foliar applied nitrogen increased foliage color and plant size, but not yield (Albregts and Howard 1986b, Albregts and Howard 1986a). In New Zealand, it was found that too much nitrogen fertilization induced Al and Mn toxicity and limited the yield (Haynes and Goh 1987).

When nitrogen and potash were applied dry, yields were similar for strawberries watered with a trickle or overhead irrigation system in Ohio (Goulart and Punt 1985). However, when part of the fertilizer was applied with the irrigation water, which is referred to as fertigation, yields were 25% greater with trickle than with overhead and 50% greater compared to no irrigation (Locascio and Meyers 1975, Locascio 1981). Trickle irrigation also required less water than overhead (Locascio et al. 1977). The soluble salt content of the soil was highest in the non-irrigated fields and lowest for the trickle irrigated plots in Florida (Locascio and Meyers 1975, Locascio et al.)
Nitrogen levels of leaf tissue were not influenced by the fertilizer treatments or irrigation, however, potash levels were greatly elevated with trickle irrigation (Locascio et al. 1977, Locascio and Martin 1985). In Cyprus, nitrogen levels in the tissue increase with increase in fertigation nitrogen (Papadopoulos 1987). Again in Florida, decreased nutrient loss was found when trickle irrigation was used to deliver the nitrogen in small portions rather than in total at the beginning of the season (Mansell et al. 1977). Leaching was higher than in non-irrigated plots. Trickle irrigation allows not only fertilizer and pesticides to be applied throughout the system, but also biological control agents, such as entomopathogenic nematodes, for the control of weevil pests of strawberries (Curan and Patel 1988).

1.4. Spacing

In North Carolina, in a hill row (HR), the closest spacings (15 and 20 cm) gave the greatest yields for 6 of 7 SD and reduced fruit size slightly for all the SD cultivars (Poling and Durner 1986). Spacing had no effect on size of the fruit in Florida (Albregts and Howard 1974, Brightwell 1964, Locascio 1972) but closer spacings produced the greatest yield (Maas and Cathey 1987) there and also in Maryland. In British Columbia, runner
production was dependent on planting age, cultivar and spacing. At the close spacing, fewer runners per area were found. Leaf size, which represents the photosynthetically active area, was greatly influenced by the interaction between cultivars and spacings, year by spacing and year by cultivar (Hesketh 1989, Hesketh et al. 1990a). In the hill row (HR) system, 'Rainier', 'Shuksan', 'Totem' and 'Sumas' plants were examined at different spacings (Hesketh et al. 1990b). There were differences among the cultivars. The highest contribution to marketable yield was from crowns per plant and trusses per crown. Decreases in yield components due to plant competition were not great enough to overcome the positive yield effects of increased planting densities on an area basis.

In Maryland, increased plant density reduced leaves and crowns per plant, root weight and yield (Swartz et al. 1989b). Runner removal increased the crown number and root weight of the mother plants, but yield was increased only in one of 3 cultivars. The effect of spacing was greater than that of runner removal and it is suggested that spacing is the most important factor. High plant density decreased the yield per plant mostly through number of fruit, and less through the size of the fruit.

In Ontario, genotypes differed in number of crowns, crown dry weight, leaf area, number of leaves, leaf dry weight, leaf area,
number of stolons, average stolon length and runner dry weight per plant (Strik and Proctor 1988a). Some of these variables can influence the ultimate density of plants in a matted row system.

In England, vegetative characters associated with yields were those associated with fruit number and fruit size (Lacey 1973). Greater yields were obtained for unthinned solid beds compared to intermediate thinned solid beds; single plant beds gave the lowest yields (Anderson and Guttridge 1976). Invariably the most crowns and trusses per plant were on the single plants, but in the MR the greater number of plants compensated for multiple crowns and trusses. The number of crowns and trusses per area was clearly higher in the MR which was made up by mostly runner plants by the time of harvest in the first fruiting year.

In North Carolina, in the planting year, yields increased linearly with closer spacings (Durner and Poling 1986). Fruit size was greater for the wider spacings but runner number per area was higher in the closer spacings. In the second year, the first full production year, yields again were greatest for the closer spacings while fruit size increased linearly with wider spacings. When MR were established at different spacings, the closer spaced plantings had the highest yields in the first year. Cultivars producing relatively high numbers of runners tend to compensate at wider spacings and differences due to the closer
spacings are minimal in the second year (Poling 1984). Fruit size was larger with the wider spacings. When 'Totem' and 'Shuksan' were compared in MR and HR in the Pacific Northwest, MR was the highest yielding system; the MR with a very high density of plants can compensate for the occurrence of virus diseases in 'Shuksan' at least (Daubeny and Freeman 1977), but probably not in 'Totem' which is relatively virus tolerant (Barritt and Daubeny 1982).

There have been contrasting results from reducing the number of runners. For example, in Nova Scotia, Craig et al. (1983) found increased fruit size but no yield differences, whereas in Norway Brandstveit (1987) found greater yields. Yield per plant was again highest in plants kept runnerless but MR generally outyielded the HR in Michigan (Hancock et al. 1982b). Spacing had varying effects on yield with different cultivars. While a removal of late season runners by machine lead to a decrease in yield, so did the wider spacings for the mother plants in Arkansas (Buckley and Moore 1982). Narrower MR beds with closer spacings, both between the beds and between the plants, outyielded the MR beds with wider spacings.

Comparisons of 2 MR widths in Maryland showed that the narrower rows received more light and the plants produced more crowns and were more productive (Trent et al. 1985, Swartz et al.
1982, Wilson and Dickson 1988). Percent rot and fruit quality were not influenced by spacing (Wilson and Dickson 1988). Comparing HR and MR in Michigan, the latter produced greater yields and larger fruit (Hancock 1984). In the HR in Norway, closer spacings resulted in greater yield and larger fruit (Nestby 1987). There were reductions in trusses per crown, percent of fruit set and fruit weight at higher crown densities in Maryland (Swartz et al. 1982).

Relatively little is known about the spacing requirements of the DN strawberries compared to the SD-types. However, a linear increase in yield with closer spacings was recorded for 'Tribute' in the first and second years in New York (Pritts and Eames-Sheavly 1989). Recent data with DN suggest that the optimum spacing is an offset planting versus a linear planting at the same density.

1.5. Planting Date and Plant Size

When runner plants were dug fresh and planted at intervals in Florida from the end of September to the beginning of November, yields in the following year were decreased with every delay in planting (Albregts and Howard 1974, Brightwell 1964, Locascio 1972); the same effect was found in England (Mason 1987, Hughes 1967). Similarly, in Norway, delayed planting in the spring or
summer resulted in reduced yields in the following year, when number of flowers were generally reduced (Nestby 1982, Nestby 1985a, Nestby 1987). A strong correlation was found between the number of branch crowns and the yield the following year (Nestby 1975).

A comparison of small and large rooted plants showed no differences in runner production, but the large plants had more crowns after one growing season in several states of the U.S. (Skirvin et al. 1987). In Lebanon, with early fruiting cultivars, large plants produced greater yields than smaller plants; these differences were not shown with later fruiting cultivars (Rice and Duna 1986). Cultivars varied in runner production in the U.S. (Skirvin et al. 1987). Plant size was found to be related to planting year yields and fruit weight in Quebec (Gosselin et al. 1985). Mother plants that produced runner plants in Scotland were not affected in number of inflorescences produced, when different grades of plant sizes were investigated (Mason 1987), but yields dropped linearly with smaller plants. With plants grown in England, the number of inflorescences increased with runner size, which in turn was related to axillary bud development, inflorescence initiation and the number of potential cropping trusses (Hughes 1967).
1.6. Waiting Bed Cultural System

In southwest British Columbia, the waiting bed (WB) cultural system, which has the potential of producing fruit on locally adapted short-day cultivars throughout the summer and into the fall, has been investigated (Baumann and Daubeny 1989). It involves the use of cold-stored multi-crowned runner plants. These are produced in the previous season by the deflowering and derunnering of single crowned plants placed in the field in late spring to concentrate development of branch crowns (Hancock et al. 1982b). Production of these multi-crowned plants is what makes the system unique. Subsequently, in late fall, dormant plants are dug and stored at \(-10^\circ\) C, until they are planted in the field at designated intervals the following growing season (Baumann and Daubeny 1989). Fruiting begins approximately 6 to 8 weeks after planting. In Holland, where the system was developed, fresh fruit is now available for at least 4 months of the year and production in greenhouses during the winter is possible from the WB. The system is currently being used successfully in England as well. There, 130 grams of fruit per plant is recognized as the break even point for profit.
1.7. Hill Row Cultural System

In British Columbia, the standard growing practice is the MR on a flat bed. Plants are set out at the rate of approximately 18,000 plants per hectare and allowed to runner freely, while cultivation restricts the runner growth to the rows. In contrast, the HR system involves the use of cold-stored single-crowned runner plants, set out at close spacing at a rate of 150,000 plants per hectare (Rotthoff 1981, Galletta and Bringhurst 1990). This system has also been named ribbon row in the literature, after Rotthoff coined the term in 1981, and was used interchangeably with HR. For the purpose of the present study HR will be used throughout the text. Many combinations of MR and HR are possible (Wetherell 1981, Unger and Strik 1988). The system has the potential of producing fruit on locally adapted short-day cultivars throughout the summer and into the fall. The plants are produced in the previous season by propagation nurseries. They are dug while dormant and stored at $-10 \, ^\circ C$, until the next year, when they are planted in the field at designated intervals throughout the following growing season. Fruiting begins approximately 6 to 8 weeks after planting.

In California, an annual system is used with HR and RB (Voth 1981). Optimum growing conditions are important for the success of the plantings. Clear (in southern California) or white (in
northern California) plastic mulch is used to cover the raised beds and plants are set at high density usually in double rows during the wintertime. Summer plantings are possible, but because of additional stress to the plants, it is even more important to give optimum growing conditions. Not all cultivars are suited to summer plantings (Voth 1967). Plants in summer plantings need to be pruned and plastic mulch applied later than in winter plantings if maximum fruit size and quality are to be achieved (Voth 1961, Voth and Bringhurst 1967). For winter plantings it is important that chilling requirements are met and the level of nitrogen is low (Voth and Bringhurst 1976).

RB are a means for control of root diseases, such as Phytophthora fragariae Hickman, on heavy, wet soils (Durner and Poling 1986). Picking is easier and earlier growth and ripening can be expected as the soil warms up quicker (Durner and Poling 1986, Gosselin et al. 1985, Goulart and Funt 1985). In a review of several papers from the U.S. (Hancock 1987), comparing the MR with the HR, RB never outyielded flat beds and were of no advantage, except when flooding was a problem. Raising the beds increased root temperature. Fruit was kept relatively clean which reduced fruit rot and increased picking efficiency. The system was more difficult to maintain, especially if mulches and irrigation systems were used in combination (Hancock and Roueche 1983, Boyce and Reed 1983). Comparing MR and HR in New York, in
the first fruiting year, mulched plots with either latex or straw were more productive than unmulched plots for the HR (Pritts and Eames-Sheavly 1988). The highest yield in the second year was obtained from MR with latex mulch. With low rates of latex, runners were able to establish, water could permeate the mulch and the mulch was almost completely degraded at the end of the life of the planting.

High plant quality is essential for the success of an out-of-season production in the planting year as plants are subjected to additional stress (Tietz and Gebhart 1979). One of the more important aspects of the production of runner plants, for storage before planting, is the degree of physiological maturity at the time of digging and storage. Plants should have at least 3 fully developed leaves and root lengths of 5 cm with many feeder roots. A laboratory test for starch content is helpful in determining the degree of maturity reached by the plants. Plants are not able to survive -10 °C storage unless they have at least 50 % starch content in the epidermis.

In Maryland, HR outyielded MR when close spacing was used. To find the point at which there is optimum production in the planting year with no negative effect through crowding in the subsequent years is very difficult (Hancock 1984, Swartz et al. 1982). It is suggested that yields of a HR have to be at least
6.7 T/ha higher than for the MR to justify a switch from MR to HR in Ohio (Funt 1983). The fruit was harvested in the planting year to make up for the extra cost to establish the HR which involve a larger number of plants and runner removal, but yields in that year were generally extremely low and therefore never covered the extra cost. In Oregon, fruit was not harvested in the planting year, but 25 T/ha in the first fruiting year and 39 T/ha in the second fruiting year were obtained from a HR-type system (Unger and Strik 1988). Runner removal was every 3 weeks in the planting year and infrequent the following years.

In the year after planting, the HR outyielded the MR at high density (spacing within the row was from 7.5 to 15 cm) only, compared to the third year, in various locations in North America (Buckley and Moore 1982, Durner and Poling 1986, Kaps and Odneal 1986, Gosselin et al. 1985, Goulart and Funt 1985, Hancock and Cameron 1986, Hancock et al. 1982a, Popenoe and Swartz 1985, Scheel 1982a, Swartz et al. 1982, Walsh and Geyer 1983). After the first year of fruit production, renovation of plants by mowing had no effect on yield, but generally MR had higher yields than did HR in South Carolina (Caldwell and Grimes 1987a). HR produced larger fruit, but MR had more fruits (Caldwell and Grimes 1987b).

Plants on RB had deeper root distribution, poorer runner
establishment, higher photosynthetically active radiation penetration and earlier yields compared to those on flat beds (Goulart and Funt 1986a). The closer the spacing, the earlier the fruiting. Yield was not effected by the different treatments (Goulart and Funt 1986a, Goulart and Funt 1986b, Craig and Aalders 1966). In the year after planting, higher yields from HR were associated with increased crown numbers and larger leaf areas per plant in Maryland and Ohio (Popenoe and Swartz 1985, Hancock et al. 1982a, Goulart and Funt 1986a). If plants were spaced in narrow rows, established early in the year and runners cut off, plant vigor was high and likely lead to overcrowding in the second full crop year. Modified MR systems, where runners were removed or row width was restricted, were not found to be an improvement for yield over the conventional MR.

In Wisconsin, it was observed that harvest is easier with the HR as fruit lays in a ribbon along the rows, fruit rot is decreased, fruit is picked clean as it is more visible and a lower percentage is damaged by the pickers (Scheel 1982a). When 'Totem' and 'Shuksan' were compared in MR and HR in the Pacific Northwest it was concluded that the MR was the highest yielding system as only the MR with a very high density of plants can compensate for the occurrence of virus disease, which is a particular problem with 'Shuksan' (Daubeny and Freeman 1977).
1.8. Runner Removal

Runner removal is quite expensive and many methods have been investigated to reduce the amount necessary. Most derunnering is still done by hand, although some chemical methods have been considered. For MR, runners are essential to make up the plant population; the excess is rotovated off by machine. In the HR system the removal of runners is essential and expensive. Runner production as such is influenced by cultivar, chilling, date of planting, day length and light intensity. It is favored by long days and high temperatures (Galletta and Bringhurst 1990). More runners are usually produced by SD cultivars than by DN cultivars. The latter are sometimes even difficult to propagate because of the lack of runners. Thus there is an added expense in propagation. When runners were left on the plants yields were reduced not only in this year but also the next for 'Tufts' but not for 'Dover' in Florida (Albregts and Howard 1986).

Although yield per plant was higher in runnerless plants, MR yielded more per plot in Michigan (Hancock et al. 1982b). The greatest effect of the variables tested was from pre-plant fumigation, cultivar selection and the width of the MR. There was no effect of raising the bed because of the growing conditions in Maryland (Walsh 1982). When vegetative vigor was enhanced by removing runners or trusses, fruit set was enhanced
dependent on the cultivar. Removal of leaves during flowering caused reduced set and yield (Swartz et al. 1989a).

Various treatments have been studied to control runner growth. In Kentucky, flurprimidol was used at 0 to 1,000 ppm on container plants. With increase in concentration of the chemical, mean petiole length, runner number per plant and runner length were reduced (Archbold 1986). At 250 ppm crown dry weights were highest. Ancymidol had no effect on growth and fruiting. Paclobutrazol applied to field grown plants reduced the growth of runners more efficiently than did flurprimidol.

In Wisconsin, paclobutrazol had been found to suppress the growth of runners while not negatively influencing yield (Stang and Weis 1985, Stang and Weis 1984). In Michigan, removal of flowers did not positively influence yield in the following year (Hancock and Roueche 1983). There have been several other growth regulators tested (6-benzylaminopurine, paclobutrazol, BAS 111-04W and Prism) for runner suppression in DN and SD strawberries, some of which unfortunately depress yield (Hasse et al. 1989). Only Prism was found to only suppress runners while yield remained the same. Response of the DN cultivars was different from that of the SD tested in New York and Oregon (Hasse et al. 1989, Martin 1985). In British Columbia, in greenhouse studies, chlormequat and paclobutrazol also inhibited runner growth,
whereas fertilization increased runner production (McArthur and Eaton 1988, McArthur and Eaton 1987).

1.9. Culture of day neutral cultivars

Recent DN releases from several breeding programs promise to be very productive over an extended time period (Bringhurst and Voth 1989). To date, the available DN cultivars have lacked the good fruit qualities that characterize most of the Pacific Northwest SD cultivars. However, California ships considerable amounts of 'Selva' for the fresh market.

In Virginia, removal of flowers helped establish DN strawberry plants and enhanced the yield in the following cropping cycles in the same year (Shaffer et al. 1986). The plants had a higher leaf, crown and root dry weight than non deflowered plants and increased rates of fruit production. Stored carbohydrates were utilized in the next cycles of fruit production (Shaffer et al. 1985). Also, the removal of the first set of flowers prevented the harvest of the DN to coincide with SD season, which would mean lower prices and competition from the higher quality SD fruit. During the first year the optimum removal period for flowers in 'Tribute' and 'Tristar' was 24 days (Leblanc et al. 1987). Fruit size was larger throughout the season with flower
removal. In the second year no effect on marketable yield or fruit size was found when flowers were removed. Similarly, maximum first year yields were obtained if cultivars were deflowered for approximately 6 weeks after planting. But length of deflowering was positively correlated with the yield in the second year of production in New York (Leblanc et al. 1987, Pritts and Worden 1988). Limited removal of flowers in the second year helped shift the production somewhat later, which avoid the main season; yield was not affected (Leblanc et al. 1987).

In North Carolina, bed height had no influence on yield in DN cultivars (Durner and Poling 1986). In New York, HR outyielded MR in the first but not the second year and mulched beds were higher yielding than were unmulched (Pritts and Eames-Sheavly 1988). Planting of DN cultivars late resulted in reduced yields, compared to earlier plantings; this suggests that no compensation took place (Pritts and Eames-Sheavly 1989). Mowing the second year plantings in the spring helped avoiding an in-season crop, but again yield compensation did not occur and fruit size was reduced.

1.10. Objectives of Research

The main objectives of the current research were to study the
possibilities of extending the fresh market season for strawberries in southwestern B.C. from the traditional 4 weeks in early summer through to late September or even into October. Several cultural methods, using both SD and DN cultivars, were investigated. An extended season would not only capitalize on the good quality of Pacific Northwest produced fruit, but would lead to a greater degree of self-sufficiency in strawberry production.

The cultural systems involved the WB which had been developed and subsequently used successfully in the Netherlands as well as in England, and the HR, which had been used successfully in several versions in California and in various other parts of the U.S. Both systems use SD cultivars planted sequentially and involve fruiting in the planting year. The DN cultivars, although of inferior fruit quality compared to the standard Pacific Northwest SD cultivars, were seen as another option in season extension and would provide a continuous supply of fruit in the year of planting from July through to October. Several cultivars were examined at various plant spacings and fertility levels.
2. MATERIALS AND METHODS

Experimental plots were located at Driediger Bros. Farms in 1986-88 and at Krause Bros. Farms in 1988-89, both in Langley, British Columbia, on sandy loam soils. Fields were prepared according to standard practices, which included the use of green manure crops and the incorporation of chicken manure and lime (British Columbia Ministry of Agriculture and Fisheries 1987). RB were mulched with black plastic. Certified strawberry plants were supplied by Sakuma Bros. Nurseries of Burlington, Washington, either from their Burlington site or from their high elevation nurseries in Northern California.

2.1. Plastic mulch

Black plastic mulch was selected on the basis of unpublished information at the Western Washington Research and Extension Center at Mt. Vernon, where trials with various other types and colors of plastic (black, white, brown, clear, white with black backing and black with white backing) concluded that for our region black plastic mulch gave the best results for both yield and weed control. The black plastic mulch is also relatively cheap, compared to other plastic mulches, and gives weed control. It also is the most durable, as the black color gives protection from ultra violet rays. This protection is very expensive to
build into other types of plastics.

2.2. Raised beds

In the formation of RB, deeply-worked, loose soil was ridged up to the middle of the row and a shaper pressed the bed into the final shape. The bed was approximately 30 cm high and was sloped to the sides for a parabolic shape to drain water away from the plants. Black plastic mulch was laid over the beds and at the same time trickle irrigation tape was rolled onto the beds with a machine high enough to clear the RB, anchoring the mulch with soil. As the mulch and tape normally last 3 to 4 years, these materials were not reapplied.

A plastic laying machine manufactured by Kenco Mfg. (Florida) was used to place the black plastic mulch and the trickle tubing. One or two rows were covered at the same time. Shoes opened the soil and the plastic mulch was pressed down into these furrows along the RB and discs closed the furrows by covering the edges of the plastic with soil. The trickle tubing was mounted above the plastic rolls and fed under the plastic, guided by 2 small rollers. There was one trickle tube per bed, in the middle if a double row was used and slightly offset from the center to allow the plants to be set into the center of the bed for a single row.
2.3. Irrigation System

At both farm sites, well water for irrigation was brought from the farm well via an existing main water line, through a connection and past a shutoff valve which was used to disengage the system in winter. A pressure reducer kept pressure at the optimum level without breaking the trickle tape. An adapter was fitted to accommodate the fertilizer injection and then a 2-filter system was used to catch particulate materials, such as undissolved fertilizer in the water supply, to prevent clogging of the trickle lines. A pressure gauge and flow gauge completed the intake portion of the system.

The water flowed through 2.5cm PVC lines to the field where electrically controlled valves fed the secondary lines which were connected to plastic risers linking the trickle tape.

The trickle tape was 2-chambered. An intermediate thickness sufficed since there is no UV light under the black plastic. A main chamber distributed the water to a secondary chamber, which reduced the flow to laser-drilled holes, 30 cm apart, where the water was emitted. The trickle line rested on the soil above the RB. As the water spurted up it was spread further by the plastic through capillary action.
Watering intervals and duration were set on an electronic controller. This system allowed watering at any time and did not interfere with planting, harvest or other maintenance operations. An automated-pump injection system was used to inject soluble fertilizer into the water stream, and allowed accurate delivery of fertilizer to the roots. Fertilizer was applied as many as 20 times per season.

2.4. Data collection

Variables measured in the yield trials included fruit size, the weight of culls and fruit and marketable yield of fruit. Mean fruit size was determined for each plot by weighing a 25-fruit sample on each harvest date and later dividing the accumulated weight by the total number of fruits. Rotten, misshapen, small and other unmarketable fruits were recorded as culls.

The yields of both culls and marketable fruit were expressed as tonnes per hectare and as percentages of total yield. Thus marketable yield represented the fruit actually sold by the grower while total yield was an underestimate of the potential yield that the particular set of factors could produce, if there were no unmarketable fruit.
2.5. Waiting bed cultural system

2.5.1. 1986 planted waiting bed trial

To produce plants of 'Hood', 'Rainier', 'Shuksan' and 'Totem' for the WB trial, normal runner plants were planted in 1985 at a spacing of 22.5 cm by 107 cm field, deflowered twice and derunnered 10 times. The plants grew multiple crowns with an average of 8 crowns per plant. The dormant plants were lifted out of the ground with a tree-nursery root-pruner in January 1986 and stored in plastic-lined bins at -10°C.

The plants were taken out of cold storage at 10-day intervals and planted in level beds, from May to July 1986 (Table 1) at a spacing of 30 cm by 85 cm. Planting was done with shovels and care was taken to set the plants at the same soil depth from which they had been dug.

The WB trial was arranged as 6 randomized complete block designs each planted on a separate date. Each date included 4 rows as blocks and 30-plant plots of 4 cultivars in each row. The cultivars used were 'Hood', 'Rainier', 'Shuksan' and 'Totem'. Harvesting commenced 6 to 8 weeks after planting. Marketable yield, weight of culls, and the weight of a 25-fruit sample were recorded for all plots at each harvest. In 1987 data on
performance were obtained during the conventional fruiting season, for SD types, of approximately 3 to 4 weeks beginning in mid-June.

2.5.2. 1987 planted waiting bed trial

In 1986, plants were prepared as in 1985, but derunnered only twice. The resulting multiple-crowned plants averaged 3.5 crowns per plant. The cultivars used were 'Hood', 'Rainier', 'Shuksan' and 'Totem'. Further multiple-crowned plants, with 3 crowns per plant were obtained from nurseries; these were discarded mother-plants which had been used for production of runner plants. These 2 types of source plants were used in 1987 to establish a second WB trial. Unlike the first WB trial, this second trial was on RB covered with black plastic mulch and trickle irrigation. The mother plant cultivars were 'Rainier', 'Shuksan' and 'Totem'.

A set of machinery from Kenco Mfg. (Florida) was used to raise and shape the beds to a height of 15 cm. The distance between the beds was kept at 107 cm for compatibility with existing tractors in use on the farm. Fertilizer was incorporated while shaping the beds at recommended rates (British Columbia Ministry for Agriculture and Fisheries 1990). This
ensured that fertilizer was placed close to the roots.

Planting was done with a wooden stick. The tip of the root mass was curled around the end of the stick and pushed through the plastic mulch. It was very important to firm the plants into the soil, as an exposed crown and root system made them vulnerable to dessication and winter damage. The plants were irrigated immediately after planting and 2 to 4 times per week for one hour per day.

The experimental design consisted of 24 randomized complete blocks with 7 cultivars per block and 30 plants per plot. Each block was thus a row of 210 plants. Twelve of the blocks or rows were in a field with sulfur coated nitrogen fertilizer while the other 12 blocks or rows were in another field with organically coated nitrogen fertilizer. In each of the fields there were 6 planting dates, with 2 rows or blocks planted on each date. The 7 plots within one row or block consisted of 'Rainier', 'Shuksan' and 'Totem' from the 2 sources described and for the WB, the addition of 'Hood'. Plant spacing within the row was 30 cm. Size, percentage culls and marketable yield were recorded. In 1988, the percentage of culls for the first planting date was determined in every harvest. For later planting dates, the percentage of culls was determined at the first harvest only and results adjusted for cultivars and fertilizer.
In both years the fertilizer rates recommended for matted rows were used (British Columbia Ministry for Agriculture and Fisheries 1987). In 1987 2 different types of slow release fertilizer were incorporated. One fertilizer was a sulfur-coated nitrogen fertilizer mix, that released N for up to 3 months and the other was a mix which used a long-chain organic coating and allowed release over a 5-month period.

In 1987, the WB planted in 1986 had grown into a MR and produced fruit in the normal June-July season. In 1988, the WB planted in 1987, as well as mother plants on the plastic mulch, had both produced large multiple-crowned plants. Yield, culls and size indices were recorded from these second year harvests as well as from their respective first year plantings.

2.6. Short-day hill row trials

The HR system, which has the potential of producing fruit on locally adapted SD cultivars throughout the summer and into the fall, involves the use of cold-stored single-crowned runner-plants available from the propagation nurseries. They are stored at -1 C, until planting in the field at designated intervals throughout the summer months. Fruiting begins approximately 6 to 8 weeks after planting. Sequential planting dates ensure continuous fresh-fruit production in the planting
year. Second year production occurring in the normal June-July season.

As in the WB system, harvest time in the HR system is determined by planting date. The cultivars used were 'Rainier', 'Sumas' and 'Totem'. 'Sumas', a recently released cultivar, is productive and has virus tolerance and winter hardiness, (Daubeny 1987). It was used instead of 'Hood' which had not performed satisfactorily in a preliminary trial in 1986. 'Shuswap' was tested as 'BC 76-7-20' and released as 'Shuswap' in 1990 (Daubeny et al. 1990). It produces particularly firm, glossy, light red fruit with some rot resistance. Spacing between rows was 107 cm on center.

2.6.1. 1986 planted short-day hill row trial

In 1986 planting was in late June on a RB covered with black plastic mulch with no trickle irrigation. The design was a randomized complete block with 2 rows as replications and the cultivars 'Hood', 'Rainier', 'Shuksan', 'Shuswap' and 'Totem' arranged randomly within each row. Spacing was 15 cm in a single row with 20 plants per plot.
2.6.2. 1987 planted short-day hill row trial

In 1987, a randomized complete block design was used with 2 fertilizers, 6 planting dates per fertilizer, 2 replications per date of 4 cultivars placed randomly within the row, 30 plants per plot. Planting dates were 10 days apart from May to July (Table 4). Plants were spaced at 15 cm in single rows in black plastic-covered beds approximately 15 cm high as described for the WB. Trickle irrigation was used. Cultivars used were 'Rainier', 'Shuksan', 'Sumas' and 'Totem'.

2.6.3. 1987 planted short-day hill row trial with double rows

This trial was similar to the previous, except that double rows, 20 cm apart, were used in the RB. 'Rainier' and 'Totem' were compared on the same fertilizer regime for 2 spacings within the double rows. Spacings were 15 and 25 cm within the rows. The design was a randomized complete block with 4 rows, 2 replications per row, 2 cultivars, 2 spacings, and 40 plants per plot.

2.6.4. 1988 planted short-day hill row trial

In 1988 2 B.C. homemade (Driediger Bros. Farms) machines were used to raise the soil and shape the beds. Two modified
subsoilers threw soil into a high wide band. A second pass over the band with a bedshaper modified the bed to new specifications close to those used in California. The bed was 30 cm high in the center, sloping to the sides as to establish a parabolic shape to the bed, that was approximately 50 cm wide. The height was needed so that the trusses of the plants would not lie on the soil and the width needed so that double rows could be planted on a single bed. The sloped crown was needed to prevent water from collecting on top of the plastic covered bed. These new specifications were the result of the trials carried out earlier, 1986 and 1987 planted SD HR.

A randomized complete block design was used with 2 planting dates, 4 replications per date (rows), 4 spacings (15, 20, 25 and 30 cm), 3 cultivars, 'Rainier', 'Sumas' and 'Totem', placed randomly within the row, and 30 plants per plot. Double rows were planted 20 cm apart. Planting dates were May 22 and June 12. Trickle irrigation was used.

2.7. Day neutral and ever bearing cultivar trials

Five cultivars were evaluated, the EB, 'Ostara' and 'Rapella' and the DN, 'Selva', 'Tribute' and 'Tristar'. Only 'Selva' and 'Tribute' were used for spacing and fertilizer trials reported
here. If not otherwise noted, plants were deflowered for 3 weeks after planting, to give the plants time to establish. The following cycles of flowers and fruit were expected to be more prolific, since the plants would be better established. Trickle irrigation and black plastic mulch on 30 cm high RB were used throughout the DN experiments.

2.7.1. 'Selva' spacing trial

In 1989, plants of the DN cultivar 'Selva' were established in double rows 20 cm apart. There were 4 rows as randomized complete blocks, 2 dates of deflowering (3 and 6 weeks after planting), 3 spacings (22, 30 and 38 cm within the rows), 2 replications per spacing and 40 plants per plot.

2.7.2. Day neutral and ever bearer cultivar yield trial

In 1989, plants of the EB 'Ostara' and 'Rapella' and the DN 'Tristar', 'Tribute' and 'Selva' were set 30 cm apart within double rows 20 cm apart. There were 3 rows as blocks of a randomized complete block design with the 6 cultivars and 40 plants per plot. Plants were deflowered for 3 weeks after planting to aid in establishment.
tral fertilizer trial

Within a 4 acre field of 'Tribute' and 'Selva', a replicated fertilizer trial was established. Two rates of nitrogen were compared, 112 and 224 kg/ha application as in section 2.3.3. The field was planted for commercial harvest and one third of the area planted with 'Tribute' and 2 thirds planted with 'Selva'. Each cultivar section had 2 areas of low and 2 areas of high nitrogen fertilization. For each of these 4 sections, 2 randomized complete block designs were placed in the field. Four plots per cultivar were placed randomly within the blocks with 20 plants per plot. Plants were spaced 30 cm apart in a double row 20 cm apart.

2.7.4. Day-neutral spacing trial

In 1990, plants of the DN cultivars 'Selva' and 'Tribute' were placed in double rows (20 cm between the 2 rows). There were 2 randomized blocks, with either a low nitrogen (N) (112 kg N/ha) and high N (224 kg N/ha) treatment. Each design had 4 rows as blocks with 2 spacings (20 and 30 cm between plants) and the 2 cultivars completely random within a row. There were 2 replications per spacing and 80 plants per plot.
The fertilizer treatments used 35 kg N/ha 13-9-16 (N-P-K) in granular slow release form, incorporated into the soil before hilling, followed by 4 applications of 12-45-10 as a starter fertilizer at planting time and then 16 applications of alternating calcium nitrate and ammonium nitrate. At the end of the growing season an application of 4-18-34 fertilizer was applied to aid in maturity prior to the winter. The total N from the different fertilizers made up the 2 N fertilizer treatments. All other elements were kept the same.

Except for the granular application, fertilizers were injected at 5 or 10 kg/ha per week. The injection was with a 0-22 l/min pump from a tank where the fertilizer was mixed. The solution was injected into the irrigation stream and delivered to the soil and plant roots via the trickle tubing. With such a system it was possible to split fertilizer applications to deliver fertilizer to the plants over the entire season.

2.8. Economic assessment of the waiting bed, hill row and day-neutrals

A comparison was made between the conventional system, the MR, and the HR system. Using the Farm Income Insurance Cost of Production Model (FII COPM) (British Columbia Federation of
Agriculture 1986), a model of a standard farm was constructed based on 8 hectares of production. The crop rotation included strawberries as the only crop. Year one was land preparation, year 2 was planting and the next 3 years were crop years. Since the HR produced in the planting year, this means there is an extra production year from the system.

All costs are estimated on the high side, all returns are estimated conservatively. The cost of runner removal is included. Assumptions applicable to all 3 comparisons mentioned above: (1) the farm produces strawberries only on 8 hectares of land; (2) crop rotation is one preparation year, one planting year and 3 full production years; (3) fruit is commercially picked. Fertilizer prices will vary considerably, depending on how much and which quality of slow release fertilizer is used.

Yields reflected very conservative estimations, the potential if applied properly can exceed the given figures. The irrigation system costs vary extremely depending on the present setup of the farm. The HR system with SD figures are based on the cultivar 'Rainier' only. DN data are based on 'Selva' and 'Tribute' yields only.

An analysis of the DN data was also conducted, but should be considered preliminary, since second-year data were not available
at the time.
3. Results and Discussion

Results given are statistically significant at the 5% level unless otherwise noted in the text. Levels of significance can be obtained from the tables. Single degree of freedom comparisons were used in the analysis, but more comparisons were computed later. Therefore Scheffe's test, a conservative method, was used for comparing the cultivar means (Steel and Torrie 1960).

3.1. Waiting bed cultural system

3.1.1. 1986 planted waiting bed trial

In the planting year of 1986 there were linear and quadratic effects of planting dates upon fruit size for the out-of-season production. With the exception of the large fruit size on the first date, size increased with planting date delay (Table 1). No effects were found of planting date upon size in the next year. Plants had more favorable conditions during the later period of the season as temperatures increased and fruit may have benefited from this. The larger size at the first date may be due to a longer interval from planting to harvest and more time for the fruit to size.
In 1986 percent culls were highest for the earlier planting dates and decreased over time. This was most likely due to the cooler and more moist weather during the earlier harvest dates and the drier and warmer conditions later. In 1987, no differences were found but culls averaged 12 % compared with an average of 7 % for 1986 (Table 1). The high percentage of culls was due to the cold and wet weather, which caused more fruit rot during the normal June harvesting period of 1987.

With later planting dates, yields increased to a maximum at the third planting date and declined toward the 6th date. The trend was similar in the second year. Again, the highest yield was recorded for the third date (Table 1). Conditions for set and development of the fruit were apparently optimal. For later planting dates, the summer heat reduced plant growth and increased fruit maturity rate giving lower yields.

'Rainier' had the largest fruit in the planting year 1986. Cultivars did not differ in fruit size in the next year, 1987 (Table 1). Fruit was smaller in the planting year than in the next year.

'Rainier' and 'Hood' produced the most culls in the planting year. In the year following, 'Totem' produced least and 'Hood' the most culls (Table 1). The firm fruit of 'Totem' proved to be
less susceptible to fruit rot in both years, whereas 'Rainier' with a rather soft fruit was highly susceptible to fruit rot (Barritt 1980). 'Hood' had many small fruits included in the culls.

'Rainier' had the highest marketable yield in the planting year, and 'Hood' the lowest. The following year, when the plants had formed a MR, 'Totem' produced more marketable yield during the regular June season than the others (Table 1). 'Rainier' is outstanding in the planting year production, which is discussed later. In the next year, the relative yields among cultivars were as expected; 'Totem' in particular, is noted for its high yield (Daubeney et al. 1990).

There were more culls in 1987 than in 1986 and more marketable fruit was produced in the former than in the planting year (Table 1). Rot during the planting year was negligible because fruit is produced during the relatively dry summer months; however, the June-season crop the following year exhibited normal amounts of rot.

It is necessary to carry over the plants into the second year to recover the costs involved in growing the multiple crown plants. The option to let the plants runner and grow into a MR is cost effective. The costs of runner removal, from plants kept
as single, multi-crown plants in a hill system, is extremely high. Further implications of the hill system will be described in the second WB trial. Yields from the MR grown from the multiple crown WB plants were high for all cultivars, except 'Hood', which already showed virus problems in the first year.

3.1.2. 1987 planted waiting bed trial

Fertilizer treatments had no effect on size, culls and marketable yield, except in the planting year, when the fruit size was smaller from the second type of fertilizer (organically coated) (Table 2). The nitrogen content of the fertilizer was the same, but the release mechanism differed. This caused a slower release of nitrogen for the second and faster release for the other fertilizer. Results show that there is not much difference from these similar fertilizers.

In the 1987 planting year, fruit size was larger from later dates but fell off in the last dates. There was a linear effect for the second year size, with the largest fruit size obtained from the later planting dates. Delayed planting resulted in larger fruit size on most dates as was observed in the first WB trial (Table 2). Plants had more favorable conditions during the later period of the season as temperatures increased and fruit
may have benefited from this; this situation also occurred in the 1986 planted WB trial.

In 1987, the amounts of culled fruit were different among the planting dates, but there was no trend (Table 2). In the next year, 1988, cull data were obtained only from the first planting date.

With later planting dates, yields decreased linearly. This trend was reversed for the second year. The highest yield was recorded on the fifth date and the minimum at the first planting date (Table 2). The differences in comparison with the first WB trial could be due to the use of the plastic mulch and trickle irrigation. Also, plants in the second year of the 1987 planted trial were not allowed to form runners and were still single plants but with many crows, whereas the plants in the 1986 planted trial were allowed to form a MR. There were higher marketable yields recorded from the second year where the MR system was used. Also, yields in 1988 from HR were rather low, as rain during the harvest caused high levels of rot.

'Rainier' had the largest fruit in 1987 and 1988, 'Hood' the smallest in both years. These results are similar to those from the 1986 planted trial (Table 2). Average fruit size was small in the first year, when the plants were under stress from the
effects of immediate flower and fruit production.

'Hood' produced the least and 'Rainier' the most culls in the planting year and 'Rainier' the most. In the next year 'Totem' produced the most culls and 'Rainier' the least. Again, because of loss of samples on the second through 6th planting date, cull means for the cultivars are adjusted for the first date (Table 2).

In the planting year, 'Rainier' had the highest marketable yield, and 'Hood' the lowest (Table 2). Again, these results are similar to the 1986 planted trial. 'Rainier' is outstanding in the planting year production. The following year in the June harvest period 'Rainier' still produced the highest yields. These results differ from the 1986 planted trial, where second year production was much higher (Table 1). Apparently 'Totem' will produce a very high yield with more runner plants but 'Rainier' again performed best with multiple-crown plants.

Fruits were larger in 1987 than in 1988 but considerably more marketable fruit was produced in the second year than in the planting year (Table 2). As fruit was produced during the summer months in the planting year, rot was negligible, however, the June-season crop the following year exhibited expected amounts of rot.
Results of the 1987 planted trial generally agreed with those from the 1986 planted trial. Second year yield was less than in the 1986 planted trial as plants were in a hill system and not allowed to runner, which was not possible with the plastic mulch. Only 'Rainier' yields seem to be high enough to make up for the increased input costs. Second year yields again compared favorably with the yields from MR on flat soil, but no major gains over the MR were obtained with this system. The only benefit was the out-of-season fruit in the planting year.

3.1.3. 1987 planted trial waiting bed trial using mother plants

This trial used the same cultivars and was part of the 1987 planted WB trial, but because the plants were produced differently, results are discussed separately.

Fertilizer treatments had little effect on fruit size. In the second year size was less for the second fertilizer. This was also found in the 1987 planted WB trial. As with the 1987 planted WB, the culls were determined only for the first planting dates and therefore means for year, fertilizer and cultivars were adjusted to that date. No influence on culls was noted (Table 3). Marketable yield was higher at fertilizer 2 (organically coated) in 1988. These results can be explained in the same way
as the results from the WB.

In the 1987 out-of-season production, fruit size increased with delayed planting, then fell off in the later dates. There were no effects of date of planting on fruit size in 1988 (Table 3). These results were somewhat similar to the WB plants but the influence of planting dates upon size was less pronounced.

In 1987, the percent culls were different for planting dates and showed a quadratic trend. In 1988, the number of culls was recorded only for the first planting date (Table 3). The greater percentage culls was due to the inclement weather during the normal June harvesting period of 1988.

Progressively later planting dates resulted in decreased yields in the planting year, this trend was reversed in the second year, when yields increased with later planting dates of the previous year (Table 3). These yields were thus similar to those produced in the 1987 planted WB, which used the same growing system. The differences between this trial and the first WB trial could be due to the use of the plastic mulch and trickle irrigation. Also plants in the second year of the 1987 trial were still single, multiple crowned plants whereas the plants in the 1986 planted trial had formed a MR. There were higher marketable yields recorded form the second year where the MR
system was used. Marketable yields in 1988 from HR were rather low, as rain during the harvest caused high levels of rot. As mother plants are cheaper for the grower, this method would be preferred to the waiting bed, however these plants are in very limited supply.

In 1987 'Rainier' had the largest fruit and 'Totem' the smallest with 'Shuksan' producing intermediate sized fruit. In the next year, 1988, there were no differences among the three cultivars (Table 3). Fruit size of all cultivars was smaller in the planting year than in the next and this reflects stress of producing fruit right after planting.

In the planting year there were no differences for percent culls among the cultivars. 'Totem' proved to be less susceptible to fruit rot in the next year, whereas 'Rainier' and 'Shuksan' with rather soft fruit were more susceptible to fruit rot and produced the most culls.

In the planting year 'Rainier' produced more marketable yield than 'Totem' (Table 3). These results are like those of the 1986 and 1987 planted WB trials and yields compared favorably with WB plants. The following year 'Totem' and 'Rainier' had more marketable yield in the regular June harvest period than 'Shuksan'. These yields were similar to those of the 1987
planted WB trial.

Fruit was larger in 1987 than in 1988, and more marketable fruit was produced in the second year of the planting than in the first (Table 3). As fruit was produced during the summer months in the planting year, rot was again negligible, however, the June crop the following year exhibited normal amounts of rot (Data adjusted to the first planting date). During the first year plants developed more crowns and therefor produced much more fruit in the next year.

Mother plants yielded slightly less than the WB plants (Tables 1, 2, 3). Mother plants are still more economical to use when the cost of producing WB plants is considered. The limiting factor is plant supply. Yields from the 1986 planted WB did not vary with planting date, but in the 1987 planted trial there was a decrease in the productivity of later plantings. From the standpoint of profit, it would still be worthwhile in the Pacific Northwest to plant so as to schedule the harvesting from the end of July to the first frost, despite a decrease in yield because of higher prices and higher total returns.

3.1.4. Evaluation of the waiting beds

The results from the 2 WB trials and the mother plants were
very similar and agreed that 'Rainier' was the preferred cultivar for this system because it can produce sufficient fruit to make harvesting fruit out of season worthwhile. One reason for 'Rainier's' relative large fruits and ultimately greater yield in the planting year may be that it fruits later than the other cultivars and thus may have more time to develop a more extensive root system and stronger plant.

'Totem' might out-produce 'Rainier' in the second year but the size and amount of fruit produced in the first year are not sufficient to justify the use of this cultivar in the system. Out-of-season fruit is entirely for the fresh market as the local processing industry will not accept fruit after the main season. Also processing prices are not high enough to compete with the out-of-season fresh market. Thirdly, 'Rainier' is better suited for the fresh market because it has a better appearance and flavor than 'Totem'. Because 'Rainier' fruit is soft, it must be sold almost immediately before deterioration due to rot and loss of color. The newly released 'Shuswap' with excellent fresh market qualities and especially firm fruit could possibly be adapted to a WB system (Daubeney et al. 1990).

'Hood' is not suited for the WB system because it is very susceptible to virus diseases and throughout the trials showed severe virus symptoms, killing at least 50% of the plants in the
second year (data not presented) and produced unmarketable and sometimes small fruit. 'Shuksan' has a good fresh market flavor, but yields in both years were not enough to be profitable and the first flush of fruits is often fasciated.

Although no comparisons can be made between the waiting bed trials and between each of these and the mother plant trial, the highest yields were obtained from the 1986 planted WB trial. This is likely due to the difference in years, but some may be due to the different system used with the 1987 WB and the mother plant trial, involving plastic mulch and trickle irrigation.

3.2. Short-day hill row trials

3.2.1. 1986 planted short-day hill row trial

As a result of harvesting in the warm and dry summer months, few culls were noted and 'Shuswap' had the least culls in the second year. No other differences were noted in this trial (Table 4). Although marketable yield differences in the planting year were great, there was no significance achieved because the trial was small.

Larger size fruit was obtained in 1987 compared to 1988, more
culls were harvested in 1987 and considerably more marketable fruit was produced in the second year of the plantation than in the planting year. As fruit was produced during the summer months in the planting year, rot was again negligible, however the normal June-season crop the following year exhibited expected amounts of rot. During the planting year plants developed more crowns and therefor produced much more fruit in the next year than was possible in the planting year when the number of flowers were predetermined before planting.

The last trial was rather small and therefor only good for detecting large differences. It gave an indication of what direction future research should take toward finding a less expensive system than the WB for producing out-of-season fruit from SD cultivars. As yield compared favorably with that from waiting bed and mother plants, the same amount of fruit might be produced from much cheaper plants. The runner plants used for the hill row trials are readily available at the nurseries and are the same plants that are currently used to establish MR plantings. This led to the further trials described in the 1987 and 1988 planted HR trials.

3.2.2. 1987 planted short-day hill row trial

Fertilizer treatments had no effect on size in either year.
Percent culls were higher for fertilizer one in 1988, not different in 1987. Marketable yield was not influenced by fertilizer (Table 5). As was true for the 1987 planted WB and mother plant trials, the nitrogen content of the fertilizer was the same, but the release mechanism differed. This caused a slower release of nitrogen for one and faster release for the other fertilizer. Results show that there really is not much difference for these similar fertilizers, except that there seemed to be more nitrogen available from one fertilizer to influence the culls. It is possible that the extra N is conducive to fruit rot development (Freeman and Pepin 1983, Turner and Muir, 1985).

In the planting year, 1987, in the out-of-season production, there were linear and quadratic effects for fruit size over the 6 planting dates. Fruit size decreased linearly with progressing planting dates, the first date was slightly too low to fit the line. The reverse was true for the next year when size increased with later planting dates. A possible explanation for this is the heat in the summer of the planting year, when later planting dates produced fruit faster and these ripened more rapidly. Therefore fruit did not size as much during later dates. In the second year all fruit is produced during the normal June season and fruit size should be influenced in a similar way by the weather (Table 5). This is different form the results of the WB
trials, where fruit size in the planting year seemed to increase with later plantings.

Later plantings tended to have a higher percentage of culls in both years (Table 5), which is likely due to the amount of unmarketable small fruit produced.

As planting dates were delayed, yields decreased to a minimum. This trend was not seen in the second year. As there was double the yield recorded in the first year in the earlier planting dates over the later dates, it seems necessary to plant quite early, especially since planting year yield brings the highest prices, because it is produced out of season (Table 5). This trend is the reverse to that of the WB trials and an explanation again can be found in the smaller fruit produced at later planting dates, when the plants were under increased stress due to hot weather.

'Rainier' and 'Shuksan' had the largest fruit in 1987, 'Totem' the smallest (Table 5). In the second year, 'Sumas' had the largest fruit. 'Rainier' produced the largest fruit in the planting year, similar to its WB performance. One reason for 'Rainier's' relative large fruit and greater yield in the planting year may be that it produces fruit later than the other cultivars and thus may have more time to develop a more extensive
root system and stronger plant.

'Sumas' produced the most culls in the planting year and 'Totem' and 'Shuksan' the least. In the next year 'Shuksan' had the most culls and the other cultivars similar smaller amounts (Table 5).

In the planting year 'Rainier' had the highest marketable yield, the other cultivars produced much lower yields. The following year 'Sumas' and 'Rainier' produced the most.

'Rainier' is the best suited cultivar for producing fruit in the planting year. This is due to the late-ripening habit which allows for the establishment of a larger plant including a more extensive root system. It not only helps to capitalize on the out-of-season fruit but also produces a respectable yield in the following year. These features are both very important for profitable returns over an entire growing cycle (Table 5).

Larger fruits were recorded in 1988 than in 1987. While more culls were discarded in 1988 than in 1987, considerably more marketable fruit was produced in the second year plantation than in the planting year (Table 5). When fruits had more time to size up, there were much larger fruits produced. As fruit was produced during the summer months in the planting year, rot was
negligible, however the normal June-season crop the following year exhibited normal amounts of rot. During the planting year plants developed more crowns and therefore produced much more fruit in the next year.

The marketable yields from the out-of-season first planting year of SD cultivars, compare favorably with those produced with the WB system. Plants are much cheaper, easier to handle and readily available, despite the fact that approximately twice as many plants have to be planted in the HR than in the other 2 systems.

Subsequently, it was important to determine the optimal spacing for the SD out-of-season production.

3.2.3. 1987 planted short-day hill row trial with double rows

At the same time as the HR with single spacing was planted in 1987, a small experiment was undertaken to study the effects of spacing variations within and between rows. 'Rainier' and 'Totem' were the cultivars used because the former had performed best in the planting years and the latter in the next years and, at the same time, was the most widely planted cultivar in the region.
With double row spacings, the yields were considerably higher in the planting year than from a single row. In the planting year, 'Rainier' had larger fruit than 'Totem', as in most of the previous trials (Table 6). In the next year this was reversed. Generally there were fewer culls, but 'Rainier' had more culls in 1987 and 'Totem' in 1988. 'Rainier' had a higher yield than 'Totem' in the first year, but in the next year 'Totem' out-produced 'Rainier', as in some previous trials. These high yields in both years represent yet another step in decreasing the cost of production per unit of fruit harvested.

The closer spacing of 15 cm produced more fruit (Table 6). The closer spacing also caused smaller fruit and more culls in 1987 although the reverse was true for culls in 1988. There was a much higher yield, as expected, in the second year, as well as more culls and larger sized fruit. There were no cultivar by spacing interactions.

This trial gave the first indication that double rows with close spacings are probably best for out-of-season production with HR. A separate trial (Hesketh et al. 1990a, Hesketh et al. 1990b) suggests, that the spacing of plants within a row should be as close as possible. As second year yields now rivaled those produced by the most prolific second year MR system, the plastic mulch and trickle irrigation were thought to have potential since
the increased costs in the planting year were quickly offset with a yield in the planting year which is non-existent for the MR. The out-of-season production also brings higher prices and gives an added benefit to the system. Fruit was extremely clean, and a premium price could be obtained for it.

3.2.4. 1988 planted short-day hill row trial

In the first year, the earlier planting gave larger size and more marketable fruit, probably because the interval from planting to harvest was longer than for the later date (Table 7). In the second year planting dates did not affect size.

There were no effects of plant spacing upon size and culls, except in the second year when fruit size increased with wider spacings (Table 7). Marketable yield increased linearly with closer spacing, both in the year of planting and in the next year. Fruit size was larger at the wider spacings than at closer spacings in the second year. It is surprising that there was no effect on the culls as one would expect more rot in a closer spaced situation with less air movement. Marketable yield was increased with closer spacings, which can be expected from the planting year, when the potential amount of fruit is predetermined at planting time. In the second year, a possible
crowding effect could limit the production of marketable yield. Competition for light, water and nutrients could explain such an effect. However at the spacings used no detrimental effects were observed.

'Rainier' and 'Sumas' had the largest fruit in 1987 and 'Rainier' the largest in 1989 (Table 7). 'Totem' produced the most culls in the planting year and 'Rainier' the most the following year (Table 7). The low culls for 'Rainier' compared to the other cultivars in the planting year can be explained by the amount of small and misshapen fruit discarded for 'Totem' and 'Sumas'. In normal production, in the next year, 'Rainier' had the most culls, because of high rot.

'Rainier' produced the greatest marketable yield in the planting year and the following year 'Sumas' had the greatest (Table 7). These results again agreed with earlier experiments but 'Totem' performed rather poorly in this trial.

Smaller fruits were found in the planting year, 1988, than in the next year, probably because of the stress of producing more fruit quickly (Table 7). There were more culls in the second year and considerably more marketable fruit was produced in the second than in the first year. When fruits had more time to size up, much larger fruits were produced. As fruit was produced
during the summer months in the planting year, rot was negligible, however in the normal June-season crop the following year more rot was evident (Baumann and Daubeney 1989). Plants developed more crowns during the planting year and therefore produced much more fruit in the next year.

Marketable yields in this trial did not reach the level of the earlier plantings, but this last experiment was situated in a different location and hills were now raised to twice the height they were in earlier trials.

3.3. Day neutral and ever bearing cultivar trials

Trials of EB and DN cultivars were started at the same time as the 1988 planted HR trial since it was thought to be advantageous to produce fruit not only out-of-season, but also to produce it from the same plants over the entire season; in other words it would be more economical.

3.3.1. Day neutral and ever bearing cultivar yield trial

The original intent of the study was to test 5 EB and DN cultivars in 1988 for the duration of one year. Subsequently most plants survived the unusually harsh 1988-1989 winter, with
temperatures below \(-10^\circ\) C and strong winds. Among the cultivars, only 'Rapella' had relative low survival rates (Table 8), probably influenced by "wide spacing" and thus lack of protection. It was decided to continue to test the plants for the second year. As DN cultivars fruit all season, flowers damaged in the beginning of the season played only a minor role and fruit production continued to October, 1989.

Data for 'Rapella' and 'Ostara' for the planting year have to be interpreted with caution since the plants arrived from Britain in poor condition and established slower than those of the other cultivars. Also plots for 'Rapella' had only a few plants surviving. Yield was estimated on a per plant basis as for the other cultivars. Therefore precision is lower for 'Rapella' and because of less crowding, means and variance may be inflated.

'Rapella' produced the largest fruit in both years, though it was not significantly different than 'Ostara' (Table 9). In the planting year, 1988, cultivars did not differ in percent culls. In 1989 'Rapella' had the least culls and only 'Tribute' differed from 'Rapella'. Most of the culls represented misshapen (some winterdamage) or small fruit and, in the case of 'Rapella' and 'Ostara' soft fruit, that was bruised. There was also some rot, since the summer was relatively wet (Table 9).
In the planting year, there were no differences in marketable yields between the cultivars despite the large differences in means. In 1989 'Ostara' and 'Rapella' had the largest yield and 'Tribute' the lowest (Table 9).

Size did not differ between years, but culls were much higher in the second year (48.0 % compared to 9.7 %) and marketable yield lower in the second year (Table 9). It is interesting that total production from 'Ostara', 'Rapella' and Tristar' was greater in the second year. However, much of the fruit produced was classed as culls. The amount of culls might be decreased by using fungicide sprays to reduce fruit rot. 'Selva' was the most consistent producer.

It is interesting to note that the conclusions from this trial are not entirely based on the interpretation of the marketable yield produced, but are partially dependent on the acceptance of the fruit on the market. It became obvious during the trial that although the fruit appeared salable, the grower who cooperated in the trials rejected the fruit because he considered the flavor unacceptable. It is therefore important to include consumer acceptance and storage trials in cultivar trials. This sort of research was not part of this thesis.

'Tristar', 'Ostara' and 'Rapella' fruit was deemed non
salable by the grower, because of poor shape and flavor and extreme softness, respectively. 'Selva' performed the best of all these cultivars and was sold successfully throughout the season. 'Tribute' produced much fruit in the beginning of the season but by the middle its small size was unmarketable.

There is interest in several of the cultivars for potential season extension. In particular, 'Selva' is promising because of its large size and good appearance which compare favorably with imported California fruit. 'Tribute', which has a better flavor and higher yields will also be of interest despite its smaller fruit size.

3.3.2. 'Selva' spacing trial

'Selva' produced smaller fruit in the planting year, when placed at closer spacings. No such effect was found in the next year. Culls were not affected by close spacings in either year. This is noteworthy as one might expect a crowding effect in the second year when the leaf canopy has grown together.

Production of marketable fruit in the planting year increased when closer spacings were used (Table 10). A similar trend was found for the second year, but was less pronounced. Yields, even in the planting year, far exceeded the yields of MR or HR in full
production. Most of the fruit is out-of-season and production from the same field continues to the end of October. The large size is exceptional and prices per unit were twice as high on the average as those for the SD cultivars in season.

3.3.3. Day-neutral fertilizer trial

'Selva' produced 33% culls, whereas 'Tribute' produced over 50% (Table 11). Culls were mostly because of small fruit. There was also some fruit rot as the summer of 1989 was relatively wet.

'Selva' produced the same amount of marketable yield as 'Tribute' (Table 11). These yields were relatively low as the farm's criteria for marketable fruit were used and a large number of fruit were discarded as unsalable. Fruit which was misshapened, damaged, showed rot and/or was considered too small, was discarded.

Cultivar by fertilizer interactions were noted for percent culls and marketable yield (Table 11). At the high nitrogen level 'Selva' fruit was large and marketable yield high. At the low nitrogen level fruit size was smaller and the yield was less. The opposite was true for 'Tribute' which produced the largest
fruit and most marketable yield at the low nitrogen level.

This trial was in a commercial field and all maintenance work was carried out by the farm crew. This and the farm grading system decreased overall yield, in comparison with similar trials maintained by the author. The large amounts of small fruit in the culls for 'Tribute' are a drawback, as that fruit has to be picked at high cost and then discarded, because abandoned fruit will serve as a source of the fruit rot causal organism inoculum. The amount of fruit rot during the relatively wet summer of 1989 gives an indication that there is still room for improvement of either cultural methods and/or that fungicidal sprays are necessary.

3.3.4. Day-neutral spacing trial

Spacings had no effect on the yield per area, which means that fewer plants and less labor for derunnering and deflowering can still produce the same yield (Table 12). 'Selva' again had the largest size fruit but 'Tribute' fruit size became too small for the market at the end of August, ending a very lucrative out of season market. Culls were extremely high as the farm criteria were used for determining undersized fruit. 'Selva' had 35% culls and 'Tribute' 47% which compares with the results from the fertilizer trial in section 3.4.3. Marketable yield of 'Selva'
was considerably higher than that for 'Tribute'. Again 'Selva' consistently produced fruit of large size throughout the season.

Fertilizer again had no main effects, but cultivar by fertilizer interactions influenced size (Table 12). 'Selva' fruit was larger at the high nitrogen level while the reverse was true for 'Tribute' which produced its largest fruit at the low nitrogen level. These results further emphasize the fact that specific cultivars may differ in their fertilizer responses and needs.

3.4. Economic Assessment of the waiting bed, hill row and day-neutrals

A comparison was made between the MR, and the HR system. Using the Farm Income Insurance Cost of Production Model (FII COPM), a model of a standard farm was constructed based on 8 hectares of production. The crop rotation included strawberries as the only crop. Year one was land preparation, year 2 was planting and the next 3 years were crop years. The HR produced in the planting year. This means there is an extra production year from the system. After comparing cost against income, the net present value was calculated and a benefit/cost ratio resulted in the HR system being 1.12 times more beneficial than the MR system. In the standard MR system, a year would elapse
before any returns could be realized. The fruit from the HR system is very clean, due to the use of plastic mulch and trickle irrigation. It is therefore of excellent quality for out-of-season fresh market production and subsequently fetches a high selling price. All costs are estimated on the high side, all returns are estimated conservatively. The cost of runner removal is included.

In all three assessments, it is assumed, that (1) the farm produces strawberries only on 8 hectares of land, (2) the crop rotation is one preparation year, one planting year and 3 full production years and (3) all fruit is commercially picked, U-pick is not considered in this model and could increase returns even further. The MR system is the common practice using flat beds, no plastic mulch and about 25,000 plants per hectare. Raising the beds, plastic mulch and trickle irrigation is optional, but helps give clean fruit of better quality.

Yields reflect very conservative estimations, the potential if applied properly can exceed the given figures. The irrigation system costs vary depending on the present setup of the farm. The HR system figures have been derived for the cultivar 'Rainier' only. DN data are based on 'Selva' and 'Tribute' yields only.
An analysis of the WB compared to the MR showed the WB system under the current conditions with plastic mulch and the trickle irrigation is not economically feasible, even though the 130 grams per plant used as a threshold in England is easily achieved in British Columbia.

An analysis of the DN data was also conducted, but should be considered preliminary, since second-year data were not available at the time. This analysis showed that it could be profitable to engage in growing DN cultivars. Up to 4 times the yields can be obtained out-of-season compared to the best performing cultivar 'Rainier' in the HR system. The main disadvantage is that the fruit doesn't have a particularly attractive fresh eating quality. Nevertheless, it has not been difficult to sell this fruit because the main competition at that time comes from imported California fruit of similar quality.
4. Recommendations and conclusions

4.1. Waiting bed system

'Rainier' was the most valuable cultivar for extended season production with the WB system. Flowering occurred an average of one week later than the other SD, Pacific Northwest cultivars. The plants therefore have more time to establish a root system before flowering and fruiting, which is the possible reason for its superior performance in the system. The other cultivars did not produce enough salable fruit for economic return in the planting year, although by standards in England, it would still be profitable (Baumann and Daubeney, 1989). This would be the high price year as out-of-season fruit is produced. Therefore there is no incentive for growers to go through the production of these rather expensive plants.

Mother plants are cheaper to use in the WB system but are usually in short supply and would not sustain a commercial industry. There are no more than a few thousand of these plants available for each cultivar per year. There are enough mother plants from 'Totem' available, since it is the most widely planted cultivar in the Pacific Northwest, but 'Totem' yields for the planting year are too low.
It seems to be economically feasible to use the WB as a method of growing out-of-season fruit, but it is essential that the plants go through at least one, and better 2, more full in-season harvests to make the system pay.

Fruit production for the WB has several advantages, including avoidance of blossom damage from late spring frosts and when raised beds and plastic mulch are used, reduction in fruit rot incidences. Water seems to be the single most important factor for the newly-planted, multi-crown, WB plants as they will emerge from dormancy into temperatures sometimes above 20°C and will produce a leaf canopy and fruit within 6 to 8 weeks.

The WB using plastic mulch is even more labor intensive than the MR or WB without mulch. Derunnering is required. After harvest the plants start growing runners, which can not root on the plastic and are not allowed to grow between the rows. Therefor they have to be removed completely. The current method of removing runners is to cut them off manually, using a knife. Attempts were made to develop new methods. A possible solution is to use a paint roller coated with a contact herbicide mounted behind the tractor to apply the herbicide. The paint roller brushes a narrow band of contact herbicide on the runners that lie on the plastic. The herbicide never touches the main plant itself. The chemical method will not work if the runners have
been allowed to mature and the tissue has lignified. Another method is to mow the runners off with a lawn edger. This requires good quality plastic and an experienced operator to not destroy the plastic mulch. This method has been satisfactory for runner removal both in the WB and the HR.

4.2. Short-day cultivars on hill rows

As in the WB system, 'Rainier' again seems to be the most valuable SD cultivar for extended season production on HR. Flowering occurred an average of one week later than all other cultivars after planting. The plants therefore had more time to establish a strong root system before flowering and fruiting.

The other Pacific Northwest cultivars tested did not produce sufficient marketable fruit for economic return in the planting year. It seems to be economically feasible to use the HR as a method of growing out-of-season fruit, but, as with the WB also, it is essential that the plants go through at least one and even better, 2 or more full in-season harvests to make the system pay. This goal is more easily achieved with the HR plants than with the WB and mother plants. The cost for the runner plants is relatively low compared to the WB plants, and runner plants are readily available and no special technology and management is needed, as it is for the WB plants.
Second-year yields come in the normal season and do not get the high price that the out-of-season, planting year, yields achieve. That is why a high yield in the second year, such as obtained from 'Sumas' or 'Totem' does not necessarily guarantee success for the system. The costs of plastic mulch and trickle irrigation have to be gained back in the year of planting in order to make this profitable.

As the fruit in the planting year is produced during the usually dry summer months, there is much less fruit rot. Raising and mulching the beds with plastic adds to that benefit. Also, there is less danger that the flowers will be damaged by late frosts. Frost often damages flowers in the regular season, but the HR plants are still dormant in cold storage then and planting occurs later when the weather is much milder.

As for the WB, immediate irrigation seems to be the single most important factor in the success for the newly planted plants as they will emerge from dormancy into temperatures sometimes above 20°C and will produce a leaf canopy and fruit within 6 to eight weeks. The late flowering 'Rainier' has an advantage over the earlier flowering cultivars. Trickle irrigation and plastic mulch contribute to the success of such a system.

The much higher beds in the later experiments are conducive
to better fruit appearance. With the lower beds the trusses and fruit lie on the soil between the rows. Any precipitation resulted in dirt on the fruits which made it unattractive for the fresh market. The high beds, however, could be still wider and higher as the rain sometimes still splashes sandy soils up onto the fruits.

The HR system is an improvement to the WB method and is viable for our region for the fresh market. A possible variation without plastic mulch and trickle irrigation may prove to be the system favored for the processing industry. The second year planting would then resemble a low density matted row. Input cost, above that of the normal MR system, arises from the ridging of the soil. This will also raise the roots out of the zone of stagnant water during the winter, which usually causes root rot organisms to proliferate and damage or even kill the plants. It has to be noted, however, that sufficient overhead irrigation must be available for the dry summer months as raised beds can dry out more quickly.

4.3. Day neutral cultivars

The taste of the local Pacific Northwest strawberries is clearly superior to that of the DN cultivars introduced from other
regions. Although this fact was acknowledged by the consumers in test marketing, it was shown that consumers invariably preferred the nicer looking fruit in the off-season, obtained from the DN cultivar 'Selva' (Data not reported). Not only do they look better, but the fruits from California are usually extremely firm and keep for several days longer on the shelf than the fruit from Pacific Northwest cultivars. Growing these cultivars locally ensures that they are picked riper and get to the markets quicker than they possibly could from California fields, and will therefore have better flavor than fruit picked at a more immature stage.

Coupled with the potential of extremely high yields, mostly in the off season, the DN lend themselves to exploitation for the fresh market. Yields can be 3 and 4 times higher than those for the SD in MR and prices obtained can be double. The plastic mulch, trickle irrigation and RB seem to be preferable, as root diseases are avoided, fruit is clean, better air circulation reduces fruit rot and fertilizer application over the entire season is more accurate. An added benefit of the plastic mulch is that no herbicides are used on the plants.

DN cultivars will produce fewer less runners throughout the season than do the SD. The removal of runners is a problem in the planting year before the first fruit is formed. Usually
cutting runners once will be sufficient. As these cultivars then produce fruit all season long, there can be no chemical derunnering and the derunnering with the lawn edger is impossible, as all the fruit would be destroyed. The best method is to do it manually using knives. The labor requirements are quite low as the production of runners is almost insignificant during fruiting. 'Selva' will produce few runners and 'Tribute' will stop runner production almost entirely under the Pacific Northwest conditions.

The EB and DN cultivars tried showed that only a few lend themselves to growing in this area with 'Selva' being the best adapted. New releases from various programs should be monitored for their use in this area.

4.4. Trickle irrigation

Trickle irrigation ensures even moisture at the root zone which is important for the establishment phase of any planting and especially for the DN cultivars which produce a large amount of fruit during the entire season. Water use, compared to that for overhead irrigation, is drastically reduced, especially in combination with a plastic mulch that prevents evaporation. Irrigation can be done any time during the season, day or night, without interfering with other farm operations. Formerly, sprays
and harvesting had to be coordinated with the overhead irrigation. No water is applied to the leaves or the fruits and this helps reduce fruit rot and leaf diseases. Trickle irrigation also allows for the exact placement of fertilizer in the root zone, with less leaching of nutrients from the soil.

4.5. Plastic Mulch

The plastic mulch prevents erosion of the beds, keeps the plant area free of weeds and helps keep the fruit clean. The warming of the soil is a mixed benefit, as flowers may emerge too early in the second year and perhaps be susceptible to damage from late frosts. The discarded plastic mulch may present a disposal problem.

4.6. Raised Beds

Red-stele (P. fragariae) root-rot has been a limiting factor in some strawberry fields in the Fraser Valley. In relatively mild winters severe damage can result from the disease. A trial with RB and plastic mulch located in a commercial field in the midst of severe red stele damage showed that plants were not affected by the pathogen. The root systems of 'Totem' and 'Hood', the same cultivars that were in the commercial field, were above the water level throughout the winter. Better
aeration in the planting through RB may also help to control fruit rots. It is very important to slope the top of the RB, otherwise water will collect, rotting the fruit or scalding it during sunshine following rainshowers. It is still questionable whether the mulch helps to prevent winter kill or exacerbates it.

Many different approaches have been taken to evaluate the potential of out-of-season production of strawberries in the Fraser Valley of British Columbia. The succession of trials reported in this thesis focused on the production of high quality fresh fruit in the planting year with the option of producing fruit in the second year for processing. While the WB and HR system with SD show some benefits, the HR with DN cultivars on RB covered with black plastic mulch and trickle irrigation, emerged as the most profitable undertaking. The quality of the fruits from the DN may not be as good, but the potentially better price in the off season, combined with continuous production over 5 months, offer a great market potential.
Literature Cited


Voth, V. and Bringhurst, R.S. 1976. Effects of time of planting and mulching on summer planted Aiko, Cruz, Tufts and Toro in southern California. California Strawberry Advisory Board 12:No.49.


Table 1. The effect of planting date upon fruit size, culls and marketable yield of four short day strawberry cultivars planted in 1986, using plants from a waiting bed.

<table>
<thead>
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<th>Year</th>
<th>Size (g)</th>
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<th>Mkt (T/ha)</th>
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<td>2.8 15.0</td>
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<tr>
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<td>11.4 12.3</td>
<td>3.8 16.4</td>
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<td>6.9 12.6</td>
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<td>5.7 17.7</td>
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<td>5.0 17.1</td>
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<td>4.6 16.0</td>
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*,**,ns Significant differences at P=0.05 and 0.01 or not significantly different, respectively.
² Means in columns followed by the same letter are not significantly different at the 5% level. Means were separated by Scheffè's test.
Table 2. The effect of fertilizer and planting date upon fruit size, culls and marketable yield of four short day strawberry cultivars planted in 1987, using plants from a waiting bed.

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*,**,ns Significant differences at P=0.05 and 0.01 or not significantly different, respectively.

Z Culls adjusted to first planting date only.

Y Means in columns followed by the same letter are not significantly different at the 5% level. Means were separated by Scheffè's test.
Table 3. The effect of fertilizer and planting date upon fruit size, culls and marketable yield of three short day strawberry cultivars planted in 1987, using mother plants.

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*,**,ns Significant differences at P=0.05 and 0.01 or not significantly different, respectively.
<sup>z</sup> Culls adjusted to first planting date only.
<sup>Y</sup> Means in columns followed by the same letter are not significantly different at the 5% level. Means were separated by Scheffè's test.
Table 4. Comparing size, culls and marketable yields of five short day cultivars planted 1986 in hill rows.

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<tr>
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Scheffé's Value

|          | ns | 3.6 | 5.7 | 10.8 | 1.4 | ns |

Z Means in columns followed by the same letter are not significantly different at the 5% level. Means were separated by Scheffé's test.
Table 5. The effect of fertilizer and planting date upon fruit size, culls and marketable yield of four short day strawberry cultivars planted in hill rows in 1987.

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*,**, ns Significant differences at P=0.05 and 0.01 or not significantly different, respectively.

² Means in columns followed by the same letter are not significantly different at the 5% level. Means were separated by Scheffè's test.
Table 6. The effect of two spacings upon fruit size, culls and marketable yield of two short day strawberry cultivars planted in double hill rows in 1987.

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*,**, ns Significant differences at P=0.05 and 0.01 or not significantly different, respectively.
Table 7. The effect of planting date and spacings upon fruit size, culls and marketable yield of three short day strawberry cultivars planted in hill rows in 1988.

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<td>30 cm</td>
<td>9.3</td>
<td>7.4</td>
<td>9.4</td>
<td>25.5</td>
<td>2.5</td>
<td>9.8</td>
<td></td>
</tr>
<tr>
<td>Linear</td>
<td>ns</td>
<td>*</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>Quadratic</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>Deviation</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>Cultivar</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rainier</td>
<td>9.8a</td>
<td>8.7a</td>
<td>5.7c</td>
<td>36.5a</td>
<td>4.7a</td>
<td>8.9b</td>
<td></td>
</tr>
<tr>
<td>Sumas</td>
<td>9.7a</td>
<td>7.5b</td>
<td>9.3b</td>
<td>15.6c</td>
<td>2.8b</td>
<td>17.5a</td>
<td></td>
</tr>
<tr>
<td>Totem</td>
<td>7.4b</td>
<td>5.7c</td>
<td>13.5a</td>
<td>25.7b</td>
<td>2.4b</td>
<td>8.2b</td>
<td></td>
</tr>
<tr>
<td>Scheffè's Value</td>
<td>0.9</td>
<td>0.5</td>
<td>3.3</td>
<td>3.3</td>
<td>0.6</td>
<td>1.6</td>
<td></td>
</tr>
</tbody>
</table>

*,**, ns Significant differences at P=0.05 and 0.01 or not significantly different, respectively.

Means in columns followed by the same letter are not significantly different at the 5% level. Means were separated by Scheffè's test.
Table 8. Day neutral and ever bearing cultivar winter survival 1989

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Survival(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ostara</td>
<td>83a</td>
</tr>
<tr>
<td>Rapella</td>
<td>36b</td>
</tr>
<tr>
<td>Selva</td>
<td>84a</td>
</tr>
<tr>
<td>Tribute</td>
<td>100a</td>
</tr>
<tr>
<td>Tristar</td>
<td>95a</td>
</tr>
</tbody>
</table>

LSD 35

* Means in columns followed by the same letter are not significantly different at the 5% level. Means were separated by Sher's protected LSD.
Table 9. Comparing size, culls and marketable yields of two ever bearing and three day neutral cultivars planted 1988 in double hill rows.

<table>
<thead>
<tr>
<th>Year</th>
<th>Size(g)</th>
<th>Cull(%)</th>
<th>Mkt(T/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>11.6</td>
<td>11.6</td>
<td>9.7</td>
</tr>
<tr>
<td>Cultivar</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ostara</td>
<td>13.5ab</td>
<td>14.2ab</td>
<td>12.0a</td>
</tr>
<tr>
<td>Rapella</td>
<td>16.5a</td>
<td>15.3a</td>
<td>14.2a</td>
</tr>
<tr>
<td>Selva</td>
<td>10.2b</td>
<td>10.0bc</td>
<td>3.8a</td>
</tr>
<tr>
<td>Tribute</td>
<td>8.3b</td>
<td>8.6c</td>
<td>1.3a</td>
</tr>
<tr>
<td>Tristar</td>
<td>9.5b</td>
<td>9.7bc</td>
<td>17.0a</td>
</tr>
<tr>
<td>Scheffè's Value</td>
<td>5.5</td>
<td>4.8</td>
<td>15.9</td>
</tr>
</tbody>
</table>

*,**, ns Significant differences at P=0.05 and 0.01 or not significantly different, respectively.

Means in columns followed by the same letter are not significantly different at the 5% level. Means were separated by Scheffè's test.
Table 10. The effect of plant spacing upon fruit size, culls and marketable yield of 'Selva' day neutral strawberry cultivar planted in 1988 in a double hill row.

<table>
<thead>
<tr>
<th>Year</th>
<th>Size (g) 1988</th>
<th>Size (g) 1989</th>
<th>Cull (%) 1988</th>
<th>Cull (%) 1989</th>
<th>Mkt (T/ha) 1988</th>
<th>Mkt (T/ha) 1989</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>17.0</td>
<td>13.9</td>
<td>6.9</td>
<td>19.2</td>
<td>13.9</td>
<td>21.5</td>
</tr>
<tr>
<td>Mean</td>
<td>15.9</td>
<td>13.7</td>
<td>6.3</td>
<td>19.5</td>
<td>16.1</td>
<td>22.8</td>
</tr>
<tr>
<td>Spacing 22 cm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30 cm</td>
<td>17.0</td>
<td>14.2</td>
<td>6.3</td>
<td>19.6</td>
<td>13.0</td>
<td>21.4</td>
</tr>
<tr>
<td>38 cm</td>
<td>18.0</td>
<td>13.9</td>
<td>8.3</td>
<td>18.6</td>
<td>13.4</td>
<td>20.3</td>
</tr>
<tr>
<td>linear deviation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>* ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>** *</td>
<td></td>
</tr>
</tbody>
</table>

*,**, ns Significant differences at P=0.05 and 0.01 or not significantly different, respectively.
Table 11. The effect of the interaction of fertilizer and cultivar upon fruit size, culls and marketable yield of two day neutral strawberry cultivars in the first year of a 1989 double hill row planting.

<table>
<thead>
<tr>
<th>Cultivar means</th>
<th>Selva</th>
<th>15.0</th>
<th>33.4</th>
<th>11.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tribute</td>
<td>12.6</td>
<td>50.2</td>
<td>10.4</td>
<td></td>
</tr>
</tbody>
</table>

| F-Test | ** | ** | ns |

Cultivar by Nitrogen interaction

<table>
<thead>
<tr>
<th>Selva</th>
<th>high Nitrogen</th>
<th>15.3</th>
<th>30.4</th>
<th>11.7</th>
</tr>
</thead>
<tbody>
<tr>
<td>low Nitrogen</td>
<td>14.7</td>
<td>36.3</td>
<td>10.4</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tribute</th>
<th>high Nitrogen</th>
<th>12.4</th>
<th>51.7</th>
<th>9.4</th>
</tr>
</thead>
<tbody>
<tr>
<td>low Nitrogen</td>
<td>12.8</td>
<td>48.7</td>
<td>11.5</td>
<td></td>
</tr>
</tbody>
</table>

| significance | ns | ** | ** |

**, ns Significant differences at P=0.01 or not significantly different, respectively.
Table 12. The effect of the interaction of fertilizer and cultivar upon fruit size, culls and marketable yield of two day neutral strawberry cultivars in the first year of a 1989 planted double hill row spacing trial.

<table>
<thead>
<tr>
<th></th>
<th>Size (g)</th>
<th>Cull (%)</th>
<th>Mkt (T/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selva</td>
<td>18.3</td>
<td>35.3</td>
<td>18.8</td>
</tr>
<tr>
<td>Tribute</td>
<td>14.6</td>
<td>47.4</td>
<td>14.7</td>
</tr>
</tbody>
</table>

F-Test ns ** **

Effect of cultivar by Nitrogen interaction upon size

<table>
<thead>
<tr>
<th></th>
<th>Selva</th>
<th>Tribute</th>
</tr>
</thead>
<tbody>
<tr>
<td>low N</td>
<td>15.6</td>
<td>17.1</td>
</tr>
<tr>
<td>high N</td>
<td>21.0</td>
<td>12.2</td>
</tr>
</tbody>
</table>

F-Test ** **

*,**,ns Significant differences at P=0.05 and 0.01 or not significantly different, respectively.