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Optimal sowing dates of three species of grain-bearing amaranth in the semi-arid Argentine Pampa

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Abstract

Determining the optimal sowing date is important when evaluating the production potential of any new crop. Field trials were performed with *Amaranthus cruentus* L., *A. hypochondriacus* L. and *A. mantegazzianus* Pass. from 1999 to 2002 in the semi-arid Argentine Pampa in order to establish the best sowing dates for grain production. Crops were sown at 15 day intervals during November, December and January. The following variables were then measured: plant height, days to anthesis, production of biomass, grain production, harvest index, final number of plants and plant losses. Rainfall strongly influenced these variables, depending on sowing date. In all years, *A. mantegazzianus* produced the lowest grain yields. The latest sowing date is not recommended since the light and temperature conditions during the final part of the phenological cycle have a negative effect on grain yield. The best results were obtained when sowing was performed from the second half of November through to the end of December.

Key words: grain, production, yield, *Amaranthus sp.*

Resumen

Fecha óptima de siembra de tres especies de amaranto granífero en la zona semiárida de la pampa argentina

La fecha óptima de siembra es un dato esencial cuando se trata de evaluar el potencial de producción de un nuevo cultivo. A fin de establecer el rango óptimo de siembra para la producción de grano en la zona semiárida pampeana de Argentina, se realizaron entre los años 1999 y 2002 ensayos de campo con *Amaranthus cruentus* L., *A. hypochondriacus* L. y *A. mantegazzianus* Pass., probando fechas de siembra cada 15 días aproximadamente durante los meses de noviembre, diciembre y enero. Se midieron las siguientes variables: altura de planta, días a la antésis, producción de biomasa, producción de grano, índice de cosecha, población final de plantas y porcentaje de plantas perdidas. Las precipitaciones en cada año tuvieron incidencia para las variables analizadas, según la fecha de siembra. *A. mantegazzianus* tuvo menor rendimiento de grano que las otras dos especies en todos los años. La última fecha de siembra no resultó conveniente por la incidencia de las condiciones de luz y temperatura sobre el final del ciclo fenológico de las plantas, originando mermas en el rendimiento. Es por tanto recomendable sembrar entre la segunda quincena de noviembre y finales del mes de diciembre.

Palabras clave: grano, producción, rendimiento.

Introduction

The genus *Amaranthus*, family *Amaranthaceae*, has 65 member species, some 50 of which are native to the Americas. Some species are cultivated for their grain, other as vegetables or forage, and still others for their pigments. Some species are weeds (Granjero Colín *et al.,* 1994; Kigel, 1994; Becerra, 2000). Their genetic variability has afforded them exceptional adaptability to a wide range of environmental conditions, although being C_4 plants they do require high temperatures (optimum 35ºC; Kulakow and Hauptli, 1994) and strong light (Putnam, 1990; Covas, 1994a; Berti *et al.,* 1996). Once a crop is established it is tolerant to drought. Growth occurs during the frost-free period, although a frost at harvest time is opportune since this helps dry the plants out and facilitates mechanical harvesting (Putnam *et al.,* 2003). Soil temperature and humidity are probably crucial factors in the germination and emergence of plantlets (AGPG, 1990).

Amaranth grain has received special attention in North America because of its high protein and lysine contents. Its starch and lipids have also been studied

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for potential use in the food and cosmetics industries (Henderson *et al.,* 2000). Guillen Portal *et al*. (2003) report that 1800 ha of amaranth were sown in the USA in 1991; the west of Nebraska (on the Great Plains; mean annual rainfall 400 mm) is where most is now produced (Williams and Brenner, 1995).

In Argentina, amaranth cultivation could be an alternative for some 5 million ha north of Patagonia in the semi-arid region of the country (Covas, 1994a). However, this crop is not traditionally grown in the region (Frecentese, 1987) and its cultivation needs to undergo extensive experimentation. Knowing the best sowing date helps to maximise yield: different sowing dates imply that growing crops will face different soil temperatures and moisture levels, have different chances of being affected by a late frost, and that their growth cycles will last different lengths of time. The aim of the present work was to determine the optimal range of sowing dates for three species of amaranth cultivated for grain production in the semi-arid Argentine Pampa.

Materials and Methods

Trials were performed at the *Campo Experimental de la Facultad de Agronomía UNLPam*, Santa Rosa (36º 32.726' S and 64º 18.271' W, altitude 135 m) during the summers of 1999, 2000, 2001 and 2002. The experimental plants were three cultivars of amaranth obtained from the *Estación Experimental Agropecuaria «Ing. Agr. Guillermo Covas» del INTA de Anguil*, *La Pampa,* all of which have outstanding productive qualities and are well adapted to extensive agriculture: *Amaranthus cruentus* L. cv. Don Guien, *Amaranthus hypochondriacus* L. cv. Artaza 412 and *Amaranthus mantegazzianus* Passer. cv. Don Juan (Covas, 1994b). *Amaranthus mantegazzianus* Passer. = *A. edulis* Spegaz. is used for both grain and forage production (Weber and Reider, 1989; Covas, 1992; Troiani *et al*., 1998).

The soil at the experimental site was an entic haplustol with a calcareous layer at a depth of 1.2 m. The characteristics of the top 0.5 m of the soil were: clay 13.2%, silt 17.8%, sand 65.0%; organic matter 1.3%, pH 6.9 (saturated soil paste), and electrical conductivity 0.64 dsm^{-1}. Table 1 shows the total monthly rainfall and mean monthly temperatures for the experimental period: maximum and minimum temperatures and rainfall were recorded daily, as was soil moisture level and soil temperature at a depth of 5 cm (using a fixed geothermometer, Cátedra de Climatología y Fenología Agrícola de la Facultad de Agronomía UNLPam). The annual mean rainfall for the experimental area is 550-600 mm, and there are approximately 120 frost-free days between November and March.

Sowing was performed four times each year at 15 day intervals: S_1 (24-11-1999, 22-11-2000, 26-11-2001), S_2 (14-12-99, 6-12-00, 17-12-01), S_3 (29-12-99, 20-12-00, 28-12-01), and S_4 (11-01-00, 3-01-01, 14-01-02). The sowing dates were not exactly the same each year since a pre-sowing rainfall was awaited. However, they were within the same fortnight.

The soil preparation techniques used were those typical for summer crops: one pass with a disc plough in September to allow water and nitrates to accumulate, and one pass with a chisel harrower two days before sowing to eliminate weeds and to level the soil surface. Sowing

Table 1. Total monthly rainfall and mean monthly air temperatures during the 1999, 2000, 2001 and 2002 seasons (means plus standard deviations)*

Years	November		December		January		February		March	
	Total	**D**	**Total**	**D**	**Total**	**D**	**Total**	**D**	**Total**	**D**
Rainfaill (mm)										
1999/00	155.8	55.2	118.2	–4.3	66.7	–28.4	65.8	–11.4	124.7	31.0
2000/01	32.6	–68.0	23.2	–99.3	68.7	–27.3	157.9	80.7	188.1	94.5
2001/02	62.4	–38.2	49.5	–73.0	176.4	81.0	19.6	–57.6	70.5	–23.1
Air temperature (ºC)										
1999/00	17.8	–1.5	20.1	–2.1	23.2	0.0	21.1	–1.1	18.4	–1.4
2000/01	17.2	–2.1	21.7	–0.5	23.8	0.6	24.1	1.1	19.1	–0.7
2001/02	16.8	–2.5	21.5	–0.7	21.7	–1.5	20.7	–1.5	19.0	–0.8

* Means are for 20 years. D: difference compared to mean. Data collected by the *Cátedra de Climatología y Fenología Agrícola, Facultad de Agronomía UNLPam.*

was performed by hand at a dose of approximately 4.5 kg seed ha^{-1}. These species autoregulate their density through vigorous competition (Covas, 1987). The maximum sowing depth was 1.5 cm. The plots used were 5.50 m long and 2 m wide, with 6 rows 0.40 m apart. The two central rows were destined for manual harvest at maturation. The contiguous rows were used to measure seed production and aerial dry matter content. The two outside rows and the first and last 0.25 m of every row were not used.

The dry matter content was obtained by drying plants in an oven at 60ºC with circulating air until they reached a constant weight.

The harvest index was calculated thus: HI (%) = (economic yield/biological yield) × 100, where the economic yield is the production of seed, and the biological yield is the dry matter content of the same plants. Plant height was also measured, as was the number of days till anthesis (from sowing until 50% of flowers reached anthesis) and the initial and final plant populations (to calculate the percentage loss). The initial population was determined for the plants in the two central rows when it was sure that all had emerged. The final population was determined at harvest by counting the plants in optimal condition for gathering with a mechanical harvester. The percentage of plants lost per plot was determined by taking into account the number of plants that did not reach harvest through stalk breakage or strong initial competition.

The plots were maintained free of weeds by a mixture of mechanical (between plots) and manual (between rows) methods during the juvenile stage of plant growth (until 25 days after emergence). No significant pest infestations or leaf diseases were observed.

The experiment had a randomised block design with four replicates. ANOVA was used to examine the effects of sowing date and years on plant height, biomass production, grain production days to anthesis, final population size, harvest index, and the percentage of plants lost (sowing dates as fixed effects, years as random effects). Data for the final plant populations were transformed into logarithms.

Results and Discussion

Emergence and establishment of plants

The mean monthly soil temperatures for the four sowing dates and the three different years varied between 19.7 and 26.9ºC, much higher than the 15.6ºC reported by Weber (1990) and the 16-18ºC recorded by Henderson *et al*. (2000), at which these authors saw good establishment of *A. cruentus, A. hypochondriacus* and *A. hibridus*.

In November and December of 1999/2000 and 2000/2001, the mean monthly air temperature was 17.2-21.7ºC (Table 1). Good plant establishment was achieved.

The germination and establishment of plants was uniform and very good in the first two years of the experiment. In the third year, however, the November rainfall came during the first days of the month (quite distant from the S_1 sowing time), and in December it came at the end of the month. Therefore, despite total rainfall for this period being greater than that of the previous year (though below the mean; Table 1), water was not provided in an adequate way. This led to the S_1, S_2 and S_3 seeds germinating at the same time. Soil moisture was therefore a limiting factor for germination at the first sowing dates of this year.

The effect of sowing date

The sowing date significantly affected plant height, days to anthesis, the production of biomass and grain, and the percentage of plants lost (Table 2). Plants sown at the last date (S_4) tended to be shorter (Table 3). The shortening of the days over the summer period had an important effect on plant development (Kigel, 1994). This also affected the production of biomass which was significantly lower for plants sown at S_4 compared to those of S_1 and S_2 in the first year, and with those sown at S_2 in the last year.

Grain production was significantly lower among the S_4 plants of 1999/00 and 2001/02. However, no significant differences were seen between sowing dates in 2000/01 with respect to this variable.

Species effect

All three species showed similar grain production values, final population sizes and percentage plant losses over the experimental period. Significant differences were seen, however, in plant height, days to anthesis, and harvest index. Very significant differences were seen with respect to the production of biomass (Table 2). *Amaranthus mantegazzianus* plants were

Table 2. Mean square values for the main effects and interactions of agronomic variables for 2000, 2001 and 2002

Source	df	Plant height (m)	Days to anthesis	Production of biomass (kg ha^{-1})	Grain production (kg ha^{-1})	Final population (plants ha^{-1})	Harvest index (%)	Plant lost (%)
Years (Y)	2	1.98	7,210.15	160,569,000	958,115	8.07	227.45	3518.61
Block(Y)	9	0.02	0.763889	2,237,510	35,502.3	0.10	14.23	206.41
Dates (D)	3	0.25***	1,197.83***	65,316,600***	222,991**	0.20 ns	13.79 ns	1,471.20***
YxD	6	0.04*	1,393.48***	22,469,300***	158,050**	0.96***	44.23*	11,22.44***
BxD (Y)	27	0.02	1.91821	3,046,530	33,999.2	0.11	12.93	97.14
Sp. (S)	2	2.76*	7,876.4*	140,889,000***	3,521,180 ns	0.54 ns	1,629.28*	612.86 ns
YxS	4	0.35***	652.542***	1,833,890 ns	688,624***	0.36***	106.2***	1,204.99***
DxS	6	0.03 ns	78.6736***	3,660,020 ns	148,157**	0.31***	18.18	165.89 ns
YxDxS	12	0.02 ns	81.1944***	2,868,490 ns	86,530.8*	0.19**	25.96***	375.76*
Error	72	0.01	1.90741	2,980,010	41,469.5	0.06	7.39	155.85
Total	143							

df: degrees of freedom. Sp: species. ns: not significant. *,**,***: indicates a significant difference (p< 0.05, 0.01 and 0.001, respectively).

taller than those of the other two species; those of *A. hypochondriacus* were the shortest (Table 4). *Amaranthus mantegazzianus* also branched more and produced significantly more biomass than the other species, the order being *A. mantegazzianus*, *A. cruentus* and *A. hypochondriacus* (Table 4). The interaction *sowing date x species* was not significant with respect to these characteristics (Table 2).

The harvest index of *A. mantegazzianus* was significantly lower than those of the other two species in all three years (Table 4). The interaction *sowing date x species* had a significant effect on this variable; the interactions *year x species* and *year x species x sowing date* had very significant effects (Table 2).

Significantly fewer days were required to reach anthesis by both *A. cruentus* and *A. hypochondriacus* compared to *A. mantegazzianus* (Table 4).

The interaction of sowing date and year

Depending on the year, sowing date led to different growth conditions for the plants. The responses of the different agronomic variables varied from year to year

Table 3. Influence of sowing date on agronomic variables (2000, 2001 and 2002)

Year	Sowing date	Plant height (cm)	Production of biomass (kg ha^{-1})	Grain production (kg ha^{-1})	Final population (plants ha^{-1})	Harvest index (%)	Days to anthesis	Plant lost (%)
1999/00	S_1	117ab	8,750a	1.033a	719,375(13.3378)a	16.10a	78.33a	49.17a
	S_2	127a	8,175a	947ab	629,167(13.3333)a	14.97a	72.00b	33.42b
	S_3	114ab	6,902ab	1.034a	784,375(13.4591)ab	18.86ab	69.33c	46.97a
	S_4	102b	5,620b	759b	771,104(13.8470)b	20.05b	70.00c	50.54a
2000/01	S_1	121ab	11,523a	932a	498,667(13.0042)ab	13.07a	86.00a	39.17a
	S_2	123ab	7,192b	768a	595,583(13.3066)a	14.68a	95.67b	66.83b
	S_3	124a	6,352b	728a	269,083(12.3221)c	12.56a	95.67b	67.50b
	S_4	117b	6,543b	833a	319,917(12.8159)bc	12.19a	95.67b	66.83b
2001/02	S_1	158a	10,680ab	1.071ab	286,750(12.6248)a	14.11a	95.33a	43.04a
	S_2	160a	11,744a	1.261a	332,000(12.8940)a	15.98a	72.67b	39.72a
	S_3	162a	11,441ab	1.138ab	287,750(12.6275)a	16.36a	63.67c	49.06a
	S_4	134b	9,196b	920b	365,167(12.6574)a	13.85a	55.67d	43.08a
MSD (0.05)		0.19	2,484	262	0.4088	5.12	1.971	14

MSD: minimum significant difference (Tukey test; p < 0.05). For each year, numbers followed by the same letter are not significantly different. The means of the final plant populations were obtained after logarithmic transformation.

Table 4. Influence of species on agronomic variables (2000, 2001 and 2002)

Year	Species	Plant height (cm)	Production of biomass (kg ha^{-1})	Grain production (kg ha^{-1})	Final population (plants ha^{-1})	Harvest index (%)	Days to anthesis	Plant lost (%)
1999/00	*A. cru.*	118	7,253	1,051	552,469 (13.1963)	20.26	69.67	52.03
	A. hyp.	104	5,936	948	862,188 (13.6784)	20.01	57.79	49.83
	A. man.	123	8,896	831	763,359 (13.6082)	12.21	89.70	49.75
2000/01	*A. cru.*	116	7,978	777	439,313 (12.9103)	11.44	89.15	70.00
	A. hyp.	87	6,291	1,133	437,875 (12.8771)	31.15	81.02	64.00
	A. man.	164	9,438	537	386,250 (12.7992)	6.86	90.58	46.25
2001/02	*A. cru.*	155	10,650	1,143	278,250 (12.6002)	15.76	62.50	43.95
	A. hyp.	129	8,738	1,525	351,313 (12.7745)	21.09	71.00	38.91
	A. man.	176	12,907	625	324,188 (12.7281)	8.37	82.00	48.32
SMD (0.05)*		0.12	ns	231	ns	3.08	1.57	14.17
Means	*A. cru.*	130ab	8,627a	990	423,344 (12.8501)	15.82a	73.94a	55.32
	A. hyp.	107b	6,988b	1,202	550,125 (13.0578)	20.75a	70.10a	50.91
	A. man.	154a	10,414c	664	491,266 (12.9930)	9.14b	93.96b	48.11
SMDby (0.05)**		0.29	663	ns	ns	5.04	12.49	ns

A. cru.: Amaranthus cruentus. A. hyp.: A. hypochondriacus. A. man.: A. mantegazzianus. SMD*: minimum significant difference (Tukey test; $p < 0.05$) for comparing species within years. SMDby**: minimum significant difference (Tukey test; $p < 0.05$) for comparing means for species between years. Numbers followed by the same letter are not significantly different. ns: not significant.

depending on temperature and rainfall (Tables 1 and 2).

The growth of amaranth plants is influenced by the distribution of rainfall not just during initial development but also before emergence (Henderson *et al.,* 1998). In 2000/01 there was a large reduction in the number of plants that reached harvest; losses were 66.8, 67.5 and 66.8% for S_2 ,S_3 and S_4 respectively (Table 3), possibly caused by strong competition for soil moisture. There was a notable water deficit during the initial development of the plants during this season (Table 1), which was more important with respect to sowing date than species.

Grain production was affected differently by sowing date each year. The greatest production was achieved by S_1 and S_3 plants in 1999/00, by S_1 plants in 2000/01, and by S_2 and S_3 plants in 2001/02 (Table 2). Grain production in 2000/01 was relatively low, as was production by S_2 and S_4 plants in 1999/00 and S_4 plants in 2002. Grain production for the last sowing date (S_4) fell in 1999/00 and 2001/02 due to the reduced time available for the plants to finish their phenological cycle, and because of the low levels of light and low temperatures during grain filling and seed maturation. The fall in production by the S_2 plants of 1999/00 may have been caused by the water deficit that occurred during anthesis. The low grain production of the 2000/01 season for all sowing dates may have been caused by water stress during November and December 2000 and January 2001; with respect to the mean monthly rainfall, values were down by 68, 99.3 and 27.3 mm respectively (Table 1). In addition, December and January had high temperatures (Table 1). For the same season, a marked fall in biomass production was seen for the S_2, S_3 and S_4 plants. A drop in the number of flowers was also noticed (data not shown). This caused the S_3 and S_4 plants to register the lowest harvest indices (12.56% and 12.19%) of the entire experimental period (although the Tukey showed there to be no significant differences) (Table 3).

For all sowing dates and all years, the final population sizes achieved were greater than those mentioned by Henderson *et al*. (1998 and 2000); using mechanical sowing these authors obtained 173,000 and 272,000 plants ha^{-1} with *A. cruentus* and *A. hypochondriacus x A. hybridus* respectively. In the present work, S_1 and S_3 of 2001/02 and S_3 of 2000/01 produced the smallest final population sizes (Table 3).

Manual sowing with a large number of seeds initially leads to too high a plant density for areas where there is competition for water during the vegetative period of growth (Weber, 1990). In general, high sowing densities promote the development of plants with reduced stem diameters, the formation of secondary inflorescences and a lack of uniformity in height. But in amaranth this facilitates stalk breakage and the loss of plants through competition (Fitter *et al*., 1996; Henderson *et al*., 2000), leading to what Covas (1987) describes as autoregulation of sowing density.

Table 3 shows that in the 2001/02 season, the number of plants obtained per hectare was similar for all sowing times. The S_1 and S_3 sowings led to the lowest density figures, although grain production was still over 1000 kg ha^{-1}. This might be due to the 'elasticity' of amaranth, which compensates for a drop in density by an increase in the amount of grain produced by each plant (Hauptli, 1977). A reduction to below 171,000 plants ha^{-1} is not beneficial, however, since the plants can then develop thick stems which might hinder mechanical harvesting (Henderson *et al*., 1998).

In the third and fourth seasons, the number of days to anthesis fell as sowing time was delayed. A notable effect was seen in 2001/02, in which the difference in time to anthesis between S_1 and S_4 was 39 days; in 1999/00 it was only 8 days. In agreement with Peiretti and Gesumaria (1998), *A. mantegazzianus* showed the greatest reduction in the number of days necessary to reach anthesis as sowing time was delayed. The same effect was reported by Henderson *et al*. (1998) for *A. cruentus* and *A. hypochondriacus x A. hybridus* in every year of their trial. This is common in plants that depend on high light intensities and temperatures for their development (Gardner *et al.,* 1985; cited by Henderson *et al*., 1998).

In the 2000/01 season, however, the number of days needed to reach anthesis changed, possibly due to the distribution and scarcity of rainfall being more important than the effect of temperature (temperatures were similar in each month in all three seasons).

The S_4 plants were the shortest every season (Table 3). This was due to the marked effect of shortening day length towards the end of summer since, after January (the last month of sowing), rainfall was both above or below the mean depending on the year.

The interaction of year and species

The interaction *year x species* had a significant effect on all the variables analysed, except for the production of biomass (Table 2). If the means for the three years together are compared, significant differences are seen between the three species, with *A. mantegazzianus* producing the most biomass (Table 4). This species, however, showed a lower grain production and harvest index than the other two; this occurred every year and was a consequence of its height (Table 4) and the number of shoots sprouting from axillary buds. Grain production by the three species did not differ significantly in the first year of the study (Table 4) when rainfall was greater and close to the mean during the first days of development (Table 1). *Amaranthus hypochondriacus* produced significantly more grain than the other species in 2000/01 and 2001/02, when rainfall deficiency was at its worst compared to the mean for the initial months of growth (Table 1); this species recovered better than the others with the rain that fell during the latter stages of development. This may have been helped by its height (shorter than *A. cruentus* and significantly shorter than *A. mantegazzianus*; Table 4).

It would therefore seem recommendable to sow amaranth after the 20th of November and during December to ensure maximum plant development and the maturation of all the grain produced. This range will allow growers to wait for adequate pre-sowing rainfall.

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References

AGPG (Amaranth Grain Production Guide), 1990. Rodale Research Center and American Amaranth Institute (L. E. Webwer, ed), Kutztown, USA. 36 pp.

BECERRA R., 2000. El amaranto; nuevas tecnologías para un antiguo cultivo. Published in internet, available in http://www.conabio.gob.mx/institucion/conabio_espanol/doctos/amaranto.html. [18 March 2003].

BERTI M., SERRI H., WILCKENS R., FIGUEROA I.,1996. Field evaluation of grain amaranth in Chile. Progress in new crops (J. Janick, ed). ASHS Press, Alexandria, VA., USA. pp. 223-226.

COVAS G., 1987. Fitomejoramiento de los amarantos. Proc. of Primeras Jornadas Nacionales sobre Amarantos. UNLPam. Fac. de Agron. La Pampa, Argentina, July 26-27. pp. 50-62.

COVAS G., 1992. Clave para la identificación de los amarantos cultivados y especies silvestres utilizables como hortalizas o forrajeras. Amarantos, novedades e informaciones No. 12. Fac de Agronomía, INTA Anguil. Santa Rosa, La Pampa, Argentina. pp. 9-12.

COVAS G., 1994a. Perspectiva del cultivo de los amarantos en la República Argentina. EEA, INTA Anguil. Santa Rosa, La Pampa, Argentina, Publicación Miscelánea. No. 13, 10 pp.

COVAS G., 1994b. Fitomejoramiento de amarantos (*Amaranthus ssp)* para la región pampeana semiárida de la República Argentina. Mendeliana (suppl) 11(1), 68-70.

FITTER S.A., JOHNSON B.L., SCHNEITER A.A., 1996. Grain amaranth harvest timeliness in eastern North Dakota. In: Progress in new crops (J. Janick, ed.). ASHS Press, Alexandria, VA, USA, pp. 220-223.

FRECENTESE M.A., 1987. Técnicas culturales de los amarantos. Proc. of I Jornadas Nacionales sobre Amarantos. Santa Rosa. La Pampa. Argentina. July 26-27, pp. 56-62.

GRANJERO COLÍN A.E., TABOADA SALGADO M., REYNA TRUJILLO T., 1994. El género *Amaranthus* en el estado de Morelos. Universidad Autónoma del Estado de Morelos. Centro de Investigaciones Biológicas, Mexico. 30 pp.

GUILLEN PORTAL F.R., BALTENSPERGER D.D., NELSON L.A., 2003. Plant population influence on yield and agronomic traits in «plainsman» grain amaranth. In: Perspectives on new crops and new uses (J. Janick, ed), ASHS Press, Alexandria, VA, USA, pp. 190-193.

HAUPTLI H., 1977. Agronomic potential and breeding strategy for grain amaranths. Proc. I Amaranth Seminar. Rodale Press, Inc. Emmaus, PA, USA, July 29, pp. 71-81.

HENDERSON T.L., JOHNSON B.L., SCHNEITER A.A., 1998. Grain amaranth seeding dates in the northern great plains. Agron J 90, 339-344.

HENDERSON T.L., JOHNSON B.L., SCHNEITER A.A., 2000. Row spacing, plant population, and cultivar effects on grain amaranth in the northern great plains. Agron J 92, 329-335.

KIGEL J., 1994. Development and ecophysiology of amaranth. In: Amaranth biology, chemistry and technology (O. Paredez López, ed). Chapter 4. CRC Press Inc., 223 pp.

KULAKOW P.A., HAUPTLI H., 1994. Genetic characterization of grain amaranth. In: Amaranth Biology, Chemistry and Technology (O. Paredez López, ed). Chapter 2. CRC Press Inc., 223 pp.

PEIRETTI E.G., GESUMARIA J.J., 1998. Influencia de la distancia entre líneas sobre el crecimiento y rendimiento de amaranto granífero (*Amaranthus spp*). Invest Agr: Prod Prot Veg 13(1-2), 139-151.

PUTNAM D.H., 1990. Agronomic practices for amaranth. Proc. of the IV National Amaranth Symposium. Minneapolis, MN, USA, pp. 151-162.

PUTNAM D.H., OPLINGER E.S., DOLL J.D.A., SCHULTE E.M., 2003. Amaranth. Alternative field crops manual. Center for Alternative Plant Animal Product, Minnesota Ext. Serv., Univ. Minnesota, 55 pp.

TROIANI R.M. DE, SÁNCHEZ T., REINAUDI N., 1998. Una amarantácea con posibilidades de consumo y cultivo granífero y hortícola. Rev. Fac. Agron. (LUZ) Universidad del Zulia, Venezuela, 15, 30-37.

WEBER L.E., 1990. Amaranth grain production guide. Rodale Press, Inc. Emmaus, USA, 50 pp.

WEBER L.E., REIDER C., 1989. 1988 Rodale amaranth germoplasm catalog. Rodale Research Center, Kutztown, USA, 89 pp.

WILLIAMS J.T., BRENNER D., 1995. Grain amaranth (*Amaranthus* species). In: Cereals and pseudocereals (J. T. Williams, ed.) Chapman and Hall, London, pp. 129-186.