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Variation among Selected *Prosopis* Families for Pod Sugar and Pod Protein Contents

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ABSTRACT

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A total of 14 half-sib families representing several *Prosopis* species were evaluated for for pod sugar and pod protein contents. Pods were collected for each of three years at three planting locations. At one location, three irrigation treatments were represented. Differences among families were observed for both pod sugar and protein contents at two of the sites. Among-site differences and family-by-site interactions were found for sugar content only. Intraclass correlations were calculated to estimate the degree of resemblance among family members for both variables. Correlation ranged from 0.30 to 0.40 for sugar content and from 0.04 to 0.60 for protein content, indicating a generally high degree of genetic control for these families in the environments tested.

INTRODUCTION

Most developing countries are faced with a rapidly rising population and a relatively static or diminishing base of fertile land. Increasing demand for wood resources in the semiarid tropics has increased pressure to consider new, underutilized plants as supplemental food for animals and humans and as aids in site stabilization and rehabilitation. The plants sought are those with agroforestry potential, trees which can be simultaneously grown for short rotation fuel wood and other tree components such as pods and leaves not previously considered for harvest.

Woody legumes are an economic source of fuel and protein, yet their potential for food and feed has not been fully developed (Sinha, 1977). Leguminous trees of the genus *Prosopis* (Mesquite) are well adapted to the arid areas of Asia, North Africa, and North, Central and South America (Felker, 1979).

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TABLE 1

Accession number, genus, species and geographic origin of evaluated *Prosopis* accessions

Accession number	Species	Geographic origin[a]
039	*Prosopis alba*	Argentina
137	*Prosopis alba*	Argentina
138	*Prosopis alba*	Argentina
166	*Prosopis alba*	Thermal, CA
016	*Prosopis articulata*	Baja, Mexico
001	*Prosopis glandulosa* var. *torreyana*	Thermal, CA
028	*Prosopis glandulosa* var. *glandulosa*	McNary, TX
133	*Prosopis nigra*	Argentina
245	*Prosopis pubescens*	Julian, CA
020	*Prosopis velutina*	Pima, AZ
025	*Prosopis velutina*	Santa Ana, Mexico
032	*Prosopis velutina*	Benson, AZ
074	*Prosopis* sp.	Mesquite, NM
080	*Prosopis* sp.	York, AZ

[a]AZ = Arizona, CA = California, NM = New Mexico, TX = Texas.

Historically, *Prosopis* pods have been used extensively by desert cultures for both animal and human food (Felker, 1981; Becker, 1982). However, their use has declined in recent years and has not been extensively investigated as a realistic crop for agroforestry.

Several studies have reported protein and sugar contents for *Prosopis* (Avgerinos and Wang, 1980; Becker and Grosjean, 1980; Felker et al., 1980; Becker, 1982). Most of these reports have been based on material from mature, wild mesquite trees. No year-to-year or site-to-site variation has been reported for pod sugar or protein concentrations in *Prosopis*.

The objectives of this study were: (1) to determine and compare pod sugar and protein contents in selected *Prosopis* half-sib families when grown in several environments, and (2) to determine the extent to which pod protein and sugar contents are under genetic control.

MATERIALS AND METHODS

The material used in this study was obtained from several sources (Felker et al., 1983; Felker et al., 1984). Table 1 shows a summary of evaluated materials.

Study areas

The three study sites were described in detail by Felker et al. (1983). The sites, located in California, were designated according to location and treatment as Riverside orchard, Riverside irrigation and Imperial Valley plots.

Riverside orchard plots were established in June 1977, using a randomized block design. The planting was composed of 25 accessions with four blocks planted at 4.5 × 6.1 m spacing in row plots. During summer months, plots were irrigated every three weeks by furrow irrigation. The July maximum temperature for this site averages 34.6 °C, and the annual rainfall averages 340.8 mm.

In July 1978 the irrigation plots were also established at Riverside. They were composed of 32 accessions planted at a 1.2 × 1.2 m spacing in three randomized blocks. During summer months the plots were irrigated when the soil moisture potentials at 30 cm depth reached −0.06 MPa, −0.2 MPa, and −0.5 MPa, respectively.

The Imperial Valley plots, established in March 1979, were composed of 55 accessions in 16 blocks with 55 trees per block as single tree replicates. They were planted at a 1.5 × 3.6 m spacing. The July maximum temperature for this site averages 41.7 °C, with mean annual rainfall of 106.6 mm.

Pod collection and chemical analysis

Pod samples were collected from 1979 to 1981. Mature pods were individually picked, oven-dried at 50 °C for a minimum of six hours (6% moisture content), catalogued and stored at −8 °C.

For analysis, collected pods were removed from the freezer and oven-dried at 50 °C for six hours. Whole pods were then ground in a Wiley mill to pass through a 1 mm mesh sieve. The ground materials were labelled and stored in plastic bags.

Pod nitrogen percentage was determined by micro-Kjeldahl analysis (Anon., 1980). Total pod protein was determined using a factor of 6.25 × percent nitrogen.

Total soluble sugars were extracted from the ground pods by the soxhlet method for 1.5 h using 70% alcohol. Total soluble sugar in the extractant solution was analyzed by the improved anthrone method for determination of carbohydrates as described by Loewus (1951).

RESULTS

Pod protein

Statistical analysis of protein content across the three sites indicated significant differences among families (Table 2). Site differences and family-by-site interactions were not significant.

There were significant differences among families in protein content at the Riverside orchard plots (Table 3). However, differences among years and family-by-year interactions were not significant. The Duncan's test shows that *P.*

TABLE 2

Pod protein comparison among *Prosopis* species across three sites (Riverside orchard, Riverside irrigation, and Imperial Valley plots)

Species	Accession number	Protein (%)[a]			Average[b]	Duncan's grouping[c]
		#Ro	Ri	I		
P. velutina	032	17.9	18.6	15.7	17.8	A
P. velutina	020	17.1	16.7	15.0	16.6	AB
P. articulata	016	—[d]	17.0	13.3	15.9	B
P. velutina	025	16.9	15.0	—[d]	15.6	B
P. glandulosa var. *torr.*	001	15.3	14.8	—[d]	15.1	B
P. glandulosa var. *gland.*	028	14.0	13.4	—[d]	13.6	C
P. alba	137	—[d]	11.0	12.0	11.4	D
P. alba	039	9.1	9.6	12.0	9.5	E

[a]Ro = Riverside orchard plots, Ri = Riverside irrigation plots, and I = Imperial Valley plots.
[b]Average based on all samples analyzed - an equal number of samples were not available for each year.
[c]Means followed with the same letter are not significantly different at $P < 0.05$.
[d]Missing values.

velutina had the highest pod protein levels while the *P. alba* accessions had the lowest (Table 2).

Significantly family differences were present at the Riverside irrigation plots.

TABLE 3

Pod protein content for *Prosopis* species at Riverside orchard plots for three years of sampling

Species	Accession number	Protein (%)			Average[a]	Duncan's grouping[b]
		1979	1980	1981		
P. velutina	032	17.5	18.5	17.8	17.9	A
P. velutina	020	17.2	17.0	17.0	17.1	AB
P. velutina	025	16.3	17.0	17.3	16.9	AB
P. glandulosa var. *torr.*	001	13.7	15.4	16.2	15.3	BC
P. glandulosa var. *gland.*	028	—[c]	14.0	—[c]	14.0	C
P. alba	039	9.0	9.0	9.3	9.1	D

[a]Average based on all samples analyzed - an equal number of samples were not available for each year.
[b]Means followed with the same letter are not significantly different at $P < 0.05$.
[c]Missing values.

TABLE 4

Pod protein content for *Prosopis* species at the Riverside irrigation treatment plots

Species	Accession number	Protein (%)[a]			Average[b]	Duncan's grouping[c]
		M1	M2	M3		
P. velutina	032	18.0	19.2	17.0	18.6	A
P. articulata	016	—[d]	14.7	18.7	17.0	AB
P. sp.	080	17.8	17.2	15.5	16.5	ABC
P. velutina	020	16.8	17.3	16.0	16.7	ABC
P. velutina	025	17.0	13.3	15.4	15.0	BCD
P. glandulosa var. *torr.*	001	15.7	15.5	13.8	14.8	CD
P. glandulosa var. *gland.*	028	13.2	13.1	14.2	13.4	D
P. sp.	074	13.0	13.2	12.7	13.0	D
P. alba	137	9.0	—[d]	11.4	11.0	E
P. nigra	133	8.7	10.0	11.7	10.4	E
P. alba	039	9.2	—[d]	10.0	9.6	E

[a]MI = −0.06 MPa (moist), M2 = −0.2 MPa (medium), M3 = −0.5 MPa soil moisture (dry). Soil irrigated to saturation when above soil water potentials occurred.
[b]Average based on all samples analyzed - an equal number of samples were not available for each year.
[c]Means followed with the same letter are not significantly different at $P < 0.05$.
[d]Missing values.

Although family-by-treatment interaction was detected, limited rank changes were present. Duncan's test indicates that, like the other Riverside tests, *P. velutina* had the highest pod protein levels while the *P. alba* accessions the lowest (Table 4).

There were no significant differences between families in protein content at the Imperial Valley plots, although *P. velutina* tended to demonstrate the highest values.

Pod sugar

The three-site analysis showed significant differences between sites, families and family-by-site interaction. Thus, analysis was performed on each site individually. There were significant differences in pod sugar concentrations among families at the Riverside orchard plots. Year and family-by-year interaction were not significant. Duncan's test indicated that *P. alba* had the highest pod sugar levels while the *P. velutina* accessions had the lowest levels (Table 5).

Riverside irrigation plots showed significant differences among families (Table 6). Although irrigation was not significant, treatment M3 tended to

TABLE 5

Pod sugar content for *Prosopis* species at Riverside orchard plots for three years of sampling

Species	Accession number	Sugar (%)			Average[a]	Duncan's grouping[b]
		1979	1980	1981		
P. glandulosa var. *gland.*	028	—[c]	38.3	—[c]	38.3	A
P. alba	039	31.5	40.3	34.0	35.7	A
P. glandulosa var. *torr.*	001	31.0	24.1	26.7	26.0	B
P. velutina	032	25.5	25.0	28.0	26.3	B
P. velutina	025	22.0	21.7	21.0	21.6	B
P. velutina	020	19.0	18.7	24.2	20.7	B

[a]Average based on all samples analyzed - an equal number of samples were not available for each year.
[b]Means followed with same letter are not significantly different at $P < 0.05$.
[c]Missing values.

TABLE 6

Pod sugar content for *Prosopis* species at Riverside irrigation plots

Species	Accession number	Sugar (%)[a]			Average[b]	Duncan's grouping[c]
		M1	M2	M3		
P. nigra	133	40.7	33.0	36.7	37.5	A
P. alba	137	45.0	—[d]	35.8	37.3	A
P. alba	039	37.2	—[d]	32.8	35.0	B
P. velutina	032	25.0	22.9	31.5	25.7	B
P. velutina	020	26.7	26.0	23.7	25.7	B
P. sp.	080	22.4	26.7	25.9	25.4	B
P. velutina	025	19.0	23.0	31.0	24.2	B
P. sp.	074	19.5	16.4	33.7	22.2	BC
P. glandulosa var. *torr.*	001	15.7	18.5	24.2	20.1	BC
P. glandulosa var. *gland.*	028	11.7	22.7	17.7	17.0	C
P. articulata	016	—[d]	3.3	6.7	5.3	D

[a]M1 = −0.06 MPa (moist), M2 = −0.2 MPa (medium), M3 = −0.5 MPa soil moisture (dry). Soil irrigated to saturation when above soil water potentials occurred.
[b]Average based on all samples analyzed - an equal number of samples were not available for each year.
[c]Means followed with the same letter are not significantly different at $P < 0.05$.
[d]Missing values.

TABLE 7

Pod sugar content for *Prosopis* species at Imperial Valley

Species	Accession number	Sugar (%) (average)[a]	Duncan's grouping[b]
P. pubescens	245	37.00	A
P. alba	137	33.25	A
P. alba	166	32.50	A
P. velutina	020	26.50	AB
P. velutina	032	25.50	B
P. articulata	016	15.67	B

[a]Average based on all samples analyzed - an equal number of samples were not available for each year.
[b]Means followed with the same letter are not significantly different at $P < 0.05$.

have higher mean sugar content (26.9%) than the other two treatments (22.3% and 23.8% for M2 and M1, respectively).

Imperial Valley plots again showed significant differences among families (Table 7). Duncan's test delineates those accessions which were significantly different from each other.

Intraclass correlations

Intraclass correlation is defined by Falconer (1981) as the degree of resemblance expressed in the between group component as a proportion of the total variance. Intraclass correlations provide a means for indicating the amount of additive genetic variance which can be used in selection of the best breeding method to be used for improvement (Falconer, 1981).

The population is random mating; since *Prosopis* is known to out-cross easily (Simpson, 1977) the progenies are not inbred and are considered to have a half-sib relationship. Intraclass correlations (t) were estimated as follows:

$$t = \frac{\sigma_\beta^2}{\sigma_\beta^2 \sigma_\omega^2}$$

where σ_β^2 = among class variance and σ_ω^2 = within class variance.

Riverside orchard (t) for protein was 0.60 and for sugar was 0.30. The Riverside irrigation (t) was 0.52 and 0.40 for pod protein and sugar, respectively. Imperial Valley (t) for protein was 0.04 and sugar was 0.40. For the three test locations the value for pod protein content was 0.40 and for sugar was 0.30.

DISCUSSION

Differences among families at each of the three sites, as well as family differences within the irrigation treatments suggest that both pod sugar and pod protein are under some degree of genetic control. Intraclass correlations for the half-sib *Prosopis* families tested, are considered high for tree species, as this correlation is assumed to be mathematically equal to 1/4 of the individual tree heritability. However, the use of single families from several species confounds species differences and among-family differences. For this reason, estimates of possible gain by selection among families cannot be made. If the population under consideration is utilized as a source of material for further breeding, assuming no reproductive barriers, then significant genetic progress can be anticipated.

Sugar content, but not protein content varied significantly across sites and among the three irrigation treatments. The Imperial Valley site and the least irrigated treatment at the Riverside irrigation plots produced the highest sugar content. This trend can be attributed to an accumulation of carbohydrates in those plots under the highest degree of moisture stress (Kramer and Kozlowski, 1979). Family × site interaction for sugar content suggests that selection and breeding programs for this trait should consider the site quality on which progeny is to be planted. Conversely, protein content was relatively stable for the environments tested.

CONCLUSIONS

Pod sugar and protein contents demonstrated a high degree of genetic control for the material tested, indicating that the potential exists for selection of families and the development of a continuing breeding program. The lack of year-to-year variation over the three years tested suggests a stability of production within each family. However, collections should be made over a longer period of time in order to fully test this hypothesis. Using this same material, Felker et al. (1984) showed the highest pod producers (kg per tree) to be *P. velutina*. Those results coupled with the data presented here suggest that pod protein production could be greatly increased through preferential planting of that species, as it produces both the highest pod protein content and the highest total amount of pods. Conversely, the highest sugar content reported in this study occurred in a species which generally had low pod production in the Felker et al. (1984) report. However, it is to be noted that the pod production was from small (1–2.5 m tall), young (less than 5 y old) trees and that the pod production of mature trees may not be well correlated with that of the young trees. An additional confounding factor is that sugar content may not be genetically correlated with protein content and as such, selection for one trait may lead to little if any improvement in the other.

Future work in this area should be directed at further evaluation of family performance across a wide range of years and sites to identify those families most suitable for use in *Prosopis* improvement programs. Pod components (i.e. pericarp, mesocarp and seed) should also be evaluated individually for genetic differences if breeding programs are to be directed at production of food for human populations, as seeds are usually separated during processing.

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