ETHNOBOTANY OF QUINTONIL: KNOWLEDGE, USE AND MANAGEMENT OF EDIBLE GREENS *AMARANTHUS* SPP. (AMARANTHACEAE) IN THE SIERRA NORTE DE PUEBLA, MÉXICO[1]

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Mapes, Cristina, Francisco Basurto *and* **Robert Bye** *(Jardın Botánıco, Instituto de Biología, Universıdad Nacional Autónoma de Méxıco, Apartado Postal 70-614, México D.F., 04510, México)* ETHNOBOTANY OF QUINTONIL . KNOWLEDGE, USE AND MANAGEMENT OF EDIBLE GREENS *AMARANTHUS* SPP (AMARANTHACEAE) IN THE SIERRA NORTE DE PUEBLA, MÉXICO. *Economic Botany 51(3):293–306, 1997. In addition to the seeds consumed as a pseudocereal, amaranths provide ımportant edible greens. In the Sierra Norte de Puebla, Mexıco, the management and utılızation of amaranths occur wıthın a wide variety of environmental, biological and cultural contexts. This paper presents both the results of ethnobotanıcal exploration ın thıs region and the comparıson of different specıes and races of amaranths used as greens that were grown in common experımental garden plots ın Chalco, Mexıco. Ethnobotanical exploration, cultural practıces and growth analysıs suggests that these plants have been selected for theır use as leafy vegetables. The experimental data support the dıvergence of amaranths used for greens from those used principally for edıble seed*

Etnobotanica del Quıntonıl . Conocımıento, Uso y Manejo de *Amaranthus* spp. Como Verdura en la Sierra Norte de Puebla, Mexıco. *Los amarantos además de proporcıonar semillas para su uso como pseudocereal producen hojas comestibles. En la regıón de la Sierra Norte de Puebla, la utılızacıón y el manejo de los amarantos tıene lugar dentro de una enorme varıedad de condicıones ambıentales, biológicas y culturales En este trabajo se presentan los resultados obtenidos a partır de la exploracıón etnobotánica realizada en la Sıerra Norte de Puebla asi como los datos obtenıdos a partir de un estudio de análisıs de crecimiento llevadp a cabo en Chalco. Estado de Méxıco, en donde se comparan diferentes especıes y razas de amaranto que se usan a manera de verdura La exploración etnobotánica, las práctıcas culturales y el estudıo de análisıs de crecımıento sugieren que estas plantas han sıdo seleccionadas para ser usadas como verdura y que difieren de las que se usan como grano*

Key Words: *Amaranthus* spp , ethnobotany; edıble greens; growth analysis, Mexıco

The seeds of amaranth have been amply utilized as a pseudocereal (Wıllıams and Brenner 1995). However, very little attention has been focused on its use as an edible green. The leaves of various amaranth species have been eaten as leaf vegetables since prehispanic times in Mexico (Sahagún 1970), and they continue to be an important food resource for many peasant communities. In the Sierra Norte de Puebla, amaranths are used as food, forage and medicine (Martínez et al. 1995)

Natural resources ın the Sierra Norte de Puebla are managed in diverse physical, biological and cultural environments and tend to intensify land use practices. Such resource management is conspicuous both in the native crop associations, such as maize, common beans, squashes, scarlet runner beans, chile pepper, husk tomato and tomato, and in the indigenous agroecosystems with useful weeds (i.e., agrestals), including amaranth. The "quintoniles" (a term applied collectively to *Amaranthus* spp. in the area) are widely consumed and are sold in the regional markets. They are greatly esteemed by both the rural and urban people.

The study area in the Sierra Norte de Puebla is located between latitudes 20°5′ and 19°48′N and longitudes 97°57′ and 97°21′W. According to Inzunza (1988), the northern and eastern sec-

[1] Received 13 August 1996; accepted 22 April 1997.

Economic Botany 51(3) pp 293–306 1997

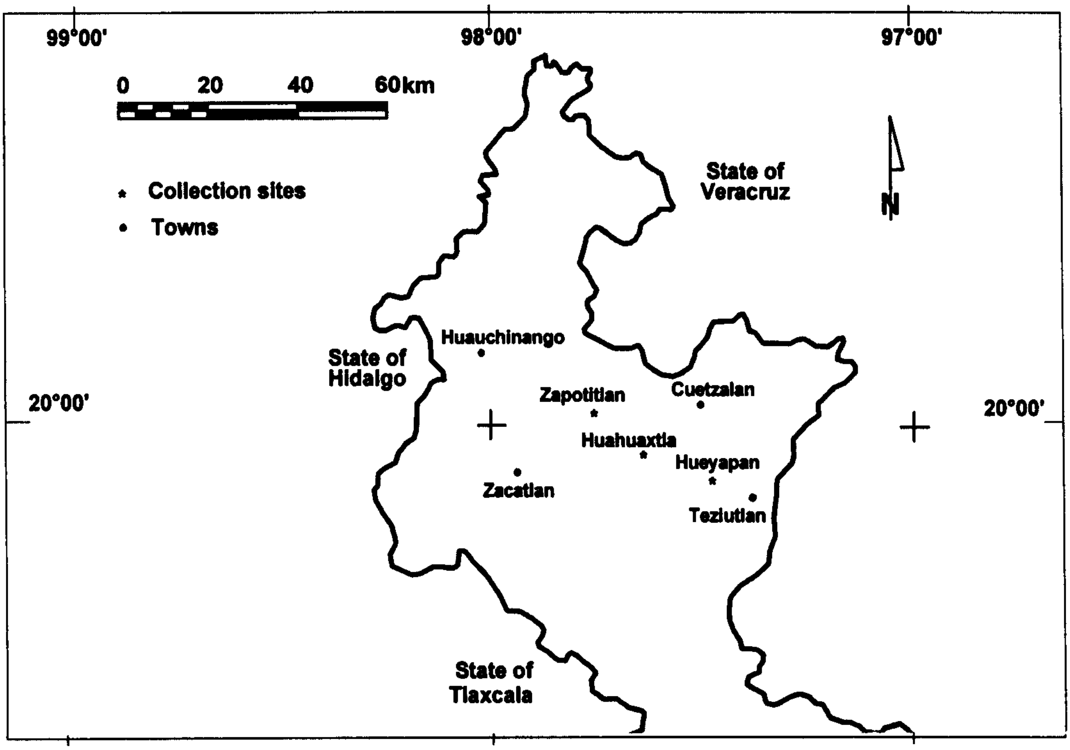

Fig. 1. The study area.

tions of the Sierra Norte de Puebla border the State of Veracruz, the southern region is limited by the Llanos de San Juan, and the western area is adjacent to the State of Tlaxcala (Fig. 1). Physiographically the Sierra Norte de Puebla is situated in the Sierra Madre Oriental mountain range and is characterized by intense folding and faulting which results in the rugged landscape, with variation in elevation from 2400 m above sea level (masl) to 200 masl, with a general slope from the north to the south direction. The bedrock of the region is sedimentary and igneous in origin. Mean annual rain precipitation ranges from a minimum of 800 mm to a maximum of 4000 mm. The mean annual temperature varies from 16°C to 22°C. As a result, one climatic gradient of temperate humid to sub humid climates extends towards the Mexican Plateau and another of subwarm to warm humid climates towards the lower Gulf of Mexico coastal plain. These two major climatic zones are recognized by local people and named accordingly as tierra fría and tierra caliente. A specific agroecosystem of the Sierra Norte de Puebla may be restricted to one of two of these climatic zones or may be present in both. Both management practices and gathering seasons differ depending upon the climatic zones.

In order to compare amaranths from different areas of the Sierra Norte de Puebla, a common garden was established in order to cultivate various species and races at Rancho San Francisco, Chalco, in the State of Mexico. It is located in southern valley of Mexico between latitudes 19°14′N and longitudes 97°57′W at an elevation of 2250 masl and has an Entisol soil (Reyna and Carmona 1991). The climate is classified as $C(w_1)b$ (Reyna 1989, based on the Köppen system modified by García 1988) which corresponds to temperate subhumid with summer rains. Annual average temperature is 15°C. Summers are cool, with highest temperatures (never above 22°C) occurring in May (Fig. 2). Ninety percent of the rainfall, 620 mm per year, occurs during the summer (June–September) with July having the greatest monthly precipitation. Frosts may occur from December until February with a monthly average of 17, 10 and 13 days, respectively. The daily average minimum temperature for December and January is 3°C while in February it is 5°C. Severe frosts may occur be-

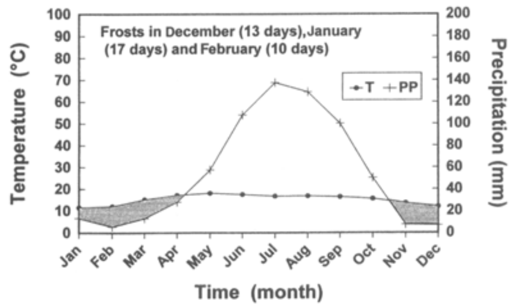

Fig. 2. Climogram of Chalco region, State of Mexico.

fore December and may damage unharvested crops.

The goals of our research has been 1. to gain knowledge about the native germplasm of amaranth in the Sierra Norte of Puebla; 2. to define the types of agroecosystems in which amaranth is grown as well as he different forms of the plant's management; 3. to measure growth and resource allocation patterns of different species and races of amaranth used for edible greens in the Sierra Norte de Puebla by means of experimental cultivation in a common garden at Chalco, Mexico.

Materials and Methods

Ethnobotany

Ethnobotanical research began in 1990 with field exploration in the study area and interviews in Spanish with 100 wives of Nahuat subsistence farmers. The following data were gathered: location of the agroecosystems in which amaranths are grown; botanical and ethno–taxonomic identification of the various species and races of amaranth present in cultivated fields; observation of the preparation methods for cooking; preference for different amaranth greens; and management practices associated with amaranths. Local markets were visited and 150 market vendors were interviewed to obtain information on: sale of amaranths; preparation methods for consumption; seasonality; provenance; and market value.

Cultivation in Experimental Plots

After the ethnobotanical exploration in the Sierra Norte de Puebla was completed, cultivation of plants from seeds obtained in the Sierra Norte de Puebla in experimental plots was started. The area of cultivation measured 4140.48 m^2 and was divided in 32 subplots, each with 100 m^2. Spacing between subplots was 1.12 m. The different species and races of grain, vegetable and weedy amaranths were assigned randomly to their respective subplots, one per subplot to produce a non-replicated design. The results from field sampling presented in this paper represent one race of *A. hypochondriacus* L. (Mixteco), two races of *A. cruentus* L. (Mexicano and Africano) and *A. hybridus* L. which are known to be used as greens.

Four months prior to planting, the area was fertilized with composted sheep manure. Two weeks before sowing, the soil was prepared with a tractor and a disk harrow. Plowing was done once and the harrow was passed twice.

On May 15, 1990, seeds were sown directly, 10 seeds per hole 2 cm deep, and afterwards watered manually. The strongest seedling per hole was allowed to grow; the others were removed. A density of one plant per 0.80 m^2 was maintained in order to permit the expression of genotype differences and biological potential of individual plants.

Manual weeding and thinning were performed 30 days after germination. Dead seedlings were replaced with transplanted seedlings of the respective species or race. During the experiment, subsequent weeding was repeated 10 times, soil was hilled around each plant five times, and, to control intense attack by insects in all four subplots, the insecticide (Foley) was applied 15 times. Cultivation initiated with sowing on May 15, 1990 and ended on November 10 when a heavy frost killed the plants.

Growth Evaluation

Plant performance in experimental plots was evaluated through measurements of height, leaf area, total plant biomass and biomass allocation to roots, stems, leaves and inflorescences. Measurements of these variables were made as described below.

Nondestructive Sampling

Ten plants from each population were randomly selected and labeled in their corresponding subplot. The absolute height for each plant was measured from the cotyledon scar to the apex at intervals of approximately 10 days starting from the day of emergence.

TABLE 1. DATE AND TIME OF HARVESTS IN EXPERIMENTAL SUBPLOTS OF RACES AND *A. HYBRIDUS*.

Harvest	Date	Time (days)
I	June 18, 1990	21
II	July 12, 1990	45
III	August 14, 1990	78
IV	September 25, 1990	120
V	October 24, 1990	149

Destructive Sampling

For each one of the four populations, six plants were randomly selected and harvested completely at approximately 30 day intervals (Table 1). Uprooted plants were placed in plastic bags and were transported to the laboratory (at the Jardín Botánico, UNAM) where they were separated into roots, stems, leaves and inflorescences. Leaf surface was measured using a Delta TRS 232 C foliar area apparatus at the Instituto de Ecología, UNAM. Total leaf area per plant was measured before drying. Plant material (roots, stems, leaves, and inflorescences) was dried in an oven at 60–65°C for 64 hrs. Dry weight of each plant part was obtained. Total biomass was obtained for each plant by adding the weight for four components. Biomass allocation for each part was calculated by dividing biomass of each plant part, roots (R), stems (S), leaves (L) and inflorescences (I), by the total biomass.

STATISTICAL ANALYSIS

To evaluate the differences among the amaranths grown, covariance analyses were performed on the observed values of plant height, total standing biomass and leaf area. In all the cases, the independent variables were the races or the species (statistical factor) and time (covariant of factor). Values of height and biomass were log transformed using the following mathematical formula: $y = \text{Log}(x + 1)$. Percentages of biomass were transformed with the following algorithm: $y = \arcsin(x/100)^{0.5}$, where y is the transformed value and x is the biomass percentage or proportion for each part (i.e., root, stems, leaves and inflorescence).

RESULTS

TAXA

The species and races of amaranth that grow in the Sierra Norte de Puebla are: *Amaranthus hybridus* ("quintonil"), *A. spinosus* ("quintonil de burro"; "quintonil de pájaro"), *A. hypochondriacus* race Mixteco ("chichiquilit"), *A. cruentus* L. races Mexicano ("iztaquilit") and Africano ("chichiquilit") (Table 2). The nomenclature follows that recognized by Espitia (1994) although the names of the races are not validly published. They are all known locally as "quintoniles" and considered edible, although people differ in their preference depending on each amaranth's flavor, color and palatability. The type of plant manipulation by humans of the races Mixteco, Mexicano and Africano is considered as that of enhancement or encouragement. This interaction consists of different activities that increase the density of populations of useful plants and includes the sowing of seeds or the intentional propagation of vegetative structures (Bye 1993; Casas et al. 1996; Colunga et al. 1986). When a new parcel is opened to cultivation, in Sierra Norte de Puebla amaranth seeds are broadcast after plowing so the plants develop together with maize. Amaranth plants in that parcel during subsequent agricultural cycles are de-

TABLE 2. SPECIES AND RACES OF AMARANTH GROWING IN THE SIERRA NORTE OF PUEBLA.

Species and races	Collection number	Collection site	Altitude	Management	Agroecosystem
Amaranthus cruentus Africano	Mapes & Basurto 769	Zapotitlán de Méndez Mpio. Zapotitlán, Pue.	750 masl	enhanced	home garden
Amaranthus hypochondriacus Mixteco	Mapes & Basurto 772	Huahuaxtla Mpio. Xochitlán, Pue	1400 masl	enhanced	milpa
Amaranthus hybridus	Mapes & Basurto 782	Maquina Vieja, Pue. Mpio Tlachichuca, Pue	2900 masl	incipient	home garden
Amaranthus cruentus Mexicano	Mapes & Basurto 791	Huahuaxtla Mpio Xochitlán, Pue.	1400 masl	enhanced	milpa

TABLE 3. AGROECOSYSTEMS IN WHICH AMARANTHS ARE GATHERED IN THE STUDY AREA.

Species and races	Common name	Habitat					
		"Milpa"	"Chilar"	"Frijolar"	Home garden	Orchard	Ruderal
Amaranthus hybridus	"quintonil" "quiltonil"				●		
A. spinosus	"quiltonil de burro" "quiltonil de pájaro"				●		●
A. hypochondriacus Mixteco	"quintonil rojo" "chichilquilit"	●	●	●		●	
A. cruentus Mexicano	"quintonil blanco" "iztaquilit"	●	●	●		●	
A. cruentus Africano	"chichilquilit"				●		

rived from the seeds that fell from mother plants of the previous year.

AGROECOSYSTEMS

The agroecosystems in which amaranths are gathered in the study area include: milpa (mixed crop fields where maize is predominantly grown), chilar (fields where chili pepper is grown), frijolar (fields where bush beans are grown), orchards, and huertos familiares (home gardens) (Table 3). In each agroecosystem, the seasonality of amaranth production varies with the agricultural calendar, the activities of which are determined by environmental and cultural factors. In the following sections two subregions and the associated agroecosystems in which amaranth is produced are described.

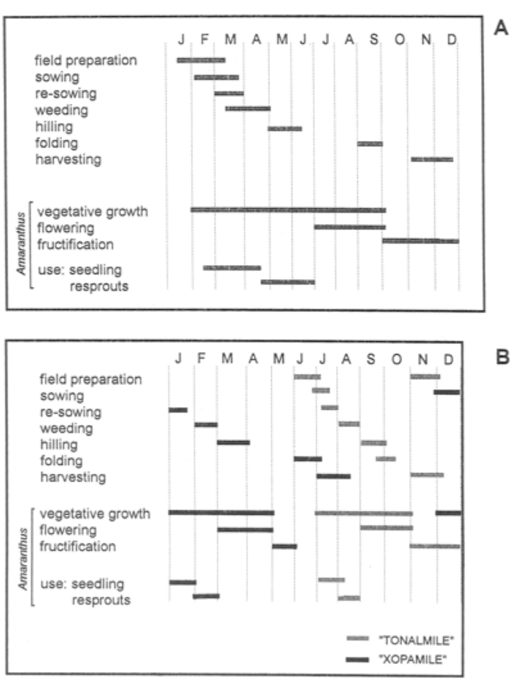

Fig. 3. Agricultural calendars for maize cultivation of the Sierra Norte de Puebla: A) tierra caliente subregion and B) tierra fría subregion.

The milpas are characterized by the cultivation of basic crops of which maize dominates. The milpas are found in both tierra fría and tierra caliente subregions. The main cultivated races of maize are Tuxpeño and Tuxpeño introgressed with Cónico or with Arrocillo (Fernández Brondo 1977). Other races said to be present in the region are Mushito and Cacahuacintle (Inzunza 1988). In the milpas maize is intercropped with numerous other annual species such as common bean (*Phaseolus vulgaris* L.), runner bean (*P. coccineus* L.), broad bean (*Vicia faba* L.), potato (*Solanum tuberosum* L.), pea (*Pisum sativum* L.), squash (*Cucurbita pepo* L.), chilacayote (*C. ficifolia* L.), peanut (*Arachis hypogaea* L.) and sesame (*Sesamum indicum* L.). Fruit trees such as prune (*Prunus domestica* L.), peach [*P. persica* (L.) Batsch], pear (*Pyrus communis* L.), apple (*Malus sylvestris* Mill.), and avocado (*Persea americana* Mill.) may be associated in the field. Ornamental plants such as hydrangea [*Hydrangea macrophylla* (Thunb.) Ser.], white lily (*Lilium longiflorum* Thunb.), red lily [*Hippeastrum puniceum* (Lam.) Voss], dahlia (*Dahlia* spp.), camelia (*Camellia japonica* L.) and marigold (*Tagetes erecta* L.) may be planted along the margins. The agricultural calendars for maize cropping in tierra fría and tierra caliente are described in Fig. 3a and 3b, respectively.

The examples for tierra fría are from Huahuaxtla, where maize is associated with herbaceous annual plants, and from Hueyapan, where maize is intercropped with fruit trees, such as prune, peach, apple, pear, avocado and Mexican cherry [*Prunus serotina* Ehrh. subsp. *capuli* (Cav.) McVaugh]. The amaranths grown in the milpas of tierra fría are *A. hypochondriacus* Mixteco and *A. cruentus* Mexicano.

In Huahuaxtla the cropping cycle of previously cultivated milpa begins in January when fields are weeded using a weeding hook and a machete and the soil is turned with a hoe or a wooden plow drawn by oxen. During February and March maize kernels are sown with the aid of a planting stick, and may resowed in March. In March or April weeding is done with a hoe; and each maize plant is fertilized with ammonium sulfate and calcium super phosphate (1:1, by volume). Individual plants are hilled during May and June with a hoe. Maize canes with mature ears are folded down during September in order to aid the drying of maize ears and to prevent water accumulation inside the husks (which could cause the grains to rot on the cob). The harvest of maize ears occurs in November and continues until December (Figure 3a).

When a new milpa parcel is opened to cultivation, amaranth seeds are broadcast after plowing so that the plants develop together with maize. From February and until the first weeding in March or April, amaranth seedlings are gathered for food. After hilling, only the young amaranth shoots and resprouts are gathered until the onset of flowering, after which leaf consumption ceases. Pruning of amaranth plants by means of cutting the resprouts and young lateral shoots is said to increase the production of tender leaf resprouts and to delay flowering. In subsequent agricultural cycles, without human intervention, the amaranth plants emerge from seeds dropped by plants of the previous year Chichiquilit (*A. hypochondriacus* Mixteco) has developed an architecture and life cycle to those of maize races with which it is cultivated, especially Tuxpeño maize. In this case chichiquilit is a tall and erect herb (up to 3 m) and grows synchronously with maize plants. The life cycle of amaranth plants in milpas is quite long (up to 10 months). The annual herb has an intense red color, produces much foliage and resprouts readily along the stem. The tender dark leaves are boiled and the resulting red-tinged, tasty watery stock is preferred by consumers. The flavor of the leaves is excellent. The mature plant has a terminal condensed inflorescence above the open lateral inflorescence branches and black seeds. As with maize, the plants are tended individually. All of these characteristics make this amaranth ideal for intercropping.

In Hueyapan the cropping calendar and the succession of field chores are similar to those in Huahuaxtla, except that in Hueyapan plowing is done with a metal plow pulled by horses or mules, which are faster than oxen. Other differences in the field from those in Huahuaxtla are that organic fertilizer is usually applied when seeds are planted and that fruit trees are much more abundant in the cultivated fields, either sparsely dispersed throughout or aligned in widely separated rows. Amaranths are consumed as seedlings from February to April, and sprouts are cut from the tall herbs during May through June. The harvest is terminated once plants begin flower. The amaranths commonly grown are the same as those in Huahuaxtla.

In tierra caliente two maize cycles occur: "tonalmile" and "xopamile." The former takes place from November to July or August, the latter from July to November. Hand tools such as hoe, machete, weeding hooks and planting sticks are used, as are wooden plows pulled by oxen. Weeding is carried out 30 days after sowing, hilling—60 days after sowing. Amaranth is gathered during the two maize cycles: December–January and July–August (Figure 3b). The amaranths commonly grown are *A. cruentus* Mexicano and *A. hypochondriacus* Mixteco.

Frijolares, are left fallow for two to three years, then slashed and burned. Without further soil perturbation, bean seeds are sown using a planting stick. Both green pods and mature seeds are harvested (Fig. 4a and 4b).

In tierra fría, frijolares are cultivated in two cycles: January–June and July–October (Figure 4a). In tierra caliente, frijolares are sown in May and harvested from August to November (Figure 4b). In these fields, amaranth seedlings are gathered until the first weeding is done. Between the first and second weeding, amaranth resprouts are utilized from the spared plants. Overall, frijolares produce amaranth edible greens from May to April in tierra fría and from July to August in tierra caliente. Amaranths grown in milpas are the same as those grown in frijolares.

Chili peppers (*Capsicum annuum*) are grown mainly in tierra caliente. This intercropping system contains up to ten species of useful plants

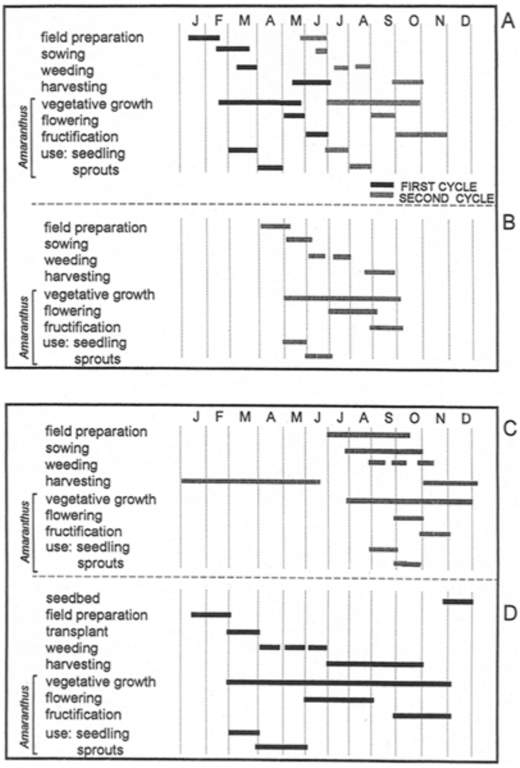

Fig. 4. Agricultural calendars for subregions A) common bean in tierra fría; B) common bean in tierra caliente; C) chili pepper in tierra caliente D) bed sown chili.

and is found in fields that have been fallow for at least three years.

Chilares are prepared by clearing the vegetation, using machetes and hooks, followed by burning. The soil is not plowed. The seeds of cultivated plants are sown in holes made with a planting stick (Figure 4c). At the upper altitudinal range of its distribution, chili peppers are first sown in beds and later transplanted in the fields (Fig. 4d). In this agroecosystem, seeds of *A. hypochondriacus* Mixteco and of *A. cruentus* Mexicano are broadcast in the plots when the chili pepper seeds are sown. Amaranth seedlings can be gathered within one month. The season for amaranth gathering is from September to March and, as in the case of the milpas, first the seedlings are consumed and later the resprouts cut from large plants.

On the average the chilares can produce 250 amaranth seedlings per m^2. Two experienced people can gather up to 10 kg of amaranth greens in about three hours which includs the time it took to walk (about one hour) to the plots. A part of the gathering is consumed at home and the remainder is sold in markets.

Cultivation of greens, including amaranths, in small plots of the orchards is common in both subregions. In the tierra fría associations with bush bean (*Phaseolus vulgaris*) and husk tomato (*Physalis* spp.), radish (*Raphanus sativus* L.), chard (*Beta vulgaris* L. var. *cicla* L.), coriander (*Coriandrum sativum* L.), and cabbage (*Brassica oleracea* L.) predominate. However, in the orchards of tierra caliente other species such as cowpeas [*Vigna unguiculata* (L.) Walp. subsp. *unguiculata*], bush bean, papaloquelite [*Porophyllum ruderale* (Jacq.) Cass. subsp. *macrocephalum* (D.C.) R. R. Johnson], husk tomato, tomato, and chili peppers -both serrano (*Capsicum annuum* var. *annuum*), and piquín [*C. annuum* var. *glabriusculum* (Dunal) Heiser et Pickersgidl] are sown. In this agroecosystem we usually find "chichiquilit" (*A. hypochondriacus* Mixteco) and "iztaquilit" (*A. cruentus* Mexicano). The most common species of amaranth in the home gardens are *A. hybridus* and *A. spinosus*; both are weedy herbs with short stature, many branches and small leaves which are consumed as greens in the seedling stage. Production is limited and they are used for home consumption. In the home gardens at Zapotitlán de Méndez, a village located at 700 masl, *A. cruentus* Africano is grown and is highly esteemed by local people. *A. hybridus* is also in home gardens and shares many characteristics of *A. hypochondriacus* Mixteco. This agricultural system is maintained throughout the year, mostly by household members. Only hand tools are employed. Soil fertility of home gardens is improved by adding household refuse (Basurto 1982). Because these intensively and continuously cultivated plots provide a diverse combination of agricultural crops, they ensure a constant production of greens for family meals and dietary supplements.

Sale, Consumption and Ecological Complementation

In the Sierra Norte de Puebla region amaranth leaves and resprouts are greatly appreciated as foodstuff and are in high demand by both mestizos and Indian groups. Amaranth edible greens are sold in local markets and their prices vary with the season and the type of greens (i.e., resprouts or seedlings). The market supplies come from two main agroecosystems: the milpas of

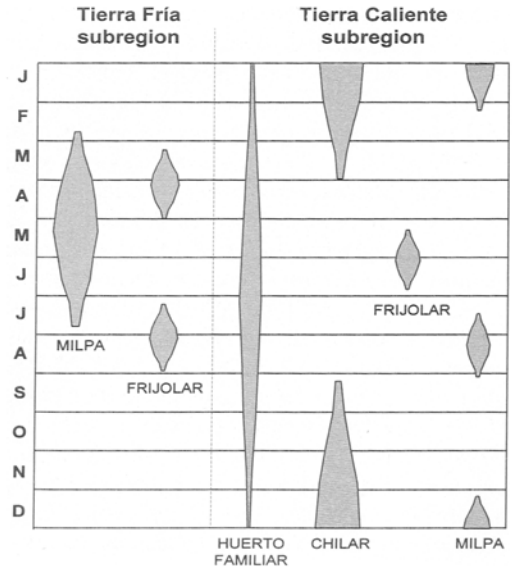

Fig. 5. Seasonal distribution of "quintonil" in the various agroecosystems in tierra caliente and tierra fría of the Sierra Norte de Puebla.

the tierra fría and the chilares of the Tierra Caliente. The amaranths from the chilares have higher prices because fewer plants are harvested; the area cultivated in chile peppers is less than that of maize. In general, amaranths are sold by the bunch which costs 50 cents (Mexican currency). The quantity of each bundle varies considerably. A handful of seedlings weighs 13.2 g (dry weight) while a large bundle of resprouts from pruned stems weighs 43.9 g (dry weight).

The amaranth of tierra fría, "arribeño," are available in the local markets between February and July. The amaranths from the tierra caliente, "abajeño," are marketed between September and February. Thus the ecological complementation of the two subregions assures the availability of amaranth greens in the markets throughout most of the year (Fig. 5).

Cultivation in Experimental Plots

Average plant height for the three races and *A. hybridus* is presented in Fig. 6. These values (cm, $\bar{x} \pm 2S\bar{x}$, n = 10), in decreasing magnitude, are: 255.9 cm ± 37.84 Mixteco; 212.3 cm ± 38.21 *A. hybridus*; 192.1 cm ± 37.84 Mexicano; 178.2 cm ± 12.53 Africano. Analysis of covariance (ANCOVA) showed significant differences for log transformed plant height data ($P < 0.05$)

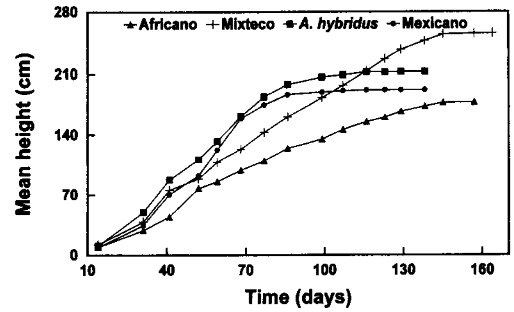

Fig. 6. Height of the three races and *A. hybridus* used as greens.

as well as for time covariant ($P < 0.05$). With respect to the number of days to reach maximum height Mixteco was the tardiest with 164, followed by Africano with 145, *A. hybridus* with 129 and Mexicano with 123. In general, life cycles are relatively long in these plants used as greens compared to those of grain (138 days as an average for *A. hypochondriacus* Mercado, Azteca, Nepal and *A. cruentus* Mexicano; Mapes et al. 1995).

Maximum values of leaf area (m^2, $\bar{x} \pm 2S\bar{x}$), showing clear differences among the races and *A. hybridus* (Fig. 7), were as follows: 2.91 m^2 ± 1.06, Mixteco; 1.44 m^2 ± 0.74, Africano; 1.26 m^2 ± 0.456, *A. hybridus*; and 0.38 m^2 ± 0.353, Mexicano. The ANCOVA for leaf area indicated that the differences between races and *A. hybridus* were significant ($P < 0.05$) as well were those of the time covariant ($P < 0.05$).

Maximum leaf area (MLA) per plant was reached by all races and *A. hybridus* at the same time, 149 days. If the MLA of these vegetable races and *A. hybridus* are compared to that of the grain producers, the latter reach their greatest value earlier (i.e., in 138 days) and tend to have

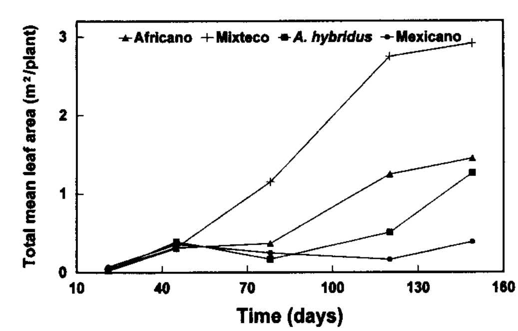

Fig. 7. Leaf area per plant of the three races and *A. hybridus* used as greens.

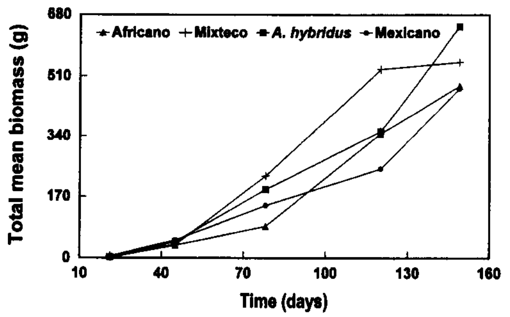

Fig. 8. Standing single plant biomass of the three races and *A. hybridus* used as greens.

less leaf surface: Azteca 0.912 m^2; Mercado 0.649 m^2; Nepal 0.741 m^2; and Mexicano 0.451 m^2 (Mapes et al. 1995).

The final standing biomass per plant (g, $\bar{x} \pm 2S\bar{x}$, n = 6) also varied among the races and *A. hybridus* (Fig. 8). *A. hybridus* produced the most with 647.09 g ± 186.06 and was followed by Mixteco (549.29 g ± 228.96), Africano (483.28 ± 120.78) and Mexicano (475.57 ± 285.67). Maximum standing plant biomass was reached at 149 days in the three races and *A. hybridus.* The ANCOVA for log transformed dry weight data indicates that differences between races and *A. hybridus* were not significant ($P > 0.05$), but were significant with time covariant ($P < 0.05$).

In all cases, highest percent biomass allocation (Fig. 9) to vegetative structures was observed during the period up to 45 days after germination. In all races and *A. hybridus,* 85% of the total plant corresponded to stem and leaf. At this time *A. hybridus* and Mexicano initiated flowering, while in the Mixteco and Africano plants the onset of reproduction occurred at day 120. These two last races have lower values of percent biomass allocated to inflorescences (6.8% and 3.0% respectively), while *A. hybridus* and Mexicano have higher values (42.8% and 22.6% respectively). During the reproductive period, percent biomass allocated to vegetative structures declined, particularly for leaves which decreased from 66% to 24% in *A. hybridus,* and from 66% to 21.5% in Mexicano. For races Mix-

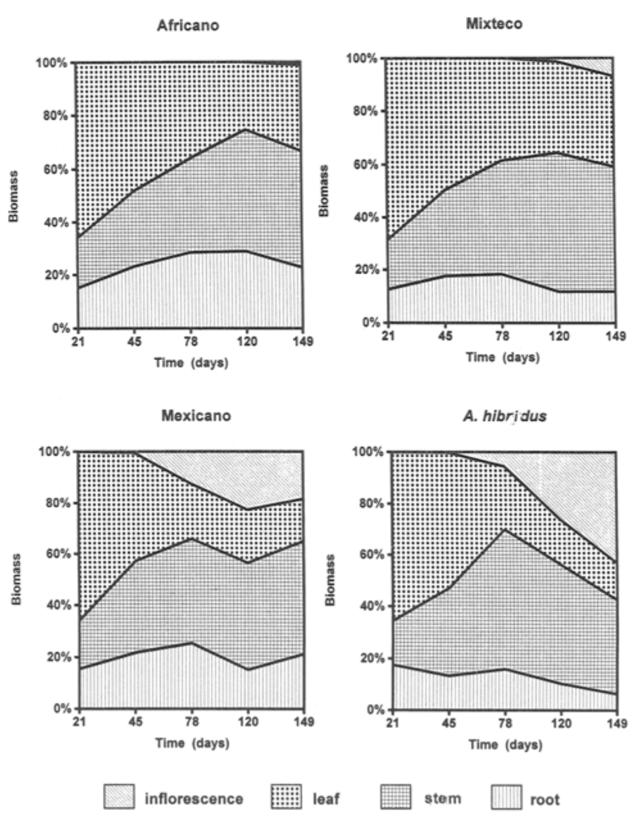

Fig. 9. Resource allocation within the plant of the three races and *A. hybridus* used as greens.

TABLE 4. SUMMARY OF PLANT CHARACTERISTICS OF THREE RACES AND *A. HYBRIDUS* GROWN IN EXPERIMENTAL PLANTS.

	Maximum leaf area MLA (m^2)	Biomass at maximum leaf area (g)	Maximum biomass MB	MLA/MB (m^2/g)	Leaf/stem ratio	Days to MLA	Height at MLA (cm)	Maximum height (cm)	Life cycle (days)
Mixteco	2 913	549.29	549.29	0.0053	0 660	149	254.6	255 9	164
A. hybridus	1.262	647.09	647.09	0.0019	0 0472	149	212.7	212.7	138
Mexicano	0.388	475.57	475 57	0 0008	0.298	149	192.1	192.1	138
Africano	1.449	483.28	483.28	0.0039	0.705	149	177.8	178.2	157

MLA = Maximum leaf area (m^2)
MB = Maximum standing biomass (g)

teco and Africano, whose resource allocation pattern remained constant until the end of the experimental period, this decrease in vegetative structures was from 68% to 38%, and from 65% to 36%, respectively.

The ANCOVA results for percent dry weight of vegetative and reproductive structures show significant differences among races and *A. hybridus* in biomass percentages of root, leaves and inflorescences ($P < 0.05$). Time covariant was significant ($P < 0.05$) in all cases except root.

DISCUSSION

The importance of amaranths in the Sierra Norte de Puebla and the role of the local farmers in their use and diversity can be seen by comparing the characteristics of their plants grown in situ by farmer and in the experimental garden with those resulting from contemporary breeding programs and agronomic studies. It is important to recall that, for practical reasons, the experimental cultivation was carried out in the Valley of Mexico, a region with different climatic and ecological conditions than those where the seeds originated. Nonetheless, these preliminary results demonstrate genetically based differences between the edible greens and the grain races of *Amaranthus* (Mapes et al. 1995). Future studies will carry out these comparative experimental growouts in the Sierra Norte de Puebla as well as in other ecological zones.

Experimental results agree with ethnobotanical information gathered in the field. *A. hypochondriacus* Mixteco (chichiquilit) is associated in polyculture, especially in milpas dominated by the tall maize race Tuxpeño. The deep red-colored plantlets mature to erect herbs that reach almost 3 meters in height and have a long life cycle of about 10 months. The sparsely branched stem has a high capacity for resprouting and, hence, is a good leaf producer. The narrowly condensed terminal inflorescence produces dark colored seed.

Under experimental conditions, the red colored seedlings of Mixteco grew to an average maximum height of 2.5 m and had the longest growth period (164 days before the frosts, which usually do not occur in its original cultivation area, killed the plants). At this time, it also reached its maximum leaf area (2.9 m^2) as well as its average maximum biomass (549.2 g) (Table 4). The MLA/MB (maximum leaf area/ maximum biomass) is the highest of those races studied (0.0053; Table 4). Plants with a high leaf to stem biomass ratio (i.e., 9.7 for *A. tricolor* seedlings) are considered to have the greatest market value for edible greens (Abbott and Campbell 1982; Grubben 1980). In this experimental study we did not obtain such high values for this parameter, the greatest being 0.66 for Mixteco because measurements were made on adult plants rather than seedlings (Table 4).

Another important aspect to consider in an edible greens plant is the availability of leaf biomass. The pattern of biomass allocation allows one to see the moment in the life cycle when the leaf production is at its peak and the leaves are available. In addition, the quality of the leaves is significant (Santos Oliveira and Carvalho 1975); the main problem in leaf protein utilization is the content of non-digestible glucide matter, which may be limiting the digestibility and absorption of nutrients. It will be necessary in the future to carry out other investigations with amaranth in order to clarify these points.

The phase of the life cycle when the plant is consumed is another factor to consider. If the vegetable is consumed as a plantlet, the herb will tend to be annual. If the sprouts resulting from pruning are favored, the herb will tend to be biennial or short lived perennial. In breeding of mutants produced by gamma ray exposure, the preferred fresh leafy vegetables have wide laminas in the reproductive stage (Mohideen and Muthukrishnan 1979) while leafy greens for repeated harvestings are those with high resprouting capacity. This latter type has economic significance for the continuous production of tender leaves over a long time period. Some mutations found in alfalfa (*Medicago sativa* L.) have a high capacity for resprouting after harvesting the basal branches. In the case of *Amaranthus,* gamma ray induced mutation resulted in new, earlier flowering and dwarf varieties that were high foliage producers of wide leaves (Mohideen 1989). This tender-leaved form has been recommended for cultivation because it can be harvested continually and produce seed earlier. Another economically important mutant was a late flowering form with many, basal branches which, after leaf harvesting, generated leafy shoots that can be continually harvested over longer periods of time. These experimental cultivars demonstrate two possible strategies for selection of plants with continual leaf production. This pattern of exploiting early stages of leaves from resprouting is similar to the various quintoniles used in the Sierra Norte de Puebla. Even though such responses of the Mexican races have not been studied genetically, these native amaranths products of long human selection reflect great potential that parallels results from scientific breeding programs.

Resource allocation patterns of Mixteco and Africano are very similar (Figure 9). In general terms, these two races delay the onset of reproduction thus lengthening the period of leaf production. Morphological characteristics observed in the field for these races, but particularly so for Mixteco, indicate a more intense selection by people, in that they show more abundant leaf production, the stems are taller, and their characteristics of texture, flavor and color are highly appreciated by consumers.

Different species of amaranth used as vegetables have been studied by Devadas and Mallika (1991). The premature flowering before plants obtain sufficient vegetative growth and incidence of pests and diseases are the important limitations of amaranth cultivation. Early flowering terminates vegetative growth resulting in poor leaf yield. Many factors such as undesirable genotype, unfavorable cultivation conditions (such as poor soil fertility), severe moisture stress, methods of cultivation, height of cutting among others can cause early flowering. Pruning significantly delays anthesis in amaranths (Deutsch 1977; Enyi 1965; Grubben 1976). Color patterns are related to initiation of flowering. In general, red amaranths flowered later than green types. The physiological reason for the delayed flowering requires further investigation (Devadas and Mallika 1991).

Amaranthus hypochondriacus Mixteco of Sierra Norte de Puebla possesses a number of characteristics associated with improved leafy greens: higher leaf/stem ratios than grain forms, leaf resprouting after pruning, extended period of leaf production, suppressed flowering and red pigmentation.

In contrast, *A. hybridus* and *A. cruentus* Mexicano exhibit a weed-like behavior in that greater resource allocation to leaves (respectively, 65% and 66%) is early in development, the stage at which they are consumed. In both collections, at the onset of reproduction, the percent biomass allocation to leaves (24.4% and 21.5%) diminishes dramatically as more resources are allocated to the reproductive structures. This pattern of resource allocation is typical of agrestal and ruderal plants that must complete their life cycle prior to weeding if the population is to survive the next season. In the agricultural cycle the plants are removed after the period for leaf and plantlet gathering so as to reduce competition with maize. Even though these latter races are encouraged by the sowing of seeds in milpas and gardens, they retain a resource allocation pattern typical of weeds. Huaptli (1977) mentioned that many weedy species and a few domesticated amaranths possesses indeterminate inflorescences. The tip of each inflorescence branch remains meristematically active and can continue to differentiate and to produce flowers and seeds long after the leaves have begun senescence. Weedy herbs are known for their greater allocation of biomass to seed (Baker 1974).

Amaranths produce considerable amounts of vegetative growth. In initial stages, the plant generates large quantities of succulent green matter. As the season progresses, the large stem and older leaves become fibrous, pithy and unpalatable. Flowering often impedes further harvests because there is less leaf production and the leaf quality is poor. Hence standarization of cultural techniques to obtain maximum tender vegetable yield is desirable. Several attempts have been made to obtain increased total vegetable yield, high leaf/stem ratio, greater number of harvests among other features (Devadas and Mallika 1991).

Management practices of vegetable amaranth include transplanting and direct seeding. Transplanting is more laborious but leads to fewer weed problems and earlier harvests. High soil fertility and shallow seeding (about 0.5 cm) are recommended (Daloz 1980; Grubben 1980). Transplanting delayed flowering and increased the total duration of the vegetative phase, thus making it possible to have more harvests and ultimately a higher yield of edible greens (Mohideen and Rajagopal 1975). For successive harvests, vegetable amaranths can be either ratooned (repeated harvest of the same plant) or clear cut and reseeded. Deutsch (1977) noted that total yields increased with increasing density up to 200 plants/m². Field experiments in Pennsylvania, USA, where amaranth was cut 35 to 56 days after sowing showed yield increase with plant age but a decline in leaf quality. In Benin, West Africa amaranth is usually transplanted either at a narrow spacing for one single harvest or at a wide spacing for 2–4 subsequent cuttings (Grubben 1980). The results of Grubbens (1980) studies in Benin and the Netherland are applicable to practice in the Sierra Norte de Puebla: a) broadcast sowing gives a higher yield; b) narrow spacing requires large quantity of seed and gives a dense growth of etiolated plants, a condition which is very competitive against weeds; c) uprooting plantlets yields easy-to–handle bundles of plants which may be kept fresh for a longer period by putting the roots in a basin of water; and d) harvesting young plants yields more succulent vegetables. In the case of resprouts from pruned, older plants, Grubben (1980) concluded that: a) cutting gives a cleaner product that does not require laborious washing and has a higher percentage of edible material; and b) pruning at a height that leaves sufficient axillary buds for new branches increased total yield per plant through repeated cutting.

In the case of 3–4 weeks old *A. cruentus* cv. Fotete an optimum harvest was produced at a density of 100–200 plants per m² (Grubben 1980). For repeated cutting of this cultivar, 20 to 40 plants per m² appear to be suitable.

TABLE 5. COMPOSITION OF EDIBLE LEAVES IN PERCENTAGE OF *A. HYPOCHONDRIACUS* MIXTECO.

Grams of dry matter	100
Total protein % (dry matter) (N × 6.25)	32.15 ± 0.13
Crude fiber	9.86 ± 0.15
Ash % (dry matter)	20.38 ± 0.02
Free extractable nitrogen	32. ± 49

The amaranth greens have high nutritional value. They are exceptionally high in calcium and contain more fiber, niacin and ascorbic acid than spinach on a fresh-weight basis and have about three-quarters as much vitamin A as spinach while the content of protein, iron and other minerals is similar (Watt and Merrill 1975). Nitrate and oxalate contents are comparable to those of other leafy garden vegetables (Marderosian et al. 1980).

The use of leaves in human nutrition has not been given the consideration it deserves in some low protein diets. When the limiting amino acid of main foods is lysine (as in the case of cereal based diets), the protein of leaves may be an important dietary complement (Santos Oliveira and Carvalho 1975). In Mexico, where maize is one of the major foods, the consumption of edible leaves can be very significant. A preliminary analysis of the edible leaves of "chichiquilit" (*A. hypochondriacus* Mixteco shows that they contain 32% total protein (Table 5).

The number of gatherings made from the plant influences the nutritional content of amaranth leaves. Biochemical composition content and nutritional factors changed in leaves of Guatemalan vegetable forms of *A. cruentus* and *A. caudatus* L. that were harvested every 7 days through out life cycle (Spillari, Garcia Soto and Bressani 1989). This information suggests that the manner and frequency of leaf harvest is critical to the quality of the vegetable. Future studies in the Sierra Norte de Puebla will compare ethnobotanical details of the cultural practices with the phytochemical and nutritional qualities of the greens.

CONCLUSIONS

Two weedy species (*A. spinosus* and *A. hybridus*) and three races (*A. cruentus* Mexicano and Africano as well as *A. hypochondriacus* Mixteco) are known collectively as quintoniles and are utilized as edible greens by the Nahuat farmers of the Sierra Norte de Puebla of Mexico. The later four taxa are encouraged in milpas, chilares, frijolares, orchards and home gardens. These amaranths form an integral part of agroecosystems both in the tierra fría and the tierra caliente of the area. Farmer management practices are based upon the coadaptation of the amaranths to the growth cycles of the cultivated crops along this ecological gradient and permits the availability of the edible greens through out the year in the region. The life cycle, biomass allocation patterns and leaf characters of seedlings as well as of pruned plants of the Sierra Norte de Puebla suggest that the quintoniles have evolved separately from their grain relatives and share desired characteristics found in amaranths produced in contemporary plant breeding programs and agronomic manipulation.

ACKNOWLEDGMENTS

This research was funded, supported and encouraged by the Programa Universitario de Alimentos (PUAL, UNAM), the Coordinación de Estudios de Posgrado, (PADEP, UNAM), and the Instituto de Biología (IBUNAM) of the Universidad Nacional Autónoma de México

The Facultad de Medicina Veterinaria y Zootecnia de la UNAM allowed the land of Rancho San Francisco in Chalco, state of Mexico, for the experimental growouts The valuable help of local farmers, Tomás Palma and Federico Valdepeña, in the establishment and maintenance of the cultivated plots is greatly appreciated Martha Gallegos Reza and Aracelí Díaz-Ortega assisted in the recording and analysis of data Salvador Sánchez Colón from the Escuela Nacional de Ciencias Biológicas, IPN was advisor of the statistical analysis The support of Miguel Angel Martínez Alfaro in this study has been very important, he introduced us to the Sierra Norte de Puebla and has shared his extensive knowledge of the area with us The authors thank Patricia Colunga García-Marín, Dr Lawrence Kaplan and two anonymous referees for their valuable contributions to the critical review of the manuscript Jorge Saldívar provided computer assistance in the preparation of the manuscript and some of the figures

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