

## Effect of drought on oil, fatty acids and protein contents of groundnut (*Arachis hypogaea* L.) seeds

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### Abstract

The rainfed groundnut (*Arachis hypogaea* L.) crop suffers from moisture stress of varying intensity at different growth stages. The effect of drought on oil, protein and fatty acid contents were studied in 12 genotypes that differed in seed quality traits. The genotypes were subjected to mid-season and the end-of-season drought in field experiments at ICRISAT Asia Center (IAC), Patancheru, India, conducted during the 1991/92 and 1992/93 post-rainy (November–April) seasons. Mid-season drought was imposed between 40 and 80 days after sowing (DAS). The crop received normal irrigation, 50 mm at 10 day intervals, before and after the imposition of mid-season drought until harvest. Using the line-source sprinkler technique, end-of-season drought of varying intensity was imposed from 80 DAS until harvest. Mid-season drought had no significant effect on the content of oil, protein and fatty acids other than eicosenoic fatty acid. End-of-season drought significantly reduced total oil, and linoleic and behenic fatty acid content, and significantly increased total protein and stearic and oleic fatty acid content. However, genotype by treatment interactions were found. In ICGVs 88369, 88371, 88381, 88382 and 88403, total oil content remained unaffected while oleic fatty acid content increased under end-of-season drought. These were identified as desirable parents for a breeding program to develop cultivars suitable for rainfed cultivation.

**Keywords:** Peanut; Seed quality; Mid-season drought; End-of-season drought; Groundnut

### 1. Introduction

Groundnut (*Arachis hypogaea* L.) is an important oilseed crop in the world. The use of groundnut as

food has gradually increased from the mid 1970's. Its consumption as food increased by 34% in the decade since 1970's and is expected to increase further (Fletcher et al., 1992).

Groundnut seeds contain 44–56% oil and 22–30% protein on a dry seed basis (Savage and Keenan, 1994). In addition, they are a good source of minerals (phosphorus, calcium, magnesium and potassium) and vitamins (E, K and B group). Besides physical (seed mass and shape, integrity of seed testae and

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blanching efficiency) and sensory (seed color, texture, flavor) factors, nutritional (oil and protein contents, fatty acid and amino acid composition) factors are important in the food trade. Oleic (O) and linoleic (L) fatty acids together account for 75–80% of the total fatty acids in groundnut (Treadwell et al., 1983; Dwivedi et al., 1993a). The nutritional and storage qualities of groundnut depend on the relative proportion of saturated and unsaturated fatty acids in the oil. A high proportion of polyunsaturated fatty acid is desirable because it lowers plasma cholesterol and low-density lipoprotein content, which may reduce the risk of coronary heart disease and atherogenesis (Jackson et al., 1978). The iodine value (IV), which provides a measure of the degree of oil unsaturation and the O/L ratio have been commonly used to predict shelf-life and measure the stability of the oil. High O/L ratio and low IV value generally indicate good stability and long shelf-life (Worthington et al., 1972; Young and Waller, 1972). Nutritional quality of the seed is strongly influenced by production location, cultivar and season, particularly soil moisture and temperature during crop growth and seed maturation (Young et al., 1972; Sanders et al., 1982; Dwivedi et al., 1993a) and seed size (Mozingo et al., 1988).

In many parts of the world, groundnut is grown under rainfed conditions. The crop often suffers from drought stress of varying intensity and duration. The adverse effect of drought on pod yield (14–88% decrease) and seed grade (100-seed mass) of groundnut is well documented (Stansell et al., 1976; Pallas et al., 1979; Nageswara Rao et al., 1985; Nageswara Rao et al., 1989). However, studies on the effect of drought on seed quality are limited, and often report conflicting results. Total oil content was not affected by early-season drought (Conkerton et al., 1989; Bhalani and Parameswaran, 1992), but declined (by up to 3%) under mid-season (50–80 days after sowing (DAS) drought (Conkerton et al., 1989). For late-season drought (110–140 DAS), different studies have reported no effect (Conkerton et al., 1989; Musingo et al., 1989) and a decline (Bhalani and Parameswaran, 1992) in total oil content. No consistent effect on protein content have been documented due to drought stress at any particular growth period; nor was protein content in any specific genotype always reduced or increased by drought stress (Con-

kerton et al., 1989). However, Musingo et al. (1989) reported that late-season (50 days before harvest) drought caused little change in total protein content of groundnut.

Fatty acid contents in a genotype are affected by drought stress and seed grade. 'Florunner' stressed for 30 days at seed maturation (80 DAS) had a higher percentage of palmitic and linoleic acids, lower percentage of stearic, oleic and eicosenoic acids, higher IV and alpha-tocopherol and lower O/L ratio than nonstressed Florunner. A similar 30-day stress during the pre-flowering (20 DAS) and pod formation (50 DAS) increased behenic and lignoceric acids and decreased IV and gamma-tocopherol. While pre-flowering stress increased O/L ratio, stress at pod formation increased alpha-tocopherol compared to stress at seed maturation. Regardless of timing of drought, with increasing seed grades, arachidic acid, behenic acid, lignoceric acid, eicosenoic acid, O/L ratio and alpha-tocopherol decreased significantly (Hashim et al., 1993). However, Bhalani and Parameswaran (1992) did not find any major changes in the fatty acid composition, except for oleic acid, due to differential irrigation regimes in a summer irrigated crop. The oleic acid content increased in regimes where one irrigation was withheld each at flowering (50–65 DAS), pod development (90–105 DAS) and pod maturation (105–120 DAS) stage. The control in the experiment received eight irrigations at 10–15 day intervals.

To breed for improved nutritional quality of groundnut, genetic resources with improved and stable nutritional quality are required. The present experiment studied the effect of mid-season and end-of-season drought on oil and protein contents and fatty acid composition in 12 groundnut (*Arachis hypogaea* L.) genotypes.

## 2. Material and methods

Eight confectionery (large-seeded) genotypes, two drought-resistant genotypes, a popular Indian cultivar (JL 24) and an early-maturing germplasm line (Chico) were included for this study. The drought-resistant (ICGVs 86635 and 86707) and confectionery (ICGVs

88365, 88369, 88371, 88381, 88382, 88391, 88403 and 88409) genotypes were developed at ICRISAT Asia Center (IAC), Patancheru, India. ICGV 86635, ICGV 88391, Chico and JL 24 belong to subsp *fastigiata* var. *vulgaris* and the other genotypes to subsp *hypogaea* var. *hypogaea*. These genotypes differ in branching pattern, pod yield (0.72 to 3.64 t ha<sup>-1</sup>), meat content (610 to 700 g kg<sup>-1</sup> pod), 100-seed mass (27 to 95 g), oil content (470 to 510 g kg<sup>-1</sup> seed), protein content (200 to 270 g kg<sup>-1</sup> seed) and O/L ratio (0.95 to 1.97).

Two experiments were conducted on an alfisol (clayey-skeltel, mixed, isohyperthermic family of Udic Rhodustalfs) field at IAC to simulate the effect of drought during the 1991/92 and 1992/93 post-rainy (November–April) seasons. Experiment 1 (mid-season drought) and experiment 2 (end-of-season drought) were located on the same field adjacent to each other. For both experiments, a basal dose of single superphosphate of 250 kg ha<sup>-1</sup> was incorporated into the soil by broadcasting during land preparation. Seeds were treated with a mixture of Thiram<sup>®</sup> and Captan<sup>®</sup> of 3 g kg<sup>-1</sup> of seed and then sown on 1.2 m wide raised beds, separated by 0.3 m wide furrows. During both seasons, two sprays of Rogor<sup>®</sup> of 0.35 kg a.i. ha<sup>-1</sup> were given to control thrips (*Thrips palmi* Karny). In 1991/92, Nuvacron<sup>®</sup> of 0.40 kg a.i. ha<sup>-1</sup> was sprayed to control leafminer (*Aproaerema modicella* Deventer). All 12 genotypes were included in both experiments. In experiment 1, the genotypes were sown in a randomized block design with three replications. The seeds were sown 10 cm apart in 4 rows separated at 30 cm intervals on a bed. The planting rows were parallel to the furrows. The plot consisted of 4 rows of 4 m length. In experiment 2, the seeds were sown in rows perpendicular to furrows with 30 cm between rows and 10 cm between seeds in a row. Each genotype was sown on eight beds, each with two rows of 1.2 m length forming a plot. The plant density of 333 000 ha<sup>-1</sup> was maintained in both the experiments. Pre-emergence herbicide, Alachlor<sup>®</sup> @ 1.5 kg ha<sup>-1</sup>, was sprayed soon after sowing and the field was irrigated with about 50 mm of water using overhead sprinklers. Subsequently, both experiments were uniformly irrigated at 10-day intervals (each irrigation with about 50 mm water) until the drought treatments were imposed. In experiment 1, mid-season

drought was imposed between 40 and 80 DAS, by withholding irrigation. From 80 DAS until harvest, the crop received regular irrigation (50 mm at 10-day interval) through overhead sprinklers. In experiment 2, the crop was irrigated regularly until 80 DAS and end-of-season drought imposed from that stage until harvest. Line-source irrigation (Hanks et al., 1976) was used from 80 DAS to create eight intensities of end-of-season drought (described later). The main source line was laid perpendicular to the beds. The lateral lines with sprinkler heads ran along the beds. The sprinkler heads had dual nozzles of 3.17 mm and 3.97 mm aperture size with an output of about 40 L min<sup>-1</sup> when operated at 1.3 MPa. The sprinklers were operated during periods when wind velocity was minimal (less than 3 km h<sup>-1</sup>). This method of irrigation created a gradient of water application across the eight beds. For each irrigation, the amount of water applied to each bed was measured in all replications using catch-cans. The bed nearest the sprinkler head (first bed, B 1) received approximately 50 mm of water at each irrigation, providing an irrigated control treatment within each replication. The amount of irrigation decreased in a linear fashion as the distance of the bed from the sprinkler head increased.

The relative water deficit (WD) for each bed was estimated as

$$WD = 100 \times (CPE - TI/CPE),$$

where CPE is the cumulative U.S. class A pan evaporation during the period of drought and TI is total irrigation applied during the period of drought.

End-of-season drought was imposed for 50 days during 1991/92 and for 68 days during 1992/93 post-rainy seasons. During the drought period, 0.8 mm rain occurred at 136 DAS in 1991/92 and 18.0 mm rain at 112–113 DAS in 1992/93. This rainfall was taken into account in the WD calculations. Cumulative evaporation over the growing season was 985 mm in 1991/92 and 995 mm in 1992/93. Other weather parameters (averaged over the entire crop period) were as follows: solar radiation 18.2 MJ m<sup>-2</sup> day<sup>-1</sup> in 1991/92 and 18.8 MJ m<sup>-2</sup> day<sup>-1</sup> in 1992/93; wind velocity 7.45 km h<sup>-1</sup> in 1991/92 and 6.6 km h<sup>-1</sup> in 1992/93; relative humidity 81.2% in 1991/92 and 84.4% in 1992/93 at 07.00 h and

29.7% in 1991/92 and 34.0% in 1992/93 at 14.00 h.

In the end-of-season drought experiment, WD values for the eight beds were as follows:

Bed	Relative water deficit (%)	
	1991/92	1992/93
B 1 (irrigated control)	22	15
B 2	30	20
B 3	40	27
B 4	52	36
B 5	64	52
B 6	78	68
B 7	90	82
B 8 (bed farthest from the sprinkler head)	96	92
	SE $\pm$ 1.5	SE $\pm$ 2.4

The quantity of irrigation applied to control plots (B 1) did not fully compensate for evaporation losses particularly during the latter part of the season. Although the irrigated control plots experienced 22% water deficit in 1991/92 and 15% water deficit in 1992/93, the crop showed no visual wilting symptoms in either season.

The average soil temperature over 2 seasons at 06.00 h recorded at 5 cm of soil depth by thermocouples for the period from 1 February until harvest ranged from 16 to 22°C in B 1 (irrigated control), from 16 to 24°C in B 5 (moderate water deficit) and from 16 to 26°C in B 8 (maximum water deficit). The average temperature at 14.00 h ranged from 26 to 31°C in B 1, from 26 to 36°C in B 5 and from 26 to 41°C in B 8.

Individual plots were harvested. After shelling, sound mature seeds were analysed for total oil, total protein and individual fatty acid contents. The samples from B 7 and B 8 were not analysed because of poor seed development due to extreme drought conditions.

Oil content was determined using nuclear magnetic resonance (Jambunathan et al., 1985). To estimate protein content, nitrogen concentration was determined using a Technicon autoanalyzer (Singh and Jambunathan, 1980). A factor of 5.46 was used to convert nitrogen into crude protein content (The United Nations University, 1980). The fatty acid methyl esters (FAME) of triglycerides were prepared (Hovis et al., 1979) and analysed to estimate individual fatty acid contents (Dwivedi et al., 1993a).

Since the two experiments were located adjacent to each other in the same field both years, the B 1 plot in the end-of-season drought experiment was used as an irrigated control for the mid-season drought experiment. For each experiment, data over the two seasons were combined for analysis. Analyses of variance were performed using a mixed model where drought treatments (mid-season and end-of-season) and seasons were treated as random and genotypes as fixed effects. Combined data from the irrigated control (B 1) and mid-season drought experiment were analysed in a randomised block design to evaluate the effect of mid-season drought on seed quality traits. The six treatments (B 1 to B 6) in the end-of-season drought experiment were analysed in a split plot design with intensities of water deficit as main plots and genotypes as subplots. The effect of end-of-season drought (relative water deficit) on oil, protein and fatty acid contents, averaged over genotypes and seasons, was estimated by regressing (b) various quality parameters against the intensity of water deficit.

### 3. Results

#### 3.1. Mid-season drought

The results of variance analyses of total oil, total protein and fatty acid contents are presented in Table 1. Genotypic (*G*) variation was highly significant for all the parameters studied, but the variation due to environment (*E*) was evident only in eicosenoic

acid, which is a minor fatty acid in groundnut. The  $E \times G$  and season ( $S$ )  $\times$   $G$  interactions for total oil content and  $E \times S \times G$  for behenic acid were significant. Compared with the irrigated control, the total oil content in two genotypes increased significantly under mid-season drought; Chico (from 457 to  $480 \pm 5.1$  g kg<sup>-1</sup> seed) and ICGV 88391 (from 459 to  $476 \pm 5.1$  g kg<sup>-1</sup> seed).

### 3.2. End-of-season drought

The results of analyses of variance for oil, protein and fatty acid contents are presented in Table 2.

$G$  for all parameters was highly significant, as was the case in mid-season drought. Variation due to water deficit treatments ( $E$ ) was also highly significant for all parameters except palmitic and lignoceric acids. More interaction effects were significant under end-of-season drought than under mid-season drought.

The sensitivity of various parameters to increasing water deficit in the end-of-season drought experi-

ment was measured by the linear regression coefficient ( $b$ ), which was significant for total oil, total protein and stearic, oleic, linoleic and behenic acids (Table 3). Compared to the irrigated treatment (B 1), total oil decreased and total protein content increased as the intensity of end-of-season drought increased. Among the fatty acids, stearic and oleic increased while linoleic and behenic decreased.

The genotypes responded differentially for all the parameters, except for protein content, to increasing end-of-season drought intensity (Table 4). Total protein content in all genotypes increased; the increase being highest in ICGV 86635 ( $b = 1.06^{**}$ ). End-of-season drought intensity did not affect oil content in ICGVs 88369, 88371, 88381, 88382 and 88403. In the remaining seven genotypes, oil content was reduced; the reduction was greatest in ICGV 86635 ( $b = -1.14^{**}$ ). A significant increase in stearic acid was observed in six genotypes, with the highest increase in ICGV 88381 ( $b = 0.23^{**}$ ). In Chico and JL 24, both oleic and linoleic acids remained unaffected. In ICGV 86635, oleic acid increased signifi-

Table 1

Analyses of variance of total oil, total protein and fatty acid contents of 12 groundnut genotypes grown under irrigated and mid-season stress environments, 1991/92 and 1992/93 postrainny seasons (mean square values)

Source	d.f.	Total oil	Total protein	Palmitic	Stearic	Oleic
Water deficit environment ( $E$ )	1	0.00	0.20	1.07	6.25	123.76
Season ( $S$ )	1	0.05	23.85	0.19	1.03	79.36
$E \times S$	1	5.52	21.62	0.23	0.81 *	35.90 *
Rep/( $E$ and $S$ )	8	2.00	4.82	0.17	0.15	3.4
Genotype ( $G$ )	11	17.72 **	25.59 **	18.41 **	5.44 **	265.72 **
$E \times G$	11	3.91 *	2.46	0.53	0.08	5.07
$S \times G$	11	5.15 **	4.80	0.44	0.26	8.83
$E \times S \times G$	11	2.31	3.39	0.38	0.12	3.89
Pooled error	88	1.65	2.34	0.29	0.17	4.74
CV (%)		3	6	5	14	5
		Linoleic	Arachidic	Eicosenoic	Behenic	Lignoceric
Water deficit environment ( $E$ )	1	229.02	0.19	0.87 **	0.00	0.23
Season ( $S$ )	1	10.03	0.64	1.36 **	4.48	1.03 **
$E \times S$	1	13.57 *	0.61 *	0.12	0.93 *	0.07
Rep/( $E$ and $S$ )	8	2.20	0.07	0.05	0.14	0.02
Genotype ( $G$ )	11	280.02 **	1.23 **	0.39 **	4.02 **	0.19 **
$E \times G$	11	5.60	0.03	0.02	0.09	0.01
$S \times G$	11	8.31	0.08	0.02	0.22	0.02
$E \times S \times G$	11	5.51	0.06	0.02	0.36 **	0.02
Pooled error	88	5.30	0.04	0.01	0.09	0.01
CV (%)		7	11	9	8	7

Table 2

Analyses of variance of total oil, total protein and fatty acid contents of 12 groundnut genotypes grown under irrigation and end-of-season drought environments, 1991/92 and 1992/93 post-rainy seasons (mean square values)

Source	d.f.	Total oil	Total protein	Palmitic	Stearic	Oleic
Replication	2	3.26	1.29	1.47	0.00	1.48
Season ( <i>S</i> )	1	216.47	513.9 **	0.00	12.37 **	118.34 *
Rep/season	2	11.85	4.36	0.68	0.02	3.78
Water deficit environment ( <i>E</i> )	5	53.68 **	163.64 **	0.13	3.11 **	167.91 **
<i>S</i> × <i>E</i>	5	6.28	9.29 **	0.12	0.24	5.73
Error	20	5.47	1.14	0.13	0.17	2.43
Genotype ( <i>G</i> )	11	172.88 **	89.47 **	53.30 **	19.42 **	919.38 **
<i>S</i> × <i>G</i>	11	4.99 **	2.88	1.17 **	0.41 **	13.61
<i>E</i> × <i>G</i>	55	5.13 **	1.25	0.25 **	0.23 **	5.61 **
<i>S</i> × <i>E</i> × <i>G</i>	55	3.01	1.77 *	0.12	0.08	2.46
Error	264	2.24	1.19	0.15	0.08	2.92
CV (%)		3	4	4	10	4
		Linoleic	Arachidic	Eicosenoic	Behenic	Lignoceric
Replication	2	3.15	0.24	0.26	0.72	0.05
Season ( <i>S</i> )	1	12.10	6.50	1.16	14.30 **	2.07 **
Rep/season	2	0.90	0.69	0.42	0.02	0.10
Water deficit environment ( <i>E</i> )	5	150.98 **	0.08 **	0.08 **	4.55 **	0.03
<i>S</i> × <i>E</i>	5	4.68	0.03	0.04	0.26 **	0.03 *
Error	20	2.08	0.01	0.02	0.05	0.01
Genotype ( <i>G</i> )	11	899.54 *	3.95 **	1.37 **	7.08 **	0.55 **
<i>S</i> × <i>G</i>	11	9.72	0.05	0.09	0.15 *	0.03 *
<i>E</i> × <i>G</i>	55	4.2 **	0.02 **	0.01	0.16 *	0.01
<i>S</i> × <i>E</i> × <i>G</i>	55	1.79	0.02	0.01	0.09 **	0.01
Error	264	2.15	0.01	0.01	0.06	0.01
CV (%)		5	6	8	7	6

cantly but linoleic acid did not decrease. In all other genotypes, oleic acid increased and linoleic acid decreased. ICGV 88382 showed the highest increase

( $b = 1.12^{**}$ ) in oleic acid and the highest decrease ( $b = -1.03^{**}$ ) in linoleic acid. The decrease in behenic acid was significant in seven genotypes,

Table 3

Effect of end-of-season drought on total oil, total protein and fatty acid contents averaged over 12 genotypes and 2 seasons

Parameter (g kg <sup>-1</sup> seed)	End of the season drought treatments						LSD (1 %)	Regression coefficient ( <i>b</i> )
	B 1	B 2	B 3	B 4	B 5	B 6		
Oil	483	476	474	468	465	459	11.1	-0.41 **
Protein	246	242	260	266	277	285	5.1	0.72 **
Palmitic	108	108	107	107	107	107	1.7	-0.01
Stearic	27	28	28	31	31	32	1.9	0.09 **
Oleic	442	445	454	460	468	483	7.4	0.73 **
Linoleic	338	334	328	321	313	299	6.8	-0.69 **
Arachidic	18	18	18	19	19	19	0.6	0.01
Eicosenoic	13	13	13	13	13	13	0.6	-0.01
Behenic	39	39	37	35	34	33	1.0	-0.12 **
Lignoceric	15	15	15	15	15	16	0.5	0.01

Table 4

Genotypic response (linear regression coefficients, *b*) to end-of-season drought for total oil, total protein and fatty acid contents averaged over 2 seasons

Genotype	Total oil	Total protein	Stearic	Oleic	Linoleic	Behenic
Chico	-0.96 **	0.81 **	-0.03	0.13	-0.17	-0.00
JL 24	-0.81 **	0.59 **	0.04	0.03	-0.18	-0.05
ICGV 86635	-1.14 **	1.06 **	0.05 **	0.73 **	-0.75	-0.09 **
ICGV 86707	-0.21 **	0.68 **	0.03	0.56 **	-0.53 **	-0.12 **
ICGV 88365	-0.38 **	0.69 **	0.10 *	0.78 **	-0.73 *	-0.14
ICGV 88369	-0.06	0.83 **	0.10	0.87 **	-0.75 **	-0.18 **
ICGV 88371	-0.01	0.78 **	0.22 **	0.95 **	-0.93 **	-0.11 **
ICGV 88381	0.12	0.45 *	0.23 **	1.02 **	-0.97 **	-0.17 **
ICGV 88382	-0.19	0.78 **	0.15 **	1.12 **	-1.03 **	-0.17 **
ICGV 88391	-0.69 **	0.66 **	-0.01	0.66 **	-0.55 **	-0.05
ICGV 88403	-0.19	0.68 **	0.14 *	0.85 **	-0.81 **	0.13 **
ICGV 88409	-0.39 **	0.66 **	0.13	1.07 **	-0.96 *	-0.21 **
LSD (1 %)	0.159	0.078	0.036	0.165	0.143	0.031

highest in ICGV 88409 ( $b = -0.21^{**}$ ). ICGV 88403, on the other hand, showed a significant increase in behenic acid.

## 4. Discussion

### 4.1. Oil and protein concentration

The chemical composition of groundnut seed is influenced, among other factors, by its stage of maturity (Pickett, 1950; Young et al., 1972; Sanders, 1980). The present study therefore included only sound mature seeds to eliminate maturity-related differences in seed chemical composition. Total oil and total protein were not affected by mid-season drought, but end-of-season drought reduced oil and increased protein. This increase or decrease was progressive, corresponding to the intensity of water deficit. Differences in oil content became significant only under moderate to intense water deficit. In contrast, differences in protein became significant even at relatively low levels of moisture deficit (Table 3). Significant negative correlation ( $r = -0.364$  to  $-0.822$ ) between total oil and total protein was observed (Tai and Young, 1975; Dwivedi et al., 1990). Holley and Hammons (1968) observed an increase in total oil and a decrease in total protein in wet years (non-stressed). Our results, however, are in disagreement with previous reports that late-season drought had

little or no effect on total oil and total protein content (Musingo et al., 1989; Conkerton et al., 1989), or that mid-season drought reduced total oil content (Conkerton et al., 1989; Bhalani and Parameswaran, 1992). This could be due to the differences in genotypes and in the timing and intensity of drought in these studies. Further, growing conditions and crop management practices (foliar diseases control) also influence total oil, total protein and fatty acids in groundnut (Nagaraj and Chauhan, 1987; Dwivedi et al., 1993a; Dwivedi et al., 1993b). In the present study, genotypes (*G*) interacted with season (*S*) and end-of-season water deficit intensities (*E*) for total oil. The  $S \times E \times G$  interaction was significant for total protein.

### 4.2. Fatty acid composition

Fatty acids are synthesised by consecutive desaturation from stearic ( $C_{18}:0$ ) to oleic ( $C_{18}:1$ ) to linoleic ( $C_{18}:2$ ) fatty acid (Harwood, 1988). In the present study, mid-season drought had no significant effect on the major fatty acids. Stearic and oleic acids increased while linoleic and behenic acids decreased under end-of-season drought. The increase or decrease was progressive with increasing water deficit. Differences in oleic, linoleic and behenic acids became significant at a low level of moisture deficit; differences in stearic acid became significant at higher deficits (Table 3). These results differ from

those of Hashim et al. (1993), who reported an increase in palmitic and linoleic acids and a decrease in stearic, oleic and eicosenoic acids when Florunner was stressed for 30 days at maturation. When a similar stress was imposed at the pre-flowering and pod formation periods, they observed an increase in behenic and lignoceric acids. These differences between the two studies could be ascribed to the larger number of genotypes in the present study and to significant  $S \times G$ ,  $E \times G$  and  $S \times E \times G$  interactions noted for some of these acids.

High temperature (27–33°C) during seed development is reported to decrease linoleic acid in several oilseed crops including groundnut (Holaday and Pearson, 1974; Harris et al., 1978; Wolf et al., 1982; Green, 1986; Golombek et al., 1995). The decrease is attributed to the effect of temperature on the activity of desaturase enzyme that converts oleic to linoleic acid. The changes in total oil and total protein contents and in fatty acid composition in the present study were probably due to the combined effect of water deficits and high temperatures during the seed-filling period with the end-of-season drought treatment. As the relative degree of water deficit increased, so did the soil temperature.

Total oil in ICGVs 88369, 88371, 88381, 88382 and 88403, oleic acid in Chico and JL 24 and linoleic acid in Chico, JL 24, and ICGV 86635 remained unaffected by end-of-season drought. Among genotypes in which oil was not influenced, oleic acid increased and linoleic acid decreased in ICGVs 88369, 88382 and 88403. These genotypes would be good parents in a breeding program to develop cultivars for rainfed conditions, because their oil content remains unaffected but oleic acid is increased by drought, thus improving the oil shelf-life and quality.

## 5. Conclusion

Mid-season drought did not affect the chemical composition (except for eicosenoic fatty acid) of groundnut seed in any significant manner. End-of-season drought significantly affected the chemical composition of groundnut seed. Whereas total oil and linoleic and behenic acids decreased, total protein and stearic and oleic acids increased due to

end-of-season drought. This increase or decrease was progressive and associated with the increasing degree of water deficit.

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