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INCIPIENT DOMESTICATION OF MUSTARDS IN NORTHWEST MEXICO

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ABSTRACT

The leaves and hypocotyls of mustard (*Brassica campestris*) are highly prized as fresh and dried edible greens by the Tarahumara Indians of Chihuahua. The plant is collected as a weed in the summer and as a cultivated plant in the fall. The seeds are sown in animal corrals in September in order to produce mostly leaves and swollen hypocotyls; this practice appears to be based on the differences in biomass allocation in the plants under different photoperiods. In addition, the mustard sown plots are said to be less weedy during the following growing season; this may be based on the allelopathic nature of *Brassica. Brassica campestris* was probably introduced as a weed in wheat seed stock by the missionaries. The Tarahumara have begun to domesticate the plant by selecting plants which primarily produce leaves and swollen hypocotyls under short daylight regimes of the fall months. It appears that this mustard may be replacing cultivated *Cucurbita* in their subsistence diet. The Tarahumara use of *Brassica* may reflect an extension of food preference for crucifers (such as *Lepidium*) which are commonly gathered or sown.

INTRODUCTION

Ethnobotany has grown rapidly since its start over 100 years ago and since its name was first published in 1896. Because of its multidisciplinary nature, the concepts and approaches vary according to the viewpoints of the investigator and his interests in the relationships of plants and man. One definition of ethnobotany is that it is the area of study which examines the biological bases of the interactions and interrelationships between man and plants in his ambient environment.

One form of interaction between plants and man is the exploitation of certain food plants which are important in the gatherer's subsistence. As interactions intensify, interrelationships between plants and man can develop such that the cultural group may incorporate the plant into its economy, diet, and cognized environment, and the plant may respond to human activity through ecological and evolutionary changes (Baker 1972). One biological process which is critical to plant-man relationships is that of domestication.

The Tarahumara Indians, who number about 50,000 and live in the Sierra Madre Occidental of Chihuahua, Mexico, are intensifying their interrelationship with an introduced mustard, *Brassica campestris* L. These hunters-gatherers/subsistence agriculturists have initiated the domestication of this weedy mustard in the temperate pine-oak forest zone of the sierras. This annual does not grow spontaneously in the subtropical barrancas or canyons and is not known to be cultivated in that zone of the Tarahumara region.

DOMESTICATION

Domestication is an evolutionary process in which genetic changes in plant populations are purposefully affected by human activity over time. The activities of man can vary in types and intensities. Time can vary in the period of initiation and in the duration. Past studies in plant domestication are often linked with the questions of origin of agriculture in terms of time and centers as well as with subsequent cultural development. In a larger context, the activities of domestication and the consequences of providing essential food and fiber elements have been viewed as a critical, sudden revolutionary *event* in human cultural, social, and economic evolution. On the other hand, as more data accumulate, domestication is better viewed as the *process* which should be studied for its own merits.

Using morphological, genetic, and chemical data from modern plants and morphological data from archaeological plant remains and associated cultural materials, most of the studies in domestication have focused on the end products of the evolutionary process and compared them to the putative wild progenitors and weeds. As recently pointed out by Harlan, De Wet, and Stemler (1976b), however, the initial and transitional conditions must be studied as well. The models of domestication of plants are largely derived from plants in which the parts desired by man are the reproductive components of the plants, such as seeds and tubers, where large amounts of nutrients (such as carbohydrates, protein, and fatty oils) are stored. Examples of these approaches can be seen in recent books on the topic (Harlan 1975; Harlan, De Wet and Stemler 1976a; Hutchinson 1965, 1974; Schwanitz 1967; Simmonds 1976; Ucko and Dimbleby 1969). These models and some of their basic assumptions may not be directly applicable to vegetable crops which are selected by man for enlarged, non-reproductive parts at the expense of reproductive parts.

One approach to domestication from the ethnobotanical viewpoint is to recognize the two components of the process: 1) interactions and 2) interrelationships. A generalized pathway may start with wild progenitors (which are often native colonizers in disturbed areas), proceed to weeds

(which are evolutionary responses to habitats disturbed by man and which may be tolerated, encouraged, or collected by man), become weed-crops (which are consciously sown in prepared habitats by man for future harvest and which represent the early stage of cultivation), and finally advance to domesticates (which are genetically altered by human selection and which depend upon conscious human activities for their survival and reproduction). Weeds, in addition, may be derived through a degeneration process from domestication which can be triggered by a number of factors and can play a critical role in maintaining genetic diversity in domesticated plants (De Wet and Harlan 1975).

In examining the two components of the ethnobotanical approach, we must recognize the roles of main participants, plants and man. In the *interactions*, plants and man must function upon each other. The plant must produce the desired material in sufficient quantity and quality for man, must be available in an acceptable form for consumption in fresh or stored states, and must exhibit beneficial morphological changes in response to human activity (the critical characters should be subject to genetic and phenotypic change through selection and manipulation by man).The function of man is to recognize the quality of the plants or its products, to expolit the plants, and to consciously propagate the plants (from seed and/or vegetative propagules) in a prepared habitat. The *interrelationships* develop as a result of intensification of the interactions over time. In the case of plants, genetic changes through directional or disruptive selection occur such that the plant populations become more dependent upon man's activities (whether unconscious in nature resulting in weeds or conscious in nature leading to domesticates) for their survival and reproduction. In the case of man and food plants, cultural changes occur which reflect the necessity of deliberate activities that maintain requisite yields in order to assure the importance of the plant's role in the peoples' diet. An interrelationship can ultimately develop to the extreme of total interdependence in which the survival and reproduction of the domesticated plants are affected by man, and the survival and reproduction of human populations are dependent upon the sustained productivity of domesticated plant populations. In this paper, I attempt to provide information on various components of these interactions and interrelationships between the mustards of the genus *Brassica* and the Tarahumara Indians of Mexico.

THE GENUS *BRASSICA*

The mustards of the genus *Brassica* comprise a group of 40 to 100 species which are indigenous to the cool temperate regions of the Old World and are presently represented by many weedy forms in all parts of the world.

The *Brassica campestris* cytodeme (Harberd 1972) has been domesticated as a food crop in Europe as the biennial turnip with its swollen hypocotyl and upper root, in the Mediterranean and northern India as the annual oil seed rape, and in the Far East as the Chinese cabbage with the short stature plants with enlarged leaves (Table 1) (Smith and Welch 1964; McNaughton 1976). In addition to these cultivated forms, weed races have evolved and are often associated with grain fields (Pickering 1879; Ridley 1930).

The introduction of *Brassica campestris* into the New World probably included the weedy as well as the cultivated forms. Rape plants may have been introduced as an oil source. The Spanish colonizers carried with them plants which supplied oils, grains, and the raw material alcohol (Crosby 1972). It appears, however, that *B. napus* L. rather than *B. campestris* was the preferred mustard oil plant (Patiño 1969). The probable mode of introduction of *B. campestris* was as a weed contaminant in grain stock (Gade 1972). Although there is no direct evidence, it is of interest to note that this mustard was a common weed following the missionary period (1769-1824) in the southwestern United States (Hendry 1931).

BRASSICA AND THE TARAHUMARA

Although there is no direct evidence, I assume that *Brassica campestris* was introduced into the Tarahumara region as a weed. The seeds were probably contaminants in the seed lots of wheat which were widely distributed by the early missionaries after their contact with the Tarahumara in the early 1600s. A review of the "Relaciones Geográficas" of 1776 for present-day western Chihuahua indicates that wheat did poorly when sown during the normal growing season but performed well when cultivated in the dry season. *Brassica* does not grow during the dry season, which may explain its absence as a weed in the present-day wheat fields of the Tarahumara who grow wheat to a limited extent during the dry months of January to May. The mustards are commonly found as weeds in cultivated fields during the normal growing season from June to October.

To date our information on the interaction between the Tarahumara and the mustard is limited to recent data. The scanty archaeological records of western Chihuahua offer no help. The historical record as seen through the Franciscan "Relaciones" of 1776 present two possible records. At Guaguachic, south of the Barranca del Cobre, Falcon Mariano (1776) described the planting and utilization of an edible green which was similar to a radish and was called *macoásali*. These data closely fit *B. campestris* as it is known today. At San Buenaventura, north of the present-day Tarahumara region, a *quelite* or edible potherb was illustrated and is referable to *B. campestris* based upon the erect fruits, shape of the inflorescence, and the caulescent bracts (Relación de San Buenaventura 1776).

Table 1. *Brassica campestris* cytodeme (n = 10).

B. campestris L. (wild and weedy races) syn. *B. rapa* L. ssp. *sylvestris* (L.) Janchen & Wendelberger
B. campestris L. (turnip) syn. *B. rapa* L. ssp. *rapa* *B. septiceps* Bailey
B. campestris L. (rape) syn. *B. rapa* L. ssp. *oleifera* DC.
B. campestris L. (Chinensis group) syn. *B. chinensis* L.
B. campestris L. (Pekinensis group) syn. *B. pekinensis* (Lour.) Rupr.
B. campestris L. (Perviridis group) syn. *B. perviridis* Bailey
B. campestris L. (Ruvo group) syn. *B. ruvo* Bailey

The first documentation of the importance of *Brassica campestris* to the Tarahumara was made by Carl Lumholtz (1902) and based upon observations and a specimen collected near Guajochic in 1892 (Hartman No. 557; GH). Subsequent references which document the importance of *B. campestris* to the Tarahumara are outlined in Table 2.

Although we consider *Brassica campestris* to be a post-Columbian introduction, it is important to consider the Tarahumara viewpoint of its origin. Most Tarahumara indicate that it was a food plant that was grown by their ancestors and passed along through generations. A few Indians indicate that the modern *B. campestris* was derived from its near relatives, species of *Pennellia*, which are colonizers of natural disturbances in the sierras. Their ancestors began planting the seeds of these native mustards, a member of the botanical family Cruciferae along with *Brassica*, and the plants became larger with increased leaves and yellow flowers.

The *interactions* between the Tarahumara and the mustard can be seen in the weedy nature of the plant and in the utilization of the herb as a quelite or edible herb. The *interrelationships* developing from the intensification of these interactions can be seen in the Tarahumara recognition of the plant, in the increased importance of the plant in their diet and land use practices, and in the selection and manipulation of the mustard populations — a start of the domestication process.

The present-day weedy nature of *Brassica campestris* reflects the probable ancestral type of this mustard as it was introduced into the Tarahumara region. Because the mustard requires adequate moisture during

Table 2. *Brassica campestris* and the Tarahumara.

Tarahumara Name	Date	Source	Reference	Specimen	Significance	Spontaneous	Cultivated	Garden	Corral	Sown	Storage	Period of Use
macúsali	1776	Falcón Mariano	Relaciones .... Guaguachic		+		+			Ag.		
makwásari mak-wá-sari	1892	Lumholtz; Hartman	1902:I-229 GH; No. 557	+	+	+	(+)				+	
maquasávi	1898-1905	Hrdlicka	1908:266		(+)						+	
makwa-so-ri makua-so-ri ma-kua-so-ri makwa-so-li	1913-4	Thord-Gray	1955:244-5				+		+		+	dry: winter
makwásoli	1930-1	Bennett & Zingg	1935:26, 143		+		+		+			
mokásari		Brambila	1952:144									
mokásori mokásari mokosári mokwásari	1955	Pennington	1963:67, 126 TEX; No. 507	(+)		+	+	+		Jn-Jy		
maquásori	1960	Kennedy	1970:63-64, 71 1976:48, 51, 64		+		+		+	Jy-Ag	+	most of year
mokuásari makwásari	1971-8	Bye	ECON, COLO, GH, CHAPA, MEXU	+	+	+	+		+	(Jn-Jy)* Sp-Oc	+	fresh: Jn-Nv dry: Dc— ...
macuásili quilibá a'lásini	1973-4	Bye & Burgess				+	+		+	Sp-Oc		
makwáso-Ri		Lionett	1972:67									

*Poor yield

the frost-free, moist growing season, it is found as a common weed in the cultivated fields of the Tarahumara from June until September. *Brassica* is not found as a weed in the small Tarahumara wheat fields of today because *Triticum* is cultivated only during the dry season. The spontaneous propagation of *B. campestris* in the Sierra Madre of Chihuahua appears to be dependent upon human disturbances. The mustard is common in cultivated and recently abandoned fields as well as in turned soil near dwellings and corrals. It is rarely found in older abandoned fields or in areas of heavy grazing or compaction. Clearly, *B. campestris* occurs as a weed which is encouraged in cultivated fields and found in early secondary successional seres as a result of human activities which turn over the soil regularly.

The exploitation of mustard is most likely the result of two factors: 1) it is found as a weed in sites where other edible greens, such as *Amaranthus, Chenopodium, Bidens*, and *Cosmos*, are found and 2) plants can be collected fresh for consumption or can be sun-dried and stored for later use, usually during the winter months when stored vegetables are in low supply. When collected for immediate consumption, the fresh herbs are pulled from the field along with other edible greens and may be prepared together with them or apart from them.

The roots are pulled off, leaving the whitish hypocotyls and green leafy rosettes. After rinsing in cold water, the plants are often allowed to sit in the sun until the leaves are limp and then are cooked in a pot of warm (not boiling) water over the coals of a slow fire. Usually the greens are allowed to simmer about an hour until they are very flaccid and then are placed in a loosely woven basket and rinsed with cold water. The cooled leaves are eaten with the hand while consuming pinole or may be mixed with other foods such as other quelites and placed in beans or on tortillas. This gathered, spontaneous weed may vary in abundance in cultivated maize fields from 2 to 25 plants per square meter and is often tolerated and encouraged along the margins. The Tarahumara prefer the plants with leaves and without inflorescences or flowering stalks. In late June and July most of the plants in the field produce only a few basal leaves and send up inflorescences soon after the seedlings are established. The Indians will collect the plants with the flowering stalks for consumption if the yellow flowers have not opened. At anthesis the Tarahumara say that the yellow flowers impart a bitter flavor to the quelites and that the flower stalks become too stringy.

The recognition of a plant by applying a taxonomic name and placing it into the native classification is an important indicator of intensification of the plant-man interactions. Although no formal study has been conducted on this aspect of ethnobotany, field data indicate that *Brassica campestris* has been incorporated into both a functional classificatory system in terms of being recognized as a form of *giribá* or edible herb as well as into the natural

classificatory system as a member of the *mekuásari* complex, which is considered here to be a generic term. The folk taxon, "mekuásari," is subdivided by the Tarahumara into three covert subunits which are distinguished by the type of fruits and the habitats (Table 3). It is interesting to note that the generic name was often applied to different biological species, and the only specific names given to the different species were combinations of Tarahumara and Spanish terms. Further field investigation and elucidation need to be done to clarify this situation. Even though informants clearly recognized differences among the various mustards, they were unwilling to name further subdivisions with Tarahumara epithets. An important point to notice is that the western Tarahumara distinguish between spontaneous weeds of *B. campestris* which are called by the generic term, *macuásili*, and the cultivated plants which are functionally labeled as *guilibá a'lásini* (edible green; cultivated land). It appears that *Brassica campestris* fits the traditional concept of mustard plant group and could serve in the same capacity as edible herbs also found in the mekuásari complex; subsequently it was incorporated into that generic Tarahumara folk taxon. Pennington (1963) also mentions another mustard, *Brassica juncea* (L.) Czern. and Coss., which is called *mokásari* as in *B. campestris*. Examination of his voucher specimen for *B. juncea* (Pennington 1955: No. 507; TEX) reveals that this plant is actually *B. campestris*. The Mexican terms frequently applied to field mustard are quelite and *coles*.

The importance of *Brassica campestris* in the Tarahumara diet is difficult to quantify at this time. Assuming that the mustard was not available in the region until the contact period of the early 1600s, however, one can readily appreciate its relatively rapid emergence from a new introduction, to a gathered spontaneous weed, to an encouraged weed, and finally to an edible weed-crop in a period of about 300 years. Both weedy (sometimes erroneously considered "wild") and sown mustard plants are prized by the Indians and considered their favorite of over 120 species of quelites exploited. Nearly every visit to a Tarahumara ranchito from June through November revealed mekuásari present in that day's menu.

An estimate of the daily amount of *Brassica campestris* consumed when available is about 100-150 grams fresh weight per adult. The leaves are rich in vitamin C, vitamin A, calcium, phosphorus, thiamine, niacin, and riboflavin when compared to spinach (Leung 1961). In addition to being preferred over other indigenous quelites such as *Amaranthus retroflexus* L., *Chenopodium berlandieri* Moq., *Cosmos parviflorus* (Jacq.) H.B.K., and *Bidens odorata* Cav., the importance of *B. campestris* can be seen in its apparent replacement of two cultivated food plants of the sierras: the winter annual peppergrass, *Lepidium virginicum* L., and the domesticated squash, *Cucurbita pepo* L. A number of informants indicated that *Lepidium* used to be sown more

Table 3. Tarahumara folk taxonomy: mekuásari complex (the Cruciferea family).

Complex generally recognized by: 1— silique fruits 2— cruciferous flowers 3— peppery taste	
mekuásari . . . . . elongated, ± terete siliques; field & disturbed habitats	
Pennellia longifolia (Benth.) Rollins	mekuásari 'silvestre'
Dryopetalon runcinatum Gray var. *laxiflorum* Rollins	mekuásari 'del monte'
+*Raphanus sativus* L.	mekuásari 'del monte'
**Thelypodiopsis wootoni* (Robinson) Rollins	mekuásari 'blanco'
Thelypodiopsis linearifolia (Gray) Al-Shehbaz	mekuásari
+*Brassica campestris* L.	mekuásari (mekuásari 'amarillo')
	macuásili W. Tar.: spontaneous
	guilibá a'lásini W. Tar.: cultivated
. . . . . elongated siliques; moist-wet habitats	
**Ornithocarpa torulosa* Rollins	nakasoti
Rorippa spp.	witajúpachi; bakisóchari; bonita; wasá
Descurainia spp.	wasá
. . . . . roundish, flattened siliques; *disturbed habitats*	
Lepidium virginicum L.	rochíwari; ro'chívari

+introduced
*endemic

frequently in the past when the seeds were planted in the fertilized corral plots. Although the seeds of this pungent tasting plant are still sown to a limited extent, the major source of peppergrass comes from weedy plants found in grazed fields, along trail margins, and in the vicinity of dwellings — areas where *Brassica* is not usually found spontaneously. In the higher altitudes of the pine-oak forests, *Cucurbita pepo* is often cultivated in recently fertilized corral plots. Occasionally the squash plants are killed by an early frost prior to the maturation of the large green fruits. Informants' statements, which have been confirmed by four seasons of observations, claim that the mustards can withstand two weeks of early, light frosts and that large amounts of leafy vegetable can be harvested within a month's growing period. Quantitative data to be obtained in the future should be able to test these concepts of longer periods of availability of preferred vegetables and less duration of production which seems to favor *Brassica* cultivation over that of the traditional squash. With the scarcity of fertile, arable land, the cultivation of the *Brassica* weed-crop rather than the traditional *Lepidium* and *Cucurbita* can be critical to the diet of these subsistence agriculturists.

Another indicator of the importance of *Brassica* in its interrelationship with the Tarahumara is related to a land use practice. Some older Tarahumara indicate that a plot of fertilized soil which was planted to mustard during the

previous year will have a less dense stand of weeds. These statements suggest that residues or excretions of the mustard inhibit the germination and growth of other plants. In June, the start of the growing season, casual observations of adjacent fertilized plots, one previously sown to *Brassica* and the other allowed to remain fallow, reveal that annual weeds are generally absent from the *Brassica* plots, while the fallow, non-*Brassica* plots contain the following plants per square meter: 100 *Amaranthus retroflexus*, 5 *Chenopodium berlandieri*, and 10 *Bidens odorata*. Allelopathy has been recognized as a form of weed control (Rice 1974). *Brassica* has been investigated with reference to its allelopathic properties (Varma 1938) which have been shown to aid in maintenance of spontaneous populations of *B. nigra* (L.) Koch in California grasslands (Bell and Muller 1973).

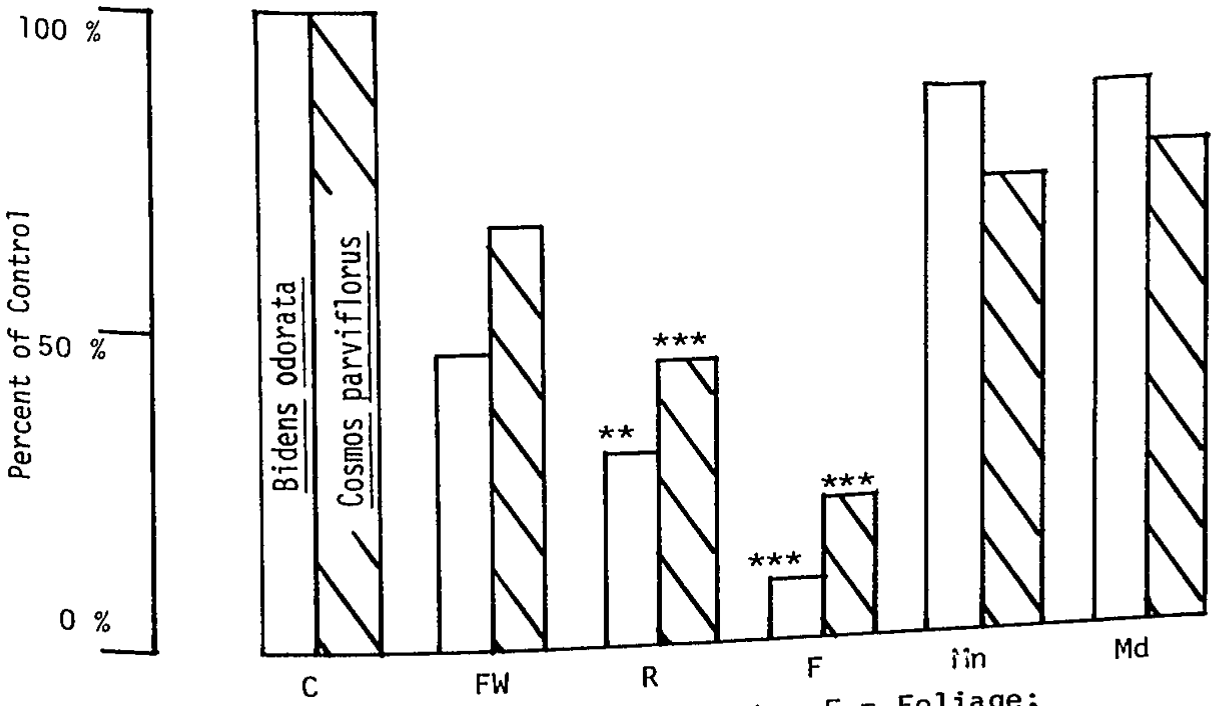
The following experiment was designed to demonstrate the potential of *Brassica campestris* from the Sierra Tarahumara to act as an allelopathic agent. The experimental treatments consisted of three forms of tissue extractions of *B. campestris* (Bye 7035; from a 50 day old plant grown in an eight hour day length growth chamber with vermiculite growing medium and quarter strength Hoagland's nutrient solution): 1) foliage soaked for one-half hour in 200 ml of distilled water, 2) foliage macerated and soaked for one half hour in 200 ml of distilled water, and 3) roots soaked for one half hour in 100 ml of distilled water. Other treatments consisted of distilled water leachate from manure from a Tarahumara goat corral (0.25 gram dry weight to 50 ml of distilled water for one-half hour) and from vermiculite. The bioassay seeds consisted of viable seeds of two common Tarahumara weeds, *Bidens odorata* (Bye 7135) and *Cosmos parviflorus* (Bye 7149).

The treatments consisted of aqueous extracts of 1) foliage wash, 2) macerated foliage wash, 3) root wash, 4) leachate from goat manure, and 5) leachate from vermiculite. The controls consisted of distilled water. The bioassay seeds were presoaked in distilled water overnight, exposed to the sun, and placed on 7 cm diameter Whatman filter disks. The filter paper was placed on a 5 × 40 × 70 mm pad of cellulose sponge and placed in a sterilized petri dish. Ten seeds per treatment were used each time. The treatment solutions and distilled water were added to the respective dishes at the rate of 15 ml per day. The petri dishes were placed in a dark box and maintained at a relatively constant temperature of 20 degrees C. The radicles of the germinated seeds were measured at the end of the 48 hour period. The results of the bioassay are summarized in Figure 1.

An important result is that the foliage wash and manure and medium leachates do not significantly reduce radicle growth while the solutions from the roots and macerated leaves decrease the rate of growth significantly. This is critical considering that the ecological mechanism (tissue containing the allelopathic water-soluble constituent) must be present at the proper time

if the process is to be carried out. The roots and desiccated leaves of the unharvested *Brassica* plants remain in the soil until the following rainy season. Because the rainfall between the end of the fall growing season and the start of the next season is low, the assumed allelopathic substance is not leached out of the soil prior to the germination period of the weed seeds. It is interesting to note that the assumed component of the allelopathic mechanism of the Tarahumara mustard (the roots and desiccated leaves) is different from that of the grassland black mustard of California (dead stalks).

The greater interrelationship between *Brassica campestris* and the Tarahumara can be seen not only in the increased dependence of the Indians upon this herb for quelites but by the necessity of the people to sow the seeds in order to increase the mustard population size and to produce plants with desired characteristics. The sowing of mustard seeds increases the density of the plant in an open habitat and also insures its availability during the end of the growing season when exploitation of spontaneous herbs is not possible. The seeds are generally collected from mustards grown during the previous year at the previous sown plots. Occasionally, if the stored seed lots are low, seeds may be obtained from spontaneous weeds in the maize fields of the current year. Although there is an intensification of the plant-man interaction and an increased interdependence of the mustards and the



C = Control; FW = Foliage Wash; R = roots; F = Foliage; Mn = Manure; Md = Medium. *, **, *** : significant differences at 5%, 2%, and 1%, respectively, by t-test.

Figure 1. Bioassay of *Brassica campestris* extracts on radicle growth.

Tarahumara above that of the gathered spontaneous weeds, the *Brassica* is not totally dependent upon human sowing practices for its sole mode of reproduction. This intermediate stage between spontaneous weed and domesticate is commonly referred to as the weed-crop stage and signals the beginning of the domestication process. As far as is known, the Tarahumara are the only group in the New World which has developed such an interrelationship with this introduced weed to this stage. Peruvian peasants occasionally collect and consume weedy mustards from grain fields and may be in the position in the future to further exploit this resource by active sowing but have not done so (Gade 1972). The Tzeltal Maya of Chiapas, Mexico, recognize two forms of weedy *Brassica campestris* which are gathered for potherbs in disturbed and cultivated fields, but they do not actively plant them (Berlin, Breedlove, and Raven 1974). The Tepehuan Indians to the south of the Tarahumara cultivate *Brassica campestris* (Pennington 1969). Although they eat the leaves of volunteer plants as quelites, the cultivated plants are sown in the spring for their seeds, which are prized as a condiment.

The seeds are stored in baskets or discarded oil cans and often amount to 4 or 5 liters. These containers are usually stored in the storage cribs along with other seeds of maize, beans, and squash. In late August and early September, the seeds are sown in fertilized plots. These plots are fertilized earlier in the year by corralled goats, sheep, and, in some cases, cattle. Between 20 and 30 animals may be kept in the corral, which is rotated over the fallow fields every 4 to 6 days. Generally one of the earlier fertilized plots of the current year is selected and the compacted soil broken and turned over. The seeds germinate readily, and the plants are ready for eating in 3 to 4 weeks (Figure 2). The density of the mustards in these plots may vary from 59 to 90 plants per square meter. One 10 m by 15 m corral plot may yield as much as 180,000 grams fresh weight of edible greens.

In contrast to *Brassica campestris* grown during the early and middle periods of the growing season, these fall plants do not readily flower. The number of leaves increases, the size of the leaves increases, and the hypocotyls and upper roots swell (Figure 3). Occasionally a flower stalk may emerge from a plant, but it is often pinched off by the woman attending the plot. Often lateral shoots are found on the plant with a pinched terminal inflorescence. The Tarahumara women, who generally are responsible for the mustard plots, prefer plants with large leaves which are picked off the plants early in the season (Figure 4). Towards the end of the mustard season, often after the first frost in early October, the whole plant is uprooted, the slender lower root removed, and the green leaves and white hypocotyl gathered. These plants may be taken home for immediate preparation for consumption or may be placed on top of a roof for sun drying and winter storage. Not all the plants are harvested from the plots, and frequently a third of the sown

Figure 2. Cultivated field of *Brassica campestris* with corral in background.

Figure 3. Cultivated plants of *Brassica campestris*. Note large leaves and swollen white hypocotyls. Plants approximately one-half actual size.

plants may remain in the fields over winter. A few older plants may have flower buds, flowers, and some fruits.

Two important points need to be examined. What is it that the Tarahumara see in *Brassica* when they grow it, and why does their sowing system provide the type of plants they seek? First, most of the Tarahumara asked indicated that the tasty green leaves and the crunchy, pungent white hypocotyls (or upper swollen roots as they see it) are the desired characteristics. The flowering stalk makes the plant bitter as a whole and indicates that it is dying. Therefore it is pinched off. An analysis of the biomass allocation indicates that nearly 80 percent of the dry weight of the weed-crop mustard is edible (Figure 5).

Figure 4. Tarahumara woman with bundle of leaves picked from cultivated *Brassica campestris*.

Second, the Tarahumara take adavntage of the photoperiodic response of *Brassica campestris*, which is known to be a facultative long-day flowering plant (Friend 1969). An experiment designed to demonstrate this phenomenon involved growing plants in a growth chamber with the same rooting medium (vermiculite), quarter strength Hoagland's solution, and diurnal temperature regimes (22 °C day; 15 °C night). Populations of plants grown from seed (Bye 7129-B) were raised under short days (8 hours light; 16 hours dark), neutral days (12 hours light; 12 hours dark), and long days (16 hours light; 8 hours dark). The results indicate that plants grown under short days and neutral days tended to allocate most of the biomass to vegetative parts such as leaves, hypocotyls, and roots, while plants grown under long days allocated more biomass to reproduction as seen in the decreased leaf biomass (numbers and dry weight) and increased stem weight, primarily associated with bolting of the flowering stalks and development of the inflorescences (Figure 6).

Comparison of the trends of biomass allocation in a sample of the Tarahumara weed-crop from the field (Bye 8401) collected in mid-October with that in the three experimental plant populations reveals that the field population more closely resembles plants grown under 12 hours of daylight (Figure 6). Plants grown under neutral days or short days tended to produce plants with relatively larger amounts of vegetative growth which is preferred by the Tarahumara.

The durations of daylight at Latitude 30° N (the Tarahumara region lies about 28° N) for mid-June, mid-July, mid-August, mid-September, and

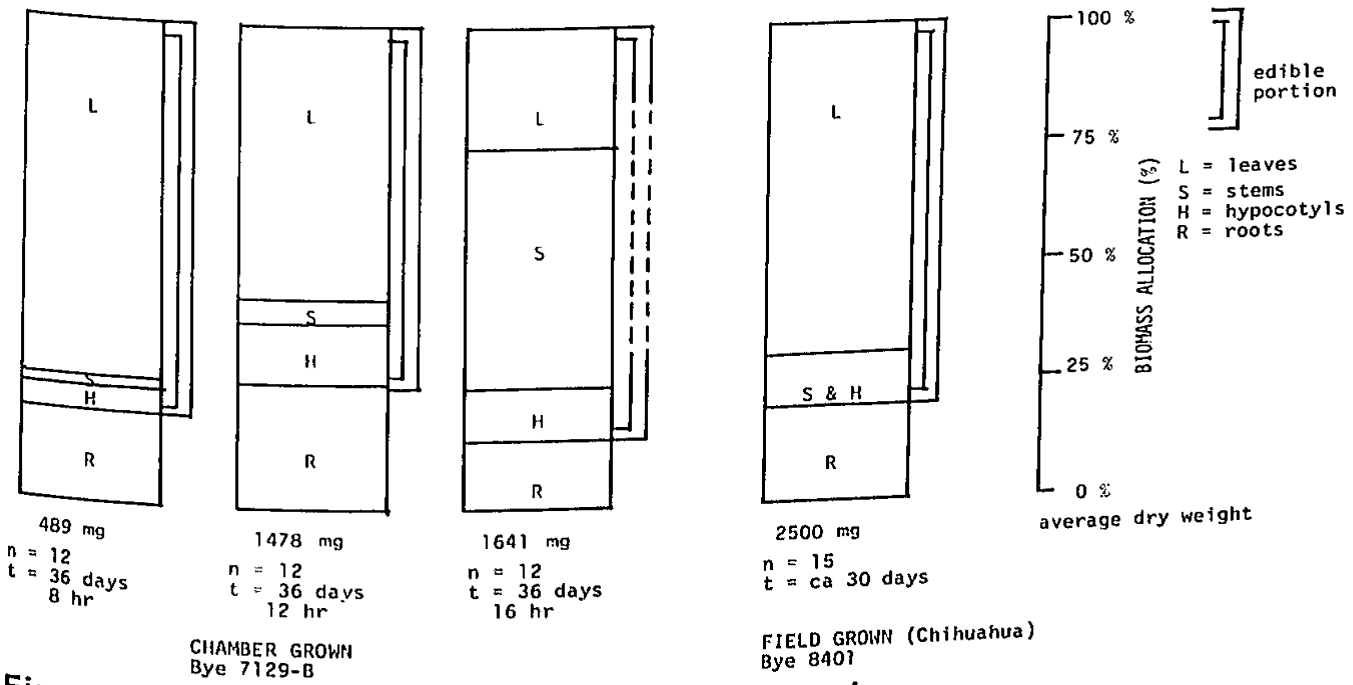


Figure 5. Biomass allocation in *Brassica campestris*.

mid-October are 14 hours 4 minutes, 13 hours 55 minutes, 13 hours 17 minutes, 12 hours 25 minutes, and 11 hours 32 minutes, respectively (Smithsonian Institution 1963). Therefore *B. campestris* growing in June-July is in the long day regime which promotes flowering and produces plants which are undesirable to the Tarahumara. Later in the growing season, however, shorter day lengths are near or below the critical photoperiod for flowering, and consequently vegetative plants are produced which are preferred by the Tarahumara. The Indians' recognition of the phenotypic plasticity of *Brassica* in response to photoperiod was critical to their extension of the period of availability and exploitation and to the increased yield of the quelites.

SUMMARY

One approach to studying the relationship between *Brassica campestris* and the Tarahumara is through the process of domestication. The interaction between the Tarahumara and this introduced weed presumably began after 1600. The introduced agricultural practices along with European cultivated plants which carried weed contaminants provided the opportunity for mustard to occur as spontaneous weeds in plowed fields. The introduced

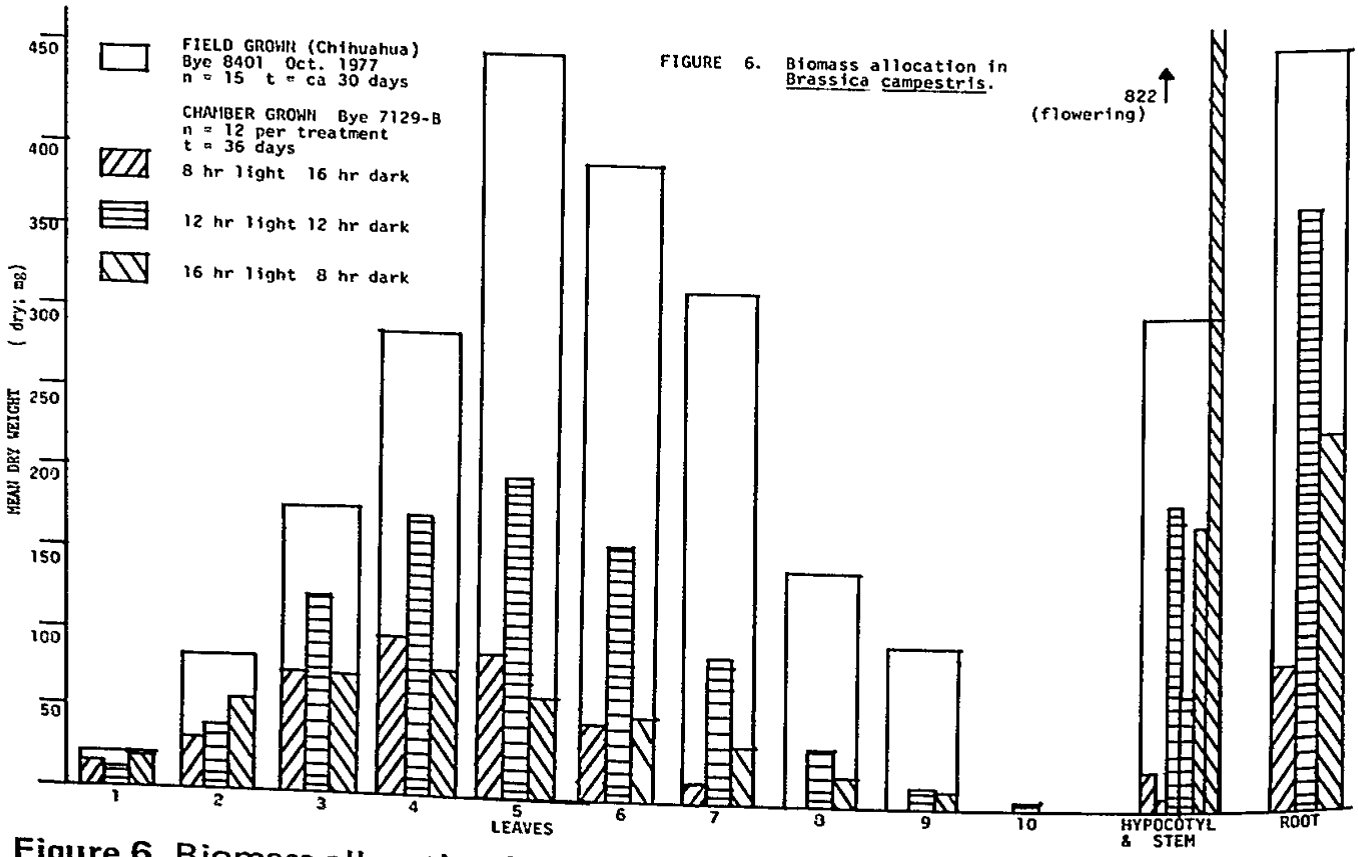


Figure 6. Biomass allocation in *Brassica campestris*.

plants were similar in appearance and taste to other native mustards and were gathered from disturbed areas as edible greens. The intensification of the exploitation of this food resource lead to the greater interrelationships of the Tarahumara and the mustard. The plant was incorporated into the folk classification and is referred to by the generic term, *mekuásari*. The plant has advanced to a weed-crop stage of domestication in which the seeds from weedy plants are consciously sown during a specific period of the year and in prepared habitats so that a greater proportion of the biomass of the plant is allocated to the preferred edible tissue and yield is increased. The Tarahumara activity is based upon the biological response of increased vegetative growth relative to reproductive growth of this long day flowering plant grown under short day conditions. Further selection and genetic fixation of such characteristics as swollen hypocotyls, biennial habit, or short day photoperiodic response may occur if the Tarahumara domestication process continues. One assumed by-product of the cultivation of *Brassica* in the highly fertile plots is the reduction in weed density during the following early growing season. This land use practice appears related to the potential allelopathic property of *Brassica*. The mustard — Tarahumara interrelationship may also be responsible, in part, for the apparent decline in the cultivation of a native weed-crop, *Lepidium virginicum*, and the domesticated *Cucurbita pepo*.

CONCLUSION

The interactions and interdependence of *Brassica campestris* and the Tarahumara have intensified over the past 300 years. The recognition of change in biomass allocation as a photoperiodic response is critical in evaluating the relationship and was apparently recognized as early as the 1770s (Falcon Mariano 1776). Because the seed source of these annuals may be from spontaneous weeds and previously sown plants and because annuals die out with the later frosts, the domestication process has only progressed to the weed-crop stage at this time. Conscious selection and propagation of seeds from plants exhibiting desired and genetically fixed characteristics must occur before the domestication process can proceed further and lead to domesticated forms.

This process may continue through one of a few pathways. First, it is possible that a biennial plant may evolve such that the plant is vegetative in the fall in one year, overwinters, and flowers and fruits during the next growing season. The swollen hypocotyl found in the weed-crops is similar to the domesticated European turnip which overwinters and flowers during the second year. Second, it is possible that the flowering, fruiting, and seed maturation could be compacted into the late growing season of the first year and the seeds gathered for the next year. Third, it is possible that a short day

flowering annual could evolve such that it is vegetative during the long days and flowers and fruits during the shorter days. A life history strategy must evolve so that selection for plants with genetically based characteristics can be carried on. The seed is critical in this process.

Also, other changes must occur in these selected populations. One factor is dormancy. Generally, domesticated plants have high and uniform rates of seed germination in contrast to wild and weedy relatives. The possibility is a relationship between mother plants of domesticated *Brassica* grown in the fall and high germination rates in contrast to spring grown mother plants which produce seed with low germination rates (Bruce Pollock, personal communication).

Clearly, more field and experimental data are needed to answer some of the basic questions raised in this preliminary investigation. By monitoring various populations of *Brassica campestris* and the Tarahumara who maintain them, a better understanding of the processes of interaction and interrelationship of plants and man in domestication can be derived and extend the present-day concepts in ethnobotany which focus on the exploitation and recognition of the vegetal resources in man's ambient environment. In addition, we can gain further insight into the possible pathways of domesticated vegetable crops. We may be able to test the proposal of Sinskaya (1928:612) dealing with the evolution of cultivated mustards:

> The introduction into cultivation has taken place, and is still taking place, in every region independently of any 'centre'. The cultivated forms are identical with local weeds; the local climatical ecotype being the first distributed as a weed, becomes afterward a cultivated crop.

The Tarahumara appear to be on the track of domesticating a local ecotype of an Old World weed in the New World independent of the European and Asian centers.

VOUCHER SPECIMENS

Field specimens of *Brassica campestris* are deposited at the following herbaria (abbreviations used here and in the text are in accordance with Index Herbariorum): ECON, CHAPA, COLO, GH, and MEXU. The plants were collected with permission of: the Tarahumara Indians, Secretaria de Agricultura y Ganaderia de México (Departamento de Forestales), Consejo Nacional de Ciencia y Tecnología de México, and Universidad Nacional Autónoma de México (Instituto de Biologia).

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REFERENCES

Baker, H. G.
1972 Human influence of plant evolution. *Economic Botany* 26:32-43.

Bell, D. T., and C. H. Muller
1973 Dominance of California annual grasslands by *Brassica nigra*. *American Midland Naturalist* 20:277-99.

Bennett, W. C., and R. W. Zingg
1935 *The Tarahumara, an Indian tribe of northern Mexico*. University of Chicago Press, Chicago.

Berlin, B., D. E. Breedlove, and P. H. Raven
1974 *Principles of Tzeltal plant classification*. Academic Press, New York.

Brambila, D.
1952 *Diccionario Raramuri – Castellano*. Misión Tarahumara, Sisoguichi, Chihuahua.

Crosby, A. W.
1972 *The Columbian exchange, biological and cultural consequences of 1492*. Greenwood Publishing Company, Westport.

De Wet, J. M. J., and J. R. Harlan
1975 Weeds and domestication: Evolution in the man-made habitat. *Economic Botany* 29:99-107.

Falcón Mariano, J. A.
1776 Descripcion de la Misión de Ntra. Sra. del Populo Guaguachic y sus anexas . . . (also known as Relacion Geografica de Guaguachic). Photocopy, Department of Geography, University of California, Berkeley.

Friend, D. K. C.
1969 *Brassica campestris* L. In *The induction of flowering – some case histories*, edited by L. T. Evans, pp. 364-75. Cornell University Press, Ithaca.

Gade, D. W.
1972 Setting the stage for domestication: *Brassica* weeds in Andean peasant ecology. *Proceedings of the Association of American Geographers* 4:38-40.

Harberd, J. D.
1972 A contribution to the cyto-taxonomy of *Brassica* (Cruciferae) and its allies. *Botanical Journal of the Linnean Society* 65:1-23.

Harlan, J. R.
1975 *Crops and man*. American Society of Agronomy, Madison.

Harlan, J. R., J. M. J. De Wet, and A. B. L. Stemler (editors)
1976a *Origins of African plant domestication*. Mouton Publishers, The Hague.
1976b Plant domestication and indigenous African agriculture. In *Origins of African plant domestication*, edited by J. R. Harlan, J. M. J. De Wet, and A. B. L. Stemler, pp. 3-19. Mouton Publishers, The Hague.

Hendry, G. W.
1931 The adobe brick as an historical source: Reporting further studies in adobe brick analysis. *Agricultural History* 5:110-27.

Hrdlicka, A.
1908 Physiological and medical observations among the Indians of southwestern United States and northern Mexico. *Bureau of American Ethnology Bulletin* 34.

Hutchinson, J., editor
1965 *Crop plant evolution*. Cambridge University Press, Cambridge.
1974 *Evolutionary studies in world crops*. Cambridge University Press, Cambridge.
Kennedy, J. G.
1970 *Inápuchi: Una comunidad Tarahumara gentil*. Instituto Indigenista Interamericano, Mexico.
1976 *Tarahumara of the Sierra Madre, beer, ecology, and social organization*. AHM Publishing Corporation, Arlington Heights.
Leung, W-T. W.
1961 *Food composition table for use in Latin America*. National Institute of Health, Bethesda.
Lionett, A.
1972 *Los elementos de la lengua Tarahumara*. Universidad Nacional Autónoma de México, México.
Lumholtz, Carl
1902 *Unknown Mexico*. Scribner's Sons, New York.
McNaughton, I. H.
1976 Turnips and relatives. *Brassica campestris*. In *Evolution of crop plants*, edited by N. W. Simmonds, pp. 45-48. Longman, New York.
Patiño, V. M.
1969 *Plantas cultivadas y animales domesticos en America Equinoccial. IV. Plantas introducidas*. Cali, Colombia.
Pennington, C. W.
1963 *The Tarahumar of Mexico*. University of Utah Press, Salt Lake City.
1969 *The Tepehaun of Chihuahua*. University of Utah Press, Salt Lake City.
Pickering, C.
1879 *Chronological history of plants*. Boston.
Relación de San Buenaventura
1776 Photocopy, Department of Geography, University of California, Berkeley.
Rice, E. L.
1974 *Allelopathy*. Academic Press, New York.
Ridley, H. N.
1930 *The dispersal of plants throughout the world*. L. Reeve and Company, Limited, Kent.
Schwanitz, F.
1967 *The origin of cultivated plants*. Harvard University Press, Cambridge.
Simmonds, N. W. (editor)
1976 *Evolution of crop plants*. Longman, New York.
Sinskaya, E. N.
1928 The oleiferous plants and root crops of the family Cruciferae. *Bulletin of Applied Botany, Genetics and Plant Breeding* 19(3-5):1-648.
Smith, P. G., and J. E. Welch
1964 Nomenclature of vegetables and condiment herbs grown in the United States. *Proceedings of the American Society of Horticultural Science* 84:535-48.
Smithsonian Institution
1963 Smithsonian Meteorological Tables. Washington, D.C.
Thord-Gray, I.
1955 *Tarahumara-English, English-Tarahumara dictionary*. University of Florida Press, Gainesville.
Ucko, Peter J., and G. W. Dimbleby (editors)
1969 *The domestication and exploitation of plants and animals*. Aldine-Atherton, Inc., Chicago.
Varma, S. C.
1938 On the nature of competition between plants in the early phases of their development. *Annals of Botany* 2:203-25.