Dynamics of Andean Potato Agriculture[1]

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The invention and development of agriculture created tremendous diversity among the species selected for domestication. This diversity is still evident in cradle areas of domestication, maintained as ancestral varieties or landraces by traditional farmers. These centers of diversity have been recognized as imporant since N. I. Vavilov's work 50 yr ago. Archaeologically, they are significant because of their association with the origins of agriculture and the resulting new way of life for human populations. Genetically, they are important to geneticists and plant breeders as sources of germ plasm for the improvement of our modern crop varieties and for backup crop genetic resources (Harlan, 1976; Oldfield, 1979). Moreover, they are areas where ongoing crop evolution occurs in and around fields. They can thus provide information as to the ancestry of modern crop cultivars and enable us to understand better the genetic architecture of our modern domesticates.

Although extensive germ plasm collecting and archaeological and botanical research have been undertaken in these areas of crop evolution and crop genetic diversity, our knowledge of the dynamics and systematics of traditional agriculture that supports this diversity remains rudimentary. Little anthropological or ethnobotanical investigation has concerned itself directly with how farmers in these areas identify, select, maintain and distribute the diverse genetic material of their crops. This lack of research contrasts sharply with recent advances in understanding the overall patterns of folk plant classification (Berlin et al., 1974; Conklin, 1972; Witkowski and Brown, 1978) and the wealth of material on the socioeconomic dimensions of traditional agriculture (e.g., Halperin and Dow, 1977; Wharton, 1969). The lack of detailed historical studies of genetic resources and agriculture in areas of crop diversity hampers our ability to model the dynamics of primitive selection, but it does not preclude attempts to extrapolate from synchronic analysis.

There is mounting evidence from virtually every center of crop genetic diversity of the vulnerability and loss of primitive germ plasm, a problem popularly known as "genetic erosion," the replacement of complex assemblages of ancestral genetic material by more uniform hybrid and high yielding varieties (e.g., Eckholm, 1978; Harlan, 1975a; Frankel and Hawkes, 1975; Myers, 1979; Oldfield, 1979). By understanding the dynamics of the agricultural systems being affected by genetic erosion, we might gain a better idea of how to cope with these endangered resources (Brush, 1980). Human cultural diversity plays an essential role in the continuing evolution of these valuable primitive crop genetic resources (Harlan, 1975a), and the crop system of agricultural people maintaining these resources

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Economic Botany, 35(1), 1981, pp. 70–88

provides an excellent arena for interdisciplinary ethnobotanical research. This article reports some results of recent interdisciplinary investigation by anthropologists, botanists and geneticists of one such crop system, that of the potato in the Peruvian Andes. Its objective is to describe patterns of identification, classification and distribution of primitive varieties in areas where subsistence production predominates. The article is also concerned with the maintenance of native varieties in areas where improved varieties have diffused during the past 3 decades.

ANDEAN POTATO

Two lines of evidence, archaeological and genetic, indicate that potatoes were first cultivated in the central Andes. Excavations in the central highlands of Peru indicate the tuber may have been cultivated by 5,800 B.P. (Pickersgill and Heiser, 1978, p. 821; McNeish et al., 1975, p. 30). Engel (1970) suggests an even earlier date of 8,000–10,000 yr ago for original domestication in the central Andes. Other archaeological evidence for Andean domestication includes the use of potatoes as an effigy in pre-Hispanic pottery (Towle, 1961). Genetically, the richest gene pool of potatoes, estimated by geneticists and taxonomists at 2,000–3,000 varieties, is found in the Andes. The area thus represents a center of domestication for the potato by Vavilov's definition (Vavilov, 1926; Harlan, 1971; Simmonds, 1976).

Europeans recognized the importance of the potato for Andean people soon after the Spanish conquest (Hawkes, 1967). More recent students of Andean society have noted the relationship between types of potato production and the expansion of prehistoric states in the area (Troll, 1958). There is a growing literature on socioeconomic aspects of potato production and use in the Andes (Werge, n.d.). Of particular importance are recent and detailed studies of potato production systems in the central Peruvian Andes (Franco and Horton, 1979).

The diversity of Andean cultural features associated with the potato is especially evident in the classification, selection and distribution of species and varieties to be discussed below. Very little ritual is associated with potatoes (Murra, 1960). A fairly elaborate variety of storage techniques and facilities are used (Werge, 1977). During storage, potatoes are protected from worm infestations by placing the tubers on layers of *muña* (*Minthostachys* spp.). No native strategies to control pest and pathogen infestation in the cultivated field were observed. Pathogens, especially golden and cyst nematodes, are reduced by a system of sectoral fallowing widely practiced in the Andes. Under this system (Mayer and Fonseca, 1979), potatoes are cultivated for 1 or 2 yr, followed by short rotations of other tubers (e.g., *Oxalis tuberosa*), grains (e.g., *Chenopodium Quinoa*) and fallow. A period of 6 or 7 yr elapses between potato plantings. Processing is confined to the freeze-drying of bitter species and wormy non-bitter tubers, fermentation in running water (to produce *tokosh* or *tongosh*), sun drying, and very limited production of starch (Werge, 1979).

Cooking is almost always done by simple boiling or steaming, and skins are not eaten. A favorite variation in cooking is the construction of sod and fieldstone ovens (*watia* or *pachamanca*) for roasting potatoes at harvest time. Chili peppers (*Capsicum* spp.) are the usual condiment with steamed potatoes, and special herbal concoctions, often based on *wakatay* (*Tagetes minuta*), are served with the tubers. Although nutritional data on subsistence-level farmers in the Andean highlands is inconclusive, little clinical evidence exists to indicate problems of malnutrition or protein deficiency in Andean populations with a high dependency on potatoes (Picón-Réategui, 1976). The basic culinary standard for potatoes is dry matter content. High dry matter is esteemed, and such potatoes are described as *machka* in Quechua or *harinosa* (floury) in Spanish. A puzzling aspect of this preference is the inverse relationship between dry matter and protein content (Gray and Hughes, 1978). Why should people who depend on potatoes, a low protein food, prefer those varieties that are lowest in protein? A possible explanation for this is that amongst primitive potato cultivars there is great variation in dry matter and protein content. A number of them have high dry matter and high protein content (Huamán, 1978).

CLASSIFICATION OF CULTIVATED POTATOES

Potatoes are included in the section Petota of the genus *Solanum* (Hawkes, 1978). That section includes 154 wild tuber-bearing species, 90 of which are found in the Andes of Peru and Bolivia (Hawkes, 1978). Today, 3 different taxonomic systems are used by scientists working with cultivated potatoes. The Dodds system divides the cultivated potatoes into 3 species (Dodds, 1962), and a Russian system recognizes 18 cultivated potato species (Lechnovich, 1971). The third, and most widely used system, was devised by Hawkes and classifies 8 cultivated species (Hawkes, 1978). In all 3 systems cultivated potatoes are divided into 4 ploidy levels, ranging from diploid ($2n = 24$) to pentaploid ($2n = 60$). The Hawkes taxonomic system was utilized in this research.

By far the most ubiquitous species in the Andes is the tetraploid *Solanum tuberosum* subsp. *andigena* (Juz. et Buk.) Hawkes. Also commonly found are the diploids *S. stenotomum* Juz. et Buk., *S. goniocalyx* Juz. et Buk., and *S. phureja* Juz. et Buk., as well as the triploid *S.* × *chaucha* Juz. et Buk. Similarly widespread are the 2 frost-resistant species generally grown at higher altitudes and processed by freeze-drying to remove glycoalkaloids. These 2 species are the triploid *S.* × *juzepczukii* Buk. and the pentaploid *S.* × *curtilobum* Juz. et Buk. Another diploid, *S. ajanhuiri* Juz. et Buk., is endemic to southern Peru and northern Bolivia.

The origin of the potato grown in Europe and North America, *S. tuberosum* subsp. *tuberosum* (Juz. et Buk.) Hawkes, has been the object of much debate (Hawkes, 1967; Salaman, 1949; Simmonds, 1976). The prevailing opinion holds that this subspecies, adapted to long photoperiod, resulted from European selection of *andigena* varieties brought to Europe following the Spanish conquest of the Andes. Recent cytogenetic research, however, suggests confirmation of an earlier theory that the progenitors of modern *tuberosum* varieties were from southern Chile—from the Chiloe Archipelago (Grun et al., 1977). Genetic material from European and North American *tuberosum* varieties has been introduced to the central Andes by the diffusion of new varieties from national and international breeding programs.

The diploid *S. stenotomum* is widely regarded as the most primitive of the domesticated species (Hawkes, 1967). The other 7 cultivated species were derived through various processes including mutation, mitotic and meiotic polyploidization, intra- and interploidy hybridization, and selection. It appears that the process of potato evolution, through polyploid development from primitive diploids, has been one of increasing genetic isolation of cultivated from wild potatoes. There is evidence that variation in the cultivated potatoes has been increased by hybridization between *S. stenotomum* and some wild potatoes (Hawkes, 1962; Huamán, 1975). At the diploid level, hybridization is favored by a mechanism of self-incompatibility. At the tetraploid level, on the other hand, hybridization in nature is more difficult because of self-compatibility. Undoubtedly, man's role as a selective agent is felt on all levels. Characteristics such as lack of tuber dormancy in *S. phureja,* frost resistance in *S. ajanhuiri, S.* × *juzepczukii* and *S.* × *curtilobum*, good palatability in *S. goniocalyx* and adaptation to long daylight in subsp. *tuberosum* are probably examples of traits selected for by humans.

Botanically, only 3 of the 8 cultivated species are identified without much difficulty by means of morphological characteristics. In the rest of the cases, chromosome counts to determine ploidy level are necessary to arrive at certain species identification. Below these levels, there are vast numbers of distinct clones, numbering in the thousands. The International Potato Center has developed a set of 53 plant and tuber descriptors to determine the identity of any single clone (Huamán et al., 1977). As in species identification, however, morphological characteristics are often uncertain, and some chemotaxonomic techniques such as electrophoresis are used to establish other identifying criteria for clones (Desborough and Peloquin, 1968; Stegeman and Loeschcke, 1976). Electrophoresis relies on the fact that each individual potato clone has a unique combination of proteins which are separated according to electrical charge and molecular weight.

As with other crops in their cradle areas of domestication, potato variation in the Andes is expressed by the existence of numerous landraces of native varieties. These are adapted to the conditions of traditional agriculture, such as low soil fertility, low plant populations, and low yield (Harlan, 1975b). Although variable, they are locally identified and named. In the case of the vegetatively propagated potato, landraces found within a single locality are comprised of a number of discrete genotypes, or clones, which are individually named.

Native agriculture associated with this diverse genetic material has 3 consequences: (a) the maintenance of numerous genotypes over space and time, (b) the wide distribution of particular genotypes, and (c) the generation or amplification of new genotypes. In order to understand these consequences, major cultural patterns of traditional potato agriculture in the Andes must be examined in relation to the genetic diversity of that crop. These patterns include the identification and naming of varieties, the selection and planting patterns of different varieties, and the exchange of varieties within and between localities. Another significant feature of native agriculture relevant to genetic diversity of potatoes is the presence of wild and weedy potatoes in and around fields. This promotes the introgression of germ plasm from those sources into cultivated stocks (Ugent, 1968).

Two principal types of studies have attempted to document the diversity and distribution of native potato cultivars in Peru. First, germ plasm has been collected for plant breeding since 1925 by numerous national and international expeditions (Hawkes, 1941; Ochoa, 1975a). Second, in order to detail more accurately and comprehensively the varietal frequency and distribution of native cultivars, ethnobotanical studies on a much smaller scale have been carried out in Peru (Jackson et al., 1980) and Mexico (Ugent, 1968). There remains, however, a dearth of information concerning the selection and planting patterns of traditional farmers responsible for the frequency and distribution of cultivars. The naming system of Andean farmers for native potato varieties has been examined by several scholars. Hawkes published over 1,000 potato names from the Andean region (Hawkes, 1947), and large individual collections from more specific regions have been published (Vargas, 1949, 1956). La Barre (1947) analyzed some 200 names from the Aymara around Lake Titicaca, noting the taxonomic structure of this nomenclature.

Our research attempts to relate botanical and cultural aspects of traditional Andean agriculture in a systematic fashion and to address several issues not included in earlier work. These issues are: a) the consistency of the native system of classification, b) the spatial distribution of names and types, c) the relationship between farmer preference and the frequency of genotypes, and (d) the agricultural regimes of small farmers applied to traditional varieties and to new hybrids and high yielding varieties.

STUDY AREA AND SAMPLING

Ancestral types of potatoes are grown throughout the Andes from Venezuela to northern Chile, with the greatest concentration of diversity in the central Andes of southern Peru and northern Bolivia. In the Peruvian Andes, where this research took place, they are grown at elevations between 3,000–4,200 m. This effective range of potato cultivation can, in most areas, be subdivided into 3 zones: 1) a commercial zone, 2) a zone of primitive, ancestral classes of non-bitter potatoes, and 3) a zone of bitter potatoes. Between 3,000–3,600 m, growing conditions are optimal, especially because of lack of frost. In most major valley systems between these elevations, potato production is often commercial, oriented to producing marketable, edible potatoes and "seed" potatoes with modern agricultural technology: the heavy use of commercial fertilizers and insecticides, machinery, and improved, high-yielding varieties for "seed." Even small scale, subsistence-oriented potato production in this zone relies primarily on these improved varieties (Franco and Horton, 1979). Above 3,600 m, peasant, subsistence-oriented farming, utilizing more traditional agricultural technology and primitive cultivars of potato is found. This technology usually involves communal control of agricultural lands, cooperative labor, a short cultivation/long fallow cycle, the use of traditional Andean farm implements such as the *chakitaklla* (footplow), and a lack of dependency on nonlocal inputs of chemicals and energy (Brush, 1977; Gade, 1975). This area may be divided into 2 zones. Between 3,600–3,900 m non-bitter potatoes are produced. Above 3,900 m bitter, frost-resistant potatoes are grown and converted into *chuño* by freeze-drying. Most households in this area produce both types of potatoes, as well as other Andean and European crops.

Two general study areas were chosen for research: the Mantaro Valley region around the city of Huancayo in the central Peruvian highlands and the Vilcanota Valley region around the city of Cuzco in southern Peru. In each area, natural vegetation zones of the traditional potato-producing areas were similar, varying between moist and wet tropical montane forest zones of the Holdridge system

(O.N.E.R.N., 1976). Generally, as one moves westward from the central Mantaro and Vilcanota Valleys, rainfall decreases to 600 mm, and frost occurs in May or June. As one moves eastward, rainfall averages 800–1,000 mm, and frost usually occurs in July or August. Topsoils along the eastern slopes are considered more fertile. In both the Mantaro and Vilcanota areas, the greatest diversity of potatoes occurs along the eastern slopes, and potatoes lose predominance to cereals as one moves westward (Mayer, 1977).

Within both regions, certain areas have been heavily influenced by changes in the types of "seed," technology and household economy occurring with the rise of commercial potato agriculture. These changes are especially evident close to the major urban centers, Huancayo and Cuzco, and along major roads.

In both the Mantaro and Vilcanota areas, villages were visited for the purposes of collecting potatoes and their associated nomenclature, observing and discussing farming methods applied to potato cultivation, and mapping fields for the distribution of genotypes. Information was collected to allow analysis of name and varietal distribution across 5 different social and spatial levels: field, household, village, microregion and region. Certain villages were sampled because they occupied different points on the same "seed" distribution networks. In the Mantaro region (Fig. 1) collecting was done in 25 villages over an area of roughly 4,000 $km.^2$ Villages were sampled in microregions (defined by small river valleys) and over broad, ecologically and linguistically diverse areas. Two villages were selected for more intensive research. Here collecting was done from a larger number (10–15) households, visits were made throughout the research period (September 1977–June 1978), and formal and informal interviews were conducted. In the Vilcanota area, collections were made from 4 villages. Here, fieldwork occurred in 2 periods, at planting and during the florescence of the potato fields (November and March).

Tuber samples of native cultivars were treated in 3 fashions. First, a collection of 486 tubers, from 4 villages and 29 farmers was planted; species and data on 18 stem, flower and tuber characteristics were recorded to determine genetic similarity or dissimilarity. Information from field mapping was used to augment the number of plants and names to be compared by over 500 cases. Second, tubers from the test plot and a large number of tubers collected from farmers during harvest were described according to 9 tuber characteristics and scored against a standard. Third, tubers were grouped according to local name, and tubers within groups were compared in 2 ways: by visual assessment and by electrophoresis. About 700 samples, divided among 86 groups, were compared by one or both of these methods. Forty groups and 200 samples were subjected to vertical slab electrophoresis (Stegeman and Loeschcke, 1976). The total sample contains 262 named varieties from the Mantaro region and 45 from the Vilcanota region.

From January through March, when potato fields were blooming, 19 fields were mapped, 11 in the Mantaro region and 8 in the Vilcanota region. Fields were chosen to reflect degrees of selection, from highly heterogeneous to generally homogeneous plantings. Three different sampling strategies were employed: 1) all plants, particularly in smaller fields containing great variety and mixture of clones, 2) transects—alternate rows, or every few rows, in the more homogeneous fields, and 3) quadrats, often combined with transects, especially in larger fields or groups of fields where varieties appeared to be clustered. In all fields, native

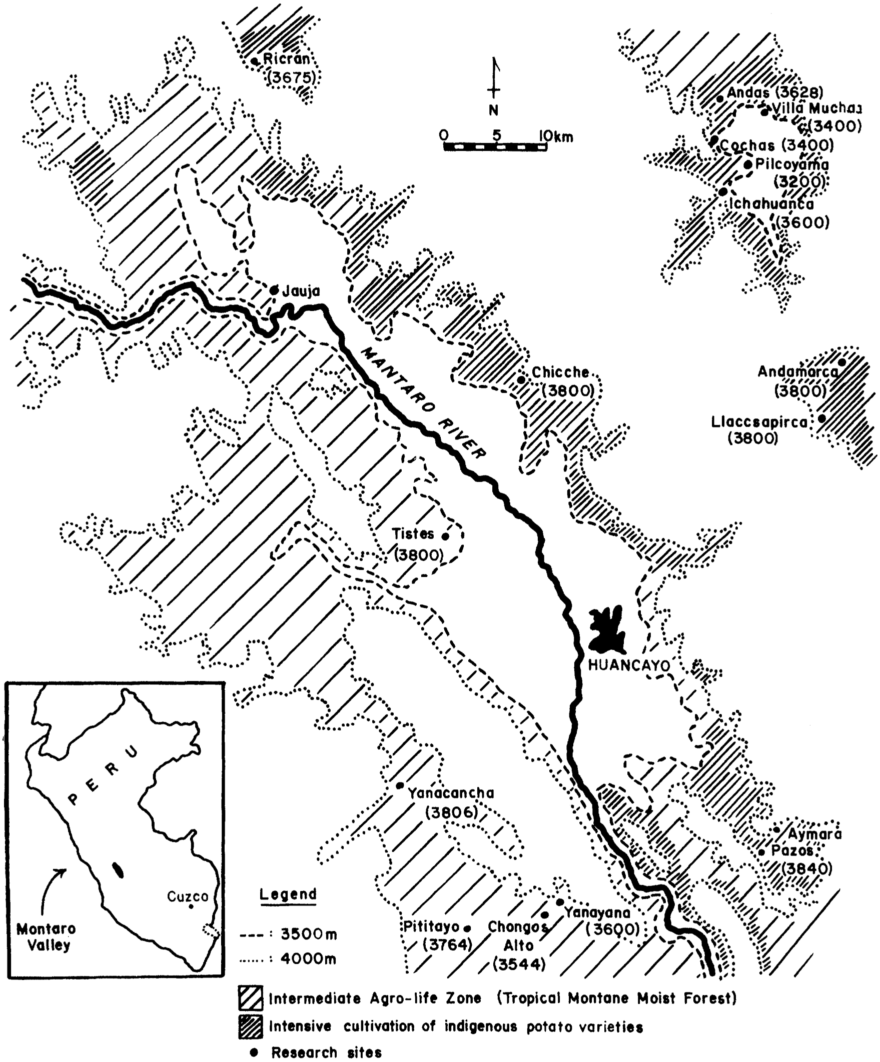

Fig. 1. Location of areas of potato cultivation and research sites in Mantaro Valley region.

informants provided local names and other information about the field. For all potato varieties encountered, the native name was noted, and plant and tuber characteristics were recorded using the International Potato Center's descriptors. Species were determined according to morphological indicators and by cytogenetic investigation to determine ploidy level (Tarn, 1967).

FOLK TAXONOMIES OF CULTIVATED POTATOES

The native classification of potatoes in the areas investigated involves 4 levels arranged taxonomically, beginning at the folk generic level and descending to the subvariety level. The term *papa* is used universally for all tuber-bearing *Solanum* species, although regional dialects may use another term, as in the Mantaro region where *akshu* replaces *papa*. As a folk genus, potatoes are distinguished from other Andean tubers (e.g., *Oxalis tuberosa* and *Ullucus tuberosa*). Below this level, potatoes are grouped into 4 distinct folk species, according to 4 criteria: a) cultivation, b) edibility, c) processing, and d) frost resistance. In the Mantaro region these 4 folk species are:

1) *akshu:* cultivated non-bitter potatoes with little or no frost resistance.
2) *shiri-akshu:* cultivated bitter potatoes which must be processed by freeze-drying to remove glycoalkaloids before eating; frost resistant.
3) *kurao-akshu:* edible, semidomesticated (uncultivated) potatoes found in midaltitude maize fields; no processing required and not frost resistant.
4) *atoqpa-akshu:* unedible, wild potatoes; some frost resistant. Literally, "fox's potato," perhaps to distinguish them from cultivated potatoes that are sometimes fed to dogs.

At the folk species level cultural divisions are clearly related to botanical species divisions. All wild, tuber-bearing *Solanum*s are lumped into the *atoqpa-akshu* class; *shiri-akshu* is comprised of *S.* × *juzepczukii* and *S.* × *curtilobum*; and the other domesticated potato species grown in the area are grouped together as *akshu*. The botanical components of the semidomesticate *kurao-akshu* have not been established, but they may be escaped *S. tuberosum* subsp. *andigena*.

Below the folk species level, the *akshu* and *shiri-akshu* groups divide into locally named varieties, based on tuber characteristics. The former has up to 100 of these named varieties in a single locality, while the latter generally has only 4. These are distinguished according to tuber skin color, meal color and consistency, tuber shape and configuration of the eyes. Some plant features, such as flower and stem color are included in the naming system, but this is rare. During field mapping, however, it became apparent that a number of clones were widely recognized for their plant characteristics as well as for their tubers.

The primacy of tuber shapes and colors in the native classification is apparent in many names. Examples include *calhuay* ("weaver's shuttle") for a long flat variety, *mishipasinghan* ("cat's nose") for a round, compressed cultivar with shallow eyes concentrated in the center, *lumchipamundana* ("potato which makes the young bride weep") for a knobby, convoluted variety, *turumangia* ("rainbow") for a multicolored type, and *chunchupañahuin* ("eyes of a jungle person") for a dark-skinned potato with light colored eyes.

The average farmer growing these varieties can name about 35 types, a number which varies according to the experience and interest of the individual. In a single locality, 50–70 potato names may be found, but perhaps 10–20% are synonyms. In gathering potato nomenclature, some informants were obviously casual and careless in naming tubers, while others were meticulous and conscientious. The latter were generally able to discuss the characteristics of a particular tuber and why it should or should not be classed as a particular variety. This indicates the presence of implicit rules in the naming and classification of tubers. Rules were also evidenced when a group of farmers was presented with a set of tubers to name. Detailed and sometimes animated discussion took place concerning the tuber in question. A name would be suggested and debated: "no this cannot be a *huayru* because it is too flat and not mealy enough, perhaps it is an *ichipsa*." In some cases, a dozen names were suggested and rejected by reference to numerous criteria. In others, a tuber was immediately recognized and named without debate.

TABLE 1. PERCENTAGES OF VISUALLY SIMILAR AND ELECTROPHORETICALLY IDENTICAL TUBERS IN LIKE-NAMED GROUPS.

	Visual		Electrophoresis	
Spatial level	No. of comparisons	% similarity	No. of comparisons	% identity
Locality	372	81.2	231	75.8
Microregion	512	71.7	185	40.5
Region	3,694	74.3	967	48.7

The fourth, and lowest, taxonomic level in the native classification is that of subvariety. This is based on secondary tuber characteristics, principally variations in tuber color. Examples are *puca suito, yurac suito* and *yana suito* which have morphologically similar tubers but with red, white and purple skin color, respectively. Twenty percent of all varieties have subvarieties, varying from 2–8. Subvarieties are not as widely recognized or agreed upon as the varietal denomination and may be considered of minor importance in the overall scheme. It appears to be equivalent to native recognition of polymorphism among closely related types.

It may be assumed that the naming system of farmers is closely related to their knowledge of potatoes on such matters as selection (Rosch and Lloyd, 1978). Consistency of the naming system, therefore, is a key issue. If the system were found to be random or highly capricious, the relevance of native selection procedures for understanding the botanical structure of Andean potato agriculture would be in question. Our research indicates, however, that the naming system is not random.

A clear indication of the consistency of the naming system is based on visual assessment of the similarity of tubers in like-named groups. The results of this comparison are reported in Table 1 along with results of electrophoretic comparison of tubers in the same groups. Tubers are compared at 3 spatial levels: those from the same locality, those from different localities in a single microregion (clustered according to geographic features such as a river valley), and those from the entire Mantaro survey region (4,000 km^2). Like-named tubers from the same locality were judged to be morphologically similar and electrophoretically identical at a high rate. It seems probable, therefore, that potatoes given the same name by farmers in one village are clones. This probability, however, falls off sharply as one leaves a locality. Even at the microregional level, most electrophoretic comparisons between like-named tubers showed them to be dissimilar. The native classification, however, is consistent at all 3 spatial levels when judged by the criteria of tuber similarity. Potato names are, thus, meaningful both within and beyond village boundaries. Andean farmers have a particular type of tuber in mind when a name is given, and this association holds over a large region. Biologically, these names are generally meaningful within a village and less so beyond.

Beyond different farmer aptitudes in naming, variation in the native classification may be linked to 3 factors. First is the very nature of folk taxonomy. This is based on implicit and usually unexpressed rules rather than on explicit ones. Second is the polymorphism of potato clones and the effects of different environmental conditions on the development of tubers. Third is the possibility of inter- and intra-ploidy hybridization producing new clones. This occurs within cultivated fields, and the presence of wild species surrounding fields makes the introgression of wild germ plasm into cultivated stocks likely, especially at the 2× level. Andean farmers are familiar with "ground keeper," or uncultivated, potatoes in their fields. These are referred to as *kipa* throughout Peru. Farmers are generally unaware of the possibility of sexually reproduced potatoes developed from true botanical seed and associate *kipa* with unharvested tubers from previous plantings. Although no formal mechanism for the incorporation of new clones into the native system was evident, an informal mechanism may exist. While most cultivars seem to be named according to relatively narrow, albeit implicit, rules, a few names are applied to tubers of dubious similarity. In some cases, these names appeared almost to constitute residual categories. New and unusual clones might easily be classified under these names. Many of these names were applied to diploid and triploid tubers. The former are likely to hybridize with wild germ plasm, and the latter are products of hybridization between diploids and tetraploids.

The relevance of the native practice of naming potato varieties to the botanical structure of Andean potatoes is indicated in 2 ways. First, there are indications of a close relationship between tuber morphology and genotypic identity in this and other research (Jackson, 1977). Therefore, a naming and selection system based on tuber morphology, such as the native Andean classification of potatoes, should have definite biological implications. Second, ethnographic information indicates that potatoes are usually exchanged and distributed according to native name. Exchange of potatoes between families was commonly referred to in terms of specific locally named varieties. Farmers in one village generally know which households have certain named varieties and their particular agronomic, culinary and perhaps commercial characteristics. When asked about a particular variety, farmers often reported that they did not have it but that it could be found in a particular household and where it was cultivated. Furthermore, it was reported that traders and farmers from other villages, sometimes distant, often request particular named varieties. Indeed, place names were commonly attached to certain varieties.

SELECTION AND MAINTENANCE OF NATIVE VARIETIES

As Harlan (1975b) points out, landraces of traditional crops are products of human selection for such characteristics as color, flavor, texture, and storage quality. The importance of these characteristics to Andean potato farmers is indicated in their naming system for potatoes. Selection may be observed in the planting patterns of potato fields and in the spatial distribution of particular varieties within a region. Although studies of native potato fields in Peru (Jackson et al., 1980) and Mexico (Ugent, 1968) have demonstrated field heterogeneity, our research indicates that the selection of ancestral varieties is more complex than previously thought. We found fields of all types of potatoes to be generally orderly. Rows were well kept, with relatively few weeds and little evidence of wild species within fields. At the margins, however, wild species were sometimes common. In the Mantaro region, "seed" tubers were usually planted individually.

In Cuzco, the more heterogeneous fields were planted in clumps containing 3–5 "seed" tubers. Selection involves planting some fields with relatively homogeneous stands of preferred varieties, as well as the maintenance of heterogeneity in others.

Three types of selection of potatoes by Andean farmers may be observed. First, on the level of folk species, non-bitter potatoes (*papa* or *akshu* in the native nomenclature) are grown separately from bitter potatoes (*luki* in southern Peru, *shiri* in the central region). In some fields around Cuzco, these varieties were interplanted, but this was never observed in the Mantaro region. Second, within the non-bitter group, certain preferred varieties are selected and grown in uniform plantings, apart from the heterogeneous collections in other fields. Third, high yielding varieties originating from breeding stations are often grown separately from native varieties. Selection may be observed in fields, in the terminology for fields, in the technology applied to different fields, and in the farmer's objective in planting different fields.

Within the native variety class of potato, selection of non-bitter potatoes establishes 2 kinds of fields. The first are fields where varieties are mixed and randomly planted. In the central highlands, such fields are referred to as *chacro*. Throughout Peru, this is the most common kind of potato field. "Seed" for this kind of field is selected for "seed" quality and size rather than for variety. The traditional planting procedure is to sow "seed" tubers into holes opened by the footplow. As many as 5 small tubers may be dropped into a single hole. When planting new land, potatoes are often planted into holes opened in untilled soil, a practice known as *tikpa*. After roughly 6 wk, the sod around each clump is turned over and mounded against the plants. The fertilizer generally applied at planting is animal dung. The objective for planting these heterogeneous fields is almost invariably to produce potatoes for home consumption. The mixture of colors, shapes, textures, and flavors enhances a diet in which many meals consist entirely of potatoes garnished with a hot pepper sauce. The native varieties are also believed to retain palatability and viability as "seed" over many months of storage.

Varietal heterogeneity of native potato fields is one of their most important attributes. The crop evolution of the cultivated potato is closely linked to the mixture of species and genotypes which promotes hybridization and crossing between ploidy levels and among clones. Table 2 summarizes the frequencies of ploidy levels and cultivars in ten fields sampled in the Mantaro Valley. The predominance of tetraploid tubers is typical for fields throughout the Andes. Pentaploids are not found in this sample since they are bitter, frost resistant potatoes grown at higher altitudes. Fig. 2 depicts a quadrat from a mixed field outside the village of Umasbamba, north of Cuzco. This field was planted by an officer in the local religious hierarchy, its harvest intended for a *fiesta*. Forty-six named varieties were randomly planted in the field, with 2 clones frequently growing from a single planting.

Besides these heterogeneous collections of native varieties, it is common for farmers throughout the Andes to select and maintain more uniform plantings of native potatoes. Selection of this type is done by farmers who market native cultivars or who are involved in "seed" distribution networks of native varieties. Selection is by "seed" quality and by variety. It usually occurs at harvest when

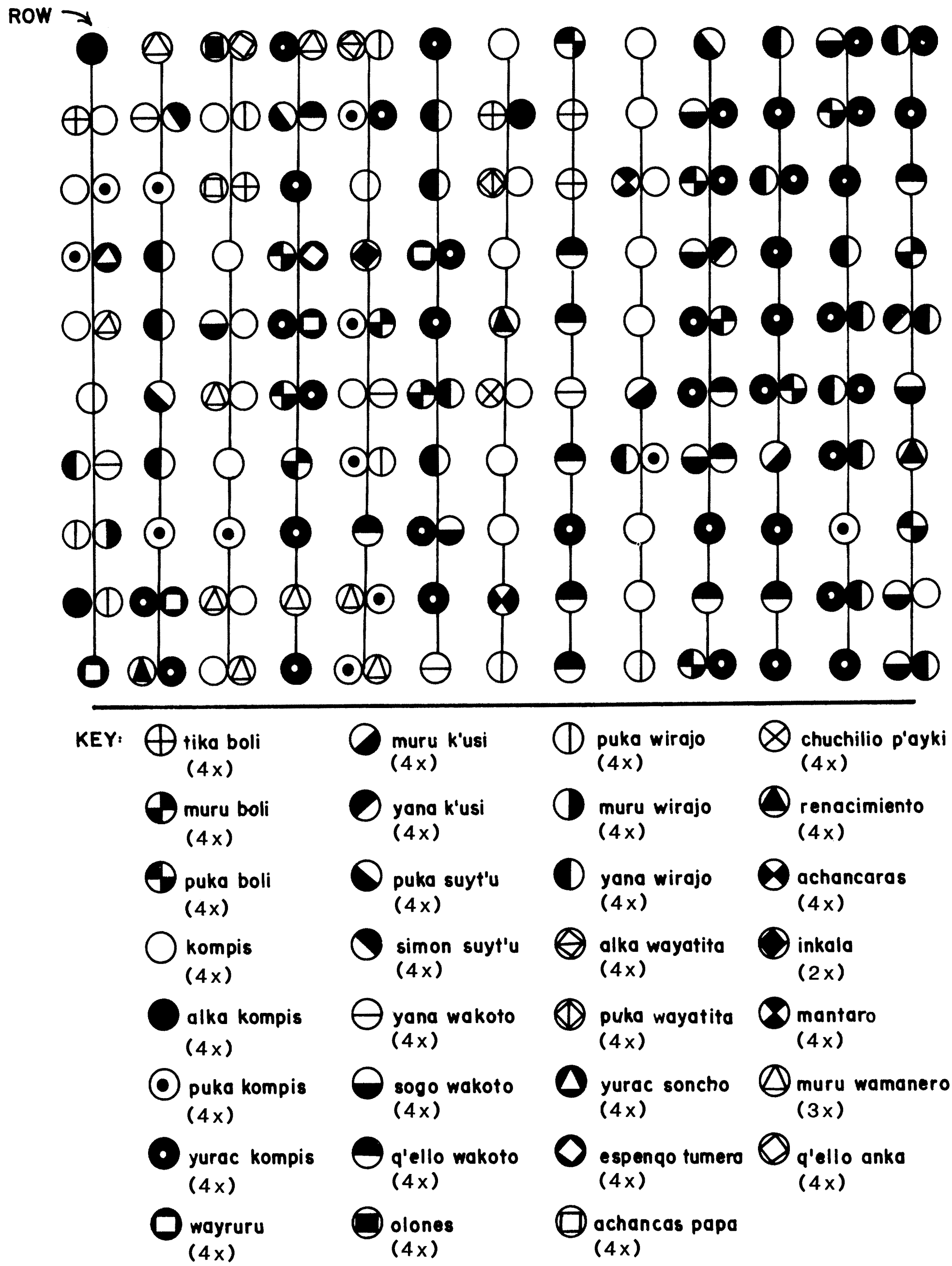

Fig. 2. Quadrat of native varieties of potato in field near Chinchero, Cuzco Dept., alt. 3,820 m.

"seed" tubers of different varieties are sorted and stored in separate mounds. Selection may also occur at planting time when "seed" tubers are desprouted. Selection of these preferred varieties relates to their demand in markets and trade networks for "seed" tubers. Important characteristics affecting this demand are culinary quality and special agronomic qualities such as frost or late blight (*Phy-*

TABLE 2. CUMULATIVE PLOIDY AND CULTIVAR FREQUENCIES FOR MANTARO VALLEY SAMPLE.

Field no.	Cultivars per field	Number of plants per ploidy level 2x	3x	4x	Total observations per field
1	23	27	40	511	578
2	19	30	15	115	160
3	11	30	7	115	152
4	7	—	235	12	247
5	6	—	35	45	80
6	13	24	11	136	171
7	11	5	—	391	396
8	5	—	—	217	217
9	30	82	18	486	586
10	18	14	16	273	303
Total		212	377	2,301	2,890
Percent		7.34	13.04	79.62	100

tophthora infestans) resistance. The development of roads, markets and urban centers in the Andean highlands encourages small farmers to market at least some of their crops. The demand for native potato varieties is evidenced by the fact that they bring a substantially higher price than the improved, high yielding ones. Selection of these preferred native varieties depends also on their demand in "seed" distribution networks which antedate more recent market development. These networks exist because some potato producing areas regularly lose "seed" to frost, drought and late blight. "Seed"-producing areas on the wetter and relatively frost free eastern slopes of the Andes export "seed" tubers westward to communities bordering the high, cold and dry plateaus of the western ranges. Traditional "seed" distribution, involving yearly treks of up to 50 km to "seed"-producing areas, is being supplanted by trucks and centralized markets, but "seed" still moves over the same range. The distribution of preferred "seed" by regular networks has produced a number (5–8 per region) of cosmopolitan varieties, clones grown by virtually every household and uniformly named over several thousand square kilometers. Recent work by Ochoa (1975b) and Jackson (1977) indicates that certain varieties are distributed throughout Peru and are like-named in widely dispersed geographic and linguistic areas. These varieties are often selected and grown separately, as demonstrated in Fig. 3, depicting the fields of a farmer in the hamlet of Aymara, Huancavelica Department. This farmer sells potatoes to "seed" suppliers dealing with farmers from the Chongos Alto area, 30 km to the west. As the map shows, he practices a high degree of selection in the 4 fields below his house. Field 1 contains sections of 90% *murunki* (subsp. *andigena*) separated by a thin corridor of 44% *mariva* (*tuberosum* × *andigena*) and 22% *duraznillo* (subsp. *andigena*). *Murunki* is a highly cosmopolitan clone in the Mantaro region; *duraznillo* is less so; and *mariva* is a hybrid-improved variety found frequently in urban markets. Field 2 is planted with 80% *pujuya* (*S. phureja*) which the farmer reported to be particularly tolerant of frosts. *Pujuya* is common in the inventories of farmers in the Chongos Alto area who report receiving "seed" from the Aymara area. Field 3 is planted in bitter *shiri* potatoes

(*S.* × *curtilobum* and *S.* × *juzepczukii*) for making *chuño*. One-half of Field 4 consists of 90% *yana huancuy* (subsp. *andigena*), while the other half consists of 90% *yana shuitu* (subsp. *andigena*), both highly prized native varieties in the Huancayo market. This farmer maintains 2 other similar fields, removed from his house. He is, however, atypical in not maintaining a heterogeneous *chacro* field.

Native varieties, dealt with above, are distinguished as *papa de regalo* ("gift potatoes") or *papas de color* ("colored potatoes") from the improved varieties, known as *papa blanca* ("white potatoes") or *papa mejorada* ("improved potatoes"). The latter have diffused widely in the Andes after their initial appearance in the early 1950s, and now appear in fields of subsistence farmers in remote villages. In areas with easy access to urban markets, improved varieties have made deep inroads into the total stock of native tubers. In many areas, farmers grow both native and improved varieties in separate fields, using different technologies and for different objectives.

Improved varieties, when selected and grown separately, are usually grown as a cash crop. Their chief advantage is their yield, often 2 or 3 times that of native varieties. This is due to the resistance bred into them, especially to *Phytophthora infestans,* and to their relative responsiveness to fertilizers. Selection of specific improved varieties depends primarily on the cost and availability of "seed" and on their marketability. Small farmers, who also grow a subsistence crop of native varieties, often plant improved potatoes in previously cultivated soil using oxen and a method referred to as *chacma,* rather than the *tikpa* method. Yield is the single most important criterion for this cash crop, and farmers utilize more fertilizer, especially manufactured types, on improved varieties than on fields of native varieties destined for home consumption. Likewise, there is a greater investment in insecticides and fungicides for these fields.

While improved varieties are selected for their commercial value, native ones are selected according to the demands of subsistence agriculture. Three major reasons are cited by farmers for retaining native potatoes: taste, storage quality, and "seed" viability. For people who eat potatoes as the primary food 2 or 3 times a day, culinary appeal is essential. Improved potatoes are regarded as insipid, watery, palatable only in soups, fried, or to undiscriminating potato eaters. The native varieties are preferred because of their floury consistency and high dry matter content. Native potatoes also retain their palatability after months of storage, while improved varieties often become bitter. This may be due to the fact that most bred varieties have a white or cream skin which turns green with bitter alkaloids when exposed to light. The heavily pigmented skin of native varieties protects them, to some extent, from becoming green.

Finally, native varieties are maintained by small farmers because of their "seed" viability. These varieties produce viable "seed" year after year, while improved varieties depend on having "seed" replenished after 1–3 yr. Farmers observe that improved potato varieties "degenerate" rapidly, losing yield and producing deformed tubers. Native varieties, on the other hand, maintain acceptable yields and tuber forms indefinitely. This difference may relate to the fact that "seed" from improved varieties often originates from lower altitudes where they are infected with virus by aphids, while native varieties are grown at high altitudes where aphid populations are greatly reduced. The use of improved varieties, however, is associated with greater expense in acquiring "seed" and

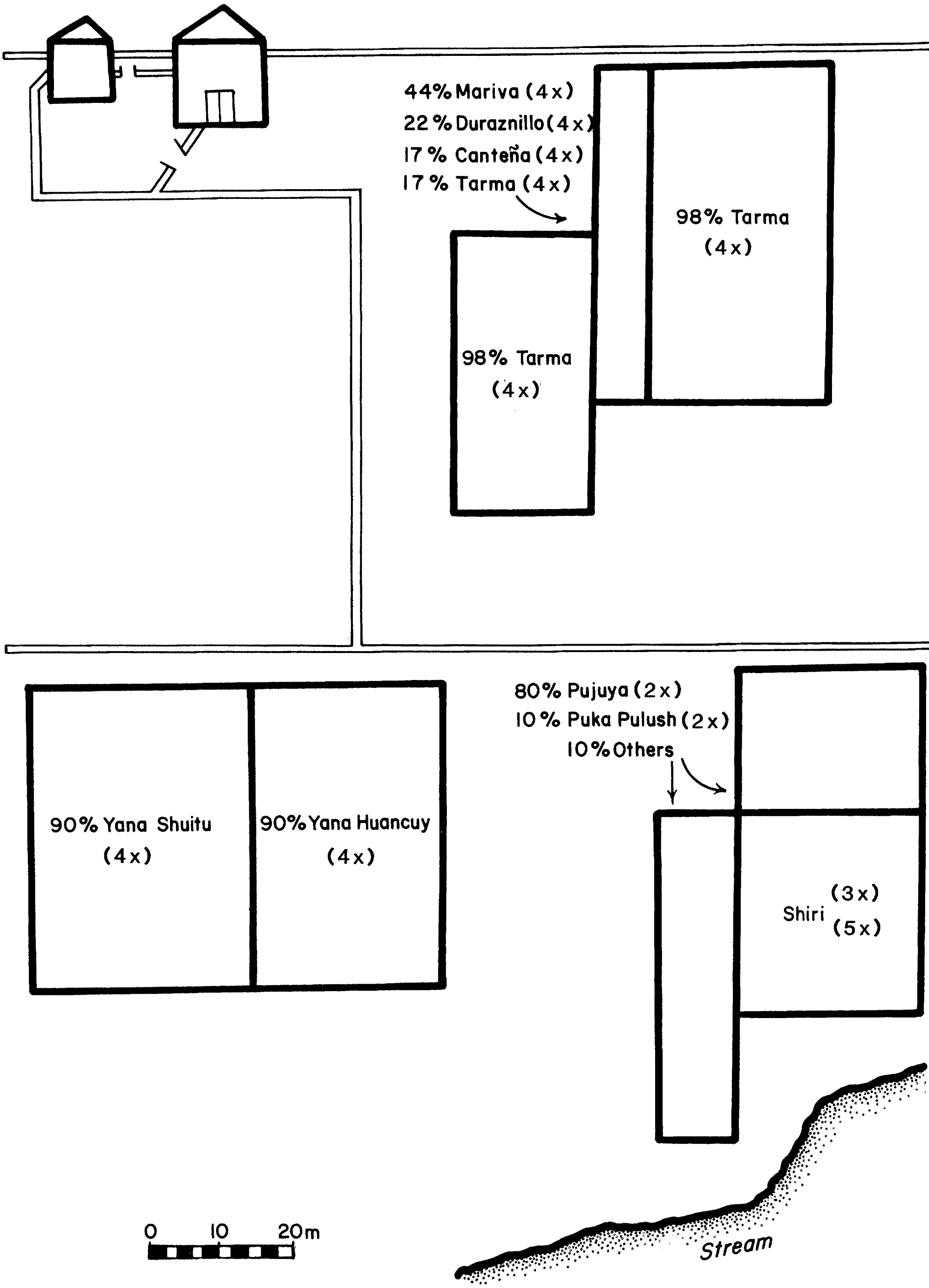

Fig. 3. Diagram of a farmer's fields planted in selected native potato varieties. Aymara, Huancavelica Dept., alt. 4,050 m.

dependency on commercial "seed" distribution systems. Purchased "seed" potatoes are sought from areas distant or ecologically distinct from the area of cultivation. Thus farmers from lower elevations seek "seed" potatoes from higher zones, and vice versa.

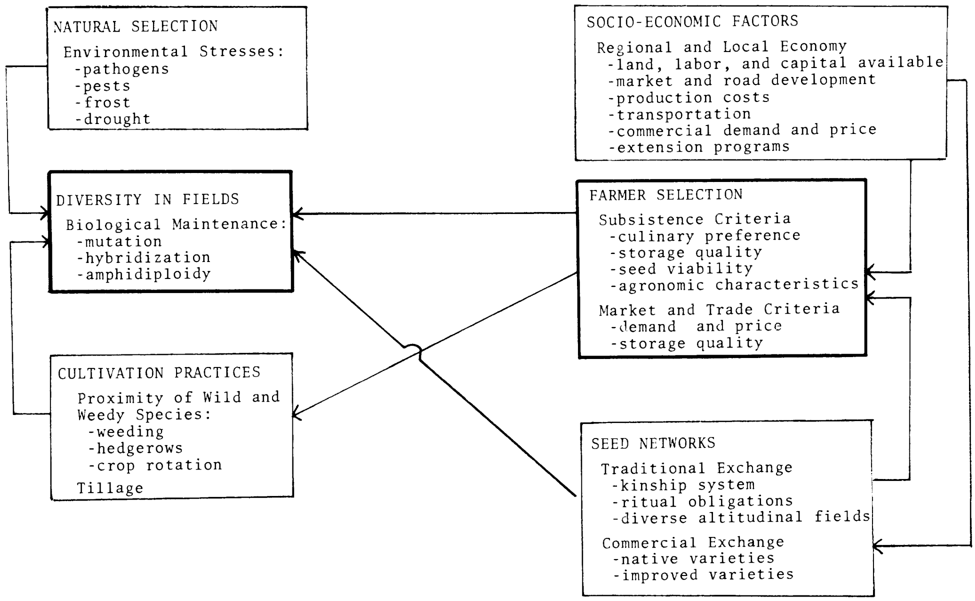

Fig. 4. Summary of the selection and maintenance of potatoes by Peruvian highland peasants.

CONCLUSION

The primary components of Andean potato agriculture are summarized in Fig. 4, a flow chart of the factors affecting the selection, maintenance and distribution of potato germ plasm in central Peru. This summary outlines the interaction of human and biological factors contributing to genetic diversity of potatoes in the area.

Botanists have suggested that native Andean potato fields are dynamic evolutionary systems (Jackson, 1977; Iltis, cited in Ugent, 1970). Inter- and intra-ploidy hybridization is made possible by the planting practices of Andean farmers reported here and elsewhere. Our research indicates, however, that selection and distribution of native potato varieties is far more complex than the random planting of numerous varieties. The maintenance of these numerous varieties is neither casual nor random. A regular system of nomenclature, organized in a taxonomic manner, accompanies this cultivation. Specific cultivars are identified according to an implicit set of criteria involving tuber and sometimes other characteristics. Selection of varieties relates primarily to culinary characteristics, but specific biological fitness is recognized in certain clones. The adaptation of native varieties to local conditions is revealed in the difference between native and hybrid or improved varieties. The latter depend on frequent replenishment of "seed" to remain viable. The maintenance of clonal heterogeneity is a regular part of native agricultural practices, as is the distribution of a few cosmopolitan clones through "seed" networks. The cultural and biotic features of Andean potato agriculture are thus interwoven and express a complex symbiotic relationship between man and plant.

There are indications, however, that this relationship is deteriorating. In many areas, subsistence-oriented potato agriculture is being supplanted by commercial agriculture relying on hybrid varieties. The genetic erosion of native varieties is increasing at an alarming rate (Ochoa, 1975a). At the least, multidisciplinary information on native agriculture and actual cultivars grown on the local and regional level should be collected before the irreplaceable agricultural heritage of Andean farmers and the invaluable clonal richness of native potato varieties are lost forever. Any efforts to preserve the diversity of native Andean potatoes must take into account the need to retain the cultural practices which maintain these cultivars.

ACKNOWLEDGMENTS

This research was supported by grants from the National Science Foundation (Grant BNS76-83067), the College of William and Mary, and the International Potato Center. We are thankful for the kind assistance of the staff of the International Potato Center during fieldwork, especially Douglas Horton, Carlos Ochoa, Peter Schmiediche, Wilman Galindez, and Robert Werge. We are also grateful to those who made suggestions for the fieldwork phase and commented on earlier drafts of this paper: Brent Berlin, Daniel Gade, Joseph Casagrande, Enrique Mayer, Gustavo Javier, H. David Thurston, Hugh Iltis, David Reed, Margery Oldfield, Janis Alcorn, Billie Jean Isbell, Valentine Cusihuaman, and Benjamin Orlove. Thanks, also, to Christine Kurtz for drafting the map and figures. Finally, we are indebted to the farmers of the Mantaro and Cuzco regions of Peru who graciously shared their knowledge with us and allowed us to tramp through their potato fields.

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BOOK REVIEW

Cashew. J. G. Ohler. 260 pp. illus. Koninklijk Instituut voor de Tropen, Amsterdam, 1979. Dfl 40.00.

J. G. Ohler has put together an impressive and very useful monograph on the cashew (*Anacardium occidentale*), based on 20 years of personal experience with this crop. The volume, illustrated with many charts and photographs (including some in color), begins with the early history of the cashew and brings the reader up to the present with a discussion of its use as an edible tree-nut crop and for the production of cashew nut-shell liquid (CNSL). The latter product, 20–25% of total nut weight, is primarily utilized in the brake linings of automobiles. In the second chapter, world production data for the past and present, along with future projections, are offered.

Twenty seven pages are dedicated to the botany and morphology of cashew, which is andromonoecious, having both perfect and staminate flowers in the same panicle. A thorough summary of agronomic and cultural practices is offered, including climatic requirements (in general a temperature no less than 7°C and rainfall 1,000–2,000 mm annually). The volume also serves as an invaluable reference to potential growers of the crop, elucidating basic diseases and pests that might be expected in a plantation. An interesting section is devoted to the processing of the nuts, where precautions must be taken to expel all of the toxic CNSL. The "fruits" (i.e., fleshy, swollen pedicels) of this species, known as "apples," produce a juice that is very agreeable in taste and contains two to three times as much vitamin C as citrus juice. It is estimated that many of the 2.5–5 million tons of "apples" produced each year go unused, left to rot under the trees. This appears a great waste, as syrup, wine, brandy, canned fruit, pickles, and jam can also be manufactured from the fresh "apples." Four hundred nineteen references are listed at the end of the text, an asset to the reader who might wish to peruse the available literature. The author is to be congratulated for a well-organized and enjoyable book that will now serve as the major work on this important but presently under-utilized food plant.

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