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Statistical Investigations of Growth Characteristics of Cherry-Bark Elm (*Ulmus villosa* Brandis) under Mid-Hill Conditions of Himachal Pradesh

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Abstract The paper deals with the usefulness of multivariate techniques viz. Principal Component and Factor analysis for determining the relative contribution of morphological characters responsible for increasing the biomass of *Ulmus villosa.*

Keywords *Ulmus villosa*, Biomass, Principal component analysis, Factor analysis, Growth characteristics.

Introduction

Multivariate techniques have emerged as a powerful tool to analyze data represented in terms of many variables. The main reason being that a series of univariate analysis carried out separately for each variable may, at times, lead to incorrect interpretation of the result. This is so because univariate analysis does not consider the correlation or inter-dependence among the variables. As a result a number of statisticians have contributed to the development of several mulitivariate techniques. Applications of multivariate techniques in practice have been accelerated because of the advent of high speed electronic computers. Principal Component Analysis is a multivariate statistical technique to reduce the data with large number of correlated variables into substantially smaller set of new variables, through linear combination of variables that account for most of the variation present in the original variables. Its purpose is to determine factors so that with few factors, we can explain maximum of total variation since Principal Component arises from a rotation of axis to achieve maximum variance. Factor Analysis is a multivariate statistical technique widely used by researchers for studying the correlation among many observed variables in terms of smaller number of unobserved variables called factors. Factor Analysis being a data reduction technique for investigating the interdependence has been used. The essential purpose of Factor Analysis is to describe if possible the covariance relationship among many variables in terms of a few underlying but unobservable random quantities called factors. Factor Analysis does not entail partially the data matrix in to criterion and pre-

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Table 1. Diameter class wise DBH, tree height and bole height of cherry-bark Elm at two sites.

Diameter Class (cm)	DBH (cm)		Tree height (m)		Bole height (m)	
	Site-I	Site-II	Site-I	Site-II	Site-I	Site-II
5-10	8.42	6.91	10.0	6.20	4.28	2.59
10-15	12.39	12.67	12.24	10.78	4.41	3.16
15-20	16.65	16.89	13.91	13.52	5.28	4.07
20-25	23.34	22.74	18.22	17.54	6.95	4.95
Mean	15.20	14.80	13.59	12.01	5.23	3.69
SE	3.19	3.34	1.74	2.38	1.23	0.52
CV (%)	41.97	45.16	25.56	39.67	23.45	28.09

dictor subsets; rather the interest is centered on relationship involving the whole set of variables. The selection of a set of biometrical characters of crop which are likely to give an adequate basis for forecasting yield is very important as yield is related to several biometrical characters of crop. Cherry-bark Elm (*Ulmus villosa* Brandis) is one of the distinctive Asiatic elms. The species is capable of remarkable longevity and belongs to the family Ulmaceae. It is a medium-to -large deciduous tree species of the North-western sub-Himalayas. The species is highly valued for its multiple uses (timber, fuel and fodder) and fast growth rate. The study constitutes an assessment of standing biomass of *Ulmus villosa.* In this paper, an attempt has been made to assess the relative contribution of morphological characters in the biomass production.

Materials and Methods

The present study was carried out at two sites i.e., Bagaur (site-I) and Majhgaon (site-II) at the main campus of Dr Y. S. Parmar University of Horticulture and Forestry, Nauni (Solan), Himachal Pradesh located in the mid-hill zone of Himachal Pradesh with the elevation of about 1250m above mean sea level. Nauni lies about 13 km from Solan with the following coordinates : Latitude 30°51′ N and longitude 76°11′ E (Survey of India Toposheet No. 55F/1) according to Survey of India. The above ground biomass was estimated separately for stem, branches and leaves + twigs of *Ulmus villosa* at two sites. An optimum sample size of 135 trees was selected randomly by following a two-step approach for recording the observations on various growth parameters viz., diameter at breast height, tree height, crown height, crown length, crown width and bole height. Principal Component and Factor Analysis were carried out to bring out the basic components associated with characters responsible for increasing the biomass of *Ulmus villosa.*

Results and Discussion

Growth behavior

The data were collected from randomly selected 135 trees of *Ulmus villosa* at two sites namely site-I and II, respectively, for various growth parameters (diameter at breast height (DBH), tree height, crown height, crown length, crown width and bole height). The trees were classified into four diameter classes with five centimeters class interval viz. 5-10 cm, 10-15 cm, 15-20 cm and >20 cm, respectively. The average DBH, tree height and bole height with respect to diameter classes is given in Table 1 for two sites along with their mean, standard error and coefficient of variation (%). The DBH, tree height and bole height exhibited increasing trend with respect to diameter class.

Crown characteristics

Diameter class wise data on crown characteristics are presented in Table 2. This table shows that average crown height (m), crown length (m) and crown

Table 2. Diameter class wise crown characteristics of *Ulmus villosa* at two sites.

Diameter Class (cm)	Crown height (m)		Crown length (m)		Crown width (m)	
	Site-I	Site- II	Site-I	Site-II	Site-I	Site-II
5-10	3.35	3.46	3.74	5.99	3.39	4.50
10-15	3.77	4.00	7.44	8.78	4.02	4.78
15-20	3.82	4.18	9.68	9.04	5.12	5.71
20-25	4.73	6.26	13.12	11.42	5.21	6.81
Mean	3.92	4.47	8.49	8.81	4.44	5.45
SE	0.29	0.61	1.97	1.11	0.44	0.52
CV (%)	14.85	27.40	46.35	25.21	19.83	19.12

width (m) increased from 3.92 m to 4.47m, 8.49 m to 8.81 m and 4.44 m to 5.45m, respectively from site I to site II.

Variability analysis and evaluation of factors responsible for biomass production

Variation among different growth characteristics

The data were collected for various growth characteristics from randomly selected 135 trees. F-test was applied to test the variation between two sites for these characters. Mean, standard deviation and coefficient of variation were computed and the results are presented in Table 3. F-test suggested that there was no significant variation among tree characteristics between two sites. The highest average values of all the characters such as tree height (13.42 m), crown height (4.29 m), crown width (5.33 m) and bole height (5.09 m) were observed at site-I, except dbh (15.93 cm) and crown length (9.17 m), which was maximum at site-II. Maximum coefficient of variation (CV%) of 41.98 was observed for crown height at site-I, whereas, 38.38 for bole height at site-II. The minimum value of coefficient of variation was observed for tree height i.e., 22.93 and 31.44 at sites I and II respectively. Total green biomass and total dry biomass were also obtained and variability parameters are presented in Table 4. Perusal of Table 4 indicates that total green biomass (117.83 kg) and total dry biomass (72.98 kg) were maximum at site-II. However, coefficient of variation for total dry biomass (85.81) and total green biomass was found to be maximum at site-I.

Principal component analysis

The main results of Principal Component Analysis have been presented in Table 5. Perusal of Table 5 reveals that two of six principal components (PCs) have eigen values greater than unity and as such these are playing the main role in the analysis. The components explain 61.25% and 19.80%, respectively

Table 3. Variability analysis for different growth characteristics.

Tree characteristics	Site-I (n=65)			Site - II (n=70)			F-test
	Mean	SD	CV (%)	Mean	SD	CV (%)	
DBH (cm)	14.92	5.09	34.16	15.93	5.58	35.05	1.19
Tree height (m)	13.42	3.08	22.93	12.84	4.04	31.44	1.72
Crown height (m)	4.29	1.81	41.98	3.94	1.36	34.62	1.74
Crown length (m)	8.83	2.56	28.98	9.17	3.41	37.16	1.77
Crown width (m)	5.33	1.38	25.96	4.59	1.53	33.33	1.22
Bole height (m)	5.09	1.85	36.31	3.85	1.48	38.38	1.57
Total green biomass (kg)	89.83	65.05	72.42	117.83	83.52	70.88	1.65
Total dry biomass (kg)	47.88	41.09	85.81	72.98	53.86	73.79	1.72

Table 4. Variability parameters for different biomass.

Biomass	Site -I (n=65)			Site - II (n=70)			F-test
	Mean	SD	CV(%)	Mean	SD	CV(%)	
Total green biomass (kg)	89.83	65.05	72.42	117.83	83.52	70.88	1.65
Total dry biomass (kg)	47.88	41.09	85.81	72.98	53.86	73.79	1.72

of the total variation. Together, they account for 81.05% of the total variation of the original variables. The variable loadings for the first principal component was highest for three characters namely tree height (m), DBH (cm) and crown length (m). However, the second principal component is a combination of crown height and bole height (m) with just 19.80% of the total variation. Thus the main contributors towards biomass of *Ulmus villosa* are tree height (m), DBH (cm) and crown length (m) with about 61.25% of the total variation.

Factor analysis

The primary field data were used for factors extraction through principal component method for two sites simultaneously. The factor F_1 has been retained in the analysis by virtue of mineigen criteria (i.e., factors having eigen value greater than one). The variation explained by this factor (F_1) was 57.785%. Ignoring the non-significant correlations, the orthogonal factor can be expressed as : $F_1 = 0.895D + 0.992H + 0.796CL$.

The factor (F_1) was a combination of DBH (D), tree height (H) and crown length (CL) and can be expressed as Stem Factor. The communalities (common factor coefficient) of the variates viz., DBH (D), tree height (H) and crown length (CL) were observed to be 0.827, 0.941 and 0.609 respectively. Thus Factor Analysis has brought out a basic factors associated with morphological character of *Ulmus villosa.*

Table 5. Eigenvectors of the PC analysis.

Variables	PC1	PC2
DBH (cm)	0.473	-0.220
Tree height (m)	0.502	-0.166
Crown height (m)	0.307	0.642
Crown length (m)	0.409	-0.507
Crown width (m)	0.370	0.054
Bole height (m)	0.355	0.501
Eigen values	3.68	1.19
% of variance	61.25	19.80
Com.% of variance	61.25	81.05

Mani and Parthasarathy (2007) studied above ground biomass estimation in the ten tropical dry evergreen forest sites of peninsular India. Russell et al. studied stand conditions influencing the partitioning of biomass to stem, needle, branch, and root components. Multivariate analysis of variance concluded that row and column spacing did not have significant effect on the relative amount of biomass among tree components. Ranot and Sharma (2013) concluded that above ground volume mean annual increment per tree basis was maximum in *Acrocarpus fraxinifolius* (0.028 m^3) followed by *Eucalyptus tereticornis* (0.026 m^3), *Populus deltoides* (0.021 m^3), *Pinus roxburghi* (0.020 m^3), *Salix alba* (0.019m^3), *Albizzia lebbek* (0.008 m^3), *Ulmus villosa* (0.008 m^3). Devi et al. (2013) attempted to estimate biomass production of different plantation ecosystems in North western Himalaya, India. Above (185.57 ± 48.99 tha^{-1}) and below ground (42.47 ± 10.38 tha^{-1}) biomass was maximum in *Ulmus villosa.* Nasir et al. (2014) and Wani et al. (2014) attempted to estimate the biomass and carbon allocation of 19 year old *Ulmus wallichiana* plantation under different diameter classes.

Conclusion

Tree height, bole height, crown height, crown length and crown width increased with increase in diameter at breast height. Two Principal Components (PCs) were extracted out of six which explains 61.25% and 19.80% of the total variation respectively. Using Factor Analysis, one factor is extracted which was a combination of diameter at breast height, tree height and crown length and explained 57.785%

of total variation. Thus Principal Component and Factor Analysis has brought out these basic factors associated with morphological character of *Ulmus villosa*.

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