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Multivariate analysis of yield data of kinnow crop for optimizing productivity in Himachal Pradesh

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Abstract

The paper deals with the usefulness of Discriminant and Principal Component analyses for determining the relative contribution of morphological and reproductive characters responsible in increasing the yield of kinnow. The technique Discriminant analysis was applied to formulate categorization rule for allocating the kinnow tree to 'high' and 'low' yielder groups. This Discriminant equation revealed that the characters plant girth (X_2), plant spread (X_3), leaves per branch (X_4) and flower per branch (X_6) are the most important characters that discriminated the two groups. The Principal Component Analysis was extracted for the assessment of relative contribution of morphological and reproductive characters responsible in increasing the yield of kinnow. In case of high yielders, three of the ten Principal Components (PCs) have Eigen values greater than unity (Gutman's lower bound) which played the main role in the analysis. These components were Fruiting or Fruitfulness, Growth characteristics and Growth and Volume characteristics which explained 36.38%, 11.61% and 11.01% respectively and collectively 68.57% of the total variation of the original variables. In case of low yielders, three principal components had been retained for the analysis. These components were Fruiting and Vigour, Growth and Volume and Vigour characteristics, which explained 38.11%, 14.68% and 12.03% respectively and in aggregate, 64.83% of the total variation of original variables.

Keywords: Kinnow, discriminant and principal component analyses

1. Introduction

The cultivation of citrus fruits is an important horticultural activity in the sub-tropical region of the state. Citrus fruits belong to the family Rutaceae, which include mainly; limes, lemons, oranges and kinnow. Among citrus fruits, kinnow mandarin has shown tremendous potential in the foothills of Himachal Pradesh. It plays an important role in the socio-economic transformation of rural masses in the low-hill zone of the state. In Himachal Pradesh, kinnow/orange crop occupies an area of 8609 hectare with production of 11010 MT (Anonymous, 2014) [2].

Kinnow yield is a complex trait which is influenced by several factors namely; tree characteristics, blooming characteristics, fruit set and crop density. Identifying a single variable representative of the complex trait i.e. yield. Therefore, an attempt to conduct a series of univariate statistical analyses carried out for each of the variables does not hold promise as it ignores the correlation among the variables and sometimes the conclusions may be misleading. On the contrary, multivariate analysis takes into account the interdependence and relative importance of the various influencing characters and yields more meaningful information.

In this paper, discriminant analysis was carried out to formulate the categorization rule for allocating the kinnow tree to High Yielder Group and Low yielder Group. An attempt has also been made to bring out the basic components with linear combination of morphological and reproductive characters contributing significantly towards kinnow yield by using Principal Component Analysis. Qurrie *et al.* (2000) [5] used Principal Component Analysis in agricultural research. The techniques are described in detail in standard statistical book such as (Anderson, 1958) [1].

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2. Materials & Methods: Field experiment was conducted during 2014-15 at farmer’s kinnow orchard in Indora block of kangra district as this area represent the main kinnow growing belt of the State. An optimum sample size of 104 kinnow trees was selected randomly by following a two-step approach as suggested by Stein (1945) [6]. and Cox (1958) [3]. Four branches from each of the tree in four directions as per the practice in vogue were selected and the following observations were recorded i.e. Yield per tree (Y), plant girth (X₂), plant spread (X₃), number of leaves per branch (X₄), annual shoot extension growth (X₅), number of flower per branch (X₆), number of fruits per branch(X₇), fruit weight(X₈), fruit set (X₉) and LD ratio(X₁₀).

The data collected were subjected to discriminant analysis to define a systematic and statistically valid procedure for categorizing the trees as high and low yielders. For these two populations, Principal Component Analysis was carried out to bring out the basic components associated with the above referred morphological characters of kinnow.

3. Results & Discussion: Discriminant analysis: The essence of discriminate analysis is to categories the observations into desired numbers of groups. In the present study, the observations was first divided into two groups namely ‘high yielder’ and ‘low yielder’ and then discriminant function was fitted. The discriminate analysis resulted into the following equations:

$$D_1 = - 6.991+ 0.079 X_2+ 0.293 X_3+ 0.007 X_4+ 0.039 X_6 \dots(1)$$

The equation revealed that the characters plant girth (X₂), plant spread (X₃), leaves per branch (X₄) and flower per branch (X₆) were the most important characters that discriminate the two groups. To test the statistical hypothesis of no difference in mean vectors (μ₁ and μ₂) of ten characters for these two groups; the value of Wilk’s lambda (λ) statistic was used. It was concluded that smaller the lambda for an independent variable, the more that variable contributes to the discriminant function. Lambda varies from 0 to 1, with 0 meaning group means differ and 1 meaning all group means are the same. The value of λ was obtained to be 0.465 and which, in turn, gave the computed value of chi-square (χ²) as 76.582 is much more than the table value of χ² at 5% level, the hypothesis of equity of group mean vectors was rejected means principle component analysis would be appropriate for data reduction. Having found that the groups differ statistically, the trees were assigned to group I (High Yielder) if $D_1 \geq m$ otherwise to group II (Low Yielder), where $m = -0.10$ is the average of groups centroids. The groups formed on the basis of allocation rule were subjected to Principal Components Analysis. The interpretation of classification rule can thus be stated as "Allocate the tree to group I (High yielder) if $D_1 > m_1$, otherwise to group II (Low yielder)."The groups formed on the basis of allocation rule were subjected to Principal Components Analysis and population-wise the results are discussed below:

3.1 Population – I (High Yielder): The main results of Principal Component Analysis pertaining to this population have been presented in Table 1. Perusal of Table 1 revealed that three of the ten Principal Components (PCs) have Eigen values greater than unity (Gutman’s lower bound) which

played the main role in the analysis, pertaining to “high yielder”. These components explain 36.38%, 11.61% and 11.01% respectively, of the total variation. Together they account 58.99 percent of the total variation of the original variables. The first component extracted in a principal component analysis accounts for a maximal amount of total variance in the observed variables. Under typical conditions, this means that the first component was correlated with at least some of the observed variables.

Table 2: Eigenvectors PC analysis of High yielder group.

Variables	PC ₁	PC ₂	PC ₃
Plant height (X ₁)	0.33	0.48	0.22
plant girth (X ₂)	0.30	0.20	0.53
Plant spread (X ₃)	0.23	0.48	-0.49
Number of leaves per branch (X ₄)	0.16	-0.20	0.53
Annual shoot extension growth(X ₅)	0.20	-0.47	-0.22
Number of flowers per branch (X ₆)	0.43	-0.19	0.03
Number of fruits per branch(X ₇)	0.49	-0.03	-0.11
fruit weight(X ₈)	0.29	-0.33	0.02
Fruit set (X ₉)	0.39	0.09	-0.23
LD ratio(X ₁₀)	0.17	-0.30	-0.19
Eigen value	3.64	1.16	1.10
% of variance	36.38	11.61	11.01
Cumulative % of variance	36.38	47.99	58.99

The variables loading for first principal component is highest for three characteristics number of flowers per branch (X₆), number of fruits per branch (X₇), and percentage fruit set (X₉), component may be interpreted as Fruiting or Fruitfulness. The second principal component (PC₂) was dominated by plant height (X₁), plant spread (X₃) and annual shoot extension growth(X₅) termed as Growth characteristics. The third principal component (PC₃) was combination of number of leaves per branch (X₄) and plant girth (X₂) termed as Growth and Volume characteristics of the plant.

3.2 Population – II (Low Yielder): Table-2 revealed that the first principal component (PC₁) had eigen value 3.81 and it explained 38.11 percent of total variation in the data set and showed relative maximum weight for number of fruits per branch (X₇) followed by number of flowers per branch (X₆) and percentage fruit set (X₉) followed by plant height (X₁). None of the characters was found to be negative in PC₁. The second principle explained the 14.68 percent of total variations with eigen value 1.47. In this component of the variables viz. annual shoot extension growth (X₅), fruit weight (X₈) and plant spread (X₃) was found to be positive. Therefore, the second component extracted was account for a maximum amount of variance in the data set that was not accounted for by the first component. The third principle component has eigen value 1.20 and explains 12.03 percent of the total variations. The contribution of the variable were plant girth (X₂) was found to be positive whereas number of leaves per branch (X₄) had negative contribution. The PC₁, PC₂ and PC₃ showed relatively large variation with eigen values 3.81, 1.47 and 1.20 respectively. These eigen values were greater than one and represented exact linear dependency.

Table 2: Eigenvectors PC analysis of low yielder group.

Variables	PC ₁	PC ₂	PC ₃
Plant height (X ₁)	0.35	-0.11	0.08
plant girth (X ₂)	0.15	-0.11	0.78
Plant spread (X ₃)	0.24	0.46	-0.26
Number of leaves per branch (X ₄)	0.29	0.06	-0.36
Annual shoot extension growth(X ₅)	0.04	0.62	0.15
Number of flowers per branch (X ₆)	0.43	-0.06	-0.10
Number of fruits per branch(X ₇)	0.48	-0.11	-0.09
fruit weight(X ₈)	0.05	0.59	0.21
Percentage fruit set (X ₉)	0.43	-0.11	-0.04
LD ratio(X ₁₀)	0.33	0.00	0.33
Eigen value	3.81	1.47	1.20
% of variance	38.11	14.68	12.03
Cumulative % of variance	38.11	52.79	64.83

The variable loading for first principal component is highest for three characteristics, number of fruits per branch (X₇) followed by number of flowers per branch (X₆), percentage fruit set (X₉) and plant height (X₁) termed as Fruiting and Vigour characteristics. The second principal component (PC₂) was dominated by annual shoot extension growth (X₅), fruit weight (X₈) and plant spread (X₃) termed as plant Growth and Volume characteristics. The third principal component (PC₃) was plant girth (X₂) and the number of leaves per branch (X₄) termed as plant Vigour characteristics. With the interpretation of vigour by Iezzoni and Pritts (1991) [7], it was now possible to apply different treatments to increase yield and to determine whether the yield increase was the result of an increase in vegetative vigour, a change in the balance of vegetative growth and fruit production, a reduction in fruit set, or a combination of these factors.

4. Conclusion: The discriminant function revealed that plant girth (X₂), plant spread (X₃), leaves per branch (X₄) and flower per branch (X₆) were the most important characters that discriminate the groups. The groups were subjected to Principal Component Analysis. In both populations, three Principal Components were extracted, which played the main role in the analysis. Thus, the Principal Component Analysis has brought out some of the basic components associated with morphological characters of kinnow and could be considered as important tool in explanatory work for optimizing kinnow productivity.

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