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# Yield Component Analysis of Strawberry Genotypes Differing in Productivity

**Bernadine C. Strik[1] and John T.A. Proctor[2]**
*Department of Horticultural Science, University of Guelph, Guelph, Ont. N1G 2W1, Canada*

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*Abstract.* **Strawberry genotypes (*Fragaria* ×*ananassa* Duchesne) varying in yield per plant were studied. In 1985, genotypes were grown in matted rows and in 1986 as individual plants. Yield per plant within genotypes was mainly dependent on the number of berries per plant, regardless of cultural system. Other variables were correlated with yield, including crown dry weight and leaf area after harvest, and number of inflorescences, which indirectly affected berry number. Potential differences in yield within genotypes apparently were established prior to flower bud differentiation. Variables associated with yield among genotypes differed with cultural conditions. When genotypes were grown in matted rows, vegetative variables were highly correlated with yield. With less interplant competition, reproductive variables were correlated with yield among genotypes. Data suggested that, in some genotypes, runnering and fruiting may have competed for assimilates. Genotypic variability in yield components suggests that genotypes with similar yield can have different routes to yield.**

A yield component analysis can be used to identify which components are most associated with yield within a particular genotype. Yield per hectare in strawberry plantings was found most correlated with the number of crowns per hectare (5, 6, 8). Various components have been found correlated with yield per plant, including number of crowns (7, 12), number of leaves per crown (9), number of leaves per plant (7), plant size (4, 10), number of inflorescences (4, 10, 12), number of berries per inflorescence (3, 4, 10, 12), number of berries per plant (7), fruit set, and total number of achenes per berry (9).

The objectives of this study were to determine which variables account for yield variation within genotypes and whether strawberry genotypes that differ in average yield per plant have a different balance of yield components. Also, genotypes were grown in matted rows and ribbon rows to determine whether cultural practices and/or the environment affected the contribution of various components to yield variation. Understanding which variables are most responsible for yield variation among

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[1]Graduate student. Present address: Assistant Professor, Dept. of Horticulture, Oregon State Univ., Corvallis, OR 97331.
[2]Professor.

genotypes may simplify plant breeding procedures and lead to adaptation of cultural or management practices to maximize yield.

## Materials and Methods

*1985.* The commercial cultivars Redcoat and Veeglow and the selections 71M59 and 62E55 were chosen because of observed differences in yield. Planting occurred 5 May 1984 on a typic hapludalf (Fox sandy loam) at the Cambridge Research Station, Univ. of Guelph. Plants were set 45 cm apart within the row, with 120 cm between rows in a randomized complete block design containing three blocks. Water was supplied by trickle irrigation, and fertilizer was applied according to standard commercial practices. Plants were deblossomed in 1984 and the runners were trained to form a matted row 45 cm wide. In 1985, prior to flowering, 10 random plants per genotype per block were tagged within the matted row. The number of inflorescences and flowers per plant were counted. Fruit were harvested from each plant as they ripened; subsamples were taken to determine berry weight, the total number of achenes per berry, and the number of achenes per square centimeter. The total number of achenes per berry was determined by slicing the berry into pieces and summing the number of achenes present on each part. The number of achenes/$cm^2$ was obtained by averaging the number of achenes visible within a circular 1-$cm^2$ aperture held against the shoulder of the berry at two random locations (2). At the end of fruit harvest, total yield per plant was calculated and various variables were measured (Table 1). Leaf area was determined using a LI-COR LI-3000 Area Meter fitted with a LI-3050A transparent belt accessory.

*1986.* The commercial cultivar Redcoat and three selections, 62E55, 83T6, and 132E57, were chosen because of differences in yield and growth habit. Planting occurred 7 May 1985 on an adjacent site. Plants were set 30 cm apart within the row, with 120 cm between rows. The design used was a randomized complete block with nine plants per genotype in each of five blocks. Watering and fertilization were done as in 1985. Plants were deblossomed and derunnered in 1985 to promote crown development. Data were collected for each plant as in 1985 (Table 1). The number of runners per plant was also counted.

Data were subjected to analysis of variance, and means were compared using Duncan's multiple range test. There was no significant block effect; thus, all data were pooled across blocks. A correlation analysis was performed on all variables. Stepwise multiple regression was performed using the measured variables or yield components as independent variables and yield as the dependent variable (Table 2). The sequence was determined by the ontogenetic appearance of the components. Only measured variables, not ratios, were used. Calculating the increase in $R^2$ contributed by each component as it was added to a multiple regression provided an estimate of the contribution of each variable to yield variability (9). The components of yield were also forced into the model in reverse sequence. If the $R^2$ was 0 for any component in the backward regression, then that component's contribution to yield must only have been through its indirect effects upon components later in the model (9).

Table 1. Measured attributes used in yield component analysis of strawberry genotypes in 1985 and 1986.

| Symbol | Attribute |
|---|---|
| 1985 | |
| C | Crown number |
| CDW | Crown dry wt (g) |
| L | Leaf number |
| LDW | Leaf dry wt (g) |
| LA | Leaf area ($cm^2$) |
| I | Inflorescence number |
| F | Flower number |
| B | Berry number |
| AC | Number of achenes/$cm^2$ |
| TA | Total number of achenes/berry |
| Y | Yield (g) |
| PLWGT | Total plant dry wt (g) |
| 1986 | |
| All of above measured except F | |
| Also: | |
| SDW | Stolon dry wt (g) |
| IDW | Inflorescence dry wt (g) |

## Results and Discussion

In 1985 and 1986, yield per plant within genotypes was mainly dependent on the number of berries per plant (Tables 3 and 4). Backwards regression indicated that all other components that were associated with yield, such as crown dry weight, number of inflorescences, and number of flowers in most genotypes, acted indirectly by affecting berry number (Tables 3 and 4). Nielson and Eaton (9) found leaf number per crown to account for 30% of the yield variability in 'Quinault'. This component and others acted indirectly by affecting fruit set (B/F) and yield per developed achene (9). The number of inflorescences was the most important factor in determining yield of 'Crusader' (3).

In 1985, berry number was significantly correlated with vegetative variables, such as crown dry weight, number of crowns,

Table 2. Models used to partition yield variation of strawberry genotypes studied in 1985 and 1986.

| | |
|---|---|
| | *1985* |
| Forward | $Y^z$ = CDW C L LA LDW I F B TA AC |
| Backward | Y = AC TA B F I LDW LA L C CDW |
| | *1986* |
| Forward | Y = CDW C L LA LDW I B TA AC SDW |
| Backward | Y = SDW AC TA B I LDW LA L C CDW |

$^z$The symbols used were defined in Table 1.

Table 3. Increases in coefficients of determination ($R^2$) as components of the yield model were added in forward and backward regression in strawberry genotypes studied in 1985.

| Genotype | CDW | C | L | LA | LDW | I | F | B | TA | AC |
|---|---|---|---|---|---|---|---|---|---|---|
| | Components of yield | | | | | | | | | |
| 62E55 | | | | | | | | | | |
| Forward | 57***$^z$ | 5 | 7 | 4 | 1 | 0 | 3 | 20*** | 0 | 0 |
| Backward | 0 | 0 | 2 | 1 | 4** | 3 | 1 | 73*** | 1 | 12 |
| Redcoat | | | | | | | | | | |
| Forward | 56*** | 0 | 3 | 3 | 2 | 7 | 8* | 19*** | 0 | 0 |
| Backward | 2 | 0 | 0 | 0 | 0 | 1 | 2 | 87*** | 2 | 4 |
| 71M59 | | | | | | | | | | |
| Forward | 1 | 0 | 2 | 8 | 0 | 31** | 20** | 30*** | 0 | 0 |
| Backward | 1 | 0 | 4* | 0 | 4* | 1 | 0 | 65*** | 3 | 14 |
| Veeglow | | | | | | | | | | |
| Forward | 25** | 1 | 1 | 0 | 3 | 20* | 4 | 40*** | 1 | 1 |
| Backward | 0 | 1 | 0 | 0 | 0 | 3** | 0 | 76*** | 16* | 0 |

$^z$Asterisks indicate a significant increase in $R^2$ when that component was added to the model at the $P \le 0.05$ (*), $P \le 0.01$ (**), and $P \le 0.001$ (***) levels.

Table 4. Increases in coefficients of determination ($R^2$) as components of the yield model were added in forward and backward regression in strawberry genotypes studied in 1986.

| | Yield components | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Genotype | CDW | C | L | LA | LDW | I | B | TA | AC | SDW |
| 62E55 | | | | | | | | | | |
| Forward | 19**$^z$ | 7 | 6 | 0 | 2 | 47*** | 11*** | 0 | 2*** | 0 |
| Backward | 0 | 0 | 1 | 0 | 0 | 0 | 38*** | 10** | 20*** | 25*** |
| Redcoat | | | | | | | | | | |
| Forward | 32*** | 1 | 4 | 1 | 3 | 9* | 35*** | 0 | 1 | 0 |
| Backward | 0 | 1 | 2* | 1 | 1 | 10 | 71*** | 3 | 1 | 5 |
| 83T6 | | | | | | | | | | |
| Forward | 37*** | 2 | 4 | 1 | 5 | 28*** | 16*** | 0 | 1 | 1 |
| Backward | 0 | 1 | 0 | 0 | 2* | 0 | 55*** | 0 | 3 | 34*** |
| 132E57 | | | | | | | | | | |
| Forward | 30*** | 3 | 2 | 2 | 2 | 26*** | 25*** | 1 | 1 | 1 |
| Backward | 1 | 0 | 0 | 3** | 0 | 0 | 84*** | 0 | 1 | 4 |

$^z$Asterisks indicate a significant increase in $R^2$ when that component was added to the model at the $P \leq 0.05$ (*), $P \leq 0.01$ (**), and $P \leq 0.001$ (***) levels.

number of leaves, leaf area, leaf dry weight, and plant dry weight in 62E55 (data not shown) and 'Redcoat' (Table 5). In 1986, berry number was correlated with the vegetative variables crown dry weight, crown number, leaf number, and plant dry weight in 62E55 and 83T6 (data not shown) and 132E57 (Table 6). Lacey (7) found that the number of berries per plant was correlated to leaf number the previous fall in several strawberry genotypes. In 71M59 (Table 7) and 'Veeglow' (data not shown) in 1985, and 'Redcoat' in 1986 (Table 8), vegetative variables were not strongly related to berry number. In 71M59, only inflorescence number, flower number, and berry number were correlated with yield per plant (Table 7). These variables were determined during flower bud differentiation (FBD) the previous fall. In the other genotypes studied, where vegetative growth appeared to affect yield indirectly through berry number, differences in vigor must have been established prior to FBD. Webb et al. (12) suggested that large variations in yield potential can arise during FBD.

In 1986, leaf number, leaf area, and leaf dry weight were not correlated with the number of berries or yield of 'Redcoat' when grown as individual plants (Table 8) as compared to the matted row (Table 5). Thus, cultural conditions or the environment affected the contribution of various components to yield variation. In all other genotypes except 71M59, leaf area was correlated with yield in both cultural systems. Hancock et al. (5) found leaf number per crown and leaf area associated with several components of yield and, although the relationship varied with cultural practice, suggested that differences in photosynthesis may have contributed to yield variation within genotypes.

In 'Redcoat' (Table 8) and 62E55 (data not shown), stolon dry weight (SDW) was negatively correlated with the reproductive variables inflorescence number, inflorescence dry weight, and berry number. Thus, when the reproductive sink was large, runner development declined (Table 9), suggesting that, in 1986, runnering and fruiting competed for assimilates in these genotypes. Increased vigor promoted runner formation, as evidenced by positive correlations of stolon dry weight with leaf area, leaf dry weight, and sometimes crown dry weight in 62E55, 83T6 (data not shown), and 132E57 (Table 6). In 132E57, there was no correlation between stolon dry weight and reproductive variables (Table 6). Perhaps runnering and fruiting did not compete for assimilates in this genotype due to a low yield and thus a small reproductive sink (Table 10). Although the runner sink strength (runner number × runner dry weight) was relatively high in this genotype (Table 9), the reproductive sink strength (berry number × berry weight) was small (Table 10).

When grown in the matted row in 1985, 62E55 had a greater yield per plant and per section of matted row than the other three genotypes (Table 10). Both 71M59 and 'Veeglow' had a low average yield. Genotypic variation in yield in 1985 was related to differences in the number of berries per plant, crown dry weight, total plant dry weight, and perhaps leaf area (Tables 9 and 10). Large berry size and perhaps high yield in the genotypes studied in 1985 were related to the total number of achenes per berry (11). In 1986, yield per plant was greater than in 1985, as plants were grown individually and thus had multiple crowns and greater vigor (Tables 9 and 10). 132E57 had a lower yield than the other three genotypes (Table 10). The lower yield of 132E57 apparently was due to a reduction in the number of berries and inflorescences per plant and perhaps to an increase in stolon dry weight (Tables 9 and 10). Webb et al. (12) found that differences in yield of 'Cambridge Vigour' and 'Gorella' were due to differences in the number of inflorescences per plant. Genotypic variation in yield was correlated with the number of berries, crowns, leaves, and plant size (7). The number of crowns was found to be an unreliable guide to the fruiting characteristics of a genotype, as reported in previous studies (4, 10). In 1985, genotypic variation in yield was most related to differences in vegetative components. Perhaps these differences

Table 5. Correlation coefficients among variables of 'Redcoat' grown in matted rows in 1985.

| | Variable | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Variable | CDW | C | L | LA | LDW | I | F | B | TA | AC | Y |
| CDW | | | | | | | | | | | |
| C | 0.49**$^z$ | | | | | | | | | | |
| L | 0.62*** | 0.74*** | | | | | | | | | |
| LA | 0.62*** | 0.52*** | 0.91*** | | | | | | | | |
| LDW | 0.64*** | 0.51** | 0.90*** | 0.99*** | | | | | | | |
| I | 0.40* | 0.56*** | 0.33* | 0.19 | 0.19 | | | | | | |
| F | 0.25 | 0.17 | −0.08 | −0.09 | −0.09 | 0.72*** | | | | | |
| B | 0.57*** | 0.33* | 0.42** | 0.48** | 0.47** | 0.61*** | 0.66*** | | | | |
| TA | −0.10 | 0.04 | 0.06 | −0.09 | −0.11 | 0.22 | 0.09 | 0.13 | | | |
| AC | −0.30 | 0.12 | −0.06 | −0.25 | −0.26 | 0.34 | 0.16 | −0.10 | 0.44* | | |
| Y | 0.71*** | 0.34* | 0.57*** | 0.64*** | 0.64*** | 0.48** | 0.49** | 0.93*** | 0.07 | −0.19 | |
| PLWGT | 0.76*** | 0.55*** | 0.90*** | 0.98*** | 0.98*** | 0.25 | −0.02 | 0.52*** | −0.10 | −0.27 | 0.68*** |

$^z$Asterisks indicate significance at $P \leq 0.05$ (*), $P \leq 0.01$ (**), and $P \leq 0.001$ (***).

Table 6. Correlation coefficients among variables in 132E57 grown as individual plants in 1986.

| | Variable | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Variable | CDW | C | L | LA | LDW | I | IDW | B | TA | AC | SDW | Y |
| CDW | | | | | | | | | | | | |
| C | 0.69*** | | | | | | | | | | | |
| L | 0.71*** | 0.77*** | | | | | | | | | | |
| LA | 0.67*** | 0.74*** | 0.90*** | | | | | | | | | |
| LDW | 0.58*** | 0.68*** | 0.75*** | 0.91*** | | | | | | | | |
| I | 0.34* | 0.48** | 0.47** | 0.25 | 0.14 | | | | | | | |
| IDW | 0.19 | 0.28 | 0.33* | 0.26 | 0.18 | 0.64*** | | | | | | |
| B | 0.49*** | 0.47** | 0.45** | 0.26 | 0.19 | 0.87*** | 0.58*** | | | | | |
| TA | 0.27 | 0.15 | −0.06 | 0.03 | 0.08 | −0.20 | 0.01 | −0.02 | | | | |
| AC | 0.18 | 0.10 | −0.08 | −0.24 | −0.24 | 0.14 | 0.00 | 0.16 | 0.58*** | | | |
| SDW | 0.30 | 0.31* | 0.30 | 0.47** | 0.47** | −0.09 | −0.10 | −0.04 | 0.20 | −0.21 | | |
| Y | 0.55*** | 0.50*** | 0.55*** | 0.44*** | 0.63*** | 0.72*** | 0.54*** | 0.89*** | 0.13 | 0.04 | 0.20 | |
| PLWGT | 0.72*** | 0.76*** | 0.85*** | 0.95*** | 0.95*** | 0.29 | 0.37* | 0.34* | 0.11 | −0.16 | 0.43** | 0.46** |

zAsterisks indicate significance at $P \leq 0.05$ (*), $P \leq 0.01$ (**), and $P \leq 0.001$ (***).

Table 7. Correlation coefficients among variables of 71M59 grown in matted rows in 1985.

| | Variable | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Variable | CDW | C | L | LA | LDW | I | F | B | TA | AC | Y |
| CDW | | | | | | | | | | | |
| C | 0.55*** | | | | | | | | | | |
| L | 0.78*** | 0.63*** | | | | | | | | | |
| LA | 0.81*** | 0.41* | 0.87*** | | | | | | | | |
| LDW | 0.81*** | 0.38* | 0.85*** | 0.99*** | | | | | | | |
| I | −0.33* | 0.17 | −0.23 | −0.41** | −0.44 | | | | | | |
| F | −0.19 | 0.20 | −0.15 | −0.31 | −0.32 | 0.85*** | | | | | |
| B | −0.26 | 0.01 | −0.15 | −0.27 | −0.28 | 0.60*** | 0.73*** | | | | |
| TA | −0.19 | −0.42* | −0.08 | 0.12 | 0.11 | −0.24 | −0.16 | 0.02 | | | |
| AC | −0.04 | −0.33 | −0.37 | −0.37 | −0.31 | −0.10 | −0.07 | −0.34 | 0.07 | | |
| Y | −0.15 | −0.04 | −0.11 | −0.12 | −0.12 | 0.52*** | 0.69*** | 0.86*** | 0.15 | −0.38 | |
| PLWGT | 0.86*** | 0.40* | 0.86*** | 0.98*** | 0.99*** | −0.47** | −0.34* | −0.31 | 0.09 | −0.25 | −0.16 |

zAsterisks indicate significance at $P \leq 0.05$ (*), $P \leq 0.01$ (**), and $P \leq 0.001$ (***).

Table 8. Correlation coefficients among variables of 'Redcoat' grown as individual plants in 1986.

| | Variable | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Variable | CDW | C | L | LA | LDW | I | IDW | B | TA | AC | SDW | Y |
| CDW | | | | | | | | | | | | |
| C | 0.55***z | | | | | | | | | | | |
| L | 0.58*** | 0.84*** | | | | | | | | | | |
| LA | 0.66*** | 0.70*** | 0.89*** | | | | | | | | | |
| LDW | 0.57*** | 0.59*** | 0.77*** | 0.87*** | | | | | | | | |
| I | 0.34* | 0.37* | 0.23 | 0.17 | 0.03 | | | | | | | |
| IDW | 0.29 | 0.11 | −0.01 | 0.04 | −0.02 | 0.58*** | | | | | | |
| B | 0.45** | 0.26 | 0.16 | 0.17 | 0.07 | 0.69*** | 0.84*** | | | | | |
| TA | −0.05 | 0.07 | 0.02 | −0.03 | 0.03 | 0.22 | 0.36* | 0.32* | | | | |
| AC | −0.10 | −0.01 | 0.03 | 0.01 | −0.03 | 0.37* | 0.08 | 0.17 | 0.08 | | | |
| SDW | 0.02 | −0.03 | 0.04 | 0.09 | 0.09 | −0.36* | −0.37* | −0.41* | −0.09 | −0.25 | | |
| Y | 0.57*** | 0.22 | 0.15 | 0.28 | 0.15 | 0.48*** | 0.76*** | 0.87*** | 0.18 | −0.03 | −0.23 | |
| PLWGT | 0.78*** | 0.68*** | 0.82*** | 0.92*** | 0.92*** | 0.18 | 0.16 | 0.28 | −0.02 | −0.07 | 0.10 | 0.39** |

zAsterisks indicate significance at $P \leq 0.05$ (*), $P \leq 0.01$ (**), and $P \leq 0.001$ (***).

among genotypes were already established prior to FBD and led to differences in berry number per plant. The importance of vegetative components also may indicate that high-yielding genotypes in the matted row compete more successfully for water and nutrients and/or have greater total photosynthesis than low-yielding genotypes. In 1986, interplant competition was reduced and vegetative components were less related to among-genotype variation in yield than in 1985.

In 1986, 83T6 had more than twice the yield of 132E57; yet, these genotypes did not differ in the number of crowns per plant, crown dry weight, leaf area, leaf dry weight, and total plant dry weight (Tables 9 and 10). However, 83T6 had a greater number of inflorescences and berries per plant (Table 10) than 132E57, and therefore had a greater number of inflorescences initiated per crown. Compensatory relationships among yield components have been observed in other genotypes (3, 10). Berry size

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