Commercial Production of Chia in Northwestern Argentina

Wayne Coates* and Ricardo Ayerza (h)

Bioresources Research Facility, Office of Arid Lands Studies, The University of Arizona, Tucson, Arizona 85706

ABSTRACT: The economy of northwestern Argentina depends heavily on sugar and tobacco. Depressed prices for these crops in recent years have caused significant economic problems, and alternative crops are actively being sought. Chia (*Salvia hispanica* L.), a source of industrial oil for the cosmetics industry and ω-3 α-linolenic acid for the food industry, is one new crop that could help diversify the local economy. A project to develop chia as a commercial crop was initiated in 1991. In 1996, 13 fields were commercially grown in two provinces of northwestern Argentina. Biomass production and seed yields were affected by weather, location, and production practices. Average seed yield was 606 kg/ha. Oil content and fatty acid composition varied between fields.

JAOCS 75, 1417–1420 (1998).

KEY WORDS: α-Linolenic acid, fatty acids, *Salvia hispanica* L.

The economies of several northwestern Argentine provinces are dependent on sugarcane and tobacco (1,2). Recently, depressed markets for these crops have caused economic hardship in this region. Replacing unprofitable traditional crops with alternative crops would help diversify the local economy. Chia (*Salvia hispanica* L.) is one crop that is particularly attractive, since it grows well in the region.

Chia is an annual herbaceous plant in the mint family (Labiatae), and is native to southern Mexico and northern Guatemala [Ayerza, R. (h), and A.M. Mealla, El cultivo de la chia en Mexico. Agropecuaria El Valle S.A., Buenos Aires, Argentina, 1993]. The plant produces numerous small seeds that mature in the fall. The seed has between 25 and 39 wt% oil (3–5). The oil contains one of the highest known proportions of ω-3 α-linolenic acid (60%), a polyunsaturated fatty acid. Linolenic acid has many uses in industrial and cosmetic products, and demand for it continues to be strong (4). The meal, which is high in protein and fiber, as well as whole seeds, can be used for human food and animal feed (3,4).

In 1991, Agropecuaria El Valle S.A., an Argentine company, initiated a project to determine the feasibility of producing chia commercially in Argentina and Colombia, with a goal of bringing it into commercial production. This work has continued, taking the crop from an early research phase to commercial status. Trials conducted in 1995 showed yield and oil content to be affected by seeding date and location, with machine-harvested yields up to 918 kg/ha recorded (6). This paper presents results from the 1996 commercial trials conducted in northwestern Argentina. This work concludes the development phase of the commercialization effort.

*To whom correspondence should be addressed.
E-mail: wcoates@u.arizona.edu

EXPERIMENTAL PROCEDURES

The chia seed selected for the trials originated in Los Altos, Jalisco, Mexico, but had been grown for several years by Agropecuaria El Valle S.A. in the Argentine provinces of Catamarca and Salta. The seed, which was sown in four geographic locations in northwestern Argentina in 1996 (Table 1), came from a June 1995 harvest in Valle de Lerma, Salta.

The fields were grown using local commercial practices, and varied in size among farms (Table 2). The seeding rate was 6 kg/ha, except Los Nietos 2 which produced a volunteer crop. High combine losses the year before led to the volunteer crop. Between the two chia crops, tobacco was grown in the field.

Row (bed) spacing in the seeded fields was either 0.70 or 0.80 m, with the volunteer crop resembling broadcast seeding. The growing season, from planting to harvest, ranged from 120 to 180 d. Since observation of crop performance under local conditions was the objective of this study, agronomic practices were not standardized over all sites. Consequently weed control, fertilization, and irrigation followed individual farm practices (Table 2).

Potential yield in each field was estimated prior to combining by hand-harvesting 1-m^2 plots. The number of plots sampled varied according to field size and ranged from a minimum of 6 to a maximum of 16. Following open air drying, the plants were weighed, and then the seed heads were threshed using a plot combine. Later the seed was cleaned and weighed. The mean weight of the samples, on an area basis, was compared with machine yields to determine mechanical harvesting losses.

The fields were harvested using a commercial combine, with modifications made to improve performance. These modifications included providing the reel with more lift, so that in taller stands it would not break off inflorescences (seed heads) and cause high losses, and replacing the lower sieve with a 3.0 mm fixed screen.

Except for the Las Pampitas and El Mollar farms, the seed harvested from each field was weighed following combining to determine machine yield. This was not possible for these two farms, as scales were unavailable. The seed was bulked for each farm, and then weighed later. Seed samples from several fields were analyzed for viability (Tetrazolium test), germination percentage, and trash content.

TABLE 1
Geographic Location of the Commercial Fields

Geographic location	Province	Latitude South	Longitude West	Elevation (m)	Rainfall mean/yr (mm)
Las Pampitas	Jujuy	24°23′	65°07′	936	606
Guemes	Salta	24°41′	65°02′	734	536
Campo Quijano	Salta	24°54′	65°38′	1520	1052
El Carril	Salta	25°03′	65°31′	1069	560

Oil quantity and fatty acid composition in the seeds were determined by Soxhlet and gas chromatographic analyses, respectively. The fatty acid contents were determined using a Perkin-Elmer 300 gas–liquid chromatograph (Norwalk, CT) equipped with a Unisole 3000-Unipor C80/100 column (Cromaquima S.R.L., Buenos Aires, Argentina). Analytical procedures followed those specified in International Standard (ISO) 5508/1990 and ISO 5509/1978. Seed samples for these tests were obtained by randomly sampling a number of 50-kg bags in which the seed was stored following machine harvest, mixing the samples, and then dividing the resulting sample in half.

Total biomass and seed yield (air dry basis) from the 1-m^2 plots, as well as oil content and composition, were compared using standard analyses of variance techniques to assess field differences. When the F-value was significant ($P < 0.05$), differences in means were analyzed for significance using Duncan's Multiple Range Test (7).

RESULTS AND DISCUSSION

The average machine-harvested yield of the 10 fields in Salta was 712 kg/ha, and of the three fields in Jujuy was 486 kg/ha (Table 3). The average Salta yield is higher than the commercial yield (530 kg/ha) for Colombia [Ayerza, R. (h), Proyecto chia: Introduccion y produccion comercial en el Valle del Rio Cauca, Colombia. AEV de Colombia Ltd., Cartago, Colombia, 1995] and the 541 kg/ha average recorded in the 1995 trials (6). The low yield at the El Mollar Farm could be caused by the extremely low precipitation (187 mm) received during the growing season, and given that the crop was not irrigated (Table 2).

The highest potential seed yield, based on the 1-m^2 samples, was 1171 kg/ha (Table 3). This was much less than the 1602 kg/ha recorded for one field grown in Salta in 1995 (6). The broad range in sample yields measured in 1995 and 1996 shows that yields are dependent upon several factors, including climatic and soil conditions, planting date, and water received by the crop.

The mean seed yield of the hand-harvested plots for seven fields was greater than the counterpart machine-harvested yield. The difference could be attributed to several factors, including less than optimal combine operation, seed consumption by birds, and inclement weather in the interim between hand-harvest and machine-harvest, which amounted to over a week in some instances. Machine-harvested yields exceeded hand-harvested yields in four fields. It was concluded that in these instances, insufficient hand samples had been taken to account for the variability in yield that existed in the fields.

Trash content, percentage of immatures, and viability of the seed varied among fields for which these parameters were measured (Table 4). The differences in trash content were attributed to the cleaning ability of the combine, and this was dramatically influenced by crop condition and weeds. Higher weed infestations, and chia that had more green leaves, even though seed maturity was equal, resulted in higher trash contents.

TABLE 2
Agricultural Practices Used, and Rainfall Received by 13 Fields that Produced Chia Commercially in 1996

Geographic location	Farm/field	Area (ha)	Plant date	Machine harvest date	Number of irrigations	Fertilizer type and amount (kg/ha)	Number of cultivations	Rainfall received (mm)
Las Pampitas	San Carlos	3.70	2/15	8/16	3	None	2	186
Las Pampitas	Las Pampitas 1	5.36	2/15	8/15	2	None	1	186
Las Pampitas	Las Pampitas 2	3.25	2/15	8/15	2	None	1	186
Guemes	El Bordo	4.29	2/5	8/14	2	None	—	246
Campo Quijano	El Mollar 1	7.16	2/10	7/2	—	None	1	187
Campo Quijano	El Mollar 2	10.4	2/10	7/3	—	None	—	187
El Carril	La Poblacion 1	11.5	2/1	6/4	3	45-0-0 (80)	3	187
El Carril	La Poblacion 2	10.0	2/1	6/5	3	45-0-0 (80)	3	187
El Carril	Los Nietos 1	3.11	2/10	6/30	3	Urea (60)	2	187
El Carril	Los Nietos 2[a]	2.45	—	6/24	3	[c]	—	187
El Carril	Los Nietos 3	8.49	2/12[b]	7/01	3	Urea (60)	2	187
El Carril	Los Nietos 6	3.37	2/13	7/01	3	Urea (60)	2	187
El Carril	Las Barrancas	5.67	2/9	6/22	1	None	1	187

[a]Volunteer crop.
[b]Reseeded 2/22.
[c]600 kg/ha of 18-46-0 applied to the previous tobacco crop.

TABLE 3
Mean Plot Biomass and Seed Yields for 13 Fields, and Comparisons Between Hand- and Machine-Harvested Yields

Geographic location	Farm/field	Biomass (kg/ha)	Hand yield (kg/ha)	Machine yield (kg/ha)	Machine loss (%)
Las Pampitas	San Carlos	2728 b,c[a]	500 c,d,e	685	–37.0
Las Pampitas	Las Pampitas 1	3700 a,b	814 b,c	288[b]	16.9
Las Pampitas	Las Pampitas 2	2000 c,d,e	250 e		
Guemes	El Bordo	3607 a,b	738 b,c,d	476	35.6
Campo Quijano	El Mollar 1	1125 e	221 e	258[d]	5.5
Campo Quijano	El Mollar 2	1321 d,e	328 e		
El Carril	La Poblacion 1	3486 a,b	1171 a	1262	–7.8
El Carril	La Poblacion 2	3614 a,b	891 a,b	955	–7.2
El Carril	Los Nietos 1	4178 a	1047 a,b	788	24.7
El Carril	Los Nietos 2[c]	2586 b,c,d	525 c,d,e	523	0.5
El Carril	Los Nietos 3	1800 c,d,e	483 d,e	385	20.4
El Carril	Los Nietos 6	1871 c,d,e	436 d,e	380	12.9
El Carril	Las Barrancas	2771 b,c	543 c,d,e	670	–23.4
	Mean	2676	611	606	
		cr[d] 1421	cr[d] 353		

[a]Means in a column followed by the same letter were not statistically different at the 0.05 level.
[b]Seed from both fields was bulked, and then weighed.
[c]Volunteer crop.
[d]Critical range for mean separation in Duncan's multiple range test.

TABLE 4
Germination, Viability, and Trash Content of Machine-harvested Chia

Farm/field	Germ (%)	Tetrazolium viability (%)	Trash content (%)	Immatures (%)	1000 seed wt (gm)
San Carlos	n/a[a]	82	13.0	n/a	n/a
Las Pampitas	n/a	75	13.0	n/a	n/a
El Bordo	n/a	84	18.0	n/a	n/a
El Mollar	n/a	n/a	17.5	1.5	0.32
La Poblacion 1	75	86	9.5	1.5	0.53
La Poblacion 2	77	89	4.5	0.5	0.46
Los Nietos 1	79	91	8.0	4.5	0.39
Los Nietos 2[b]	77	90	17.5	0.5	0.38
Las Barrancas	n/a	n/a	39.0	1.5	0.42

[a]Not all parameters were determined for all samples. n/a, not available.
[b]Volunteer crop.

TABLE 5
Oil Content and Fatty Acid Composition of Commercially Produced Chia Seed

		Fatty acid composition				
Farm/field	Oil content (%)	Palmitic (%)	Stearic (%)	Oleic (%)	Linoleic (%)	Linolenic (%)
San Carlos	32.8 e[a]	7.4 a	3.0 a	6.65 c,d	18.8 e	63.45 a,b
Las Pampitas	33.9 d	7.2 b	3.0 a	6.65 c,d	19.8 c	62.75 e
El Bordo	35.6 b	7.2 b	3.0 a	7.15 a	20.0 b,c	62.15 f
El Mollar	32.2 f	6.9 c	2.8 b	6.65 c,d	19.0 e	63.75 a
La Poblacion 1	32.7 e,f	7.2 b	3.0 a	6.50 d	20.0 b,c	62.85 d,e
La Poblacion 2	36.8 a	6.9 c	3.0 a	6.80 b,c	20.2 b	62.40 f
Los Nietos 1	34.5 c	7.2 b	3.0 a	6.85 b	19.2 d	63.10 c,d
Los Nietos 2[b]	33.1 e	7.2 b	3.0 a	7.05 a	20.4 a	61.55 g
Las Barrancas	33.9 d	7.0 c	3.0 a	6.50 d	19.2 d	63.35 b,c
	cr[c] 0.58	cr[c] 0.12	cr[c] 0.09	cr[c] 0.20	cr[c] 0.25	cr[c] 0.35

[a]Means in a column followed by the same letter were found not to be statistically different at the 0.05 level.
[b]Volunteer crop.
[c]Critical range for mean separation in Duncan's Multiple Range Test.

Statistical differences in oil content and composition between fields were detected (Table 5). The oil content of the seed produced by the volunteer crop was one of the lower values, with the α-linolenic concentration the lowest of all fields. Oil contents, in general, were higher than those reported for the 1995 tests (6). Climatic factors probably were the cause of these differences, since oil content and composition of chia and other oilseed crops have been shown to vary among locations and when grown under differing climatic conditions (5,8,9).

In conclusion, these data indicate that chia productivity in northwestern Argentina, as with many other crops here and in other regions, is sensitive to weather, location, and production practices. Additional studies could be conducted to assess the effects of these factors on chia yield, oil content, and composition fully. However, given the size of the present market, and considering the favorable returns that growers are realizing, $580/ha as compared to $250–390/ha for crops such as beans and corn, such studies appear to be unwarranted at this time.

ACKNOWLEDGMENTS

This research was completed as part of the Northwestern Argentina Regional Project, which is composed of The University of Arizona, the University of California, Partners of the Americas, Inc., Pulares Agricultural Group S.A., CREA Los Lapachos, and Agropecuaria El Valle S.A.

REFERENCES

1. De Las Carreras, A., *El Azucar en la Argentina y el Mundo,* Editorial Hemisferio Sur, Buenos Aires, 1990.
2. Instituto Nacional de Estadistica y Censos, *Datos para el Analisis del Sector Publico de las Distintas Juridicciones de la Republica Argentina*, Instituto Nacional de Estadistica y Censo, Buenos Aires, 1995, pp. 134–141.
3. Jojoba Growers and Processors, Inc., *Oil of Chia,* Jojoba Growers and Processors, Inc., Apache Junction, Arizona, 1990.
4. Ting, I.P., J.H. Brown, H.H. Naqvi, J. Kumamoto, and M. Matsumura, Chia: A Potential Oil Crop for Arid Zones, in *New Industrial Crops and Products, Proceedings of the Association for the Advancement of Industrial Crops,* The University of Arizona, Office of Arid Lands Studies, Tucson, Arizona, 1990, pp. 197–200.
5. Ayerza, R. (h), Oil Content and Fatty Acid Composition of Chia (*Salvia hispanica* L.), from Five Locations in Northwestern Argentina, *J. Am. Oil Chem. Soc. 72:*1079–1081 (1995).
6. Coates, W.E., and R. Ayerza (h), Production Potential of Chia in Northwestern Argentina, *Ind. Crops Prod. 5:*229–233 (1996).
7. SAS Institute, *SAS/STAT User's Guide,* Release 6.03 Edition, SAS Institute Inc., Cary, 1988, p. 595.
8. Talha, M., and F. Osman, Effect of Soil Water Stress on Water Economy and Oil Composition in Sunflower, *J. Agric. Sci. 84:*49–56 (1975).
9. Carver, B.F., J.W. Burton, T.E. Carter, and R.F. Wilson, Response to Environmental Variation of Soybean Lines Selected for Altered Unsaturated Fatty Acid Composition, *Crop Sci. 26:*1176–1180 (1986).

[Received September 29, 1997; accepted June 15, 1998]