Influence of imposition of soil moisture deficit stress on some quality components of groundnut kernel

1 author:

Prakash Nautiyal
Indian Agricultural Research Institute

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Influence of imposition of soil moisture-deficit stress on some quality components of groundnut, *Arachis hypogaea* L. kernel

J.B. Misra and P.C. Nautiyal

National Research Centre for Groundnut, Post Bag No.5, Ivnagar, Junagadh-362 001, Gujarat

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Abstract

Four Spanish cultivars of groundnut *viz.* Ak 12-24, J 11, GAUG 1, and GG 2 were studied for the quality components of kernel such as total sugars, phenolics, protein, and fatty acid composition as influenced by the soil moisture-deficit stress imposed during different phenophases, in the summer season. Increase due to stress during pod development phase, in plamitic acid was observed only in cv. GAUG 1. For stearic acid, increase due to stress during pod development, was observed in all the cultivars except GG 2. Oleic acid percentage increased due to stress at pod development in cv. AK 12-24, and only marginally in GAUG 1 and GG 2. Compared to control, soil moisture-deficit stress caused a significant increase in the protein content. There was, however, a greater increase in protein content due to stress during flowering, and pod development as compared to the stress during vegetative phases. Stress during vegetative (short), and flowering phases caused a significant reduction in sugar content. The interaction between cultivars and treatments were significant only for the changes in fatty acid composition, protein and sugar contents, while it was not significant for phenolics. In conclusion, the changes in the composition of fatty acids and contents of sugars and phenolics are governed more by cultivar and its interaction with the environmental conditions rather than by the time or the intensity of imposed soil moisture-deficit stress.

Key words: Kernels quality, soil moisture-deficit stress, groundnut, fatty acid composition, proteins, sugars, phenolics

Introduction

Groundnut is an important oilseed crop of India as well as of the world. In India, besides a limited area under irrigated conditions, the crop is generally raised in rain fed conditions owing to its drought tolerant nature. As such, the crop is quite popular among the marginal farmers of Saurashtra region of Gujarat, where due to erratic and frequent low precipitation; the crop is often subjected to water deficit stress. The adverse effects of drought on yield of groundnut crop are well known (Ravindra *et al.* 1991, Nautiyal *et al.* 1999) but how the water-deficit stress affected the kernel quality of this crop has not been studied extensively. The major constituents of groundnut kernel are oil (42-56%), protein (12-36%), and carbohydrates (22-32%) - starch, sucrose, mono-saccharides and some oligosaccharides. Oleic and linoleic acids are the major fatty acids of groundnut oil and together with palmitic acid they account for 90% of the total fatty acids of groundnut oil (Savage and Keenan, 1994). Though present in relatively small quantities free amino acids, phenolics, minerals, tocopherol etc. also have a bearing on the quality of kernels.

There are only a limited number of reports on the effect of water deficit stress on the quality of the groundnut kernels. Musingo *et al.* (1989) studied the effect of drought and temperature stress on chemical components of quality and also market grade seeds (jumbo, medium and No.1) by raising a single cultivar, Florunner, in environmental control plot facility at Dawson, USA. Eight identical cultivars were raised by Ross and Kvien (1989) and by Conkerton *et al.* (1989) at Tifton, USA to study the effect of drought on seed composition whereas Hashim *et al.* (1993) raised only one cultivar, Florunner, at the same farm to find out the effect of drought on fatty acid composition and tocopherol content of seed. In India, Sarma and Sivakumar (1989) raised a single Indian cv. Robut 33-1 at Patancheru (Andhra Pradesh) to study the effect of drought on oil and protein content which was followed by another experiment, conducted by Dwivedi *et al.* (1996), at the same place by raising twelve cultivars, including one popular Indian cv. J 11, to study the effect of drought on oil and protein contents whereas Bhalani and Parameswaran (1992) studied the effect of differential irrigation on kernel lipid profile of one cv. GG 2 by conducting experiments at Anand (Gujarat). However, there is no consistency in the results reported by various authors. As Saurashtra region of Gujarat is considered to be the groundnut bowl of India, it was of interest to conduct experiments in this region with four Indian cultivars to generate information on the effect of water deficit on quality of kernels.

Materials and methods

Four cultivars of groundnut (*Arachis hypogaea* L. ssp. *fastigiata*), Ak 12-24, J 11, GAUG 1, and GG 2 were raised in summer season (February-June) of 1993 at the experimental farm of the National Research Centre for Groundnut at Junagadh (latitude 21°31'N, longitude 70°36'E; soil: Vertic Ustochrept, pH 8.5; low in organic matter, available nitrogen and phosphorus). The crop was raised following standard cultural practices. The seeds were sown in 5 m x 3 m plots, with an inter-row spacing of 30 cm and intra-row spacing of 10 cm. Thus a 4 x 5 factorial (4 cultivar and 5 stress treatments) experiment was arranged in a Randomized Block Design with 3 replicates. Urea (25 kg N/ha) and single superphosphate (40 kg P_2O_5/h) were applied as fertilizers at the time of sowing. The crop was irrigated regularly at 10-day intervals during February to March and subsequently 8-day intervals from April onward to meet the enhanced evaporative demand.

A differential irrigation schedule was, however, followed for imposing moisture-deficit stress at various vegetative and reproductive stages of the crop. The treatments included i) Control, regular irrigation at 10-d intervals during the vegetative phase and 8-days(d) intervals, until harvest; ii) V1, a stress in the vegetative phase (prolonged), irrigation withheld for 30 days (starting 20 d after sowing); iii) V_2, a moderate stress in the vegetative phase (short), irrigation withheld for 25 d (starting 20 d after sowing) followed by two successive relief irrigations at an interval of 5 d; iv) F, stress in the flowering phase, irrigation withheld for 30 d (starting 40 d after sowing); and v) P, stress in the pod development stage, irrigation withheld for 20 d starting 60 d after sowing. Thus withholding of irrigation during certain phenophases constituted the moisture stress treatments and except for the periods of stress the irrigation for all the treatments was same as that for control plots. The crop was sown in 5 m x 3 m plots, with 30 cm between rows and 10 cm between plants within rows. Each experiment was a 4 x 5 factorial (4 cultivar and 5 drought treatments) arranged in a Randomized Block Design with 3 replicates. Fertilizers were applied as urea (25 kg N/ha) and single superphosphate (40 kg P_2O_5/ha).

Produce obtained in the summer season was shelled after one month of harvest and kernels were used for various chemical analysis. The fatty acid composition of the oil was determined after converting the constituent fatty acids into their methyl esters (Morrison and Smith, 1964) which were then separated on Nucon Gas Chromatograph (AIMIL, India) model 5700, fitted with a DEGS column (I.D. 2 mm, length 180 cm). The temperature of the column was kept at 195°C while that of injection and FID detector ports was kept at 250°C. The flow rates of carrier (nitrogen), fuel (hydrogen), and air were 40, 30, and 300 ml/min., respectively. The fatty acids were identified by comparison of their retention time with those of authentic samples. The area of a peak as fraction of the total area under all the peaks was expressed as percent. Percentages of only 6 fatty acids have been indicated here. The stability index (SI) was defined as the ratio of oleic acid to linoleic acid (Ahmed and Young, 1982).

The nitrogen content was determined by micro-Kjeldahl method (Ballentine, 1957) using a Kjeltech auto nitrogen analyzer and the protein content was obtained by multiplying the nitrogen content of meal with a factor of 5.46 (St. Angelo and Mann, 1973). Groundnut meal (200 mg) was extracted twice in 80% methanol under reflux for 1 hour. Both the extracts were pooled. The phenolics in the alcoholic extract were determined according to Bray and Thorpe (1957). Total sugars were first obtained in aqueous medium by evaporating methanol in vacuum and then determined by the method described by Ashwell (1957).

Results and discussion

Fatty acid composition, stability index and nutritive value index: The cultivar differences though too narrow, were significant for palmitic, oleic, linoleic, and arachidic acids only and were not significant for stearic and behenic acids. The contents of palmitic, stearic, oleic, linoleic, and arachidic acids were significantly affected by all the treatments but the differences were marginal whereas the content of behenic acid remained unaffected. Compared to control, the palmitic and stearic acids were affected the most due to stress in pod development registering a reduction by 7.7% and 13.1%, respectively; oleic and linoleic acids due to stress in vegetative (short) phase registering a reduction by 2.9% and an increase by 6.6%, respectively; and arachidic acid due to stress in vegetative (short) and pod development phases registering and equal increase of 3.5%. The interactions between the cultivars and treatments were also significant for of all the fatty acids but the effect did not differ much from the general trends.

Values of both stability index (SI) and nutritive value index (NVI) are derived on the basis of fatty acid composition. Thus any change in fatty acid composition is bound to affect the values of both these indices. The SI values of the cultivars ranged from 1.20 to 1.28. The soil moisture-deficit stress affected significant changes in the SI values as compared to control. Stress during vegetative (prolonged), flowering, and pod development phases significantly improved the SI value, with a maximum of improvement by 6.9% due to stress in vegetative (prolonged) phase. There was, however, a significant reduction (3.3%) in SI value due to stress in vegetative (short) phase. The NVI values of cultivars ranged from 2.12 (J 11) to 2.42 (GAUG 1) and compared to control, all the treatments effected an improvement in the NVI value except stress (short) during vegetative phase.

Table 1 Fatty acid composition of kernels of four spanish groundnut cultivars subjected to various transient soil moisture-deficit stress

Cultivar	Treatment	Palmitic (16:0)	Stearic (18:0)	Oleic (18:1)	Linoleic (18:2)	Arachidic (20:0)	Behenic (22: 0)
Ak 12-24	C	13.96	1.50	45.43	35.36	2.00	0.83
	V_1	13.60	1.50	46.80	35.33	2.03	0.80
	V_2	14.60	1.56	43.50	37.10	2.40	0.83
	F	14.56	1.26	46.53	34.63	2.10	0.83
	P	13.26	1.13	47.60	35.80	1.86	0.90
J 11	C	15.50	1.30	45.23	34.90	1.90	0.90
	V_1	14.40	1.80	45.40	35.16	2.20	0.90
	V_2	14.03	1.20	43.50	38.43	1.76	0.90
	F	13.60	1.60	45.70	36.70	1.76	0.60
	P	12.73	1.06	45.20	38.50	2.10	0.76
GAUG 1	C	15.10	1.40	44.86	35.20	1.70	0.90
	V_1	16.33	1.36	44.26	35.30	1.60	0.90
	V_2	14.80	1.30	45.10	36.30	1.66	0.60
	F	14.76	1.60	45.76	35.23	1.76	0.76
	P	15.80	1.21	45.60	35.10	2.20	0.86
GG 2	C	15.10	1.26	45.10	35.53	2.03	0.80
	V_1	15.56	1.21	46.70	34.36	1.20	0.63
	V_2	14.43	1.36	43.20	38.50	2.06	0.86
	F	14.10	1.76	44.03	37.40	2.05	1.04
	P	13.26	1.33	44.53	38.46	1.76	0.86
	CD (P=0.05)	0.24	0.14	0.51	0.33	0.18	0.12
Treatment	C	14.91	1.37	45.16	35.25	1.91	0.86
	V_1	14.97	1.47	45.79	35.04	1.76	0.81
	V_2	14.46	1.36	43.83	37.58	1.98	0.80
	F	14.25	1.56	45.52	35.99	1.93	0.82
	P	13.76	1.19	45.73	36.96	1.98	0.85
	CD (P=0.05)	0.12	0.07	0.25	0.16	0.09	N.S.
Cultivar	Ak 12-24	14.00	1.39	45.97	35.65	2.08	0.84
	J 11	14.05	1.40	45.01	36.74	1.95	0.81
	GAUG 1	15.36	1.38	45.12	35.43	1.79	0.81
	GG 2	14.49	1.39	44.72	36.85	1.83	0.85
	CD (P=0.05)	0.11	N.S.	0.23	0.15	0.08	N.S.

C= 10 d interval; V_1= 20 DAS for 30 days; V_2= 20 DAS for 25 days; F= 40 DAS for 30 days; P= 60 DAS for 20 days

Table 2 Stability nutritive value indices and protein, sugars and phenolic contents of kernels of four groundnut cultivars subjected to various transient soil-moisture-deficit stresses

Cultivar	Treatment	Stability Index	Nutritive Value Index	Proteins mg/g	Sugars mg/g	Phenolics mg/g
Ak 12-24	C	1.22	2.25	113.3	192.1	3.57
	V_1	1.32	2.34	152.3	238.7	3.47
	V_2	1.17	2.32	125.3	151.2	2.50
	F	1.34	2.14	171.0	167.1	2.58
	C	1.33	2.45	188.6	238.2	5.78
J 11	C	1.20	2.21	135.9	145.3	2.62
	V_1	1.28	2.17	182.5	221.0	3.06
	V_2	1.12	2.53	172. 9	151.2	1.63
	F	1.25	2.41	190.7	167.0	2.21
	P	1.17	2.79	173.3	198.7	5.06
GAUG 1	C	1.23	2.00	150.0	154.1	2.97
	V_1	1.24	1.98	139.7	221.7	3.11
	V_2	1.25	2.38	177.2	186.8	1.82
	F	1.30	2.15	189.7	94.8	1.93
	P	1.30	2.06	173.1	174.2	5.19
GG 2	C	1.20	2.03	195.6	190.5	3.06
	V_1	1.36	2.04	182.6	182.1	3.36
	V_2	1.12	2.43	172.6	120.5	2.01
	F	1.16	2.33	202.1	175.4	2.16
	P	1.16	2.68	228.8	116.0	4.85
	CD (P=0.05)	0.03	0.14	28.7	0.4	N.S.
Treatment	C	1.21	2.12	148.7	170.5	3.02
	V_1	1.30	2.14	164.3	215.9	3.25
	V_2	1.17	2.42	162.0	152.5	1.99
	F	1.26	2.26	190.6	151.1	2.22
	P	1.24	2.50	191.0	181.8	5.22
	CD (P=0.05)	0.02	0.07	14.4	0.7	0.27
Cultivar	Ak 12-24	1.28	2.30	150.1	197.5	3.58
	J 11	1.21	2.42	171.1	176.7	2.92
	GAUG 1	1.27	2.12	167.7	166.3	2.97
	GG 2	1.20	2.31	196.3	156.9	3.09
	CD (P=0.05)	0.01	0.06	12.8	0.6	0.24

C= 10 d interval; V_1= 20 DAS for 30 days; V_2= 20 DAS for 25 days; F= 40 DAS for 30 days; P= 60 DAS for 20 days

Protein: Cultivars differed significantly in their protein content, which ranged from 150 to 196 mg/g. Compared to control; all the treatments caused a significant increase in the protein content. There was, however, a greater increase due to stress during flowering and pod development phases (28% each) than due to stress during vegetative phase, both prolonged and transient (10.1 and 8.7%, respectively). The interactions between the cultivars and treatments were also significant.

Sugars: The total soluble sugar content of cultivars ranged between 157 and 198/g. Stress during vegetative (prolonged) and pod development phase caused a significant increase in sugar content. However, the increase caused due to stress in vegetative phase (prolonged) was substantial (26.6%) and that due to stress in pod development was relatively small (6.6%). Stress during both vegetative (short) and flowering phase caused a significant reduction in sugar content and the extent of reduction was also comparable (10.6 and 11.4%, respectively). The interaction between the cultivars and treatments also was significant but pattern of effect varied with cultivars.

Phenols: The phenolic content of seed of cv. Ak 12-24 was slightly higher than the other three cultivars which all had statistically equal phenolic contents. Prolonged stress during vegetative phase did not significantly affect the phenolic content while transient stress during vegetative and flowering phases caused a significant reduction (34.1 and 26.5%, respectively) and stress during pod development caused a substantial significant increase (72.8%). The interaction between cultivars and treatments were not significant.

Hashim *et al.* (1993) have reported that imposition of stress at pod maturation phase (for 20 days, commencing 80 days after planting) in cv. Florunner caused an increase in percentages of palmitic and linoleic acids and decrease in percentages of stearic and oleic acids. Bhalani and Parameswaran (1992), however, did not find any significant effect of imposition of differential irrigation on the fatty acid composition in cv. GG 2. Whereas Dwivedi *et al.* (1996) in their experiments conducted with 12 cultivars (eight confectionery type, two drought resistant types, a popular Indian cultivar and an early-maturing type) observed that there was no significant effect of mid-season drought on the fatty acid composition but the end-of-season drought reduced the percentages of linoleic and behenic acids while the percentages of stearic and oleic acid increased. In the present experiment, however, a significant increase, due to stress during pod development, in plamitic acid was observed only in cv. GAUG 1. In case of stearic acid, increase due to stress during pod development was observed only in three cultivars, while a decrease was observed in GG 2. As far as changes in the fatty acid composition are concerned, the trends observed in present study agree neither with those reported by Dwivedi *et al.* (1996) nor with those reported by Musingo *et al.* (1989). Thus the results of the present study and those reported earlier lead us to believe that the effect of various types moisture deficit stresses, on the fatty acid composition (and consequently on SI and NVI) of groundnut may be highly cultivar specific and on the basis of published data it may be difficult to give a general picture. As far as increase in protein content due to imposition of end-of-season drought is concerned, the results of this study confirm the earlier observations of Dwivedi *et al.* (1996) but disagree with those of Conkerton *et al.* (1989) and Musingo *et al.* (1989) as both of these groups did not observe any significant change on protein content. Ross and Kvien (1989) have reported an increase in phenolics due to imposition of mid-season drought irrespective of cultivar, however, cultivars differed considerably in their response to end-of-season drought, some registering an increase while others registering a decrease indicating there by a significant cultivar by treatment interaction. In the present study, however, all the four cultivars responded in the similar fashion and the cultivar by treatment interaction was not significant. The pattern of variation in the total soluble sugar content of seed was by and large similar to those reported by Ross and Kvien (1989) for sucrose (which comprises most of the soluble sugars) content in the seed with a significant cultivar by treatment interaction. Musingo *et al.* (1989), on the basis of experiments conducted under environmental control facilities, have reported increase in both total and soluble carbohydrates as a result of drought stress.

As a matter of fact it is not possible to compare the results obtained by various authors due to differences in the cultivars used, agro-climatic conditions of crop growth and also the duration and the intensity of the drought imposed besides the methods of imposing water deficit stress i.e. either by withholding a flood irrigation due (this report and Bhalani and Parameswaran) or by creating a gradient on the basis of distance from sprinkler irrigation system (Sarma and Sivakumar, 1989; Dwivedi *et al.*, 1996). Moreover, it now known that imposition of soil moisture-deficit stress on groundnut cultivars by withholding irrigation may not result into a uniform physiological moisture-deficit-stress as is reflected by significantly different relative water content of leaves (Nautiyal *et al.*, 1995). This could, to some extent, explain the lack of uniformity in pattern of response of groundnut cultivars under uniform soil-moisture deficit conditions.

Though in the present experiment oil content of kernels was not determined there are reports to indicate that imposition of the end of season drought results in reduction in oil content of the seed (Conkerton *et al.*, 1989; Sarma and Sivakumar 1989; Bhalani and Parameswaran, 1992). This type of decrease however, may not be universal (Dwivedi *et al.*, 1986), as in some cultivars the oil content may remain unaffected (Musingo *et al.*, 1989; Dwivedi *et al.*, 1986). Thus on the basis of the results obtained in the present investigation and those reported earlier it can be concluded that the imposition of soil moisture-deficit- stress in end-of-season may result in increased protein content and reduced oil content. So far as changes in the composition of fatty acids and contents of sugars and phenolics are concerned, they are governed more by cultivar and its interaction with the conditions of growth and crop management practices than by the time or the intensity of imposed soil moisture-deficit.

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