RESEARCH

IMPACT OF CLIMATE CHANGE ON OIL FATTY ACID COMPOSITION OF PEANUT (*Arachis hypogaea* L.) IN THREE MARKET CLASSES

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Peanut (*Arachis hypogaea* L.) is one of the most important oilseed crops of the world. The fatty acid composition plays an important role in oil quality. Experiments were performed to examine the variation in oil fatty acids of three normal oleic peanut market types (Virginia, Valencia, and Spanish) in 2008, 2009, and 2010. Variations of botanical variety, year and their interaction were highly significant for oil content and all 13 fatty acids studied. Oil content in different peanut market types exhibited significant differences. The maximum oil content (51.993%) was found in Virginia (NC-7), while Valencia (New Mexico Valencia A) accumulated the minimum oil content (47.197%). Virginia had also the highest oleic acid percentage. Higher temperatures during seed development in 2010 resulted in greater oleic contents than 2008 and 2009 while lower temperatures post anthesis in 2009 caused higher linoleic acid. It was observed different effects of years in oil fatty acid composition according to peanut types. The highest percentages of linoleic acid for Virginia, Valencia, and Spanish were observed in 2010, 2008, and 2009, respectively. The highest negative correlation was noted for oleic and linoleic acids (r: -0.985). Oleic acid was also correlated negatively with arachidic and behenic acids.

Key words: *Arachis hypogaea* subsp. *fastigiata*, temperature, correlation.

The peanut (*Arachis hypogaea* L.) is known by several names throughout the world, such as groundnut and earth nut. The peanut plant is unusual because it flowers above ground and pods containing one to five seeds are produced underground. It seeds are rich source of edible oils, and is fifth most important oilseed in the world.

The peanut is a member of the genus *Arachis*, subtribe *Stylosanthinae*, tribe *Dalbergieae* of family *Fabaceae*. *Arachis hypogaea* is an annual herb of indeterminate growth habit, which has been divided into the two subspecies, *hypogaea* and *fastigiata*, each with several botanical varieties. Subspecific and varietal classifications are mostly based on location of flowers on the plant, patterns of reproductive nodes on branches, numbers of trichomes, and pod morphology. Peanut production and marketing have resulted in designation of four market classes which generally correspond to subspecific and varietal groups as follows: Runner (subsp. *hypogaea* var. *hypogaea* – var. *hirsuta*: Peruvian Runner), Virginia (subsp. *hypogaea* var. *hypogaea*), Spanish (subsp. *fastigiata* var. *vulgaris*), and Valencia (subsp. *fastigiata* var. *fastigiata*) (Stalker, 1997; Tillman and Stalker, 2009).

Oil content of peanut varies from 40% to 60% depend on market types and years. Peanut oil varies both in quantity and relative proportion of fatty acids. The fatty acid composition plays an important role in determining shelf life, nutrition, and flavor of peanut. Since fatty acids make up the major portion of weight of an oil molecule, physical and chemical properties of the oil tend to be determined by properties of the predominant fatty acids (Aruna and Nigam, 2009).

Modification of fatty acid composition has been a major goal of breeding programs. Main factors that influence oil and other composition components of peanut include variety and environmental production conditions such as light, temperature, water stress, and atmospheric constituents (Pattee, 2005). Oil content and fatty acid composition of peanut have been studied in different cultivars and different environments (Berry, 1982; Hinds, 1995; Dwivedi *et al*., 1996; Anderson *et al*., 1998; Golombek *et al*., 2001; Reddy *et al*., 2003; Hassan *et al*., 2005; Asibuo *et al*., 2008; Nadaf *et al*., 2009). But there is limited literature about climatic effects on fatty acid composition in differing botanical peanut types.

Knowing better combination effects of climatic fluctuations and botanical types on fatty acid composition would be useful in designing management practices to obtain a specific oil quality and in improving predictions of crop models. The main objective of this work was to investigate the effects of growing years in three different market types (Virginia, Spanish, and Valencia) on fatty acid composition of peanut oil.

MATERIALS AND METHODS

Crop varieties

In this research, normal oleic cultivars NC-7, New Mexico Valencia A, and 96 Australia were used as material belonging to Virginia, Valencia, and Spanish market types,

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respectively. Runner-type has a very long growing period and some problems with fully maturity in this region (Onemli, 1990), thus, it was not included in this study. Some comparative characters of Virginia, Spanish, and Valencia genotypes are presented in Table 1. Virginia has large seeds and pods, long growth period, spreading growth habit, no floral axes on main stem, alternating pairs of floral and reproductive axes on branches. Valencia usually has three or more small kernels per pod and covered in a red skin, and earliness for pod maturity, floral axes on main stem, alternating pairs of floral and vegetative axes on branches, little branched, curved branches. Spanish has smaller kernels covered with cream skin, floral axes on main stem, alternating pairs of floral and vegetative axes on branches, more branched, upright branches (Onemli, 1990; 1995; Tillman and Stalker, 2009).

Experimental site and management

Experiments were conducted at a farmer field in Kesan (40°51' N, 26°38' E, 185 m a.s.l.), Turkey, on a silty clay loam series in 2008, 2009, and 2010. Planting dates were in the first week of May for all years. The experimental design was a randomized complete block with three replicates for every year. Peanut was sown with a 0.7 m spacing between rows and 0.3 m spacing between plants in a row. Soil fertility was adjusted to 60 kg P ha^{-1}. Genotypes were harvested separately at 85% pods maturity according to shell out method. Some climatic data during peanut growth seasons in 3 yr are given in Table 2. There were significant differences for rainfall, humidity, and temperature values especially during pod development of peanut amongst years.

Seed oil and fatty acids analysis

Seed oil and fatty acid analysis were conducted at the laboratory of Trakya Birlik, a Turkish Agricultural Cooperative. Seed oil content was determined with a pulsed NMR instrument (Bruker Minispec-Bruker Analytische Messtechnik, Karlsruhe, Germany). Oil contents are expressed as a percentage of dry seed weight (Warnsely, 1998).

Gas chromatography (GC) of fatty acid methyl esters (FAME) was performed with an Agilent 6890 N gas chromatography equipped with a flame ionization detector (FID). Analyses were conducted on an Agilent capillary column with column with 100 m × 0.25 mm i.d., 0.2 μm according to ISO 5508 (Ackman, 2002). The column temperature was programmed from 120 to 230 °C; and injector and detector temperature set at 250 °C using helium, air, and hydrogen. Thirteen fatty acids were identified as percentage of total fatty acids These fatty acids were palmitic (C16:0), palmitoleic (C16:1), margaric (C17:0), heptadecanoic (C17:1), stearic (C18:0), oleic (C18:1), linoleic (C18:2), linolenic (C18:3), arachidic (C20:0), eicosanoic (C20:1), behenic (C22:0), erucic (C22:1), and lignoceric (C24:0).

Statistical analysis

Statistical analyses were conducted by using standard procedures using variety and year factors. The least significant difference (LSD) at 5% probability was used to compare factors. Collected data were analyzed using the SAS statistical computer package (SAS Institute, 1997).

Table 1. Some comparative characters of Virginia, Spanish, and Valencia genotypes.

Characters	Virginia (NC-7)	Valencia (New Mexico Valencia A)	Spanish (96 Australia)
Growth period	long (175 d)	short (120 d)	medium (150 d)
Growth habit	spreading	bunch	bunch
Pod size	medium to large	medium to long	very small
Seed per pod	usually 2, occasionally 3	usually 3-4	usually 2
Shell thickness	thick	thick	thin
Testa color	light brown	red	cream
Seed size	medium to large	small to medium	small
Seed dormancy	moderately present	little	little
Branching	moderate to profuse	sparse to moderate	more-upright branches
Flowering pattern	alternate	sequential	sequential
Lateral branches	longer than stem	shorter than stem	shorter than main stem

Table 2. Some climatic data during peanut growth season in 3 yr.

	Rainfall			Rainy day number			Relative humidity			Temperature								
										Means			Maximum			Minimum		
	2008	2009	2010	2008	2009	2010	2008	2009	2010	2008	2009	2010	2008	2009	2010	2008	2009	2010
	mm			d			%			°C								
May	33.4	27.7	16.0	10	8	9	62.7	66.1	68.6	18.0	19.1	18.1	35.1	32.1	33.6	5.0	7.5	3.3
June	45.7	25.9	30.8	8	7	12	62.1	62.5	72.3	23.3	22.6	22.5	36.7	36.4	38.7	8.7	9.3	12.0
July	34.0	89.4	72.3	4	5	8	51.9	55.3	66.4	25.2	24.5	24.7	37.3	39.7	35.5	14.1	15.4	14.6
August	8.1	17.0	0	3	1	0	49.2	51.9	56.9	26.3	25.0	28.1	38.6	37.0	39.6	15.7	14.2	15.8
Sept.	71.6	74.1	31.4	8	6	4	62.3	67.7	64.8	19.6	19.9	21.2	35.4	36.9	33.8	7.0	6.6	9.0
October	17.0	112.6	68.5	4	16	18	72.6	82.3	82.1	14.9	15.1	13.0	26.5	28.9	23.8	3.5	2.9	-0.7

RESULTS AND DISCUSSION

Variations of botanical variety and year were highly significant for all the parameters. Interaction varieties × years were also found to be statistically significant for oil and all the fatty acids studied (Table 3).

Varietal effects

Oil content in different peanut market types exhibited significant differences (Table 4). The maximum oil content (51.993%) was found in Virginia genotype (NC-7), while Valencia type (New Mexico Valencia A) accumulated the minimum oil content (47.197%).

Fatty acid composition of peanut seed oils has been reported to be influenced by varietal effects, and Virginia cultivars, which belong to subspecies *hypogaea*, had higher oil content than Spanish and Valencia market types, which belong to subspecies *fastigiata* (Onemli, 1990; Savage and Keenan, 1994; Onemli, 1995; Asibuo *et al*., 2008; James Yaw *et al*., 2008). Important factors influencing fatty acid composition are the variety and genetics of the seed (Gecgel *et al*., 2007).

The highest percentage of palmitic acid was found in Valencia and Spanish genotypes. Valencia-type had also highest stearic acid. Cultivars for every botanical variety in this study were selected as normal oleic type from traditional genotypes. Oleic acid was within the range of 38.851-45.694% obtained for three genotypes. Virginia-type gave the highest percentage of oleic acid while Valencia had the lowest value. This trend was reverse with respect to linoleic acid concentration. The highest percentage of linoleic acid (38.505%) was observed in Valencia genotype, while the lowest content (32.802%) was in Virginia. As the results of fatty acids with market type, Valencia had also the higher percentages of arachidic, behenic, and lignoceric acid than Virginia and Spanish. Bansal *et al*. (1993) reported that fatty acid contents are related to the growth habit. The previous studies indicate the presence of peanuts and its products in the diet reduces the risk of heart disease by 21% (O'Byrne *et al*., 1997).

Year effects

Table 5 includes the variations in oil content and fatty acids response to years. Mean of oil percentages of genotypes in 2010 was lower than 2008 and 2009. The highest percentages of palmitic acid and stearic acid were recorded in 2009 with 11.58% and 3.203%, respectively. In 2010, oleic acid percentage in peanut oil was the highest although this year gave the lowest linoleic acid. Oleic, linoleic and saturated fatty acids were significantly affected by climatic fluctuates in years. Higher means of temperature during seed development (especially August and September in Table 2) in 2010 according to other 2 yr resulted in greater oleic contents. Inversely, the lower temperatures post anthesis in 2009 occurred higher linoleic and total of saturated fatty acids. Fatty acid composition of peanut seed oils has been reported to be influenced by climate effects (Howell, 2001; Pattee, 2005). The variation of fatty acid composition with

Table 3. ANOVA of oil and fatty acid contents in peanut with variety, year, and interaction variety × year.

Oil and fatty acids	Mean square			
	Variety	Year	Variety × year	CV
Oil content	57.955**	64.957**	5.311**	0.611
Palmitic (C16:0)	0.292**	1.338**	4.246**	0.637
Palmitoleic (C16:1)	0.246**	0.232**	0.217**	1.721
Margaric (C17:0)	0.002**	0.003**	0.001**	8.118
Heptadecanoic (C17:1)	0.001**	0.002**	0.005**	9.702
Stearic (C18:0)	0.484**	0.097**	1.113**	0.854
Oleic (C18:1)	109.528**	35.257**	78.155**	0.096
Linoleic (C18:2)	78.544**	17.743**	29.130**	0.106
Linolenic (C18:3)	0.001**	0.001**	0.001**	3.388
Arachidic (C20:0)	0.045**	0.061**	0.086**	0.408
Eicosanoic (C20:1)	0.035**	0.086**	0.123**	0.273
Behenic (C22:0)	0.232**	1.205**	0.693**	0.747
Erucic (C22:1)	0.003**	0.004**	0.005**	4.159
Lignoceric (C24:0)	1.479**	0.480**	0.814**	0.239

**Significant differences are shown at P < 0.01 based on ANOVA.
CV: The coefficient of variation, which is used to describe the amount of variation for oil and fatty acids content in the variety, year, and interaction variety × year.

Table 4. Variations in oil content and fatty acids (%) in differing peanut groups.

Oil content and fatty acids	Variety			
	Virginia	Valencia	Spanish	LSD
Oil content	51.993a	47.197c	48.159b	0.300
Palmitic (C16:0)	11.080b	11.371a	11.409a	0.072
Palmitoleic (C16:1)	0.389a	0.095c	0.111b	0.003
Margaric (C17:0)	0.084a	0.062b	0.088a	0.006
Heptadecanoic (C17:1)	0.046a	0.028b	0.047a	0.004
Stearic (C18:0)	2.884c	3.346a	3.159b	0.027
Oleic (C18:1)	45.694a	38.851c	43.450b	0.041
Linoleic (C18:2)	32.802c	38.505a	34.318b	0.037
Linolenic (C18:3)	0.063a	0.059b	0.063a	0.002
Arachidic (C20:0)	1.413c	1.553a	1.497b	0.006
Eicosanoic (C20:1)	1.173a	1.097b	1.049c	0.003
Behenic (C22:0)	2.889c	3.179a	3.153b	0.023
Erucic (C22:1)	0.080b	0.107a	0.072c	0.004
Lignoceric (C24:0)	1.582b	1.627a	0.903c	0.003

Means within a row followed by same small letters are not different according to LSD test (P < 0.05).

Table 5. Variations in oil content (%) and fatty acids response to years.

Oil content and fatty acids	Years			
	2008	2009	2010	LSD
Oil content	50.813a	50.517a	46.019b	0.300
Palmitic (C16:0)	10.850c	11.580a	11.430b	0.072
Palmitoleic (C16:1)	0.101c	0.111b	0.384a	0.003
Margaric (C17:0)	0.085b	0.057c	0.092a	0.006
Heptadecanoic (C17:1)	0.056a	0.028c	0.037b	0.004
Stearic (C18:0)	3.174b	3.203a	3.011c	0.027
Oleic (C18:1)	41.657b	41.393c	44.946a	0.041
Linoleic (C18:2)	35.907b	36.127a	33.592c	0.037
Linolenic (C18:3)	0.074a	0.055b	0.055b	0.002
Arachidic (C20:0)	1.551a	1.518b	1.394c	0.006
Eicosanoic (C20:1)	1.212a	1.020c	1.086b	0.003
Behenic (C22:0)	3.430a	3.092b	2.699c	0.023
Erucic (C22:1)	0.086b	0.064c	0.109a	0.004
Lignoceric (C24:0)	1.143c	1.605a	1.364b	0.003

Means within a row followed by same small letters are not different according to LSD test (P < 0.05).

climatic conditions, particularly moisture and temperature during the growing season, was indicated by (Gecgel *et al*., 2007).

Variety × year interaction effects

Peanut composition is also influenced by interaction varietal type × year (Table 6). The accumulation of oil and fatty acids in differing market types exhibited significant variations depend on years. Oil contents of Virginia and Valencia type were highest in 2008. Oil percentages of Spanish-type in 2008 and 2009 were statistically in the same group. Gecgel *et al*. (2007) reported that climatic factors during growing season, maturity, variety, and location influence oil concentration. It was observed different effects of years in oleic and linoleic acid composition according to peanut types. The highest oleic acid percentages were observed for Virginia in 2008 and for Valencia and Spanish in 2010. Virginia, Valencia, and Spanish had their greatest linoleic contents in 2010, 2008, and 2009, respectively. The highest palmitic contents were recorded for Virginia and Valencia in 2010, while Spanish gave the highest value in 2009. The highest stearic percentages were recorded in 2010 for Virginia, and in 2009 for Valencia and Spanish. Although Valencia and Spanish gave the highest behenic and arachidic acid percentages in 2008, it was in 2010 for Virginia. The similar effects of interaction variety × environment have been reported in Virginia and Spanish types by Bansal *et al*. (1993), in Runner-type by Branch *et al*. (1990) and Grosso *et al*. (1994), in only Spanish-type by Anderson *et al*. (1998), and with different breeding lines by Isleib *et al*. (2008). Market types have different growth period. The order of maturity of these market types from earliness to late is Valencia, Spanish, and Virginia (Onemli, 1990; 1995; Tillman and Stalker, 2009). They were exposed in this study differing climate fluctuates such as temperature during seed development in every year, thus the significant differences for oil content and fatty acids were exhibited in years by different market types.

Correlations among oil fatty acids

No significant correlation was observed for oil content with fatty acid percentages of peanut oil (Table 7). Palmitic acid was correlated positively with stearic, linoleic, arachidic, and behenic acids, and negatively with margaric, heptadecanoic, oleic, linolenic and eicosanoic acids. Percentage of stearic acid was shown to be correlated positively with linoleic, arachidic and behenic acids, and negatively with oleic and eicosanoic acids.

The highest negative correlation was noted for

Table 6. Variations in oil content and fatty acids (%) of different peanut groups in 3 yr.

Oil and fatty acids	Virginia				Valencia				Spanish			
	2008	2009	2010	LSD	2008	2009	2010	LSD	2008	2009	2010	LSD
Oil content	54.61a*	53.52b	47.85c	0.19	48.25a	47.60b	45.72c	0.32	49.58a	50.41a	44.49b	1.23
Palmitic	10.12c	10.82b	12.30a	0.19	10.74c	11.39b	11.98a	0.12	11.69b	12.53a	10.01c	0.19
Palmitoleic	0.12b	0.12b	0.93a	0.01	0.09b	0.12a	0.08b	0.01	0.10b	0.01b	0.14a	0.01
Margaric	0.10a	0.06b	0.10a	0.02	0.07a	0.06b	0.06b	0.01	0.08b	0.06c	0.12a	0.01
Heptadecanoic	0.10a	0.04b	0.01c	0.02	0.03a	0.02b	0.03b	0.01	0.04b	0.02c	0.08a	0.01
Stearic	2.79b	2.38c	3.48a	0.09	3.44b	3.50a	3.10c	0.05	3.29b	3.73a	2.46c	0.06
Oleic	47.46a	46.73b	42.89c	0.05	37.88c	38.87b	39.80a	0.16	3.96b	38.58c	52.14a	0.04
Linoleic	31.87c	32.31b	34.23a	0.04	39.46a	38.35b	37.72c	0.11	36.40b	37.72a	28.83c	0.11
Linolenic	0.08a	0.06b	0.05c	0.01	0.06	0.06	0.06	ns	0.09a	0.04c	0.06b	0.01
Arachidic	1.38b	1.33c	1.53a	0.01	1.63a	1.60b	1.43c	0.02	1.64a	1.63b	1.22c	0.01
Eicosanoic	1.32a	1.29b	0.91c	0.01	1.13b	0.94c	1.23a	0.01	1.20a	0.83c	1.12b	0.01
Behenic	2.79b	2.90a	2.98a	0.08	3.49a	3.21b	2.84c	0.04	4.01a	3.17b	2.28c	0.04
Erucic	0.09a	0.08a	0.07b	0.01	0.08b	0.01c	0.18a	0.01	0.09a	0.05c	0.08b	0.01
Lignoceric	1.69b	1.78a	1.27c	0.01	1.74a	1.64b	1.50c	0.01	0.01c	1.39a	1.32b	0.01

*Means among years within a variety followed by same small letters are not significantly different according to LSD test ($P < 0.05$).

Table 7. Correlation coefficients of fatty acids and oil content in peanut.

	C16:0	C16:1	C17:0	C17:1	C18:0	C18:1	C18:2	C18:3	C20:0	C20:1	C22:0	C22:1	C24:0
Oil	-0.163	-0.139	-0.190	0.253	-0.181	0.097	-0.140	0.327	0.015	0.352	0.174	-0.248	0.147
C16:0		0.369	-0.498*	-0.840**	0.734**	-0.690**	0.596**	-0.453*	0.633**	-0.623**	0.407*	0.024	-0.304
C16:1			0.310	-0.437*	0.229	0.073	0.158	-0.296	0.051	-0.412	-0.113	-0.225	-0.061
C17:0				0.558*	-0.361	0.687**	-0.706**	0.245	-0.472	0.131	-0.407*	-0.134	-0.207
C17:1					-0.666**	0.712**	-0.656**	0.468*	-0.638**	0.593*	-0.455*	0.071	0.134
C18:0						-0.860**	0.816**	-0.322	0.915**	-0.740**	0.595*	-0.255	-0.199
C18:1							-0.985**	0.159	-0.921**	0.417*	-0.754**	-0.038	0.168
C18:2								-0.188	0.868**	-0.374	0.686**	0.087	-0.046
C18:3									-0.029	0.679**	0.405*	0.135	-0.519*
C20:0										-0.515*	0.857**	-0.271	-0.338
C20:1											-0.103	0.565*	0.017
C22:0												-0.161	-0.583*
C24:0													0.013

Palmitic (C16:0), Palmitoleic (C16:1), Margaric (C17:0), Heptadecanoic (C17:1), Stearic (C18:0), Oleic (C18:1), Linoleic (C18:2), Linolenic (C18:3), Arachidic (C20:0), Eicosanoic (C20:1), Behenic (C22:0), Erucic (C22:1), Lignoceric (C24:0).
*Significant at $P < 0.05$ and **Significant at $P < 0.01$.

oleic and linoleic acids (r: -0.985). Oleic acid was also negatively correlated with arachidic and behenic acids. Positive relationships occurred between linoleic acid and arachidic, and behenic acids. Arachidic acid was highly correlated with behenic acid.

Similar correlations have been reported in previous studies (Dwivedi *et al*., 1993; Hammond *et al*., 1997; Anderson *et al*., 1998). Mercel *et al*. (1990) has also suggested that fatty acid composition should not affect the oil content of seed.

CONCLUSIONS

The significant differences exhibited by different cultivars in this study during 3 yr for oil content and fatty acids could be attributed to the genetic make-up of a particular cultivar, its place of the environmental to reach high oil quality. Knowing better combination effects of climatic fluctuations and botanical types on fatty acid composition would be useful in designing management practices to obtain a specific oil quality and improving predictions of crop models.

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Impacto del cambio climático en la composición de ácidos grasos del aceite de maní (*Arachis hypogaea* L.) de tres clases comerciales. El maní (*Arachis hypogaea* L.) es uno de los cultivos oleaginosos más importantes del mundo. La composición de los ácidos grasos juega un rol importante en la calidad del aceite. Los experimentos se llevaron a cabo en los años 2008, 2009, y 2010, para determinar la variación en la composición de ácidos grasos de tres clases comerciales de maní (Virginia, Valencia y Spanish) con contenido normal de ácido oleico. La variación entre variedades botánicas, año, y su interacción fueron altamente significativas para el contenido de aceite y los 13 ácidos grasos estudiados. El contenido de aceite en las diferentes clases comerciales exhibió marcadas diferencias. El máximo contenido de aceite (51.993%) se obtuvo en la clase Virginia (NC-7), mientras que en la clase Valencia (New Mexico Valencia A) se obtuvo el menor contenido de aceite (47.197%). La clase Virginia también obtuvo el valor más alto de ácido oleico. Temperaturas más altas durante el desarrollo de la semilla en el 2010 resultaron en contenidos más altos de ácido oleico que en el 2008 y el 2009, mientras que temperaturas más bajas post antesis en el 2009 condujeron a un contenido más alto de ácido linoleico. El efecto del año en la composición de los ácidos grasos fue distinto dependiendo de la clase comercial de maní. El contenido más alto de ácido linoleico para las clases Virginia, Valencia y Spanish se observó en el 2010, 2008, y 2009, respectivamente. La correlación negativa menor se observó entre el contenido de los ácidos oleico y linoleico (r: -0.985). El ácido oleico también se correlacionó negativamente con los ácidos araquídico y behénico.

Palabras clave: *Arachis hypogaea* subsp. *fastigiata*, temperatura, correlación.

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