Full Length Research Paper

Determination of the best blackberry cultivar using various statistical techniques

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This study was conducted to determine the best blackberry cultivar using jointly various statistical techniques such as Chi-Square, G, and Correspondence statistics. For this aim, data of pomological traits such as fruit weight, cane number, cane diameter, cane height, cane yield per plant of Ness, Cherokee, Arapaho, Chester Thornless, Navaho, Black Satin, Dirksen Thornless and Jumbo cultivars were collected during 2002-2006. With respect to chi-square and G statistics, associations between cultivar and each pomological trait (fruit weight, cane number, cane diameter, cane height, and cane yield per plant) were found more significant (P < 0.0001). The relationship between year and cane number was significant (P < 0.0001 and year and cane diameter was significant (P < 0.05). The highest cane number was produced in 2004, followed by 2005. The relationship between fruit weight and cane diameter or cane yield per plant were more significant (P < 0.0001). Although Blacksatin and Jumbo blackberry cultivars had the highest cane number, Chester Thornless from blackberry cultivars had the highest cane diameter, the highest cane yield per plant and the highest fruit weight. It was concluded that Chester Thornless cultivar was the most appropriate cultivar for Central Anatolia region.

Key words: Adaptation, blackberry, cane, fruit, Chi-square statistic, G statistic, correspondence analysis.

INTRODUCTION

The blackberry is an aggregate fruit from, genus Rubus in the family Rosaceae. They are perennial plants and bear biennial stems ("canes") from the perennial root system. They do not produce flowers during first year, which are produced during second year on the stems that does not grow longer, but the flower buds break to produce flowering laterals.

In horticulture of blackberry, the effects of yearly environmental and genotype (cultivar) factors have a variable effect on pomological traits such as fruit weight, cane diameter, cane length, cane height, cane per plant, and others (Atila et al., 2006a; Atila et al., 2006b; Eyduran and Agaoglu, 2006; Eyduran et al., 2007). These factor effects are generally examined by using Analysis of Variance (ANOVA) in the adaptation and other studies (genetic improvement; determination of chemical

components) on blackberries (Strik et al., 1996; Finn et al., 1999; Siriwoharn et al., 2005; Clark et al., 2005; Yorgey and Finn, 2005; Connor et al., 2005a, b; Finn et al., 2005a, b, c, d, e). However, there are no studies on selection of the best Blackberry cultivars, using the effects of relationships between pomological traits and their effects on each other. These are generally calculated using Correspon-dence Analysis (CA), Chi-Square and G statistics can be used jointly for obtaining different information. Using CA and other statistical techniques could be equally important for horticulture of this plant.

In general, Chi-Square, Likelihood Chi-Square, Fisher's Exact and Log-linear, Logistic Regression, and Corres-pondence are used in statistical analysis of contingency (two-way) tables (Everitt, 1992; Baspınar and Mendes, 2000; Eyduran et al., 2005a; Eyduran and Ozdemir, 2007). Chi-square, Likelihood Chi-square and Fisher's Exact statistics gives an idea about whether association between categorical variables is significant (Dugan's,

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Table 1. Monthly temperature and preciption in each year for Ankara ecology.

	Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
							Months							
2002	Precip. (mm)	39.6	9.3	23.8	102.7	29.6	41.9	42.9	12.2	31.7	25	41.3	29	429
	Temp. (°C)	-3.3	4.9	9.4	11.6	17.7	22.1	25.8	23.5	19.6	14.2	7.8	-0.2	12.8
2003	Precip. (mm)	51.6	43.7	6.9	61.7	27.3	17.7	7	39.1	1.1	65	0	0	321.1
	Temp. (°C)	5.6	0.6	4.2	10.7	20.6	24.1	24.9	25.8	19.3	14.9	8.1	2.5	13.4
2004	Precip. (mm)	77.9	20.1	39.5	37.3	18.6	25.8	4	22.3	9.3	44.2	22.9	0	321.9
	Temp. (°C)	1.2	2.3	7.8	12.7	17.1	21.4	25.7	24	20.9	15.5	7.8	2.7	13.3
2005	Precip. (mm)	29.7	48.2	68.4	62.7	27.5	47.6	18.7	1.8	4.8	15.9	43.9	17	386.2
	Temp. (°C)	3.6	3	6.8	12.5	17.6	20.9	26.3	26.6	20.3	12.2	7.1	3.6	13.4
2006	Precip. (mm)	60.9	84.7	43	14.1	13.3	9.2	39.1	0.3	82.8	19.9	17.5	1.8	386.6
	Temp. (°C)	-0.8	-0.4	8.1	14.3	18.1	23.1	24.7	28.7	19.5	14.9	6.3	1.3	13.2

State Meteorology Instute, Ankara 2006.

1983; Everitt, 1992; Sokal and Rohlf, 1996), but correspondence analysis provides more information than others because it visualizes interaction with levels of categorical variables (Keskin, 2001).

As regards the best choice between Chi-Square and Likelihood Chi-Square statistics, many authors reported that observed frequency for each cell of contingency tables should be at least five. If any cells frequency were less than five, Likelihood Ratio Chi-square statistic might be more superior to Chi-square statistic, whereas Agresti (2002) reported that Chi-square has more advantageous than other if $n/(r*c) < 5$ where n, total sample size; r, row number and c, column number. Eyduran et al. (2006b) reported that SAS program gave warning "*Chi-square may not be valid statistic*" when more than 20% of cells expected counts less than five. In addition, it was well-known that both statistics values increases probability of being resemble on each other as total sample size increases (Sokal and Rohlf, 1996; Agresti, 2002; Eyduran and Ozdemir, 2005; Ozdemir et al., 2006a).

It was stated by many authors that in order to determine the best statistic, power analysis for Chi-Square, Likelihood Chi-Square statistics should be performed under every condition and the statistic with a power of at least 80% should be desired (Agresti, 2002; Eyduran and Ozdemir, 2005).

Contrary to Chi-Square and Likelihood Chi-Square statistics, Correspondence Analysis (which has been widely used for studies on genetics, ecology, economy, marketing, plant and animal breeding) might help to determine the relationship that categories of one variable can be interacted with each other and categories of other variable. Its advantages have no assumptions and hypothesis on distribution of data set (Gauch, 1982; Eyduran et al., 2006c; Akturk et al., 2007).

The first aim of this study is to determine the best adaptation performance among 8 blackberry cultivars to recommend the best one(s) to blackberry farmers and breeders for use in the continental climate of Central Anatolia, Turkey. The second one is to determine amount of association between pomological traits of 8 blackberry cultivars using power analysis of Chi-Square, Likelihood Chi-Square statistics, using special macro written in SAS program reported by Ozdemir et al. (2006b). The third aim is to show interaction among categories graphically for two variables (pomological traits) using Correspondence Analysis.

MATERIALS AND METHODS

The adaptation experiment was carried out on eight blackberry cultivars Ness, Cherokee, Arapaho, Chester Thornless, Navaho, Black Satin, Dirksen Thornless and Jumbo at Farm of Horticulture Research and Application, Faculty of Agriculture, University of Ankara during 2002-2006,   located at 32°52´ north, 39°56´ east, continental climate with wide variations in temperature, both between seasons and between different times of the day. Its summers are hot and dry, but its winters are cold and wet. Meteorological data of experimental site is given Table 1.

Two rows for each blackberry shrub plant set at 2 x 2 m spacing were harvested during August-September interval. All the traits had 120 observations in the adaptation experiment (8 cultivars x 5 years x 3 replications).

Berries were weighed fresh (fruit) and averages of fruit weight were calculated from 30-sample randomly selected from three plots for each blackberry cultivars. Cane weight, diameter, and height of shrub plants were calculated as recommended by Eyduran et al. (2007). Descriptive statistics of all traits are given in Table 2.

Variable structures

Categorical variables

Year (2002, 2003, 2004, 2005, and 2006) and Cultivar variables (Ness, Cherokee, Arapaho, Chester Thornless, Navaho, Black Satin, Dirksen Thornless, and Jumbo) are naturally ones with categorical structure.

Table 2. Descriptive statistics of pomological traits in blackberry.

Pomological trait	N	Mean	Standard error	Minimum	Maximum
Fruit Weight (FW)	120	3.44	0.10	1.00	5.50
Cane Number (CN)	120	10.65	0.20	6.60	15.2
Cane yield per plant (CYP)	120	104.17	4.17	52.60	210.7
Cane Diameter (CD)	120	17.81	0.35	9.0	28.4
Cane Height (CH)	120	226.93	3.52	100	300

Table 3. The cut-off values of pomological traits.

Categories	Pomological traits				
	Fruit weight (FW)	Cane number (CN)	Cane yield per plant (CYP)	Cane diameter (CD)	Cane height (CH)
Low (1)	1.00-2.49	6.6-9.4	52.6-105.2	9.00-15.4	100-166.6
Middle (2)	2.50-3.99	9.5-11.9	105.3-157.9	15.5-21.8	166.7-233.2
High (3)	≥4.00	≥12.00	≥158	≥21.9	≥ 233.3

Grouped (Categorized) variables

Pomological traits such as Fruit weight, Cane number, Cane yield per plant, Cane diameter, Cane height have generally variables with continuous structure. However, these traits can be transformed from Continuous structure to categorical one. In the adaptation experiment, the pomological traits have transformed as follows: after averages of these traits were found, all observations for each trait were categorized to 3 groups; namely, little (1), middle (2), more (3). The cut-off values of all traits (grouped variables) are presented in Table 3. These were graded and coded into three categories that is, (1) little with fruit weight of 1.-2.49 g, (2) middle with fruit weight of 2.50-3.99 g (3) more with fruit weight of >4.00 g.

The notation of Chi-Square (1) and Likelihood Ratio Chi-Square statistics (2) are written as follows (Everitt, 1992; Agresti, 2002; Eyduran and Ozdemir, 2005):

$$\chi^2 = \sum \frac{(f - f_i)^2}{f_i} \qquad (1)$$

$$G = 2\sum f.\ln\left(\frac{f}{f_i}\right) \qquad (2)$$

Where, f, observed frequency and f_i, expected frequency.
Power theory for Chi-square and G statistics

Assume that H_0 is the same to model M for a contingency table. Let π_i indicate the true probability in i^{th} cell and Let π_i (M) represent the value to which the Maximum likelihood (ML) estimate $\hat{\pi}_i$ for model M converges, where $\sum \pi_i = \sum \pi_i(M) = 1$. For multinomial sample of size n, the non-centrality parameter for Chi-square (3) can be expressed as follows:

$$\lambda = n \sum_i \frac{[\pi_i - \pi_i(M)]^2}{\pi_i(M)} \qquad (3)$$

Expression 3 is the similar form of Chi-square statistics, with the sample proportion p_i and $\pi_i(M)$ in place of $\hat{\pi}_i$. The non-centrality parameter for Likelihood Ratio Chi-Square Statistics (4) can be written in this manner:

$$\lambda = 2n \sum_i \pi_i \log \frac{\pi_i}{\pi_i(M)} \qquad (4)$$

In order to obtain reliable results from both statistics, one should achieve a power value of at least 80% (Agresti, 2002; Ozdemir et al., 2006a, b). The highest value for power analysis of both statistics is 1. The data were analyzed using Minitab ((Minitab, 2007; released version 15) and SAS (2006, version 9.0) package programs. Power Analysis Chi-square and G statistics were performed using a special SAS macro at web site:
(http://ftp.sas.com/techsup/download/stat/powerrxc.html)

Correspondence analysis

Correspondence analysis (CA) is called a variety of names in the literature: Contingency table analysis, RQ-technique, reciprocal averaging, reciprocal ordering, dual scaling, optimal scaling, optimal scoring, and quantification method or homogeneity analysis (Statsoft, 1997; Eyduran et al., 2006b). CA, which is analogous to Principle Components, is a descriptive analysis technique which is designed to analyze two-way and multi-way tables containing measures of correspondence between the row and column variables (Ender, 2005; Gauch, 1982). In other word, it supplies a statistic method for representing data in a Euclidean space so that the results can be visually observed for structure.

The Pearson Chi-square Statistic, χ_p^2, is a sum of squared χ_{ij} values, which are computed every cell ij of the contingency table. Each χ_{ij} value is the standardized residual of a frequency f_{ij} after fitting a null model to contingency table. The null model states

that there is no relationship between the rows and the columns of the table. For each cell:

$$\chi_{ij} = \frac{O_{ij} - E_{ij}}{E_{ij}} = \sqrt{f_{++}}\left[\frac{p_{ij} - p_{i+}p_{+j}}{\sqrt{p_{i+}p_{+j}}}\right] \qquad (5)$$

CA is based on the matrix Q:

$$\overline{Q} = [\overline{q}_{ij}] = \left[\frac{p_{ij} - p_{i+}p_{+j}}{\sqrt{p_{i+}p_{+j}}}\right] \qquad (6)$$

Where; the $\overline{q}_{ij}$ values are the basis of CA and only differ from χ_{ij}'s by a constant $\sqrt{f_{++}}$. Thus, all of the eigenvalues become equal to ≤ 1.

The sum of squares of all the values in the $\overline{Q}$, $\sum \overline{q}_{ij}{}^2$ measures the total inertia in $\overline{Q}$. It is also equal to the sum of all of the eigenvalues to be extracted.

Singular value decomposition (SVD) is then applied to the $\overline{Q}$ matrix. While this process computationally a bit involved, the similar response more straightforwardly derived by applying eigenvalue analysis to covariance matrix $\overline{Q}'\overline{Q}$, which would produce the matrices of eigenvalues Λ and eigenvectors U. Once U is acquired, one can easily solve for $\hat{U}$ because of the relationship:

$$\hat{U}_{(rxc)} = \overline{Q}U\Lambda^{-1/2} \qquad (7)$$

The process always yields one null eigenvalue owing to the centering in the determination of $\overline{Q}$.

Matrices U and $\hat{U}$ may be used to plot the positions of the row and column vectors in two separate scatter diagrams. For joint plots, different scaling types of the row and column scores have been suggested.

Matrices U and $\hat{U}$ can be weighted by inverse of the square roots of the column and row scores, which were written out in diagonal matrices $D(p_{+j})^{-1/2}$ with dimension cxc and $D(p_{i+})^{-1/2}$ with dimension r x r, respectively:

$$V_{(cxc)} = D(p_{+j})^{-1/2}U \qquad (8)$$

$$V_{(cxc)} = D(p_{i+})^{-1/2}\hat{U} \qquad (9)$$

Matrix F, which gives the positions of the rows of the two-way table in the CA space, obtained from the transformed matrix of the eigenvectors V, which gives the columns in that space. This can be matrix Q, with division by the row weights:

In the similar approach, matrix $\hat{F}$, which presents the columns of the contingency table in CA space is derived from the transformed matrix of eigenvectors $\hat{V}$.

$$F(rxc) = V\Lambda^{1/2} \text{ or } F(rxc) = D(p_{i+})^{-1}Q'\hat{V} \qquad (11)$$

With this scaling, matrices F and V form a pair such that rows which were given by matrix F are at centroid of the columns in the matrix V.

In the same way, matrices $\hat{F}$ and $\hat{V}$ form a pair such that the columns (given by the matrix $\hat{F}$) are at the centroids of the rows in matrix $\hat{V}$.

As a result, matrices F and V or $\hat{F}$ and $\hat{V}$ can be used to construct scatter diagrams.

RESULTS AND DISCUSSION

This experiment was conducted in the experimental area of the Department of Horticulture , Faculty of Agriculture, Ankara University, Ankara Turkey at Ayas (latitude 40°10'N longitude 31°56'E, altitude 675-750 m above sea level) with dominant semi arid characteristics during 2002-2006.

Annual mean precipitation and temperature values during 2002, 2003, 2004, 2005 and 2006 were 429 mm and 12.8°C, 321.1 mm and 13.4°C, 321.9 mm and 13.3°C, 386.2 mm and 13.4°C, 386.6 mm and 13.2°C respectively (State Meteorology Institute, Ankara).

The values of power and non-centrality parameter (NC) of Chi-Square and G Statistics for each contingeny table (at 5% level) are presented in Table 4 which shows that,

i) Association between year and Cane Number (CN) was significant.
ii) Association between year and Cane height(CH) was insignificant (P < 0.5431)
iii) Association between year and Cane Diameter (CD) was significant (P < 0.05). Similarly, association between year and Cane height (CH) was insignificant (P < 0.7576).
iv) Association between year x cane diameter (CD) was insignificant.
Association between Cultivar (CULT) and Cane Number (CN) was significant (P < 0.0001)
v) Association between Cultivar (CULT) and Cane Height (CH) was significant (P < 0.0001)
vii) Association between Cultivar (CULT) and Cane Diameter (CD) was significant (P < 0.0001)
viii) Association between Cultivar (CULT) and Cane Yield per plant (CYP) was significant (P < 0.0001)

$$F(rxc) = \hat{V}\Lambda^{1/2} \text{ or } F(rxc) = D(p_{i+})^{-1}QV \qquad (10)$$

done by applying the usual equation for component scores to data

ix) Association between Cultivar (CULT) and Fruit Weight (FW) was significant (P < 0.0001)
x) Association between Fruit Weight (FW) and Cane

Table 4. The values of power and non-centrality parameter (NC) of Chi-Square and G Statistics for each contingeny table (at 5% level).

	Cross tabulation	Chi-square statistic				G statistic			
		Value	Prob	Power	NC	Value	Prob	Power	NC
1	Year × CN	36.49	<0.0001	0.99761	36.49	42.72	<.0001	0.99949	42.72
2	Year × CH	6.94	0.5431	0.41368	6.94	6.21	0.6232	0.36983	6.21
3	Year × CD	19.69	0.0116	0.91057	19.69	24.66	0.0018	0.96596	24.66
4	Year × CYP	5.00	0.7576	0.29644	5.00	7.11	0.5249	0.42387	7.11
5	Year × FW	7.80	0.4530	0.46503	7.80	7.94	0.4394	0.47306	7.94
6	CULT × CN	73.76	<0.0001	1.00000	73.76	85.41	<0.0001	1.00000	85.41
7	CULT × CH	106.3	<0.0001	1.00000	106.299	128.78	<0.0001	1.00000	128.77
8	CULT × CD	76.894	<0.0001	1.00000	76.894	78.85	<0.0001	1.00000	78.85
9	CULT × CYP	200	<0.0001	1.00000	200	160.33	<0.0001	1.00000	160.33
10	CULT × FW	179.46	<0.0001	1.00000	179.461	197.91	<0.0001	1.00000	197.91
11	FW × CN	3.67	0.4530	0.29462	3.666	3.497	0.4784	0.28168	3.497
12	FW × CH	4.73	0.3161	0.37581	4.731	5.03	0.2839	0.39870	5.033
13	FW × CD	24.69	<.0001	0.98849	24.6885	25.075	<0.0001	0.98956	25.075
14	FW × CYP	38.15	<.0001	0.99971	38.1513	43.79	<0.0001	0.99994	43.79

Table 5. Results of correspondence analysis for year x cane number.

Axis	Inertia	Proportion	Cumulative	Histogram
1	0.2717	0.8935	0.8935	*****************************
2	0.0324	0.1065	1.0000	***
Total	0.3041			

number (CN) was insignificant (P < 0.4530)
xi) Association between Fruit Weight (FW) and Cane height (CN) was insignificant (P < 0.3161)
xii) Association between Fruit Weight (FW) and Cane Diameter (CD) was significant (P < 0.0001)
xiii) Association between Fruit Weight (FW) and Cane Yield per plant (CYP) was significant (P < 0.0001).

Although a total of sample size (120 observations) used in adaptation experiment was sufficient for above cross-tabulations (with 1, 3, 6, 7, 8, 9, 10, 13, and 14 number) it was not sufficient for below cross-tabulations (with 2, 4, 5, 11, and 12 number)

i) Association between Year and Cane Height (CH) was non-significant.
ii) Association between Year and Cane Yield per plant (CYP) was non-significant.
iii) Association between Year and Fruit Weight (FW) was non-significant.
iv) Association between Fruit Weight (FW) and Cane number (CN) was non-significant.

In order to achieve reliable power values (0.800) for Chi-square and G statistics, A total of sample sizes for cross-tabulations with 2, 4, 5, 11, and 12 numbers was found to be 260 (0.80045) and 291 (0.80153); 361

(0.80062) and 254 (0.80085); 232 (0.80201) and 228 (0.80201); 391 (0.80046) and 410 (0.80046); 303 (0.80035) and 285 (0.80071) for Chi-square and G statistics in agreement with Ozdemir et al. (2006b), respectively (data not shown).

In the adaptation experiment, Correspondence Analysis (CA) was applied to cross-tabulate (with 1, 3, 6, 7, 8, 9, 10, 13, and 14 number) because their power values ranged 0.91057 to 1.0000.

Results of correspondence analysis for year x cane number (Cross-tabulation 1) are presented in Table 5. As seen from Table 5, of total inertia, 89.35% was explained by the first component and 10.65%.

As shown in Figure 1, low cane number was obtained during 2002. High cane number was taken during 2004 year, followed by 2005 year. Cane number with Medium level was realized during 2003. Cane number during 2006 tended to be at medium level.

Results of correspondence analysis for year x cane diameter (Cross-tabulation 3) are presented in Table 6. Of total inertia, 95.30% was explained by the first component and 4.70% by the second component (Table 6).

Correspondence Analysis Graph of year × Cane diameter is given in Figure 2. Cane diameter with low level was taken during 2002, one with medium level corresponded to 2006 year. Although year 2005 showed
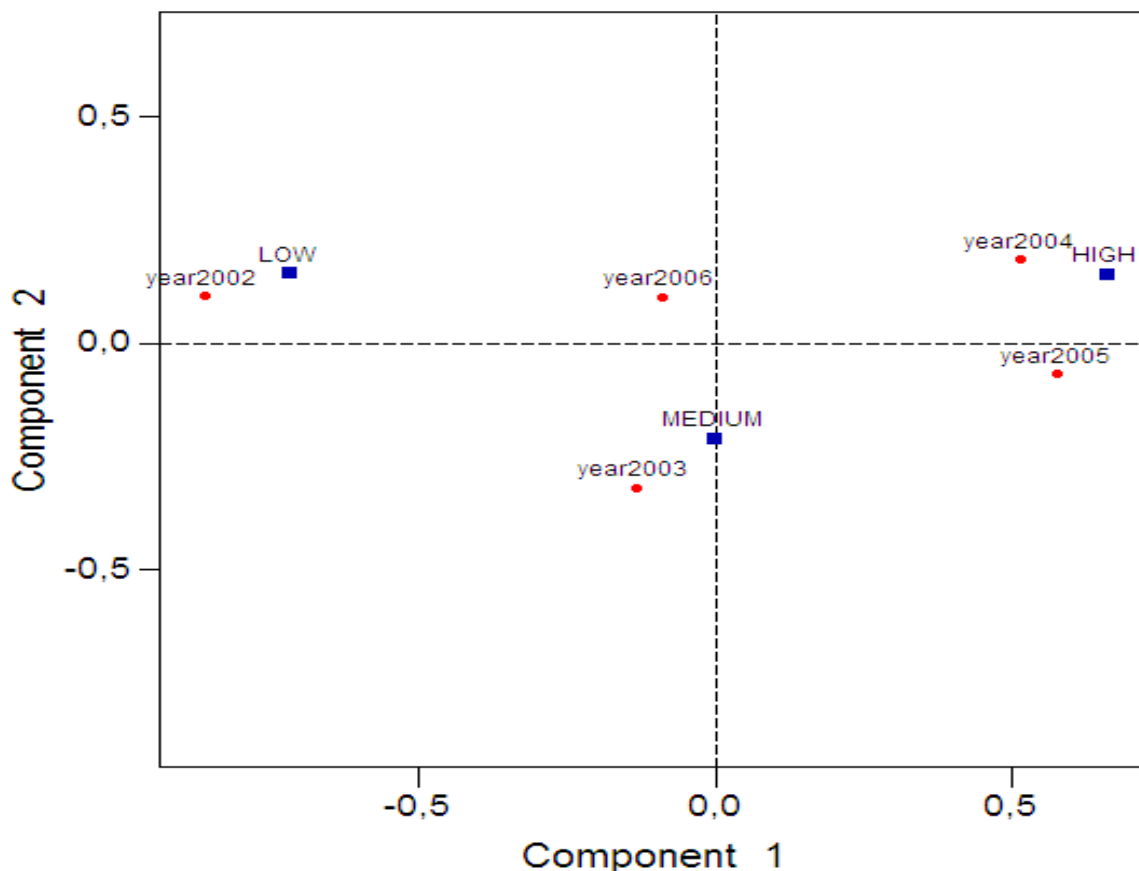
Figure 1. Correspondence Analysis Graph of year × Cane number.

Table 6. Results of correspondence analysis for year × cane diameter.

Axis	Inertia	Proportion	Cumulative	Histogram
1	0.1564	0.9530	0.9530	*****************************
2	0.0077	0.0470	1.0000	*
Total	0.1641			

equal distance to Cane diameter with high and with medium levels, 2005 year with high level along with year2004 with medium level was similar coordinate area 2003 year had equal distance to low and medium levels.

Results of correspondence analysis for Cultivar x cane number (Cross-tabulation 6) are summarized in Table 7. Of total inertia, 64.54% was explained by the first component and 35.46% by the second component (Table 7).

Correspondence Analysis Graph for cultivar × Cane Number is presented in Figure 3. Figure 3 shows that Blacksatin (bsatin) and Jumbo blackberry cultivars had high Cane Number. Ness and Dirkseen Thornless (dthornless) was found to have low cane number. The cultivars having cane number with medium level was Navaho, Chester Thornless, Cherokee and Arapaho blackberry cultivars.

Results of Correspondence analysis for Cultivar × cane height (Cross-tabulation 7) are given in Table 8. Of total inertia, 93.7% was explained by the first component and 6.30% by the second component (Table 8).

Correspondence Analysis Graph of cultivar × Cane Height is presented in Figure 4. As seen from Figure 4, Arapaho and Cheroke cultivars overlapped each other, and stayed at same distance to high cane height. Ness, Navaho, Black Satin, Dirksen Thornless cultivars also overlapped, and were at equal distance to medium cane height.

As shown in Figure 4, cv. Chester Thornless was closer to high level than medium level, whereas, Jumbo cultivar was closer to medium level than high level.

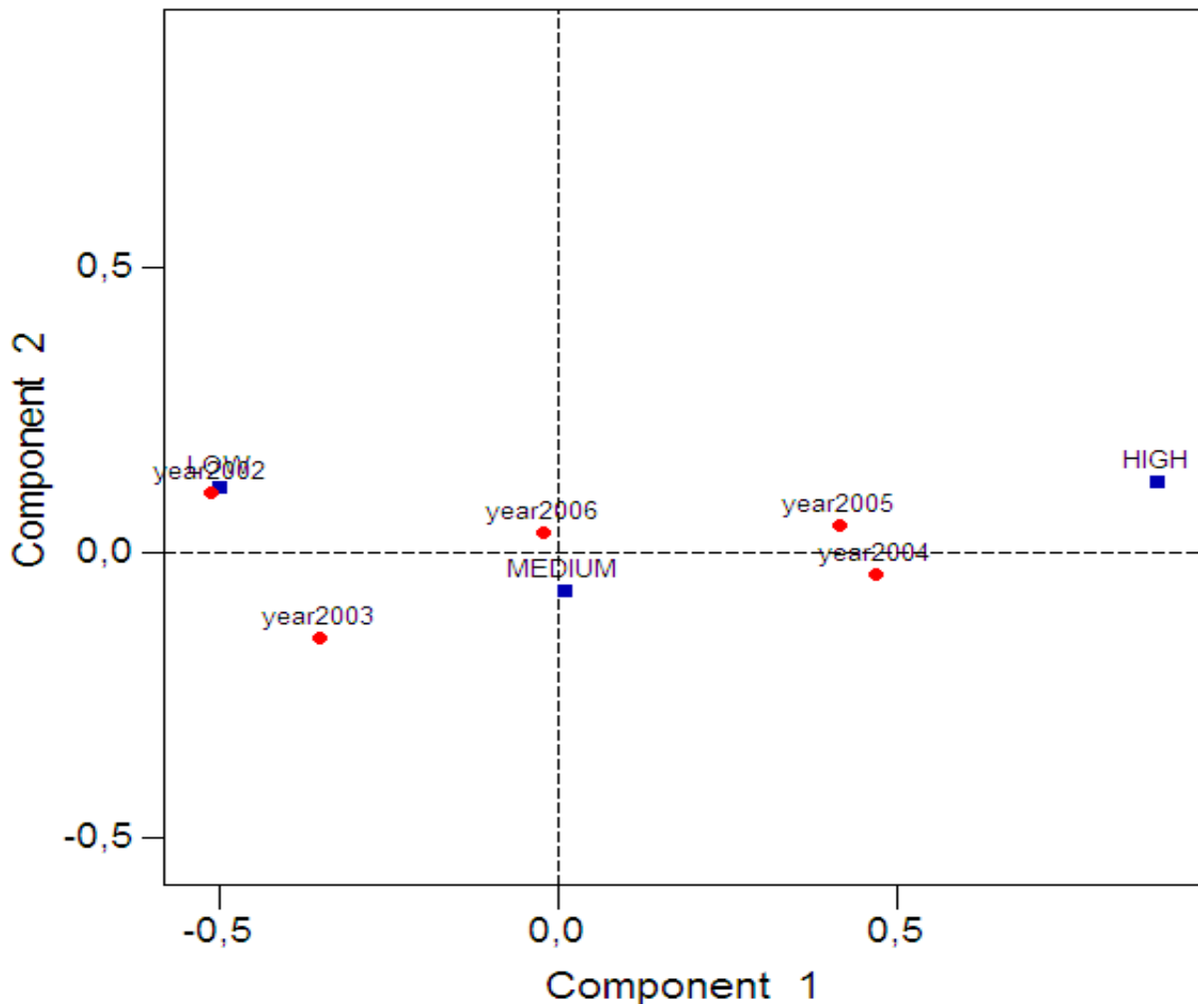Results of Correspondence analysis for Cultivar × cane

Symmetric Plot

Figure 2. Correspondence analysis graph of year x cane diameter.

Table 7. Results of correspondence analysis for cultivar × cane number.

Axis	Inertia	Proportion	Cumulative	Histogram
1	0.3967	0.6454	0.6454	******************************
2	0.2179	0.3546	1.0000	*****************
Total	0.6146			

Table 8. Results of correspondence analysis for cultivar × cane height.

Axis	Inertia	Proportion	Cumulative	Histogram
1	0.8300	0.9370	0.9370	******************************
2	0.0558	0.0630	1.0000	**
Total	0.8858			
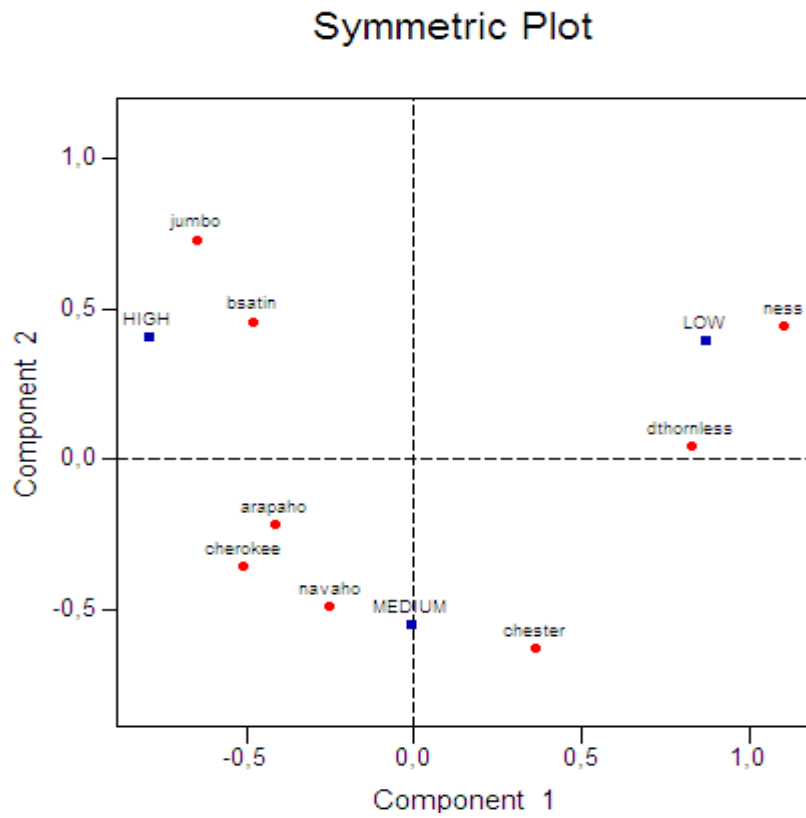
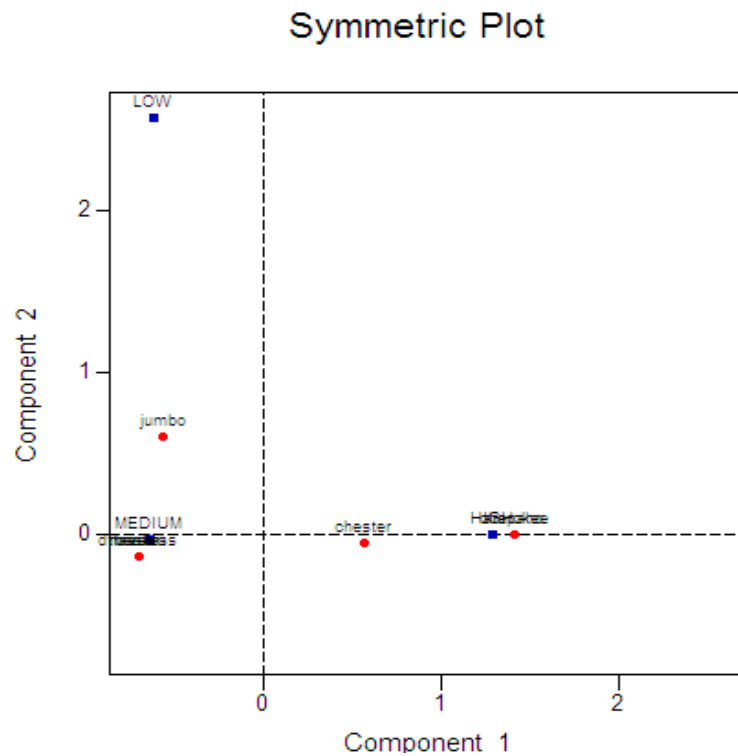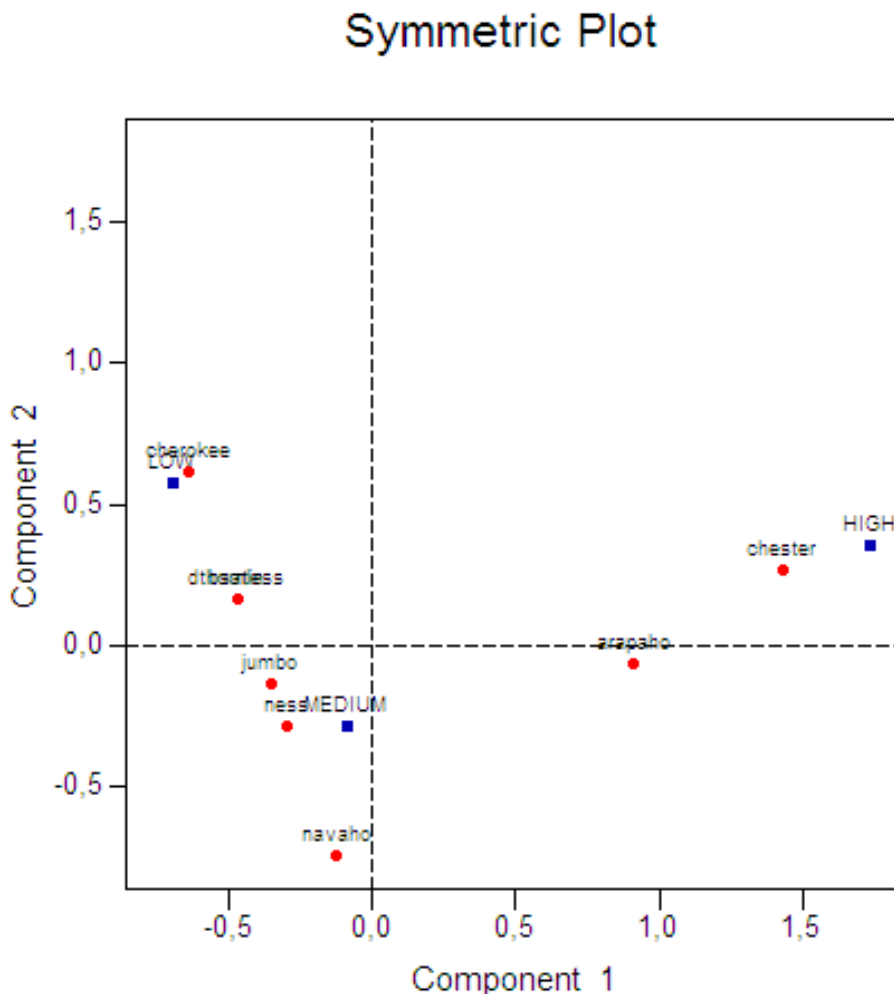**Figure 3.** Correspondence analysis graph of cultivar × cane number.

Figure 4. Correspondence analysis graph of cultivar x cane height.

Table 9. Results of correspondence analysis for cultivar x cane diameter.

Axis	Inertia	Proportion	Cumulative	Histogram
1	0.4960	0.7741	0.7741	******************************
2	0.1447	0.2259	1.0000	********
Total	0.6408			

Figure 5. Correspondence analysis graph of cultivar × cane diameter.

diameter (Cross-tabulation 8) are given in Table 9. Of total inertia, 77.41% was clarified by the first component and 22.59% by the second one (Table 9).

Correspondence Analysis Graph of cultivar × Cane Diameter is presented in Figure 5. As shown in Figure 5, Cheeroke cultivar was determined to have low cane diameter. Chester Thornless from blackberry cultivars had high cane diameter. Dirksen Thornless and Black Satin overlapped and was placed exactly between medium and low cane diameter. Jumbo, Ness, and Navaho cultivar were shown to have medium cane diameter. Arapaho cultivar was roughly between medium and high cane diameter.
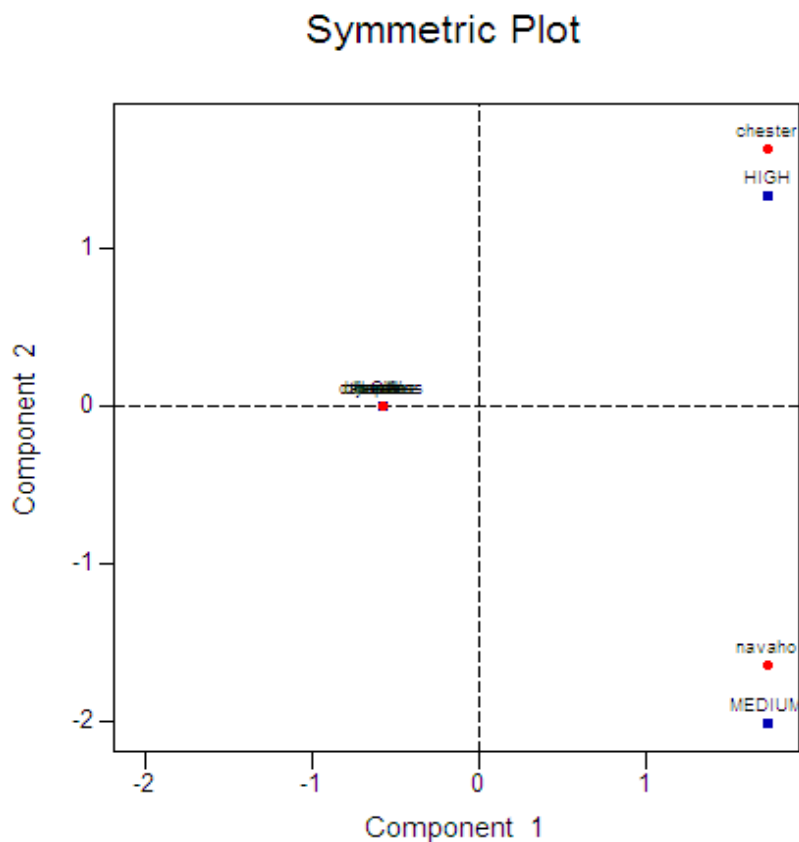
Results of Correspondence analysis for Cultivar × cane yield per plant (Cross-tabulation 9) are given in Table 10. Of total inertia, 60% was explained by the first component and 40 % by the second one (Table 10).

Correspondence Analysis Graph of cultivar × Cane yield per plant are presented in Figure 6. According to Figure 6, Chester Thornless cultivar had high cane yield per plant, but Navaho cultivar had medium cane yield per plant.

Table 10. Results of correspondence analysis for cultivar × cane yield per plant.

Axis	Inertia	Proportion	Cumulative	Histogram
1	1.0000	0.6000	0.6000	*****************************
2	0.6667	0.4000	1.0000	*******************
Total	1.6667			

Figure 6. Correspondence analysis graph of cultivar × cane yield per plan.

Other cultivars overlapped, and had low cane yield per plant.

Results of Correspondence analysis for Cultivar × fruit weight (Cross-tabulation 10) are given in Table 11. Of total inertia, 61.28% was explained by the first component and 38.72 % by the second one (Table 11).

Correspondence Analysis Graph of Cultivar × Fruit Weight is presented in Figure 7. It is clear from Figure 7 that Black Satin cultivar had low fruit weight, Arapaho, Navaho, Ness cultivars had medium fruit weight, whereas Chester Thornless and Dirksen Thornless cultivars (which overlapped) were found as high fruit weight as well as Jumbo.

As a result, comparing with chi-square and G statistics, associations between cultivar and each pomological trait (fruit weight, cane number, cane diameter, cane height, and cane yield per plant) were significant (P<0.0001).

The relationship of fruit weight and cane diameter or cane yield per plant was more significant (P<0.0001). The relationship between year and cane number or cane diameter was more significant (P<0.0001).

This is in agreement with Atila et al. (2006a,b); Eyduran et al. (2005a,b); Eyduran and Agaoglu (2006); Siriwoharn et al. (2005); Clark et al. (2005); Yorgey and Finn (2005); Connor et al. (2005a, b); Finn et al. (2005a, b, c, d, e); who reported that genotype, year and genotype by year interaction factors in various studies on blackberry were generally the most crucial factors during selection.

i) Results of the study can be summarized as as high fruit weight was taken in 2004, followed by 2005
ii) Blacksatin and Jumbo blackberry cultivars had the highest cane number.

Table 11. Results of correspondence analysis for cultivar × fruit weight.

Axis	Inertia	Proportion	Cumulative	Histogram
1	0.9164	0.6128	0.6128	*****************************
2	0.5791	0.3872	1.0000	******************
Total	1.4955			
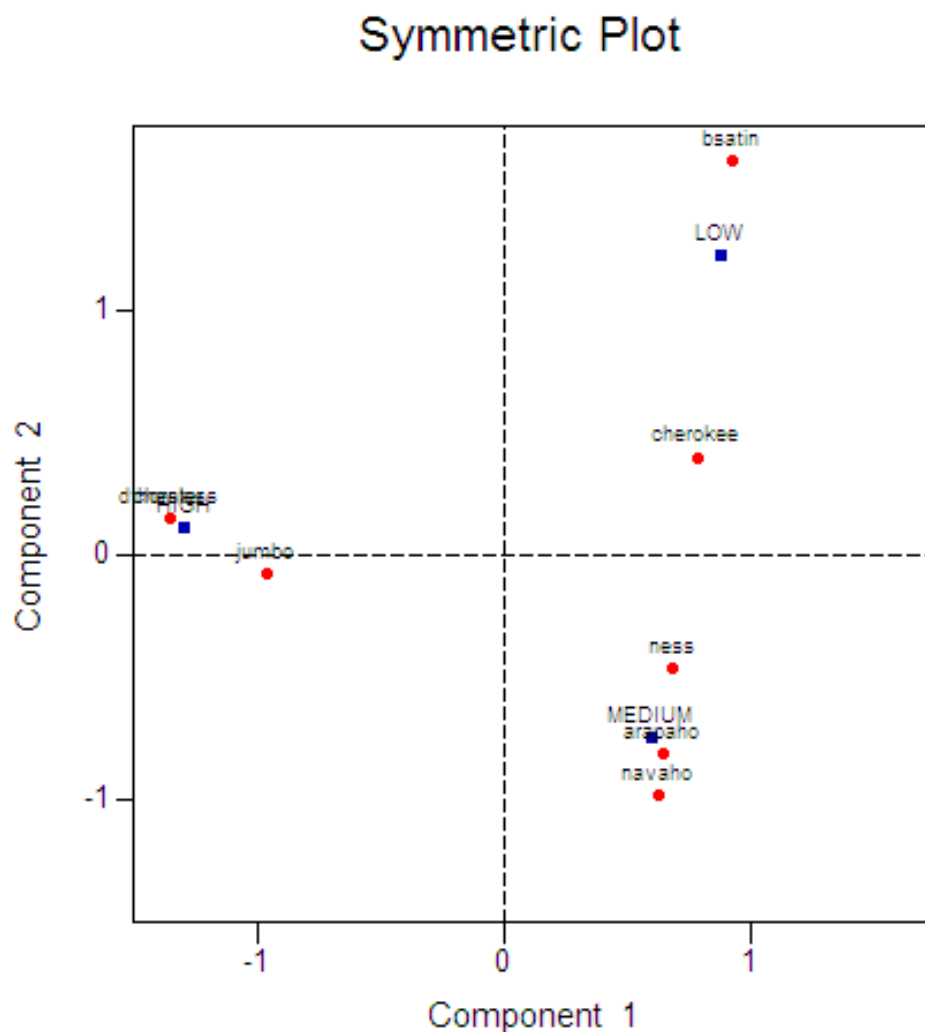
Figure 7. Correspondence analysis graph of cultivar × fruit weight.

iii) Arapaho and Cheroke cultivars overlapped each other, and kept the same distance to high cane height.

iv) Chester Thornless blackberry cultivars had the highest cane diameter.

v) Chester Thornless cultivar had the highest cane yield per plant.

vi) Chester Thornless and Dirksen Thornless cultivars had the highest fruit weight.

In view of the above results, cv. Chester Thornless was found as the best blackberry cultivar under conditions of Central Anatolia, Turkey.

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