Variation in Oil Content Among Mexican and Peruvian *hirsuta* Peanut Landraces and Virginia-Type *hypogaea* Lines[1]

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ABSTRACT

Many consumers in the U.S. claim to prefer low fat foods, and this has encouraged the search for peanut (*Arachis hypogaea* L.) cultivars with low or reduced oil content. A collector's note on the low oil content of PI 576616, a Peruvian-type peanut (*A. hypogaea* subsp. *hypogaea* var. *hirsuta* Köhler) prompted screening of similar landraces from Mexico. PI 576633, PI 576634, PI 576635, PI 576636, PI 576637, and PI 576638 were collected in 1993 and imported to the U.S. for evaluation. In 1994, 120 plants per landrace were planted in the field, using Peruvian *hirsuta* PI 501296 as a control. In 1995, 24 selections from each Mexican landrace, 10 selections from PI 501296, and North Carolina State Univ. (NCSU) breeding line N91026E were planted. Based on oil analysis of the lines tested in 1995, 23 low oil and eight high oil selections were planted with four NCSU virginia-type breeding lines (N91026E, N92038, N94006L, and N94014L) used as controls in 1993. Nuclear magnetic resonance (NMR) was used for oil content determination. From the 1994 planting, selections from PI 576633 and PI 576638 had the lowest oil content. Five selections from PI 576634 and PI 576635 with low oil content also were identified. Earlier screening of 580 entries in the NCSU germplasm collection identified only three lines with similar oil contents. In 1995, significant ($P \leq 0.01$) oil content differences were found between landraces collected from the states of Puebla and Guanajuato (482 vs. 504 g kg^{-1}). Significant variation was found among Puebla landraces, but no differences were found among Guanajuato landraces. In 1996, significant year-to-year variation was found for some of the 31 selections. Low oil lines have been identified with the potential to be used as parents in breeding for reduced oil content.

Key Words: *Arachis hypogaea* L., germplasm, groundnut, nuclear magnetic resonance, NMR, plant introduction.

Peanut (*Arachis hypogaea* L.) is one of the main oil crops of the world. In countries such as India, Korea, Argentina, and China, peanuts are primarily used as an oil source. Peanuts in the U.S. are mainly consumed as roasted and/or salted peanuts, peanut butter, confectionary peanuts (Cobb and Johnson, 1973), or as in-shell peanuts. In the U.S., lowering and modifying the oil are objectives in many peanut breeding programs. According to Cobb and Johnson (1973), the average oil content of U.S. peanut germplasm is 500 g kg^{-1}, but ranges from 440 to 560 g kg^{-1}. Other reports give ranges of 358 to 560 g kg^{-1} (Salunkhe *et al.*, 1992), 358 to 542 g kg^{-1} for peanut butter samples (Freeman *et al.*, 1954), 370 to 530 g kg^{-1} for 800 breeding lines (ICRISAT, 1986), and 404 to 603 g kg^{-1} for 286 lines introduced and developed in Korea (Rural Development Admin., 1992). Jakkula *et al.* (1993) described a shriveled mutant peanut with low oil content, and breeding lines from this mutant vary in oil content averaging as low as 320 g kg^{-1}.

The wide variation of oil content can be attributed to many different factors. Genotypic variation in oil content was reported by Holley and Hammons (1968). Other reports regarding germplasm collections and/or groups of different genotypes/varieties also have found variation among accessions (ICRISAT, 1986; Desai *et al.*, 1992; Rural Development Assoc., 1992; Mozingo *et al.*, 1997). Cobb and Johnson (1973) listed seed maturity, environment, post-harvest treatment, insect infestation, and disease as factors likely to affect peanut seed composition. Other factors reported to affect oil content are early and late planting (Gupta *et al.*, 1983); early and late harvest (Court *et al.*, 1984; Knauft *et al.*, 1986); planting density and plant nutrition (Reddy and Murthy, 1989; Moussa *et al.*, 1996); *Bradyrhizobium* inoculation (Singh and Ahuja, 1985); irrigation (Desai *et al.*, 1992); and diseases affecting the peanut plant as a whole (Ali and Prasada Rao, 1982; Sharma and Bhowmik, 1987; Chen, 1991). Thus, management practices can alter oil content if they affect maturity, nutrient availability, or biotic or abiotic stresses that affect plant development.

Consumers in the U.S. have become more health conscious and have requested low fat foods. The food industry has thus put emphasis on advertising products as "low fat," "reduced fat," or "light," and a specialty market may exist for peanuts with naturally lower oil content. The U.S. Food and Drug Admin. established regulations whereby a product can be labeled "reduced fat" only if it has one-quarter less fat than the normal product. Peanut processors have developed methods to partially remove oil from their products, but there are no processes to decrease oil content of in-shell peanuts. Therefore, breeding is the only alternative to achieve oil reduction for this market segment.

In the U.S., the hirsuta-type peanut (*A. hypogaea* subsp. *hypogaea* var. *hirsuta* Köhler) has not been used in breeding programs, in part because of the historically poor representation of this botanical variety in the USDA

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Nat. Plant Germplasm System (NPGS). Before 1992, there were only three accessions of the *hirsuta* type in the NPGS (PI 260688, PI 501296, and PI 501297). Eighteen *hirsuta* accessions from Mexico were added to the NPGS in 1992-1993 (Table 1). These accessions were landraces from different localities within Puebla and Guanajuato, two states in the central highlands of Mexico. Sanchez-Dominguez and Williams (1993) reported superior flavor quality of Mexican *hirsutas*, and six bulk samples of *hirsuta* type (PI 576633, PI 576634, PI 576635, PI 576636, PI 576637, and PI 576638) were imported into the U.S. in 1993. A collector's note (Williams, 1995) stated "local people considered [PI 576616] to be good for children because it was 'less oily,'" suggesting the utilization of similar Mexican *hirsuta* peanuts as a source of low oil content for breeding purposes. Grimm *et al.* (1996) reported that the landraces imported in 1993 had variation in oil and sugar content.

The objective of this research was to evaluate the genetic variation for oil content among and within six Mexican *hirsuta* introductions and the possible use of selected *hirsuta* lines for peanut improvement in a breeding program.

Materials and Methods

Plant Material. Samples from the six Mexican *hirsuta* peanuts were obtained in 1994 by subsampling the 1993 bulk collections of PI 576633, PI 576634, PI 576635, PI 576636, PI 576637, and PI 576638. One hundred twenty pods per landrace were randomly chosen for field planting.

Field Trials. Tests were conducted at the Peanut Belt Res. Sta. at Lewiston, NC following standard cultural practices. One seed from each of the 720 pods was planted on 12 May 1994. Twenty-six seeds of Peruvian hirsuta PI 501296 ("mani murado" or "purple peanut") were planted as a check. Pods were handpicked from surviving hirsute plants after digging in mid-October, and single-plant lines with low yield were discarded. Twenty-four single-plant progenies from each of the six Mexican *hirsutas* (144 progenies total) were planted on 11 May 1995 in single-plant plots arranged in a randomized complete block design with four replications. Ten single-plant progenies from Peruvian hirsuta PI 501296 were included as a control. North Carolina State Univ. (NCSU) breeding line N91026E, an early maturing virginia-type peanut, was included 10 times in each replicate. Pods were harvested by hand from individual plants after mechanical digging in mid-October 1995. For the 1996 planting, 31 lines were selected from the 1995 study based on the following criteria: (a) low oil lines could have a maximum oil content of 475 g oil (kg seed)$^{-1}$ at 0% moisture and (b) high oil lines could have an oil content no lower than 523 g oil (kg seed)$^{-1}$ at 0% moisture. Twenty-three low oil and eight high oil selections were planted on 9 May 1996 in a randomized complete block design with four replications. The controls for this study were a group of NCSU virginia-type breeding lines—N91026E, N92038, N94006L, and N94014L. The last three lines were identified previously as having relatively low oil content as compared to other NCSU breeding lines. Peanut plants were mechanically dug on 14 Oct. 1996. Approximately 300 pods from plots of the first replication were handpicked for seed and all plots were then harvested with

Table 1. Accession information of all Mexican *hirsuta* peanuts represented in the U.S. National Plant Germplasm Collection.

PI	Local name	Location/county/state	N Lat.	W Long.	Elev.	Mean annual Rainfall	Mean annual Temp.
					m	mm	C
576612	Cacahuate criollo	Cacaloxuchil, Huaquechula, Puebla	18°.45'	98°30'	1680	-	-
576613	Cacahuate criollo	Santiago Tetla, Huaquechula, Puebla	18°.45'	98°30'	1670	920.8	22.0
576614	Cacahuate criollo	Tezonteopan de Bonilla, Huaquechula, Puebla	18°.43'	98°31'	1650	920.8	22.0
576615	Cacahuate criollo	Tezonteopan de Bonilla, Huaquechula, Puebla	18°.43'	98°31'	1650	920.8	22.0
576616	Cacahuate criollo	Huiluco, Huaquechula, Puebla	18°.47'	98°26'	1800	920.8	22.0
576617	Cacahuate huazulqueño	Huiluco, Huaquechula, Puebla	18°.47'	98°26'	1800	920.8	22.0
576618	Cacahuate criollo morado	Tlapanala, Huaquechula, Puebla	18°.40'	98°32'	1450	-	-
576619	Cacahuate criollo	Salvatierra, Salvatierra, Guanajuato	20°.13'	100°53'	1798	732.1	18.5
576620	Cacahuate criollo	San Isidro, Salvatierra, Guanajuato	20°.18'	100°55'	1770	-	-
576621	Cacahuate criollo	El Sabino, Salvatierra, Guanajuato	20°.15'	101°00'	1780	-	-
576622	Cacahuate criollo	Tarimoro, Tarimoro, Guanjuato	20°.15'	100°40'	1790	755.2	18.1
576623	Cacahuate criollo	Tarandacuao, Tarandacuao, Guanajuato	20°.01'	100°31'	2050	804.3	16.5
576633		Huiluco, Huaquechula, Puebla	18°.47'	98°26'	1800	920.8	22.0
576634		Santiago Tetla, Huaquechula, Puebla	18°.45'	98°30'	1670	920.8	22.0
576635		Tezonteopan de Bonilla, Huaquechula, Puebla	18°.43'	98°31'	1650	920.8	22.0
576636		Tarandacuao, Tarandacuao, Guanajuato	20°.01'	100°31'	2050	804.3	16.5
576637		Tarimoro, Tarimoro, Guanajuato	20°.15'	100°40'	1790	755.2	18.1
576638		Salvatierra, Salvatierra, Guanajuato	20°.13'	100°30'	1798	732.1	18.5

[a]Information obtained from the nearest meteorological station listed in the Normales Climatol6gicas (1941-1970), Segunda Edici6n 1988, Secretaria de Agricultura y Recursos Hidraulicos, Subsecretaria de Planeaci6n. Direcci6n General de Estudios, Informaci6n y Estadistica Sectorial; Servico Meteorol6gico Nacional

a combine.

Hirsuta peanuts are generally late maturing, and the length of the growing season in North Carolina is substantially shorter than that of central Mexico. To avoid the confounding effect of immaturity on oil content in the 1994, 1995, and 1996 experiments, seeds for analysis of oil content were selected from pods exhibiting darkened color of the interior pod wall, an indicator of seed maturity (Pattee and Johns, 1975).

Determination of Oil Content. The gravimetric method (Oupadissakoon *et al.*, 1980) was used for preliminary screening of bulk samples of the six Mexican *hirsuta* landraces. Samples from the 1994, 1995, and 1996 plots were analyzed by nuclear magnetic resonance (NMR) (Collins *et al.*, 1967) after oven drying. All values for oil content are reported at 0% moisture content (dry weight) except for the initial screening of the bulk samples that are reported at approximately 7% to be comparative to the results of Grimm *et al.* (1996).

Statistical Analysis. The General Linear Models procedure (PROC GLM) of SAS (SAS Inst., 1997) was used for analysis of variance with partitioning of sum of squares and contrasts for the variable oil content. Comparisons in oil content were based on mean values adjusted to a common replication effect.

Results and Discussion

Gravimetric oil extraction of the six Mexican *hirsuta* landrace bulk samples indicated that on average the landraces from the state of Puebla had lower oil content than those from Guanajuato state (398 vs. 444 g kg^{-1}). The oil contents at approximately 7% moisture for the *hirsuta* landraces were 445 g kg^{-1} for PI 576633, 383 for PI 576634, 365 for PI 576635, 443 for PI 576636, 444 for PI 576637, and 445 for PI 576638. These values agree closely with those reported by Grimm *et al.* (1996) for the same Mexican *hirsuta* landraces. Furthermore, they stated that PI 576634 and PI 576635 had unusually low oil contents when compared to Florunner (460 g kg^{-1}) and NC 7 (450 g kg^{-1}).

Oil contents of 16 selections from PI 576634 and PI 576635 were compared to those of genotypes in the NCSU peanut breeding program, including 584 accessions (introductions, mutants, old breeding lines, and cultivars) in the NCSU germplasm collection, 64 plant introductions, 100 jumbo-pod selections, and 224 improved breeding lines. Five selections from PI 576634 and PI 576635 were identified with low oil content (389 to 423 g kg^{-1}). By comparison, only three irradiated mutants and a few late maturing breeding lines in the NCSU breeding project were identified with oil contents within this range. In India and Korea, accessions with oil contents of 370 and 400 g kg^{-1} have been reported (ICRISAT, 1986; Rural Development Admin., 1992). These values are similar to the ones found here for the six Mexican *hirsuta* bulk samples. Based on the preliminary screening of the Mexican *hirsutas* in this study, it is concluded that this botanical variety includes genotypes with oil contents near the low extreme for the species.

Oil Content Screening During 1994. Analysis of variance showed a difference ($P \leq 0.01$) in oil content between the Mexican and Peruvian *hirsutas*, and variation ($P = 0.01$) among the Mexican *hirsuta* landraces in their oil content (Table 2). The 1994 overall mean oil content for the *hirsutas*' oil content was 484 g kg^{-1}. The adjusted mean oil content for the Peruvian *hirsuta* was 520 g kg^{-1} (Table 3), 37 g kg^{-1} higher than the mean for the Mexican *hirsutas* ($P = 0.01$). Among the Mexican *hirsutas* the average oil content varied from 470 (PI 576633) to 498 g kg^{-1} (PI 576637). Low and high values were found in the sets of lines from landraces of both states (Table 5). The widest oil range within a landrace was for PI 576633 (393 to 584 g kg-1). More than half of the Mexican *hirsutas* had oil contents between 450 and 500 g kg^{-1} while more than half of the Peruvian *hirsuta* lines had between 500 and 550. PI 576635 and PI 576636 had almost one-third of their entries and PI 576637 almost half of its entries with more than 500 g kg^{-1} oil content. The only landraces with more than 10 entries with less than 450 g kg^{-1} oil content were PI 576633 and PI 576634. The others had fewer than six entries within this range.

The *hirsutas* were grouped based on significant differences ($P \leq 0.01$) in oil content (Table 3). The grouping did not correspond to the state from which they originated. The lower range group included PI 576633 of Huiluco, Puebla and PI 576638 of Salvatierra, Guanajuato. Overall, there was wide variation in oil content among the landraces from the state of Puebla and little among those from Guanajuato state.

Table 2. Analysis of variance of oil content of *hirsuta* landraces in field trials (1994-1996).

Year	Source	df	MS
			g kg^{-1}
1994	Mexican vs. Peruvian landraces	1	220.50**
	Among Mexican landraces	5	84.84**
	Error	499	5.44
	Corrected total	505	
1995	Rep.	3	2.81ns
	Hirsuta vs. N91026E	1	240.36**
	Mexican vs. Peruvian *hirsuta*	1	86.25**
	Among Mexican *hirsutas*	5	122.67**
	Among selections within *hirsutas*	146	8.85**
	Error	385	4.06
	Corrected total	541	
1996	Rep.	3	16.33**
	Hirsuta vs. virginia checks	1	25.28**
	Mexican vs. Peruvian *hirsuta*	1	142.27**
	Among Mexican *hirsutas*	3	15.27**
	High oil *hirsutas* vs. low oil *hirsutas*	1	187.43**
	N91026E vs. low oil virginia checks	1	1.68ns
	Among low oil virginia checks	2	4.85ns
	Error	95	2.73
	Corrected total	133	

ns,**Denote nonsignificance and significance ($P = 0.01$), respectively.

Table 3. Adjusted means and oil content range for the *hirsutas* and control groups studied in 1994 and 1995.

Year	Origin	Identity	Oil content Min.	Max.	Mean[a]
			g kg^{-1}		
1994	Mexico (Puebla)		393	584	479
	"	PI 576633	393	584	470 a
	"	PI 576634	420	535	478 b
	"	PI 576635	431	536	489 c
	Mexico (Guanajuato)		407	571	487
		PI 576636	417	540	488 c
	"	PI 576637	411	570	498 d
	"	PI 576638	407	512	476 ab
	Peru	PI 501296	454	571	520 e
	Mexico	Mexican *hirsutas*			483
	Mexico & Peru	All *hirsutas*			502
1995	Mexico (Puebla)		369	553	482
	"	PI 576633	390	531	484 b
	"	PI 576634	432	553	488 b
	"	PI 576635	369	548	472 a
	Mexico (Guanajuato)		448	550	504
	"	PI 576636	448	550	503 c
	"	PI 576637	452	532	502 c
	"	PI 576638	466	542	506 c
	Peru	PI 501296	460	563	507 c
	USA	Virginia type N91026E	452	545	522 d
	Mexico	Mexican *hirsutas*			492
	Mexico & Peru	All *hirsutas*			500

[a]Different letters indicate group differences by the t-test ($P \leq 0.01$).

Oil Content Screening During 1995. When the 24 highest yielding selections from each Mexican landrace and the 10 highest yielding selections from Peruvian PI 501296 were grown in 1995, there was a difference in oil content between mean of all the *hirsutas* and the virginia-type breeding line N91026E (500 vs. 522 g kg^{-1}, $P \leq 0.01$) (Table 3). There were also differences between the mean of the Mexican *hirsutas* and the Peruvian *hirsuta* (492 vs. 507 g kg^{-1}, $P \leq 0.01$). There was variation ($P \leq 0.01$) in oil content among the Mexican *hirsuta* landraces and within landraces (Table 2). Among the Mexican *hirsuta* landraces, mean oil content varied from 472 in PI 576635 to 506 g kg^{-1} in PI 576638. The range of oil content for individual selections varied from 432 to 545 g kg^{-1}. The lowest oil content values were 432 and 435 g kg^{-1} for selections 86 and 41, respectively, from PI 576635. Selections from PI 576634 and PI 576633 also had values close to 450 g kg^{-1} oil content. The highest oil content values were for the Peruvian PI 501296. A total of 31 selections were made with eight high and 23 low oil lines chosen for further evaluation in 1996. Lines selected for low oil had oil content no higher than 475 g kg^{-1}, and lines selected for high oil had oil content no lower than 523 g kg^{-1}.

The grouping of the Mexican *hirsutas* in 1995 differed from the 1994 ranking. This was mainly the result of discarding progenies from 1994 that had very few seeds. Some of the plants with lower oil contents had few pods and seeds. Because this was the first time these Mexican *hirsutas* had been planted in the U.S., they were exposed to a new environment and natural selection within genetically heterogeneous populations could be expected. Some components of the landraces grew well while others did not mature fully. At least two plants in each landrace had stunted growth and produced few flowers and no pods. Lack of adaptation was reflected in poor development and low seed yield. This may have been aggravated by mechanical harvest in the experimental plots because Mexican *hirsutas* have weak pegs in comparison to U.S. varieties and breeding lines. In Mexico, peanut growers usually harvest peanuts manually and glean pods that fall from the plant upon digging. Another important factor is the nature of their long growth cycle so the plants may not have reached their full yield potential. In spite of the general shifting of rank, PI 576633 of Huiluco, Puebla remained in the lower range group.

Oil Content Screening During 1996. The analysis of variance showed differences in oil content between the *hirsutas* and the virginia type control group (511 vs. 506 g kg^{-1}, $P = 0.01$) and between the Mexican and Peruvian *hirsutas* (496 vs. 526 g kg^{-1}, $P = 0.01$) (Table 4). There was also variation ($P \leq 0.01$) in mean oil content

Table 4. Means and ranges for 1995 oil selections and controls grown in 1996.

Origin	Identity	n[a]	Oil content Min.	Max.	Mean[b]
			g kg^{-1}		
Means by origin					
Mexico (Puebla)	PI 576633	20	455	531	494 ab
"	PI 576634	44	431	547	489 a
"	PI 576635	44	456	519	483 a
Mexico (Guanajuato)	PI 576636	4	510	525	516 cd
Peru	PI 501296	12	491	577	526 d
USA (controls)	Virginia-type	16	472	539	506 cd
"	N91026E	4	505	539	516 cd
"	N92038	4	498	517	514 cd
"	N94006L	4	472	517	490 a
"	N94014L	4	486	516	502 be
Mexico	Mexican *hirsuta*	112			496
Mexico & Peru	All *hirsutas*	124			511
USA	All virginia types	16			5065
Low oil selections		92			483
Mexico (Puebla)	PI 576633	16			494 be
"	PI 576634	32			480 a
"	PI 576635	44			483 ab
High oil selections		32			516
Mexico (Puebla)	PI 576633	4			500
Mexico (Puebla)	PI 576634	12			512 d
Mexico (Guanajuato)	PI 576636	4			516 d
Peru	PI 501296	12			526 e

[a]Number of observations across the four replications of the 1996 test.

[b]Means followed by the same letter are not significantly different by t-test ($P \leq 0.01$).

among the Mexican *hirsuta* landraces with values ranging from 483 g kg^{-1} for PI 576635, Tezonteopan de Bonilla, Puebla to 516 for PI 576636, Tarandacuao, Guanajuato. The range of oil content for individual selections varied from 470 (selection PI 576635-080) to 551 g kg^{-1} (PI 501296-016) (Table 5).

There was a difference of 67 g kg^{-1} ($P \leq 0.01$) between the high and low oil groups identified in 1995. In 1996 the difference between the groups was smaller (33 g kg^{-1}) but still highly significant ($P \leq 0.01$), indicating that selection for low oil content was effective. The correlation between oil contents measured in 1995 and 1996 was r = 0.80 (29 df, $P \leq 0.01$) across all the selections, r = 0.34 (21 df, ns) for the low oil selections, and r = 0.44 (6 df, ns) for the high oil selections. The mean for the low oil selections from Puebla landraces was 483 g kg^{-1} with a range of 431 to 531 across individual plot values. The mean for high oil selections was 518 g kg^{-1} ranging from 489 to 547 (Table 4). No significant differences were found among the virginia-type checks, and their mean was 506 g kg^{-1} (Tables 2 and 4).

Table 5. Oil contents of *hirsuta* sublines selected in 1995 and retested in 1996.

			Oil content			
			1995		1996	
Origin	Landrace	Selection	Low	High	Low	High
			----g kg^{-1} ---		--- g kg^{-1}---	
Mexico	PI 576633	016	475	-	520	-
		019	469	-	493	-
		021	-	487	-	500
		056	446	-	475	-
		085	461	-	483	-
	PI 576634	009	445	-	479	-
		018	459	-	471	-
		025	470	-	484	-
		042	434	-	479	-
		048	-	523	-	506
		057	450	-	489	-
		059	448	-	482	-
		062	461	-	484	-
		065	-	530	-	506
		079	470	-	474	-
		081	-	572	-	522
	PI 576635	021	471	-	487	-
		030	465	-	481	-
		041	435	-	489	-
		042	459	-	483	-
		046	463	-	479	-
		071	462	-	483	-
		078	470	-	487	-
		080	451	-	470	-
		082	450	-	481	-
		086	432	-	482	-
		120	451	-	480	-
	PI 576636	030	-	524	-	516
Peru	PI 501296	001	-	486	-	504
		006	-	524	-	551
		016	-	540	-	522

Differences were observed between the *hirsuta* lines selected in 1995 and planted in 1996. The trend was a slight increase in oil content, with the greatest change being 45 g kg^{-1}. In contrast, the high oil selections and the virginia-type controls had a slight decrease in oil content on average, but exceptions to these trends were observed. Decrease in oil content for some of the high-oil lines may have been attributable to the incidence of tomato spotted wilt virus (TSWV) in the 1996 test, but this does not necessarily hold for the *hirsuta* plots affected by TSWV. Ali and Prasada Rao (1982) reported that incidence of TSWV in peanut can cause a significant reduction in oil content. In general, the Mexican *hirsutas* appeared healthier than the virginia-type control group and plots of other neighboring studies. Although genetic variability for oil content was found in the studied *hirsuta* landraces, it is important to take into consideration the other factors related to oil content, namely environment and management practices.

Based on the results of this study, it is concluded that the botanical variety *hirsuta* has a wide range of variation with respect to oil content. Comparison of the lines selected in 1995 from the state of Puebla (PI 576633, PI 576634, and PI 576635) with the low oil peanut lines available at the NCSU peanut breeding program showed that the *hirsutas* match the lowest oil contents represented in this collection. There was genetic variation for oil content within the Mexican landraces. Selection within landraces was effective, and significant differences were found between progenies of low and high oil selections. The Mexican *hirsuta* landraces represent a new source of low and high oil lines, and the Peruvian *hirsuta* landrace is a source of high oil content that has potential for use in a breeding program.

Literature Cited

Ali, M. I. M., and R. D. V. J. Prasada Rao. 1982. Effect of tomato spotted wilt virus on the oil content of peanut seeds. Madras Agric. J. 69:269-270.

Chen, S. S. 1991. Classification of peanut pod rot disease and its relation with soil characteristics. J. Agric. Forestry 40:65-75.

Cobb, W. Y., and B. R. Johnson. 1973. Physicochemical properties of peanuts, pp. 209-263. *In* C. T. Wilson (ed.) Peanuts - Culture and Uses. Amer. Peanut Res. Educ. Assoc., Inc., Stillwater, OK.

Collins, F. I., D. E. Alexander, R. C. Rodgers, and L. S. Silvela. 1967. Analysis of oil content of soybeans by wide-line NMR. J. Amer. Oil Chem. Soc. 44:708-710.

Court, W. A., R. C. Roy, and J. G. Hendel. 1984. Effect of harvest date on agronomic and chemical characteristics of Ontario peanuts. Can. J. Plant Sci. 64:521-528.

Desai, N. D., S. Raman, and R. S. Joshi. 1992. Quality of groundnut as influenced by irrigation, varieties and their interaction. J. Indian Soc. Soil Sci. 40:358-360.

Freeman, A. F., N. J. Morris, and R. K. Willich. 1954. Peanut butter. USDA AIC-370. U.S. Govt. Print. Ofc., Washington, DC.

Grimm, D. T., T. H. Sanders, H. E. Pattee, D. E. Williams, and S. Sanchez-Dominguez. 1996. Chemical composition of *Arachis hypogaea* L. subsp. *hypogaea* var. *hirsuta* peanuts. Peanut Sci. 23:111-116.

Gupta, S. K., K. Dhawan, A. L. Bhola, and T. P. Yadava. 1983. Effect of date of sowing and variety on oil content, protein content, iodine value and fatty acid composition of groundnut. Indian J. Agric. Sci. 53:859-860.

Holley, K. T., and R. O. Hammons. 1968. Strain and seasonal effects on peanut characteristics. Georgia Agric. Exp. Sta. Res. Bull. 32.

ICRISAT. 1986. Annual report of the International Crops Research Institute for Semi-Arid Tropics. ARE-013. ICRISAT, Patancheru,

A.P., India.
Jakkula, L.R., D.A. Knauft, and D.W. Gorbet. 1993. Characterization of a shriveled seed mutant in peanut. Proc. Amer. Peanut Res. Educ. Soc. 25:34 (abstr.).
Knauft, D.A., A.J. Norden, and D.W. Gorbet. 1986. The effect of three digging dates on oil quality, yield, and grade of five peanut genotypes grown without leafspot control. Peanut Sci. 13:82-86.
Moussa, B.I.M., M.S.A. Dahdoh, and H.M. Shehata. 1996. Interaction effect of some micronutrients on yield, elemental composition and oil content of peanut. Commun. Soil Sci. Plant Anal. 27:1995-2004.
Mozingo, R.W., II, T.G. Isleib, R.W. Mozingo, H.E. Pattee, and R.F. Wilson. 1997. Variation in oil content in Virginia-Carolina area peanuts. Proc. Amer. Peanut Res. Educ. Soc. 29:55 (abstr.).
Oupadissakoon, C., C.T. Young, and R.W. Mozingo. 1980. Evaluation of free amino acid and free sugar contents in five lines of Virginia peanuts at four locations. Peanut Sci. 7:55-60.
Pattee, H. E., and E. B. Johns. 1975. Composition changes of peanut fruit parts during maturation. Peanut Sci. 1:57-62.
Reddy, K.C., and P.K. Murthy. 1989. Influence of applied nutrients on protein content, amino acid composition, and oil quality of groundnut on sandy loam soils. Indian J. Agric. Res. 23:93-100.
Rural Development Admin. 1992. Peanut Breeding and Agronomy in Korea. Crop Exper. Stat., Rural Development Admin., Suwon, Korea.
Salunkhe, D.K., J.K. Chavan, R.N. Adsule, and S.S. Kadam. 1992. Peanut, pp. 140-216. *In* World Oilseeds: Chemistry, Technology, and Utilization. Chap. 5. Van Nostrand Reinhold, New York.
Sanchez-Dominguez, S., and D.E. Williams. 1993. Results of a recent plant exploration in Mexico to collect the hirsuta peanut. Proc. Amer. Peanut Res. Educ. Soc. 25:35 (abstr.).
SAS Inst., Inc. 1997. SAS/STAT Software: Changes and Enhancements Through Release 6.12. SAS Inst., Cary, NC.
Sharma, R. C., and T. P. Bhowmik. 1987. Effect of *Macrophomina phaseolina* infection on the physico-chemical components of groundnut seed. J. Phytopath. 118:181-186.
Singh, K. P., and K. N. Ahuja. 1985. Dry matter accumulation, oil content and nutrient uptake in groundnut (*Arachis hypogaea* L. cv. T 64) as affected by fertilizers and plant density. Indian J. Agron. 30:40-45.
Williams, D.E. 1995. Collection of peanut germplasm - Mexico 1992. Tech. Rep. presented to the USDA-ARS, Plant Exploration Ofc., Washington DC.