AN ABSTRACT OF THE THESIS OF

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Title: Growth and Development of Primocane Fruiting Red Raspberry, (Rubus ideaus L.), and Influence of Nitrogen Fertilizer and Pruning

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A cultivar comparison study was conducted to identify similarities and differences in cane characteristics between 2 primocane fruiting red raspberry cultivars and to determine if the differences and similarities can help determine cultural practices that may improve productivity. The comparison of the cultivars 'Amity' and 'August Red' showed a difference in vegetative and fruiting characteristics. 'Amity' is much more vigorous having a greater cane length and diameter, greater leaf area and longer distance to the first fruiting node. 'August Red' had a greater number of fruiting sites, more fruits set per cane and a higher percentage fruit set. Both cultivars increased in vigor and productivity over the 2 year period. Cane length, cane diameter and leaf area were positively correlated with fruit numbers for both varieties.

A crop response study was conducted to determine the effect of 2 nitrogen and 3 pruning methods on earliness of flowering and the subsequent effect on yield and cane characteristics. The treatment effect on the canes self supportiveness was also observed. Time of

flowering and the time required for fruit ripening to occur were unaffected by any treatment. The distribution of fruit on the cane was greatest at the basal end fewest at the apical end. The largest fruits were found at the apical end and the smallest at the basal end. High N, 135 kg/ha vs. 67 kg/ha, increased yield late in the harvest season resulting in 14% higher total yield (8.1 vs. 7.0 MT/ha). Pruning back the current season primocane growth to 40 cm above the ground had a detrimental effect on yield per cane but due to an increase in the number of branched canes total yield was greater (not significantly however); 8.0 MT/ha vs. 7.5 or 7.0 MT/ha for dormant cane pruning at 20 cm and 0 cm respectively. None of the pruning treatment improved the self supporting cane characteristic.

GROWTH AND DEVELOPMENT OF PRIMOCANE FRUITING RED RASPBERRY, (Rubus ideaus L.) AND INFLUENCE OF NITROGEN FERTILIZER AND PRUNING

by

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GROWTH AND DEVELOPMENT OF PRIMOCANE FRUITING RED RASPBERRY (Rubus ideaus L.) AND INFLUENCE OF NITROGEN FERTILIZER AND PRUNING

INTRODUCTION

Red raspberry in the Pacific Northwest is an important crop, with 2,000 hectares harvested in Washington and Oregon in 1980 (33). Production has been almost exclusively limited to the floricane or summer fruiting cultivars. Producers and processors have wanted to extend the use of their equipment and labor with primocane or fall fruiting types. The primocane fruiting type offers a crop at the time of the year when machine harvesters and processing plants are not operating at full capacity. In order for growers and processors to begin producing and processing this type of raspberry fruit has to be of acceptable quality and yields sufficient. Fruit quality is measured by how well flavor, firmness and color of the berries are maintained through the shipping, canning and freezing processes. Acceptable yields are determined by the cost of production in relation to the yield and the price paid for the fruit. Yields can be lower with primocane fruiting types because production costs are less than with floricane types. Pruning (dormant cane removal) can be done with a tractor mounted mower and there is no need of a trellis system with primocane fruiting red raspberry. Industry concensus is that yields by September 15 must be over 5.6 MT/ha for production to be profitable.

The primocane fruiting cultivars available have not been suitable

to the Pacific Northwest region because of poor fruit quality and/or late maturing fruit. For these reasons breeding work has been going on to develop a cultivar suited to this region. A new cultivar 'Amity' was selected and released by USDA Small Fruits Breeder Dr. Francis Lawrence, stationed at Oregon State University.

'Amity' has good fruit quality characteristics but many production problems remain to be solved. It fruits later than desired and its ability to be machine harvested without trellising is uncertain. In an attempt to understand 'Amity', I studied its yield and cane characteristics and the cane characteristics of another cultivar 'August Red'. 'August Red' is early fruiting and does not require trellising, however its fruit quality is poor.

The objectives of the cultivar comparison study were: 1) to compare the vegetative and fruiting characteristics of 'August Red' and 'Amity', and 2) to determine if the differences and similarities can help determine cultural practices that may improve the productivity of primocane fruiting cultivars. The objectives of the 'Amity' crop response study were: 1) to determine influence of nitrogen fertilizer on earliness of flowering and fruiting and subsequent early season yields, and 2) to evaluate effects of pruning methods on cane self supportiveness and yield.

REVIEW OF LITERATURE

Red Raspberry Morophology

Introduction

Red raspberry forms an erect or nearly erect woody biennial cane on a creeping perennial root system. Two flowering types are found, the most common is the biennial type that flowers on the floricane or one year cane, and the less common annual type that flowers on the newly elongated shoot or primocane.

Root Bud Development

The roots and basal cane buds at or below the soil surface are the common source of new canes. The development of a new cane from the root begins with the initiation of a root bud which elongates only during periods conducive to growth from August through April. This period is termed the "on" season for root bud initiation (12, 41). Shoot development starts when the root bud begins rapid growth, forming a subterranean sucker (12). The suckers emerge from the soil from March to early May as a tight rosette of leaves. The newly emerged sucker, now termed a shoot, elongates rapidly from mid May to July. During this period no new suckers emerge (41). Suckers emerging in late summer or autumn drop their leaves and become dormant winter shoots. The following spring dormant shoots begin to elongate and continue to grow through fall reaching up to 2.5 meters long in temperate zones. The elongated shoot is now refered to as the primocane or first year cane (12, 41).

Basal Bud Development

Buds at or below ground level originating from axils of leaves or leaf scales will develop on the primocane. These buds swell the first year and during the second year grow into a replacement shoot (12). These shoots may begin growth prior to the original shoots breaking dormancy (42).

Blossom Bud Differentiation (floricane types)

Depending on the variety, flower bud initiation occurs as shoot elongation ceases, generally from September to the beginning of April (26, 32, 37, 40, 44). A rest period or pseudo-dormancy occurs for approximately 6 weeks during late fall and early winter, at which time bud development ceases (32, 37, 40). Bud differentiation starts at the apical end of the cane and proceeds downward (26, 32, 40, 43, 44). All nodes are potential flower sites and will produce flower buds under heavy pruning (4, 20, 44). Haltvich (10) noted that failure of buds to develop on the lower nodes of unpruned canes was possibly due to shading or early leaf drop in the basal region. Vasilakakis (38) concluded that the failure of lower nodes to initiate flower buds was due to a lack of warm temperatures late in the growing season.

Blossom Bud Differentiation (primocane types)

Waldo (40) observed that some cultivars begin to form fruit buds in the summer as soon as elongation has ceased. Fruit bud formation starts at the terminal end and progresses down the cane. Later studies found that some cultivars begin to initiate flowers as soon as all nodes are developed, but prior to internodes reaching their

final length (14, 44). The primocane of these cultivars will over winter and fruit on the floricane just as the floricane types discussed earlier, however they will not fruit on nodes that flowered during the previous season (12, 22, 38). Vasilakakis (39) determined that flowering is the final part of an endogenously controlled cycle. The cycle can be altered with temperature only in that low temperatures shorten the length of the cycle.

Fruit Set

Most red raspberry varieties are self fertile but a pollinator can increase fruit set and fruit size (7, 9, 27). Daubeny (8) found that larger buds have a higher fruit set percentage than smaller buds.

Distribution of Fruit

The unbranched untopped cane increases the number of fruit per node in a basipetal direction except for the basal 10% of the cane which produces close to the average of all the sections (13, 21). Locklin (21) found the largest fruit are on the central part of the cane with the smallest near the base and tip of the cane. Johnston (13) found the largest berries grew at the base of the cane and the smallest at the apical end. The differences seen are most likely due to cultivar variation of cane characteristics.

Senescence

After fruiting the floricane dies back to the position from which a replacement shoot has grown (12). The replacement shoot is either a root bud below ground level or a basal cane bud near or just below

ground level.

Cane Characteristics Effect on Yield

Vegetative Characteristics

Many workers have associated higher yields with greater cane diameter (4, 5, 6, 13, 21, 23, 45). Crandall et. al. (29) reported a positive correlation between cane diameter and yield. Darrow and Waldo (6) in 1934 observed that five of six cultivars had greater numbers of berries on canes of larger diameter. However, Martin et al. (25) found that cane diameter was not correlated to yield in their study of 'Meeker'. Cultivars vary in their habits and characteristics and apparently do not produce greater numbers of berries as cane diameter enlarges.

Researchers (6, 13, 25) found that a greater number of buds/cane did not contribute to higher yields/area.

Number of fruiting laterals

Darrow and Waldo (6) reported that an increased number of fruiting laterals/cane did not increase yields. As the number of laterals increased the number of berries per lateral decreased.

Cane density

Generally as cane density (cane per ha) increases yields likewise go up (4, 30). Norton (30) observed that as canes per plot increased, yield per plot increased although yield per cane dropped. Lawson and Waister (16) saw in the establishment years that greater cane numbers increased yield; however in later years higher numbers of canes with reduced yield per cane and contributed to overall lower yields.

Effect of Nitrogen on Cane Characteristics and Yield

Primocane Fruiting

Vegetative Characteristics. Locksin and Elfving (22) in their study on the effects of nitrogen (N) on the cultivar 'Heritage' concluded that N had a positive effect on vegetative growth by increasing cane height, total dry weight, total nodes and internode length. Increasing N also reduced time for flowering to occur. Flower initiation of 'Heritage' is dependent on developing all nodes prior to flowers being initiated. Elongation of the nodes need not occur prior to flower initiation.

Yield. Skirvin and Otterbacher (36) found that yields steadily declined over 3 years when using 45 kg N/ha. An unpublished recommendation from a New York experiment station suggested increasing the N rate applied to primocane fruiting cultivars from 45 kg N/ha to 90 kg N/ha.

Floricane Fruiting

Vegetative Characteristics. Shoemaker (35) saw that N had a positive effect on cane diameter, however in later studies, Martin et al. (25) and Hill (11) did not see any effect on cane diameter. Cultivar may have been a reason for the differences in these studies but even more probable was that Shoemaker carried out his experiments on soils of low fertility. Cane length can be affected by N depending on the cultivar (20). Hill (11) and Martin et al. (25) found N to have no effect on cane length whereas Lawson & Waister (16) saw a

slight increase in cane length with high N. Lawson and Waister (16) found no change in number of laterals per cane with N treatment. Hill (11) observed that N had no significant change on leaf area.

Response to N and its effect on cane density is not consistent. In one study N increased cane populations (35). In another study it increased the number of canes the first year but not in subsequent years (15). And in other studies it had no effect on cane density over the course of the study (25, 26). N probably increased first year cane density because the population was low initially, but as the planting matured factors other than N such as light and space become more limiting.

Fruiting Characteristics. Number of berries per cane can increase with the addition of N (15). However, Ljones (19) observed increases in berries per cane the first year with added N, no effect the second year and a decrease the next two years. Ljones and Sakshaug (20) found no effect of N on number of berries per cane. They found berry weight to increase with increased N, whereas Martin et al. (25) found no effect and Lawson & Waister (16) found an increase in one out of four years with high N. Differences in berry weight with higher N rates may be due to cultivar and its response to the level of N used in the experiment.

Increased N has a varied result on vegetative growth and berry characteristics, however N tends to have a positive effect only in the first or early years of most plantings. As Hill (11) concluded that this may be due to maturing of the planting and that the best method of determining N needs is to determine foliar N levels. Lawson and Waister (16) question whether increased N is of value and felt that

cane morphology and cane density could best be controlled with effective sucker control.

Yield. The effect of N on yield of red raspberry has not been well defined; cultivars, soils and geographical areas have much to do with response.

Shoemaker (36) observed increased yields due to N application in both years of the study on "Cultbert". Martin et al. (25) found greater yields due to increased N two of four years with 'Meeker'. Several workers (11, 19, 20) found that N increased yields the first year but declined in subsequent years with greatly reduced yields with high N by the fourth year. The early increased yields with high N applications may be due to initially low soil fertility but as the planting becomes established and soil fertility is improved the need for high rates of N decreases. A young planting's positive response to N may be due to additional canes produced in the early years (11). A young planting need not compete for light, and space as a mature planting must thus the young planting can utilize the additional N for increasing cane numbers. Lawson & Waister (16) observed that the yield per cane was high with high N in early years when there were fewer canes per plot. As the planting matured the high and low N applications produced the same number of canes per plot and yields per cane with high N were reduced.

Ljones (19) found that in the later years under high N yield was reduced and foliar samples showed very high N levels whereas boron (B) was deficient. Ljones & Sakshaug (20) observed that foliar B levels were correspondingly low as N levels increased, B being an essential element for fruit development. Hill (11) concluded that the only

effective method of determining N needs was through foliar analysis during the growing season with 2.9 to 3.2% N being a sufficient level of N in leaves taken in mid-summer on non-bearing shoots.

Effect of Pruning on Cane Characteristics and Yield

Primocane Fruiting

Skirvin and Otterbacher (36) conducted an experiment to determine if removal of the primocane after fall harvest gave greater total yields than to "double crop" (harvest the primocane in the fall and the floricane in the spring) they found that double cropping produced greater yields but that the single harvest from the primocane was greater than any one harvest in the double crop system. Primocane yields with either system declined over the three year study, whereas floricane yields increased. This may be due to a lack of adequate N since only 45 kg/ha was applied per year. This amount is the standard rate applied to floricane fruiting types, but possibly is inadequate for primocane fruiting types.

Floricane Fruiting

Vegetative Characteristics. Martin et al. (25) determined with 'Meeker' that as the severity of pruning increased so did cane diameter. Brierley (2, 3) found with 'Latham' raspberry that increased pruning caused greater lateral length. Locklin (21) study of 'Cuthbert' did not find that pruning height had an effect on lateral length. Number of buds/cane was reduced with the increased severity of the pruning treatment (25). Johnston and Loree (13) reported that the effect of pruning on buds/cane was dependent on the vigor of the canes. The number of buds/cane in vigorous plantings was increased with pruning whereas it decreased in weak plantings. Brierley (2) concluded that canes with less pruning bloomed and

ripened fruit a few days earlier than severly pruned canes.

Fruiting Characteristics and Yield. All buds of a raspberry cane may become flower buds but they may not all flower (25, 44). Pruning has been used to induce flowering at all cane nodes. The unpruned cane has a greater fruit to bud ratio at the basal than the apical cane region. Pruning (heading back dormant canes) have tried to increase yields at the basal end by stimulating lateral growth (30, 31).

Heading back is commonly used to reduce the height of the cane to enable pickers to reach the fruit on the upper ends of the cane. Locklin (21), and Johnston & Loree (13) found that heading back of the dormant canes reduced yields. When canes were severely headed back, yields were greatly reduced (21). Johnston and Loree (13) used varying degrees of heading back and yields dropped progressively as heading back increased. Other workers (2, 5, 11, 25), headed back canes to different heights and found less heading produced the greatest yields.

Berry size was greater as heading back increased (2, 5, 21, 25). On headed back canes, as yields increased, berry size was reduced but as yields decreased, berry size was larger. Hill (11) did not see a difference in yield with heading heights but he did conclude that increased berry size accounted for yields not dropping with greater heading back.

Red Raspberry Machine Harvesting

Machine harvesting of red raspberries has been under investigation since the 1960's. By the early 1970's mechanization was replacing hand picking in Europe, New Zealand, Canada and the United States. In 1980, 300 machine harvesters were in operation in the U.S. with approximately 75% of the 1983 Oregon crop being machine harvested (31). Red raspberry breeders and producers feel it is important that new varieties be adapted to machine harvesting.

Cane Characteristics

Lawrence (15) thinks that primocane fruiting red raspberries have good potential as a non-trellised machine harvestable crop. In order for a primocane fruiting cultivar to be well suited for machine harvest it should meet a specific set of criteria: 1) It must be self-supporting to reduce production costs associated with trellising. Primocane fruiting cultivars are typically lower yielding than floricane types (15). 2) Berries must easily shake off the receptacle at the proper stage of ripeness (31). 3) Cane, lateral and pedicel strength are important factors. Damage to these parts can cause loss of berries or bruises that will be susceptible to disease (31). 4) Fruit ripening rate should be slow enough to prevent over ripening between harvests (31). Machine harvesting is typically done on a three to four day schedule (18, 31). 5) The fruit must be firm enough to withstand damage during the harvesting process (31). 6) Fruit must be born at the proper height to accomodate the machines picking capabilities. Machines vary as to the minimum and maximum

harvestable berry height; from 25 to 60 cm on the base of the cane to 2 m on the upper end (17, 29). 7) Fruit on the outer edges of the row are easier to harvest whereas fruit in the center of the row tend to fall to the ground unharvested (29).

Cultural Practices

Certain cultural practices can alter the ability of a machine to harvest effectively. 1) Heading back of dormant canes causes laterals to lengthen (2, 3, 29). Long laterals can hang below the minimum harvestable height of most machines. 2) A training system should be used that will keep canes short enough (below 2 m) to allow their entire length to be harvested. Single horizontal wire trellis systems that bundle and wrap canes to the wire do not work well for machine harvesting. Individual cane training on a two wire trellis which reduces the concentration of fruit spurs increases the amount of fruit harvested (17, 29). 3) Removal of lower fruiting laterals that are too close to the ground for a machine harvester will eliminate a source of over ripe fruit which is susceptable to fungus disease. Removal of these lower canes can be done by hand pruning or with a chemical compound such as dinoseb (34).

CANE CHARACTERISTICS ASSOCIATED WITH PRIMOCANE FRUITING RED RASPBERRY

Thomas E. DeGomez

Additional index words. Rubus ideaus, vegetative growth, fruit.

Abstract

Cultivars 'Amity' and 'August Red' showed differences in vegetative and fruiting characteristics. 'Amity' is much more vigorous having greater cane length and diameter, larger leaf area and the first fruiting node is higher above ground level. 'August Red' possesses a greater number of fruiting sites and fruits set per cane and a higher percent fruit set. Vigor and fruiting ability of both cultivars improved over a two year period. In both cultivars, vegetative characteristics of cane length, cane diameter and leaf area where positively correlated with number of fruit per cane.

Introduction

Little is known about the morphology of primocane fruiting (PF) red raspberry. To better understand their vegetative and fruiting habits a comparative growth analysis of two cultivars was made. The cultivars were 'August Red', the most widely grown PF red raspberry in the Pacific Northwest and 'Amity' a new cultivar developed in Oregon.

'August Red' has many traits that are desirable for a PF cultivar. It produces a reasonable size crop early in the summer on well-supported canes. However its fruit is light colored and crumbly (F. Lawrance, personal communication). 'Amity', though not a good early producer has excellent fruit quality on well-supported canes (5). The purpose of this study was to gain a better understanding of the vegetative and reproductive characteristics of PF red raspberries in order to improve their culture and management.

Cane growth and development of floricane fruiting types have been studied, providing a better understanding of how cane characteristics influence their yield. Studies as early as 1927 found cane diameter to be associated with increasing yields (4,7). Darrow and Waldo (3) in 1934 found that five of six cultivars had a greater number of berries on larger diameter canes. The number of buds/cane did not contribute to greater yields in several studies (3, 4). Both Johnston (4) and Locklin (7) found that the number of fruit/node increases in the basal direction. Much of this early work has encouraged later researchers to look at these and other cane characteristics that may contribute to greater yields. Crandall et al. (1, 2) in two studies found a positive correlation between cane diameter and yield and

between cane density and yield. Martin et al. (8) in 1980 didn't find the cane characteristics studied to influence yield. Most certainly cultivar has a great deal to do with whether cane characteristics influence yield. For this reason this study will compare cane characteristics of 2 cultivars over a 2 year period and determine similarities and differences in the vegetative and reproductive structures of the canes.

Materials and Methods

In the spring of 1981 the Malensky farm (MF) near Hillsboro, Oregon established adjacent commercial fields of 'Amity' and 'August Red' red raspberry. Dormant plants were planted 76 cm apart in rows separated by 3 m. In the fall of 1982, after growth had ceased, five 'Amity' canes were randomly selected and removed at ground level from the middle 30.5 m of five 91.5 m rows. In the fall of 1982 and 1983, after growth ceased, five 'August Red' canes were randomly selected and removed at ground level from the middle 30.5 m of five 91.5 m rows. In the spring of 1980 the North Willamette Experiment Station (NWES), near Aurora, Oregon established a row of 'Amity'. Dormant plants were planted 76 cm apart in one 125 m row. In the fall of 1982 and 1983, after growth had ceased, 25 canes were randomly selected and removed at ground level from the middle 30.5 m of the row.

The vegetative characteristics determined from the removed canes were cane diameter 30 cm from base, cane length, total leaf area (using an electronic area meter), length from soil surface to the first fruiting node, and number of vegetative (non-flowering) nodes. Reproductive characteristics measured were: flowering nodes, number of fruit produced per cane, number of flowers and fruiting sites (buds and flowers) per cane and percentage of fruit sites that set fruit. All measurements were taken at the end of the growing season prior to senscence of the leaves.

Results and Discussion

'Amity' vs 'August Red', 1982. Vegetative and fruiting characteristics were much different for 'Amity' and 'August Red'. 'Amity' cane diameter and leaf area were greater but not significantly, however, cane length and distance to the first fruiting node were significantly greater (Table 1.1). The increased vigor of the 'Amity' canes did not result in greater numbers of fruit being set, the smaller 'August Red' canes had 68 fruits compared to only 40 for 'Amity'. The greater number of fruits set on 'August Red' canes was due to more fruit sites/cane and greater percent set (Table 1.1).

The longer 'Amity' canes would not hinder machine harvesting. The greater distance to the first fruiting node would enable mechanical harvesters to pick a higher percent of the ripe berries. Low growing fruit, below 25 to 60 cm, are difficult or impossible to machine harvest (6, 9, 10).

'August Red' sets a greater percentage of its fruit by the end of the season than does 'Amity'. Breeders classify 'August Red' as early ripening and 'Amity' as a mid season cultivar (F. Lawrence, personal communication). Since 'Amity' appears to be inherently later maturing the correlation of cane characteristics to the setting of fruit may reveal which cane characteristics contribute to increased fruit numbers.

Both cultivars had a positive correlation between the number of fruits set/cane and cane diameter, cane length and leaf area (Table 2). Thus cultural practices enhancing vegetative growth to increase growth may lead to PF red raspberries having a greater number of

fruits set per cane.

'August Red', 1982 vs 1983. Differences in cane and fruiting characteristics due to year were not significant, except for cane length, which was 16.3 cm higher the second year. Cane diameter increased from one year to the next (Table 1.3). Non-significant increases in number of fruit sites per cane, fruits set per cane and fruit set percentage occurred from 1982 to 1983 (Table 1.3). Even though these figures were not significant it appears that a trend was towards larger more fruitful canes.

Correlations (Table 1.4) indicate that as canes become more vigorous that number of fruit sites and number of fruits set increase. 'August Red' canes appear to become more vigorous over time. Improved cultural methods may increase vigor and enhance fruiting capability.

'Amity', 1982 vs 1983. From 1982 to 1983 there was a significant increase in cane diameter and cane length. Cane length increased over 24 cm from the previous year (Table 1.5). Number of fruit sites per cane increased slightly from 1982 to 1983 and number of fruits set per cane increased but neither were significant. Fruit set percentage rose signficantly 57.1% to 74.4% which explains the increase of 10.4 fruits set per cane with only 2.9 additional fruiting sites (Table 1.5).

As with 'August Red', correlations indicate that larger more vigorous canes carry more fruit (Table 1.6). 'Amity' canes become larger and more vigorous over time thus the investigation of management practices to enhance 'Amity's' vegetative growth may

improve fruiting capability.

The general trends for both cultivars, compared separately, is that older canes are more vigorous and possess a greater fruiting potential. When compared together 'Amity' has the more vigorous canes but 'August Red' has the greater fruiting capacity. For both cultivars, increased vigor corresponds to greater fruiting capacity.

Cultural practices that increase vegetative growth will increase fruiting capacity. Good soil fertility, proper irrigation, disease and insect control, plastic mulches and clouches may be ways to optimize vegetative growth.

Table 1.1. Cane Characteristic data for 'Amity' and 'August Red' red raspberries MF[z], 1982.

Cane Characteristic	'Amity'	'August Red'
Cane diameter (cm)	.74a[y]	.68a
Cane length (cm)	123.0a	96.4b
Number of vegetative nodes	19.9a	12.9b
Number of fruit nodes	14.1a	15.6a
Number of flowers	62.3a	74.9a
Number of fruits set	40.1b	67.6a
Fruit set (percentage)	61.9b	80.4a
Leaf area (cm^2)	1462a	1190a
Length to 1st fruiting node (cm)	81.0a	44.3b

[z]Malensky Farm, Hillsboro, Oregon.
[y]Mean separation within rows by Duncan's multiple range test, 5% level.

Table 1.2. Correlation of cane characteristics for 'Amity' and 'August Red' red raspberries MF[z], 1982[y].

	Correlation Coefficients		
	Cane diameter	Cane length	Leaf area
Number of fruits set	.599**[x]	.489*	.681**
	.765**	.469*	.567**

[z]Malensky Farm, Hillsboro, Oregon.
[y]Values in bold face type for 'Amity', italicized for 'August Red'.
[x]**Double asterisks indicate correlation significant at 1% level, * single asterisk at 5% level.

Table 1.3. Cane Characteristics of 'August Red' red raspberries MF[z], 1982 and 1983[y].

Cane Characteristic	1982 'August Red'	1983 'August Red'
Cane diameter (cm)	.68a	.76a
Cane length (cm)	96.4b	112.7a
Number of vegetative nodes	12.9a	11.2a
Number of fruit nodes	15.6b	17.8a
Number of flowers	74.9a	91.0a
Number of fruits set	67.6a	81.7a
Fruit set (percentage)	80.4a	90.6a
Leaf area (cm^2)	1190a	1193a
Length to 1st frt. node (cm)	44.3a	43.3a

[z]Malensky Farm, Hillsboro, Oregon.
[y]Mean separation within rows by Duncan's multiple range test, 5% level.

Table 1.4. Correlation of cane characteristics for 'August Red' red raspberry MF[z], 1982 and 1983[y].

	Correlation Coefficients			
	Cane diameter	Cane length	Leaf area	Number of fruit sites
Number of fruits set	.765**[x]	.469*	.567**	.846**
	.640**	**.559****	**.749****	**.972****
Number of fruit sites	.832**	.382*	.753**	
	.594**	.600**	.666**	

[z]Malensky Farm, Hillsboro, Oregon.
[y]Values in bold face for 1982, italicized for 1982.
[x]**Double asterisks indicate correlation significant at 1% level, *single asterisk at 5% level.

Table 1.5. Cane Characteristics of 'Amity' red raspberries NWES[z], 1982 and 1983[y].

Cane Characteristic	'Amity' 1982	'Amity' 1983
Cane diameter (cm)	.66b	.78a
Cane length (cm)	93.4b	117.5a
Number of vegetative nodes	19.4b	23.5a
Number of fruit nodes	12.9b	15.4a
Number of flowers	54.0a	56.9a
Number of fruits set	33.2a	43.6a
Fruit set (percentage)	57.1b	74.4a
Leaf area (cm^2)	1299a	1423a
Length to 1st frt. node (cm)	44.3a	43.3a

[z]North Willamette Experiment Station.
[y]Mean separation within rows by Duncan's multiple range test, 5% level.

Table 1.6. Correlation of cane characteristics for 'Amity' red raspberry NWES[z], 1982 and 1983[y].

	Correlation Coefficients			
	Cane diameter	Cane length	Leaf area	Number of fruit sites
Number of fruits set	.706**[x]	.744**	.846**	.924**
	.509*	.443*	.637**	.945**
Number of fruit sites	.592**	.637**	.800**	
	.607**	.554**	.651**	

[z]North Willamette Experiment Station.
[y]Values in bold face for 1982, italicized for 1983.
[x]**Double asterisks indicate correlation significant at 1% level, *single asterisk at 5% level.

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EFFECT OF NITROGEN AND PRUNING ON PRIMOCANE FRUITING RED RASPBERRY (Rubus ideaus L.) 'Amity'

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Additional Index Words. Fruit set, machine harvest, fall fruiting, cane characteristics.

Abstract

Two nitrogen and 3 pruning methods were studied for their effect on earliness of flowering and the subsequent effect on yield and cane characteristics. The treatment effect on the canes self supportiveness was also observed. Time of flowering and the time required for fruit ripening to occur were unaffected by any treatment. The distribution of fruit on the cane was greatest at the basal end fewest at the apical end. The largest fruits were found at the apical end and the smallest at the basal end. High N, 135 kg/ha vs. 67 kg/ha, increased yield late in the harvest season resulting in 14% higher yield increased 14% (8.1 vs. 7.0 MT/ha). Pruning back the current season primocane growth to 40 cm above the ground had a detrimental effect on yield per cane but due to an increase in the number of branched canes total yield was greater (not significantly however) 8.0 MT/ha vs. 7.5 and 7.0 MT/ha for dormant cane pruning at 20 cm and 0 cm respectively. None of the pruning treatments improved the self supporting cane characteristic.

Introduction

Self supporting, machine harvestable, primocane fruiting (PF) red raspberries could offer many advantages to growers in the Pacific Northwest if production and fruit quality problems are overcome (6). A newly released cultivar, 'Amity', has excellent fruit quality but production problems still need to be resolved. Non-supporting canes and late maturing fruit, which is damaged by early fall rains, are two major difficulties that need to be overcome. The possibility of reducing these production problems with the use of nitrogen fertilizer and pruning treatments was examined.

Lockshin and Elfving (10) concluded that N stimulated vegetative growth and shortened the time required for flowering to occur in PF 'Heritage'. Neither height of dormant cane pruning or pruning during growing season which stimulates branching, have been tested as a means to promote self-supporting canes for machine harvesting. Brierley (2) concluded that pruning of mature canes increased the number of laterals. Increased lateral growth of PF canes has been observed by the author to contribute to the self-supporting characteristic. Greater cane diameter may lead to a sturdier, self supportive cane. N and pruning treatments have increased cane diameter (11, 13).

Vegetative and fruiting characteristics may be linked to earliness, self supportiveness and yield. Past studies have shown that growth and fruiting habits can be indicators of yield (3, 5, 9, 11).

Materials and Methods

In April 1982, dormant plants of 'Amity' were planted on a silty loam soil 76 cm apart in six rows separated by 3 m. Using a randomized block design, the four inner rows were partitioned into 7.6 m plots with 6 treatments per row (two nitrogen x three pruning methods). Nitrogen, as ammonium nitrate, was side dressed by hand at either 67 or 135 kg N/ha. Nitrogen was split into three applications (March 14, April 21 and May 27, 1983) to minimize leaching by heavy spring rains. Pruning treatments consisted of cutting one year old canes to; a) ground level on March 14, 1983 (0 cm); b) at 20 cm above ground level (20 cm); and c) at ground level in March followed by a second cut at 40 cm on May 13 (0 + 40 cm). Ten canes were randomly selected from each plot to measure growth and yield characteristics.

Earliness of flowering and fruiting was determined by monitoring the uppermost four buds of the 10 canes for dates at which anthesis, fruit set and fruit ripening occurred. Four buds at the apical end were selected because they would be the first buds to reach anthesis (14). Self-supporting characteristics were observed visually and notes made as to whether machine harvesting could have been possible without a trellis.

Number of fruit per cane was counted by cane section; top (apical nodes 1-5), middle (nodes 6-10) and bottom (all lower fruiting nodes, an average of 7); from the 10 randomly selected canes. Branching and long lateral growth occurred on many canes and was common with pruning treatment 0 + 40 cm. Laterals with 15 or more nodes were designated branches and were considered separate from the original cane.

Laterals with less than 15 nodes were considered part of the cane from which they originated. Fruit weight and number of berries from each cane section were used to determine mean berry weight (weight ÷ number of berries) and number of berries per cane. Yield per cane was determined by maintaining records on the 10 select canes. Total yield was obtained by hand harvesting all remaining canes and adding this to the yield of the 10 canes. Fruit was picked from the 10 canes on 13 dates from August 8 until September 27. Harvesting for total yield occurred 14 times starting on July 28, lack of pickers ended harvesting on September 12.

At the end of the harvest season, five canes each were randomly selected from the 10 canes and the following measurements were taken: cane diameter 30 cm from base, total leaf area (using an electronic area meter), cane length, number of vegetative and flowering nodes, number of flower and fruiting sites per node, and percent fruit set (number of fruit ÷ number of flowering sites x 100). Total number of canes and branches per plot were also determined.

Results and Discussion

Nitrogen did not appear to effect early flowering or early fruit ripening (Figure 2.1). Days from anthesis to fruit set and from fruit set to ripening averaged 4.4 and 27.0 days respectively for both N treatments. Since early yield differences were not significantly different and the ripening process was not shortened it appears that N had no effect on earliness of harvest. More days were required to ripen fruit as the season progressed possibly because of shortening of day length and light availability.

Total fruit yield was significantly, 10% level, greater at the high than low N treatment, 8.1 and 7.0 MT/ha respectively. This increase resulted from greater yields late in the season under high N (Figure 2.1). Fruit yields were low in early harvest and there may not have been high enough fruit to justify commercial harvesting by machine until August 15 when 223 kg of fruit/ha was obtained with high N. From August 15 until the end of the season yields for the high N treatment averaged 1.0 MT/ha per harvest, with yields increased through the season with the heaviest picking (2.0 MT/ha) on September 12. The combined fruit yield of the last four harvest dates was 20% greater at high than low N. The increase in yield of 'Amity' with high N agrees with past work. High N has been linked with increased yields in many studies but increases generally occur only in the early years of the experiment while the planting is becoming established (4, 7, 8, 11).

Producers in the Pacific Northwest could take advantage of the enhancement of yield due to N since in most years harvesting could

continue through mid-September. Brierley (1) plotted yield of the floricane fruiting red raspberry cultivar 'Latham' through the season and found that peak yield was at mid-season. If harvesting of 'Amity' from the whole plot had continued after mid September a decline in yield would have been observed. Fruiting characteristics from the 10 canes can be used to illustrate the inevitable late season decline. The average cane had 92 fruit sites (Table 2.1) and by September 27, 64 (70%) of these sites had produced ripe fruit (Table 2.2). Individual cane yield peaked during the September 2 to 12 harvest period (Table 2.3). The two additional pickings of the 10 canes, September 19 and 27 yielded increasingly less fruit per individual cane (Table 2.3).

Yield components did not vary significantly with N treatment. Mean berry weight declined whereas number of fruit per cane increased during the season then declined after mid-September (Table 2.3). The number of fruit produced per cane section increased markedly in the basipetal direction with the bottom section yielding 6 times that of the top section, however, fruit size decreased from top to bottom of the cane (Table 2.2). Late season increases in yield came from berries ripening on the lower nodes (Figure 2.2). Other workers (5, 9) have found that number of fruit increased in a basipetal direction on the cane. Fruit size, though smaller at the end of the season, did not appear to be a major factor in reducing late season yield. The smaller size fruit was offset by a much greater number of berries. In floricane cultivars, Locklin (9) found the heaviest fruits at the central part of the cane whereas Johnston & Loree (5) found the largest berries at the base of the and the smallest at the apical end

of the cane.

Pruning at 0 + 40 cm yielded 8.0 MT/ha compared to 7.5 and 7.0 MT/ha, for the 20 cm and 0 cm treatments, respectively. The higher total yield with 0 + 40 cm pruning resulted from greater yields very late in the season (Table 2.2). However individual canes pruned at 0 + 40 cm yielded 37% less fruit than those pruned at 20 cm (Figure 2.3). Even though individual canes in the 0 + 40 cm treatment were less productive than those in other pruning treatments total yields were greater due to a 2.6 fold increase in branching stimulated by the 40 cm pruning on May 13 (Table 2.1). As was seen by Norton (12) and Lawson & Waister (7), individual cane yields did not determine total yield as much as the number of canes/ha. Johnston & Loree (5) reported that heading back dormant canes increased yields by stimulating branching. As number of canes per plot rose in the 0 cm and 20 cm treatments the number of branched canes decreased (Table 2.4). Whereas with the 0 + 40 cm pruning treatment branches multiplied as the number of canes increased (Table 2.4), suggesting that branching is due to a physiological control mechanism and not spacing. Brierley (2) found a similar response with canes that were headed back in the dormant state.

The ground level pruning produced the largest berries but pruning at 20 cm yielded a great many more fruits especially in the bottom section, the highest producing cane section (Table 2.2).

The 20 cm treatment canes increased fruit set percentage, number of fruits set and number of fruit sites per cane with a fewer number of fruit nodes per cane compared to 0 cm. 0 + 40 cm pruned canes had the lowest fruit set percent, fewest number of fruits set, fruit sites

and fruit nodes per cane (Table 2.3). 20 cm pruned canes produced greater cane diameter, cane length and possessed the most leaf area per cane, 0 cm was similar to 20 cm. 0 + 40 cm pruned canes had the smallest cane diameter and cane length with a much reduced leaf area (Table 2.3). The fruiting and vegetative characteristics further illustrate that the 40 cm pruning decreased individual cane size and fruiting capacity.

PF cultivars have shown to be self supporting (6) however we did not find 'Amity' to have self supporting canes. Pruning treatments affected cane diameter and cane branching (Table 2.1) however this change did not alter the cultivars ability to be self supportive. Early in the season we observed the young canes standing upright but as the fruit load developed many canes fell into the rows. Machine harvesting would not have been possible without a trellis after mid-August.

Table 2.1. Effect of pruning on vegetative and fruiting characteristics, 'Amity' red raspberry[z].

	Pruning treatment			
	0 cm	20 cm	0+40 cm	Average
Vegetative				
Cane diameter (cm)	.92ab	1.00a	.82b	.91
Cane length (cm)	122.5	122.8	111.0	118.8
Leaf area (cm^2)	2789a	2947a	1827b	2521
Canes per plot	14.3	12.1	12.9	129.8
Branches per plot	35.5b	34.8b	92.6a	54.3
Vegetative nodes per cane	21.0	20.5	20.2	20.6
Fruiting				
Fruiting nodes per cane	18.0	17.5	16.3	17.3
Fruiting sites per cane	97.8a	109.5a	67.1b	91.5
No. of fruitings set	84.1a	93.1a	56.5b	77.9
Fruiting set percentage	84.0	85.8	83.0	84.3
Berry weight (g)	3.27a	3.01b	3.08ab	3.12
Anthesis to fruit set (days)	4.3ab	4.7a	4.1b	4.4
Fruit set to ripening (days)	27	27	27	27

[z]Mean separation within rows by Newman-Kuels multiple range test, 5% level.

Table 2.2. Effect of pruning on total yield by harvest date, fruit weight and number of fruit by cane section, 'Amity' red raspberry.

Pruning treatment	Total yield by date (MT/ha) 8-23	8-26	8-30	9-2	9-7	9-12	Weight/fruit (g) per cane section Top	Middle	Bottom	Number of ripe fruit by cane section Top	Middle	Bottom	Total
0 cm	0.6	0.9	1.1	1.0	1.1	1.5b[z]	3.7a	3.3bc	2.8d[y]	6.7e	18.1d	41.4b	66.2
20 cm	0.7	1.0	1.0	1.1	1.1	1.6b	3.1cd	3.1cd	2.9cd	7.2e	19.0d	49.8a	76.0
0+40 cm	0.6	1.1	1.2	1.1	1.3	2.2a	3.4ab	2.9cd	2.8d	6.5e	13.2de	31.2c	50.9
Mean	0.7	1.0	1.1	1.1	1.2	1.8	3.4r	3.1s	2.8t[x]	6.8t	16.8s	40.8r	64.4

[x]Mean separation within rows by Newman-Kuels multiple range test, 5% level.
[y]Mean separation within rows and columns by Newman-Kuels multiple range test, 5% level.
[z]Multiple comparison within columns by Bonneferroni, 5% level.

Table 2.3. Effect of nitrogen on number of fruit by harvest interval and fruit weight by cane section and harvest interval, 'Amity' red raspberry.

Nitrogen treatment	July 28 - August 11	August 15 - Aug. 30	September 2 - Sept. 12	September 19 - Sept. 27	Weight/fruit (g) by cane section[z]		
	Number of fruit per cane by harvest interval				Top	Middle	Bottom
67 kg/ha[z]	.7d	22.0b	27.5a	13.0c	3.3b	3.1b	2.7d
135 kg/ha	.8d	19.1b	26.5a	19.3b	3.5a	3.2b	2.9c
Mean[y]	.8o	20.5m	27.01	16.2n	3.4	3.2	2.8
	Weight/fruit (g)[y]						
Mean	3.7r	3.5r	3.1s	2.4t			

[z]Mean separation within rows and columns by Newman-Kuels multiple range test, 5% level.
[y]Mean separation within row by Newman-Kuels multiple range test, 5% level.

Table 2.4. Correlation for cane density vs. branch density by pruning treatment, 'Amity' red raspberry.

Pruning treatment	cane density vs. branch density
0 cm	-.531[z]
20 cm	-.602
0 + 40 cm	+.910

[z]Correlation significant at 1% level with value of ±.835.

Figure 2.1. Yield by harvest date for nitrogen treatments, 'Amity' red raspberry.

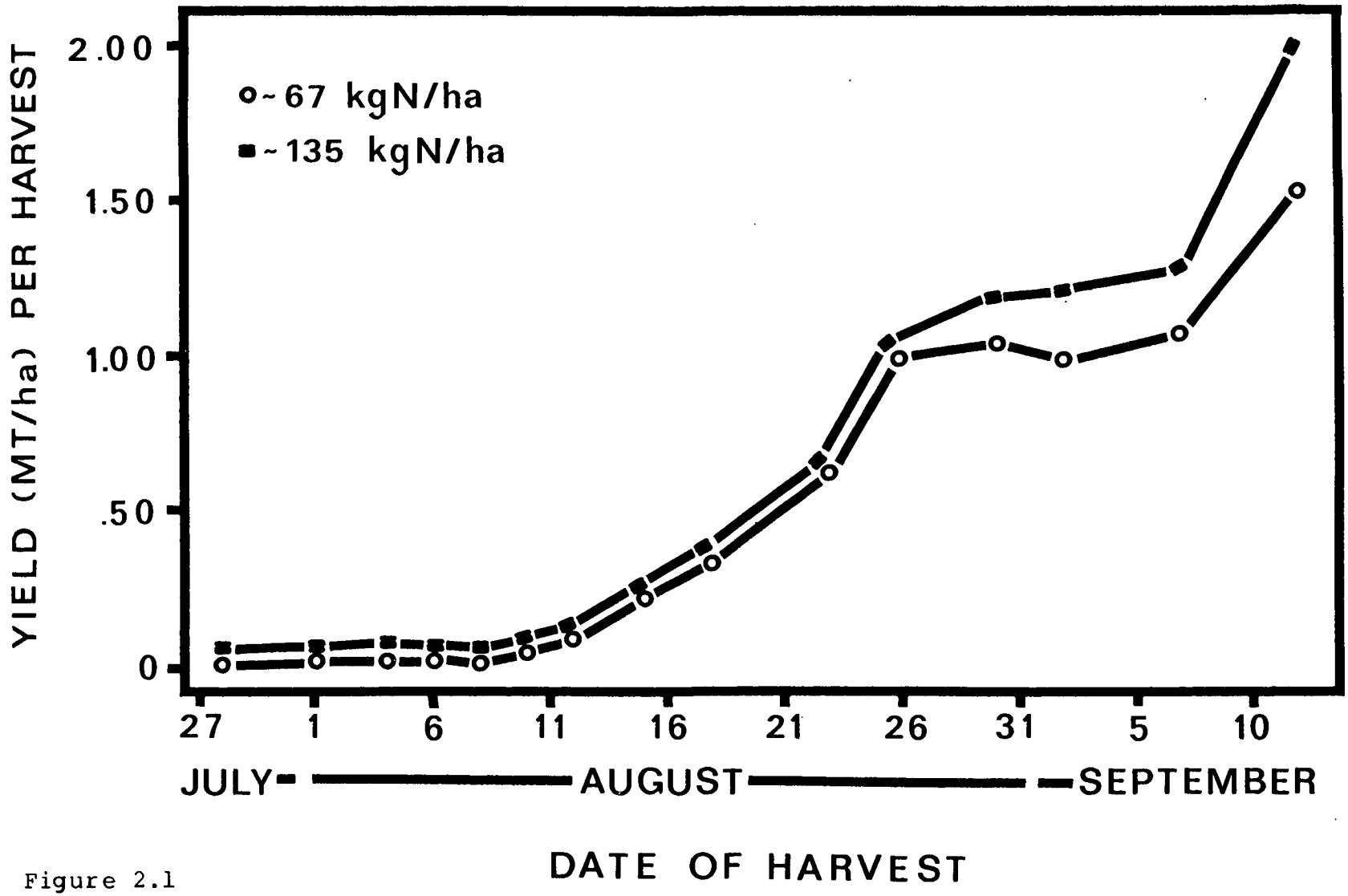
YIELD (MT/ha) PER HARVEST
2.00
1.50
1.00
.50
0
~67 kgN/ha
~135 kgN/ha
27
1
6
11
16
21
26
31
5
10
JULY
AUGUST
SEPTEMBER
DATE OF HARVEST

Figure 2.1

Figure 2.2. Number of fruit per cane section by harvest period. Cane sections are; top (apical nodes 1-5), middle (nodes 6-10), and bottom (all lower fruiting nodes, an average of 7). Mean separation by Newman-Kuels multiple range test, 5% level.

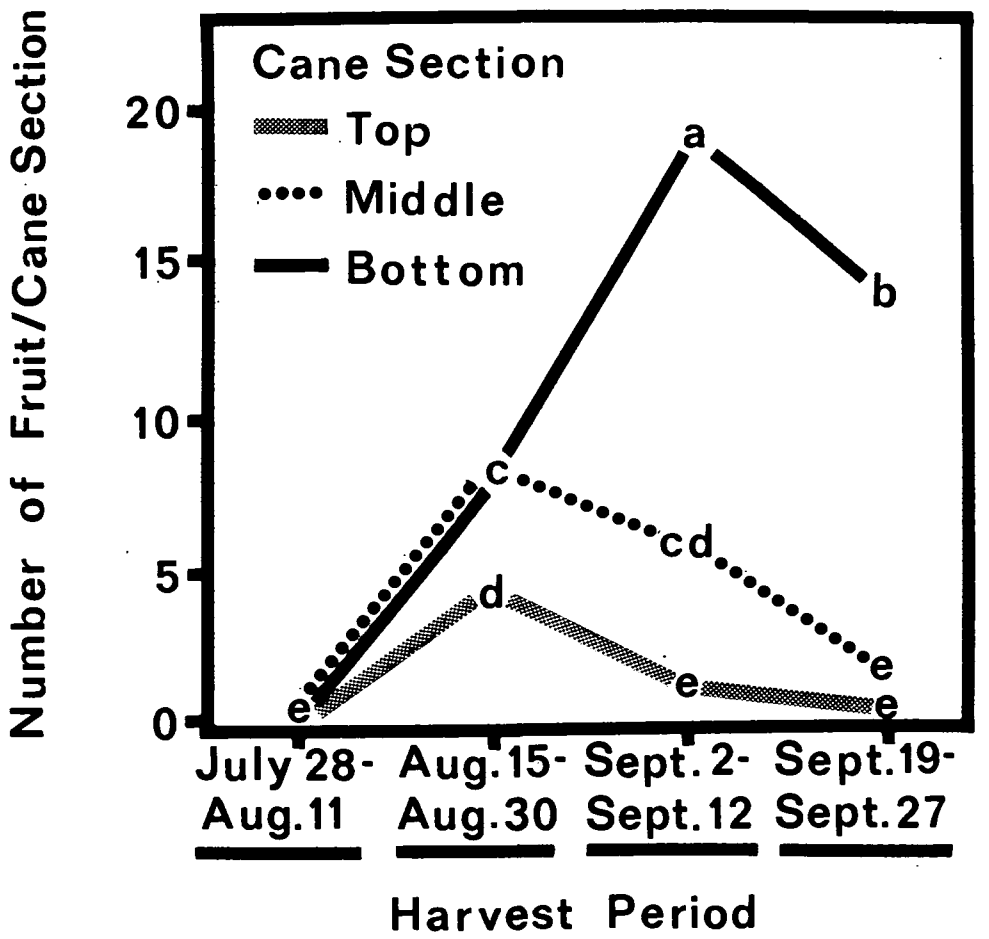
Number of Fruit/Cane Section
Cane Section
Top
Middle
Bottom
20
15
10
5
0
a
b
c
cd
d
e
e
e
July 28-
Aug.11
Aug.15-
Aug.30
Sept.2-
Sept.12
Sept.19-
Sept.27
Harvest Period

Figure 2.2

Figure 2.3. Yield per cane accumulated during the harvest season for pruning treatments, 'Amity' red raspberry. Pruning treatments consisted of cutting one year old canes to ground level on March 14, 1983 (0 cm), at 20 cm above ground level (20 cm), and ground level in March followed by a second cut at 40 cm on May 13 (0 + 40 cm). 0 + 40 cm treatment is significantly different than 0 cm or 20 cm treatments by Newman-Kuels multiple range test, 5% level.

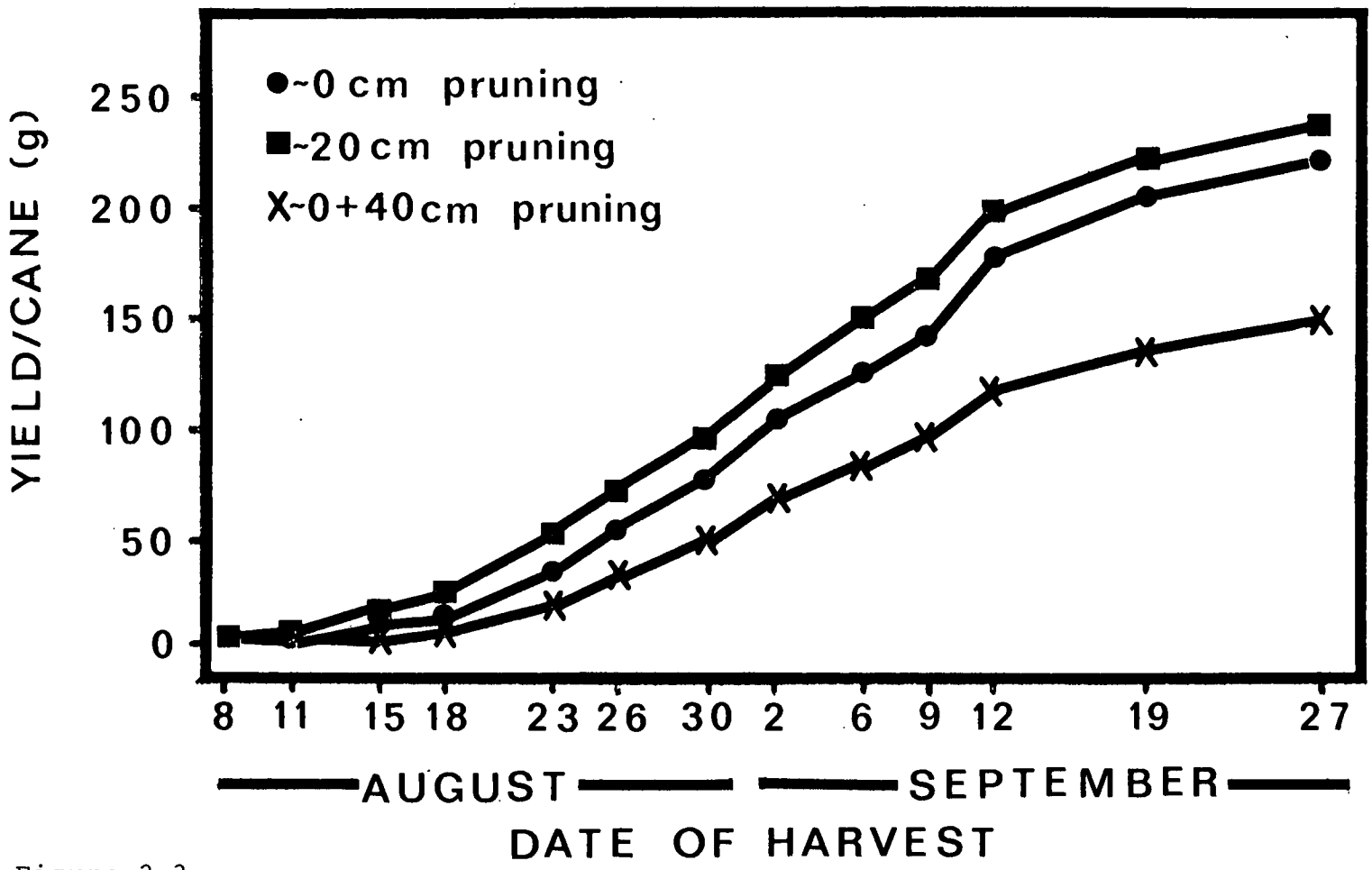
●~0 cm pruning
■~20 cm pruning
X~0+40cm pruning
YIELD/CANE (g)
250
200
150
100
50
0
8 11 15 18 23 26 30 2 6 9 12 19 27
AUGUST
SEPTEMBER
DATE OF HARVEST

Figure 2.3

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GENERAL CONCLUSION

Even though earliness of flowering and cane self supportiveness was not affected by the treatments the quantity of fruit harvested prior to September 15 was encouraging. The high nitrogen treatment yield of 8.1 MT/ha is well above the 5.6 MT/ha the industry needs to make primocane fruiting red raspberry culture profitable.

Producers using machine harvesters can expect estimated yields to be 10 to 25% less than hand picked yields (18). The 8.1 MT/ha hand picked would drop to 6.1 to 7.3 MT/ha when machine picked (assuming 25% loss due to machine harvesting). Machine harvesting would not be feasible as early in the season as was hand picking for this study. Time of first machine harvest would vary depending on the market price of the fruit. As the price of the fruit increases early harvesting becomes profitable. If the price paid for berries had been $.66 per kilogram, at the beginning of the harvest of this study, profitable machine harvesting could have started on August 17 (Figure A-1). At $.88 per kilogram picking could have started 3 days earlier.

According to observations and the conditions of this study, 'Amity' could not have been machine harvested without a trellis system. Trellising the floricane type red raspberry is a labor intensive practice. The old canes must be hand pruned out of the rows and the new canes hand tied to the support wires. However the system used to train PF red raspberries need not be as costly. Short, light weight wire support posts easily removed for machine pruning is all that appears to be required. The canes need not be tied to the two wires but simply allowed to grow up between the wires. Alternatively, the system could be installed prior to harvest by training the canes

up as the wires are lifted into the support posts.

Further investigations of 'Amity' should include a continuation of the effect of nitrogen fertilizer and pruning method on older stands. The trend in previous studies is that the greatest response to nitrogen occurs during the establishment years, thus a continuation of this study will help to determine nitrogen needs for established PF red raspberries. Pruning methods should be tested for their suitability to machine harvesting. The canes that were pruned during the growing season (0 + 40 cm) had a great amount of branching and those branches may be susceptible to breakage by machine harvesting. The canes that were pruned 20 cm above the ground had early fruit produced on short low growing laterals. This fruit may be too close to the ground to be mechanically harvested and may become a source of disease.

Different types of trellis systems should be tested for their adaptability to PF red raspberry culture and machine harvesting, taking into account the labor required to implement the system, its initial cost, and its adaptability to mechanical pruning.

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APPENDICES

Table A-1. Effect of nitrogen on vegetative and fruiting characteristics, 'Amity' red raspberries.

	Nitrogen Treatment		
	135 kg/ha	67 kg/ha	Average
Vegetative			
Cane diameter (cm)	.91	.92	.91
Cane length (cm)	117.4	120.2	118.8
Leaf area (cm^2)	2284	2758	2521
Cane per plot	127.9	131.6	129.8
Branches per plot	46.3	62.3	54.3
Vegetative nodes per cane	20.6	20.5	20.6
Fruiting			
Fruit nodes per cane	17.4	17.1	17.3
Fruit sites per cane	84.8	98.1	91.5
No. of Fruits set	72.5	83.4	77.9
Fruit set %	85.9	82.9	84.3
Berry weight (g)	3.04	3.19	3.12
Anthesis to fruit set (days)	4.4	4.4	4.4
Fruit set to Ripening (days)	27	27	27

Table A-2. Leaf analysis values for 'Amity' red raspberry, by nitrogen treatment, sampled on July 1 and August 23, 1983.

Nitrogen treatment	Percent Dry Matter					ppm
	N	P	K	S	Mg	B
July 1						
67 kg/ha	3.73	.48	1.83	.14	.46	15
135 kg/ha	3.80	.48	1.88	.14	.46	14
August 23						
67 kg/ha	2.28	.24	.78	.11	.58	53
135 kg/ha	2.69	.24	.76	.12	.69	42

Figure A-1. Machine harvest breakeven point using hand harvest yield data. Assuming 3 day machine harvest intervals, with 'Littau Harvester' at $47.00 per hour operation costs and 75% picking efficiency, 66 and 88 cents per kilogram of berries.

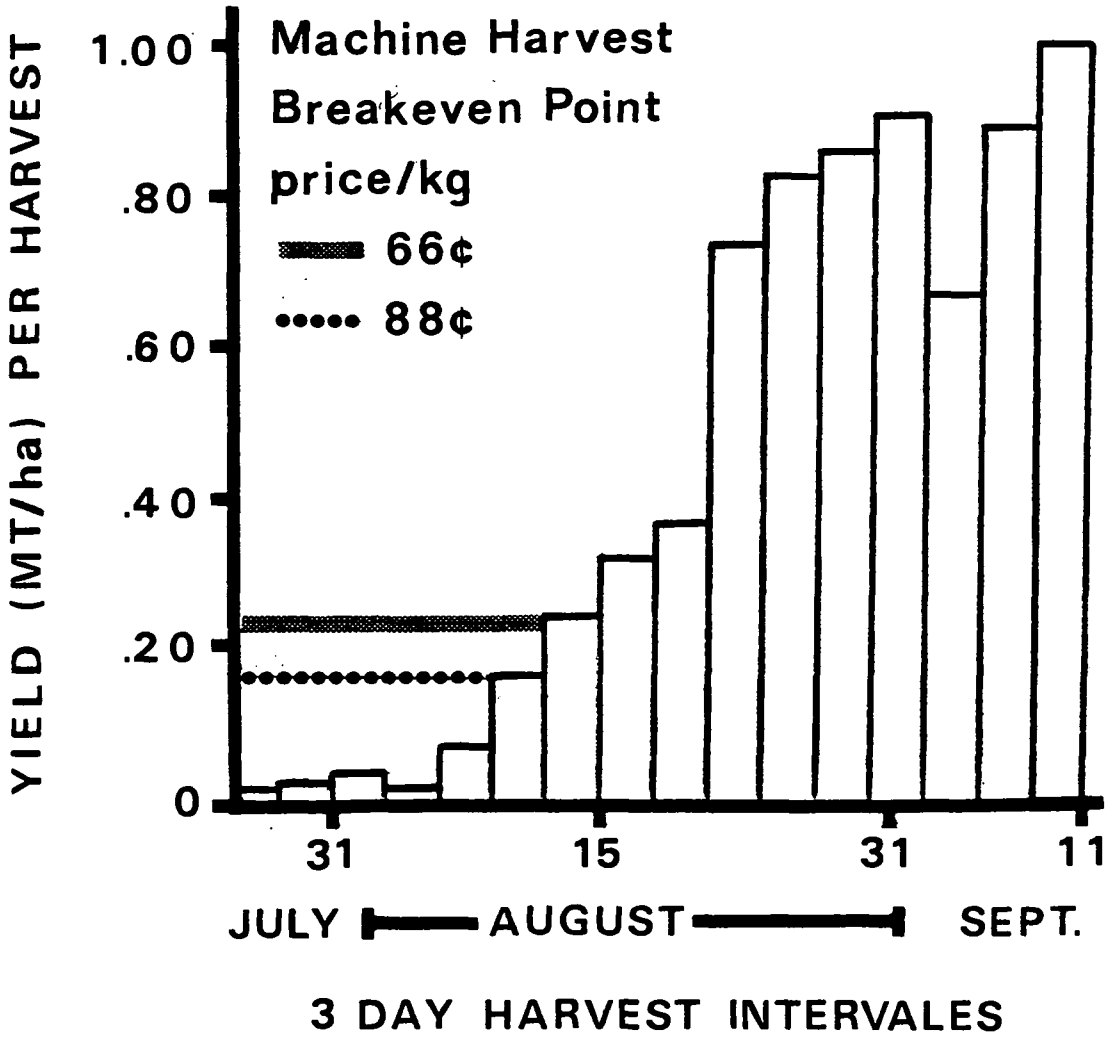
YIELD (MT/ha) PER HARVEST
1.00
.80
.60
.40
.20
0
Machine Harvest
Breakeven Point
price/kg
66¢
88¢
31
15
31
11
JULY
AUGUST
SEPT.
3 DAY HARVEST INTERVALES

Figure A-1