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Heritability estimates, correlation and path analysis studies for nut and kernel characters of Pecan (*Carya illinoensis* [Wang] K. Koch)

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This study was undertaken to work out heritability estimates, correlation and path analysis on 34 pecan selections and three standard cultivars Western Schley, Mahan, and Burkett. High heritability estimates coupled with low genetic advance for most nut and kernel characters indicate higher influence of environment and presence of non-additive gene action suggesting that selection in pecan may not be effective. However, relatively higher values of genetic advance with high heritability recorded in kernel recovery, fat content and nut length indicates that the selection can be exercised on the basis of these characters. Significant correlations have been observed between most of the nut and kernel characters. The positive correlation towards nut yield with other desirable characters like nut weight, kernel weight, nut length and kernel length would be favourable to breeders for their simultaneous genetic improvement.

Key words: Pecan, correlations, genetic variability, kernels, nuts, path analysis.

INTRODUCTION

Pecan [*Carya illinoensis* (Wang) K.Koch] is an important edible nut crop that belongs to the family Juglandaceae. Pecan is a monoecious, heterodichogamous (protandrous and protogynous), wind pollinated and deciduous nut tree. Pecan is native to United States and has adapted to a wide climatic range between 30° to 42°N latitude ranging from mild to extremely harsh winters and from very humid to semi-arid, suggesting thereby substantial genetic diversity (Sparks, 2005). Major differences exist among genotypes by climatic regions. Diversity occurs for growth rate, dormancy inception, days required for fruit growth, nut size, kernel recovery and cold hardiness. Even now, tens of thousands of seedling Pecan trees occur in the native habitat and elsewhere in the Pecan groves and orchards exhibiting tremendous variability in nut size, shape, shell features, flavor, precocity, maturity and yield potential. In India, its cultivation has a tremendous scope in the mid hills of Himachal Pradesh and similar other areas of the country falling between elevations of 500 to 1500 m above mean sea level (Badyal and Upadhayay, 2004).

However, the genetic improvement in Pecan in India is still in a primitive stage, almost all the Pecan plantings in semi-wild state comprise trees of seedling origin of unknown pedigree and breeding efforts for its improvement have been negligible. The present scenario represents a potential gene pool to exploit genetic variability as every tree in itself is a unique genotype, largely owing to dichogamy favouring out crossing (Worley, 1994). Efforts in the past to select superior strains have not yielded much, and still warrant the development of locally adapted Pecan genotypes with

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Table 1. Genetic variability analysis for nut and kernel characters of Pecan seedling selections and cultivars.

Trait	Mean	Coefficient of variation		Heritability (%)	Genetic advance	Genetic gain (%)
		Phenotypic (%)	Genotypic (%)			
Nut yield (kg/tree)	3.98	22.63	21.04	85.45	1.40	44.10
Nut yield efficiency (kg/cm^2)	0.01075	10.5	9.84	84.57	0.11	26.40
Nut weight (g)	5.55	20.20	19.50	93.60	2.17	40.27
Nut width (mm)	15.3	24.76	24.61	98.34	6.80	44.10
Nut height (mm)	17.6	23.46	23.45	99.96	8.75	48.30
Nut length (mm)	35.4	21.33	20.49	96.04	13.34	42.21
Shell thickness (mm)	0.85	17.62	16.71	89.96	0.30	34.40
Kernel weight (g)	3.45	23.64	21.74	84.54	1.46	44.70
Kernel width (mm)	14.5	18.90	18.60	96.39	5.65	38.30
Kernel height (mm)	15.5	19.09	18.84	97.43	6.08	38.80
Kernel length (mm)	27.3	18.76	18.05	92.59	9.41	37.19
Kernel recovery (%)	62.4	19.34	18.33	89.70	23.15	37.70
Fat content (%)	45.2	21.46	21.41	99.58	20.70	44.10
Protein content (%)	7.9	33.40	33.10	98.39	4.68	54.49

higher yield, better nut and kernel characters. To initiate an efficient breeding programme, there is absolute need to develop selection criteria for nut and kernel characters through understanding the breeding system coupled with statistical analysis of inheritance data.

This study was, therefore, undertaken to work out, coefficient of variation, heritability estimates and correlations, on 34 bearing Pecan selections and three standard cultivars Western Schley, Mahan, and Burkett.

MATERIALS AND METHODS

The present study was carried out in the experimental farm of Nauni-Solan, located near Kalaghat at 1275 m above mean sea level. The experimental plant material included 34 bearing Pecan trees (12 to 14 years old) raised through seed collected from different areas of Himachal Pradesh, along with 3 standard cultivars: Western Schley, Mahan, and Burkett. For nut and kernel quality characters 20 randomly collected nuts were taken for recording observations. Standard procedures were followed to analyze the data statistically as suggested by Panse and Sukhatme (1985). Augmented block design (Sharma, 1998) was used for testing the significant difference between different varieties with respect to nut and kernel characters. Coefficient of variability was calculated at phenotypic, genotypic, and environmental levels by the formula suggested by Burton and DeVane (1953). Heritability (%) in broad sense and the expected genetic advance resulting from selection of 5% selection intensity was calculated as per method suggested by Allard (1999). Genetic gain is genetic advance expressed as per cent of population mean and was calculated by the formula suggested by Johnson et al. (1955). The observed data was subjected to path analysis by using pooled correlation matrix as suggested by Dewey and Lu (1959).

RESULTS

The estimates of average mean performance and the genetic variability parameters for nut and kernel characters in 34 Pecan trees of seedling origin and three cultivars: Western Schley, Mahan, and Burkett were worked out from analysis of variance and are presented in Table 1. Maximum heritability (99.96%) was observed for nut height and minimum (84.54%) for kernel weight.

Phenotypic coefficient of variation was recorded to be higher as compared to genotypic coefficient of variation for all the nut and kernel characters studied. Highest phenotypic coefficient of variation (33.30%) and genetic gain (54.49%) was recorded for protein content while the corresponding minimum values were observed for nut yield efficiency (10.5 and 26.40%, respectively).

The results obtained were with respect to character association studies between various nut and kernel characters (Table 2). In the present study, simple correlation indicated that nut weight

Table 2. Correlation coefficients among various nut and kernel characters in pecan seedling selections and cultivars.

S/N	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	1													
2	0.988	1												
3	0.090	0.092	1											
4	- 0.125	-0.088	0.399	1										
5	-0.189	-0.186	0.636	0.752	1									
6	0.498	0.523	0.113	-0.128	-0.257	1								
7	-0.087	-0.062	0.231	0.227	0.233	-0.168	1							
8	0.186	0.155	0.469	0.253	0.289	0.183	-0.110	1						
9	-0.115	-0.086	0.717	0.592	0.711	-0.188	0.274	0.296	1					
10	0.452	0.450	0.474	0.446	0.483	0.106	0.128	0.273	0.435	1				
11	0.448	0.442	0.117	-0.025	-0.161	0.797	-0.263	0.354	-0.050	0.128	1			
12	0.090	0.060	-0.449	-0.072	-0.275	0.061	-0.343	0.569	-0.350	-0.146	0.243	1		
13	-0.169	-0.201	0.096	-0.004	0.103	0.087	-0.078	0.126	0.036	-0.175	0.120	-0.005	1	
14	-0.437	-0.412	0.052	-0.115	-0.033	-0.080	0.277	-0.181	0.114	-0.269	-0.086	-0.252	0.058	1

1, Nut yield, 2, nut yield efficiency; 3, nut weight; 4, nut width; 5, nut height; 6, nut length; 7, shell thickness; 8, kernel weight; 9, kernel width; 10, kernel height; 11, kernel length; 12, kernel recovery;13, fat content; 14, protein content.

was positively correlated with nut yield (0.09) and nut yield efficiency (0.092). Shell thickness was positively correlated with nut weight (0.231), nut width (0.227) and nut height (0.233). Kernel weight was positively correlated with nut yield (0.186), nut yield efficiency (0.155), nut weight (0.469), nut width (0.253), nut height (0.289) and nut length (0.183). Kernel recovery was positively and significantly correlated with nut yield (0.09), nut yield efficiency (0.06), nut length (0.06), kernel weight (0.569) and kernel length (0.243).

In the present study for path analysis, 13 different nut and kernel characters were considered as independent variables and nut yield was taken as dependent variable. The direct and indirect effects of various characters were worked out from pooled correlation matrix and are presented in Table 3. Path analysis revealed that nut yield efficiency (P = 0.964) had highest positive direct effect on nut yield followed by kernel weight (P = 0.226), kernel length (P = 0.087), kernel height (P = 0.039) and nut height (P = 0.033). Kernel height (P = 0.434) had highest positive indirect effect on nut yield through nut yield efficiency and protein content (P = -0.397) gave highest negative effect on nut yield via nut yield efficiency.

DISCUSSION

The variability studies (Table 1) revealed the higher magnitude of phenotypic coefficient of variation and high heritability estimates (more than 80%) for all nut and kernel characters in Pecan. However, high heritability accompanied with low genetic gain as well as low genetic advance reported the majority of the characters: nut weight, shell thickness, kernel width, kernel height and kernel length, indicates that most likely the high heritability is being exhibited due to favourable influence of environmental rather than genotypic and selection for such traits may not be rewarding in early selection generations, due to the presence of dominance in available gene pool. Thompson and Baker (1993) reported that heritability (h^2) estimates for nut and kernel characters were low to moderate (nut weight = 0.35, nut buoyancy = 0.18, nut volume = 0.35, nut density = 0.03, kernel weight = 0.38 and percentage kernel = 0.32). The low values reported by them were probably due to the extreme alternate bearing tendency of this species, since crop load affects Pecan nut characteristics so directly.

Significant correlations have been observed between most of the nut and kernel characteristics

Table 3. Pooled direct and indirect effects of various nut and kernel characters in pecan seedling selections and cultivars.

S/N	1	2	3	4	5	6	7	8	9	10	11	12	13
1	0.964	-0.014	0.005	-0.006	-0.058	0.0001	0.035	0.006	0.018	0.038	-0.012	-0.003	0.012
2	0.089	-0.153	-0.025	0.021	-0.012	-0.0001	0.106	-0.056	0.019	0.010	0.092	0.001	-0.001
3	-0.085	-0.061	-0.063	0.025	0.014	-0.0001	0.057	-0.046	0.017	-0.002	0.014	-0.0001	0.003
4	-0.180	-0.097	-0.047	0.033	0.028	-0.0001	0.065	-0.056	0.019	-0.014	0.056	0.001	0.001
5	0.505	-0.014	0.008	-0.008	-0.110	0.0001	0.041	0.014	0.004	0.069	-0.012	0.001	0.002
6	-0.059	-0.035	-0.014	0.007	0.018	-0.0003	0.025	-0.021	0.005	-0.023	0.070	-0.001	-0.008
7	0.149	-0.072	-0.016	0.009	-0.020	0.0001	0.226	-0.023	0.010	0.031	-0.116	0.002	0.005
8	-0.083	-0.110	-0.037	0.024	0.020	-0.0001	0.067	-0.078	0.017	-0.004	0.071	0.0006	-0.003
9	0.434	-0.073	-0.028	0.016	-0.011	0.0001	0.061	-0.034	0.039	0.011	0.030	-0.003	0.008
10	0.426	-0.018	0.001	-0.005	-0.088	0.0001	0.080	0.004	0.005	0.087	-0.049	0.002	0.002
11	0.058	0.069	0.004	-0.009	-0.006	0.0001	0.128	0.027	-0.005	0.021	-0.205	-0.0001	0.007
12	-0.194	-0.014	0.0003	0.003	-0.009	0.0001	0.028	-0.002	-0.007	0.010	0.001	0.017	-0.001
13	-0.397	-0.008	0.007	-0.001	0.008	-0.0001	-0.040	-0.009	-0.010	-0.007	0.051	0.001	-0.030

Residual effect = 0.0152, Bold figures represent direct effects and others indirect effects. **1,** Nut yield efficiency; **2,** nut weight; **3,** nut width; **4,** nut height; **5,** nut length; **6,** shell thickness; **7,** kernel weight; **8,** kernel width; **9,** kernel height; **10,** kernel length; **11,** kernel recovery; **12,** fat content; **13,** protein content .

(Table 2) in the present study. Correlations studies suggest that weight and length of nuts and kernels could be important selection criteria for higher nut yield and nut yield efficiency in Pecan. These observations are in line with the findings of Thompson and Baker (1993) who reported that phenotypic correlations among nut and kernel traits showed that larger or heavier nuts had significantly higher kernel weight, buoyancy, and percentage kernel. Earlier, Worley et al. (1972) had also found positive correlation of yield with nuts per pound and tree circumference over several years.

In the present study, nut yield was found to be negatively and significantly correlated with fat content (r = -0.169) and protein content (r = -0.437). This finding is further corroborated by the work of McMeans and Malstrom (1982) who reported that nut yield was inversely correlated with total oil content. Therefore, these chemical quality characters may not serve as good selection criteria for improving nut yield in pecan.

Since a correlation study measures the mutual association without regard to causation, so, correlation may not always provide a true picture of the association. The association becomes complex when many correlated characters are affecting a particular variable. In such situations, a path coefficient analysis enables us to evaluate the direct effect of one cause on an effect and its indirect effect through other causes. Path analysis (Table 3) carried out in the present study revealed that only nut yield efficiency had direct effect of high magnitude (P = 0.964) whereas kernel weight had direct effect of low magnitude (P = 0.226) on nut yield. However, other characters like kernel height (P = 0.434) and kernel length (P = 0.426) had indirect effect on nut yield via yield efficiency.

On the whole, it can be concluded that nut weight, kernel weight, nut length, and kernel length could be used as selection indices for genetic improvement in Pecan especially with respect to economically important characters like nut yield and size.

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