J. Amer. Soc. Hort. Sci. 113(6):824–826. 1988.

Vegetative and Reproductive Yield Components of Primocane-fruiting Red Raspberries

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Additional index words. ever-bearing, fall-fruiting, *Rubus*, path analysis

Abstract. **Selection criteria to identify primocane-fruiting red raspberry seedlings (*Rubus idaeus* L.) with high, early yield are desirable in regions with short growing seasons. To identify possible parents contributing these desirable characteristics, 'Heritage', 'Redwing', and two genotypes from the Minnesota breeding program were subjected to yield component analysis. In all genotypes, yield was determined by canes/meter of row, fruit per node, and fruit weight. Over the 3-year period, 'Heritage' had the highest yield/meter of row, yield per cane, fruit per cane, and number of fruit per fruiting node among all genotypes. Component compensation was highest for 'Redwing', while MN 652 had the greatest degree of independence among components. In selecting seedlings for early fruiting and high yield, high cane densities and/or large fruit size will be needed.**

Primocane-fruiting red raspberries flower during summer at the apices of current season's growth. Fruit ripens in late summer and fall (11). This fruiting habit has evoked considerable interest because it a) allows the harvest season to be extended, b) allows pruning costs to be reduced by mowing canes in the dormant season, c) avoids winter injury to canes and d) precludes extensive trellising of these sturdy primocanes (18).

'Heritage' is the most productive and widely grown primocane-fruiting cultivar. The major production problem with 'Heritage' in northern areas is relatively late flowering and the subsequent loss of fruit during early fall freezes (10). Earlier flowering and fruiting can be obtained in 'Heritage' by early promotion of growth (14, 24). Suppression of primocane growth with butanedioic acid mono (2,2-dimethylhydrazide) (daminozide) also induces earlier flowering (1, 2, 4). These cultural manipulations affect assimilate partitioning by reducing the number of vegetative nodes and hastening anthesis, thus having a positive effect on early yield. Breeding for time of anthesis is an alternative to cultural manipulations for producing earlier fruit.

Yield component analysis has provided information on the partitioning of resources within the plant and is useful in evaluating breeding material and selecting parents (6, 7, 19). This analysis can also be used to predict the effects of cultural modifications such as pruning (22), improved pollination (21), plant spacing and irrigation (20), planting date (19, 23), and fertilization (15). We compare yield component analyses of primocane-fruiting red raspberry genotypes from the Minnesota breeding program with 'Heritage'. The analyses were designed to determine which components are important within genotypes for contributing characteristics that influence yield.

Materials and Methods

'Heritage', 'Redwing' (16), MN 652 ('Reveille' x MN 618), and MN 659 ('Reveille' x 'Chief') plants were set in 1979 in 3.6 × 0.5 m plots on a Hayden sandy loam at the Horticultural Research Center, Excelsior, Minn. Standard cultural practices for fertilization, pest, and weed control were followed. In the Spring of 1982 through 1984, plots were mowed in early spring and yield component data were collected during the summer. The center 2.4 m of each plot was harvested every 4 to 7 days, starting on 1 Aug., and a 20-fruit sample was weighed. Cane density, total number of nodes, and number of fruiting nodes, fruit per lateral, fruit weight, and total yield were determined at the end of each fruiting season. The plot was designed and data were statistically analyzed as a randomized complete block with four replications, blocking over years.

The "W" statistic of Hardwick and Andrews (8) was calculated for each genotype as described by Siefker and Hancock (22). Values of W approaching 0.5 indicate independence of components, while values near 0 indicate compensation and values near 1.0 indicate additivity.

Path coefficients (standardized partial regression coefficients) also were calculated to examine the interrelationships among yield components (6, 7, 13, 25). For path analysis, data were combined across years, logarithmically transformed to make the dependence structure linear, and standardized to a mean of zero and unit variance to equalize component weighting (5). Multiple regression equations were based on the path diagrams, which reflected the dependence structure of the sequential development of components (Fig. 1). Yield was the product of its components: fruit weight, number of fruit per node, percentage of fruitful nodes, number of nodes per cane, and number of canes/meter.

Results and Discussion

The genotypes varied significantly in their mean yield component values (Table 1). 'Redwing', MN 652, and MN 659 began fruiting 7 to 14 days earlier than 'Heritage' (9, 16). However, during the 3 years of our study, 'Heritage' had the highest yield/meter of row, yield per cane, fruit per cane, and number of fruit per fruiting node of any of the genotypes. The higher yield of 'Heritage' also was associated with a higher percentage of nodes fruiting per cane, although average fruit weight was significantly lower throughout the study. 'Redwing' had a larger number of total nodes and more canes/meter of row, but a lower percentage of nodes fruiting than 'Heritage'. The fewer number

Received for publication 3 Aug. 1987. Paper no. 15,478 of the Scientific Journal Series, Minnesota Agricultural Experiment Station. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

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Table 1. Mean values of yield components and degree of component interaction (W) of four primoncane-fruiting red raspberry genotypes (1982–84).

Cultivar or genotype	Yield component									
	Yield ($g \cdot m^{-1}$ row)	Fruit weight (g/fruit)	No. fruit/ fruiting node	Nodes Fruiting cane (%)	No. total nodes/ cane	No. canes/ m row	Yield/ cane (g)	Yield/ fruiting node (g)	No. fruit/ cane	W
Heritage	1584	1.9	1.7	39	37	33	48	3.3	26	0.378
Redwing	997	2.0	0.9	31	41	45	22	1.8	11	0.225
MN 652	860	2.2	0.9	36	29	40	22	2.0	10	0.573
MN 659	1050	2.5	1.0	31	33	42	25	2.5	10	0.349
LSD (0.05)	453	0.1	0.4	5.6	1.1	6	14	0.9	7.4	

of fruit per fruiting node in the other three genotypes was due to less lateral branch formation, thus leading to fewer nodes per lateral than in 'Heritage'. MN 659 had the highest weight per fruit, but few fruit per cane.

Path analysis indicated that the number of fruit per node had the strongest direct effect on yield for each genotype and cane number had the second strongest direct effect (Fig. 1). However, the path coefficients for total number of nodes, percentage of fruiting nodes, and fruit weight were also highly significant and positive for all four genotypes.

In 'Redwing', MN 652, and MN 659, cane number did not have a significant effect on fruit size and tended to be positively related to node number per cane. Only 'Heritage' demonstrated a significant negative correlation between increasing number of canes and number of fruit per node. This negative relationship may be, in part, due to lateral branch development. As the cane density increases, light within the canopy may become limiting and fewer laterals would form, thus limiting yield.

Unlike the other genotypes 'Heritage' exhibited a strong negative relationship between node number and fruit weight. There was also a negative relationship of node number to the number of fruit per node in 'Redwing'. However, increasing total node number in MN 659 had a positive effect on the percentage of fruiting nodes. Finally, as the percentage of fruiting nodes increased in 'Redwing', there was a significant decrease in fruit weight. None of the other genotypes illustrated this correlation.

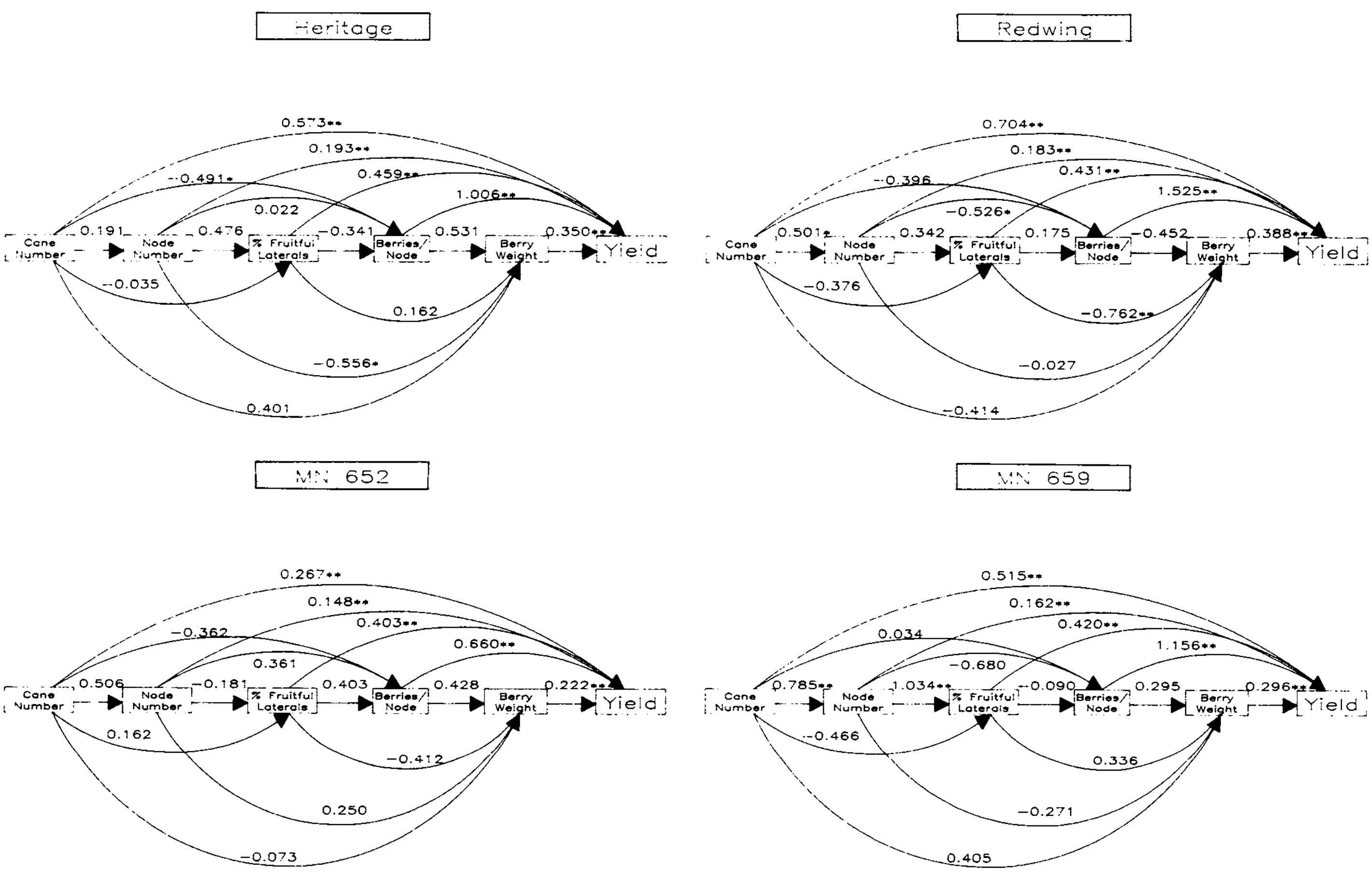

Fig. 1 Path diagram illustrating the relationships among yield and the components of yield for four genotypes. Corresponding numbers are path coefficients. Significant relationship between variables indicated at 0.05 (*) and 0.01 (**) levels.

Overall, 'Heritage' had highest yield and the fewest negative associations among components, perhaps explaining the widespread adaptation of this cultivar and its successful use as a parent.

'Redwing' had a lower W-value (Table 1) than the other three genotypes, which indicated more intense component compensation. Because of the strong component compensation, attempts to improve yield using 'Redwing' as a parent will be difficult. For example, selection of seedlings for more fruit/node would result in reduced fruit size. However, these data do suggest that cultural practices that increase the number of canes/meter of row may improve yield of 'Redwing'.

The components contributing to total yield vary among genotypes of summer-bearing red raspberries. Crandall et al. (3) demonstrated that although there was a positive relationship between cane vigor and fruit number, this only partially accounted for variation in yield. Nehrbas and Pritts (17) found that, with summer-bearing raspberries, cane number always had the strongest direct effect on yield and negative effects on all other yield components, especially fruit size. Further, fruit number per node did not have a strong direct effect on yield and cane thinning had a large, direct impact on yield through effects on number of fruiting nodes and fruit size (17). Our results with primocane-fruiting cultivars, as based on component analysis, indicated that retaining all primocanes should have a positive effect on yield without affecting fruit size. Additionally, treatments that reduce node number in 'Heritage' would have a negative impact on yield.

Lawrence (12) made progress in selecting for early fruiting in primocane-fruiting types, but observed that yield were generally lower than for summer-bearing red raspberries. He suggested that selecting for fruit size might result in higher yields in the earlier-fruiting genotypes. Our data suggest that the success of this strategy would depend on the intensity of yield component compensation with theses genotypes. For example, 'Redwing' exhibited a negative association between fruit size and all other yield components. In selecting for high yield in primocane-fruiting red raspberries, number of fruit per node in combination with percentage of fruitful laterals may be the best criteria because of the large positive path coefficients with yield exhibited by these four genotypes. High yields in primocane-fruiting red raspberries will also require high cane densities and rapid development of fruiting laterals. Our data indicate genotypes with high yields can continue to be selected through improved component performance.

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