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ocial Science Department
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1980-5

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September 1980

INTERNATIONAL POTATO CENTER
Aptdo. 5969 Lima-Peru

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THE DYNAMICS OF ANDEAN POTATO AGRICULTURE

Stephen B. Brush, Heath J. Carney and Zósimo Huamán *

ABSTRACT

The Central Andes Mountains is a cradle region for domestication and development of the cultivated potato (Solanum spp.), and many Andean farmers continue to produce landraces of native potatoes. This paper, based on anthropological and ethnobotanical research in the central and southern highlands of Peru, discusses indigenous patterns of identification, selection, maintenance and distribution of native Andean potato cultivars. Andean farmers utilize a four-leveled system of classification, integrating wild, semi-domesticated, and domesticated species. The richest nomenclature is associated with non-bitter, table potatoes. Based on morphological characteristics of the tuber, this nomenclature is consistent over large regions. Electrophoretic analysis, however, reveals that consistency in naming is botanically accurate only within villages.

Regular patterns of selection of native cultivars was observed and appears to be a regular feature of native potato agriculture. Farmers maintain several fields which may vary from highly heterogeneous collections of native germ plasm to relatively homogeneous plantings of native or improved varieties. Generally, mixed plots are grown for household consumption, while selected plots are intended for market or exchange. Regular trade systems distribute native varieties within localities and over large regions. Finally, farmer rationales for selection of native varieties as against improved ones are discussed, and a model for the selection process is presented.

RESUMEN

La región montañosa de los Andes Centrales es el centro de domesticación y desarrollo de la papa cultivada (Solanum spp.) y muchos agricultores andinos aún siguen produciendo nuevos cultivares de papas nativas. En este artículo, basado en una investigación antropológica y etnobotánica llevada a cabo en las montañas del centro y el sur del Perú, se discuten los patrones nativos de identificación, selección, mantenimiento y distribución de los cultivares de papa andina. Los agricultores andinos utilizan un sistema de clasificación en cuatro niveles e integran especies de papas silvestres, semidomesticadas y domesticadas. La nomenclatura más rica está asociada con papas cultivadas no amargas. Esta nomenclatura, basada en caracteres morfológicos del tubérculo, es consistente dentro de grandes regiones.

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Sin embargo, el análisis electroforético indica que la consistencia en las determinaciones es confiable sólo dentro de aldeas.

Se observaron patrones regulares de selección de variedades nativas cultivadas y esto parece ser una característica del cultivo de la papa nativa. Los agricultores conservan varios campos que pueden variar ampliamente desde colecciones heterogéneas de germoplasma nativo hasta plantaciones relativamente homogéneas de variedades no sólo nativas sino también mejoradas. Generalmente las parcelas con mezclas de variedades son destinadas al consumo doméstico, y aquellas con variedades seleccionadas son destinadas al mercado o a intercambio. Sistemas cotidianos de comercialización distribuyen las variedades nativas dentro de las localidades y en regiones extensas. Finalmente, en este artículo, se discuten los criterios que usa el agricultor para seleccionar variedades nativas en vez de variedades mejoradas, y se presenta un modelo para el proceso de selección.

ACKNOWLEDGEMENT

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 comments 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 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.

INTRODUCTION

The invention and development of agriculture released tremendous diversity among the species selected for domestication. This diversity is still evident in the cradle areas of domestication, maintained as ancestral varieties or landraces by traditional farmers. These centers of diversity have been recognized as important since N. I. Vavilov's work fifty years 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 back-up crop genetic resources (Harlan, 1976a; 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 better understand the genetic architecture of our modern domesticates.

Although extensive germ plasm collecting, 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, Breedlove and Raven, 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 assembledges 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 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.

THE ANDEAN POTATO

Two lines of evidence, archaeological and genetic, indicate 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.C. (Pickersgill and Heiser, 1978: 821; McNeish, Patterson and Browman, 1975: 30) Engel (1970) suggests an even earlier date of 8,000 - 10,000 years ago for original domestication in the central Andes. Other archaeological evidence for Andean domestication includes the use of potatoes as an effigy in prehispanic pottery (Towle, 1961). Genetically, the richest gene pool of potatoes, estimated by geneticists and taxonomists at 2,000 to 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 socio-economic 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, 1969). A fairly elaborate variety of storage techniques and facilities are used, (Werge, 1977). During storage, potatoes are protected from worm infestations by placing them 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 one or two years, followed by short rotations of other tubers (e.g. Oxalis tuberosa), grains (e.g. Chenopodium Quinoa) and fallow. A period of six or seven years 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 always removed before eating. A favorite variation in cooking is the construction of sod and fieldstone ovens (watia or pachamanca) for roasting potatoes at harvest time. Chile 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 defiency in Andean populations with a high dependency

on potatoes (Picón-Reátegui, 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?

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, three different taxonomic systems are used by scientists working with cultivated potatoes. The Dodds system divides the cultivated potatoes into three 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 eight cultivated species (Hawkes, 1978). All three systems divide cultivated potatoes into four 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. stenotonum Juz. et Buk., S. goniocalyx Juz. et Buk., and S. phureja Juz. et Buk., as well as the triploid S. x chaucha Juz. et Buk. Similarly widespread are the two frost-resistant species generally grown at higher altitudes and processed by freeze-drying to remove glycoalkaloids. These two species are the triploid S. x juzepczukii Buk. and the pentaploid S. x 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 cytoplasmic research, however, suggest confirmation of an earlier theory that the progenitors of modern tuberosum varieties were from southern Chile, on the Chiloe Archipelago (Grun, Ochoa and Capage, 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. stenotonum is widely regarded as the most primitive of the domesticated species (Hawkes, 1967). The other seven cultivated species were derived through various processes including mutation, mitotic and meiotic polyploidization, intra and interploidy hypridization, 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. stenotonum and some wild potatoes (Hawkes, 1962; Huaman, 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 their self-compatibility. Undoubtedly, man's role as a selective agent is clear on all levels. Characteristics such as lack of tuber dormancy in S. phureja, frost resistance in S. ajanhuiri, S. x juzepczukii and S. x curtilobum, good palatability in S. goniocalyx and adaptation to long daylight in subsp. tuberosum are examples.

Botanically, only three out of the eight cultivated species are identified by plant morphology without much difficulty. 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, Williams, Salhuana, and Vincent, 1977). As in species identification, however, plant 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; Stegemann and Loescheke, 1976). This process 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 divide into a number of discrete genotypes, or clones, which are individually named.

Native agriculture associated with this diverse genetic material has three 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 level of wild and weedy potatoes in and around fields, promoting 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, 1975) 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). LaBarre analyzed some 200 names from the Aymara around Lake Titicaca, noting the taxonomic structure of this nomenclature (LaBarre, 1947).

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 this 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.

THE 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 and 4,200 meters. This effective range of potato cultivation can, in most areas, be subdivided into three 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 and 3,600 meters, 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 chemical 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 meters, 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 chaquitaclla (footplow), and a lack of dependency on nonlocal inputs of chemicals and energy (Brush, 1977; Gade, 1975). This area divides into

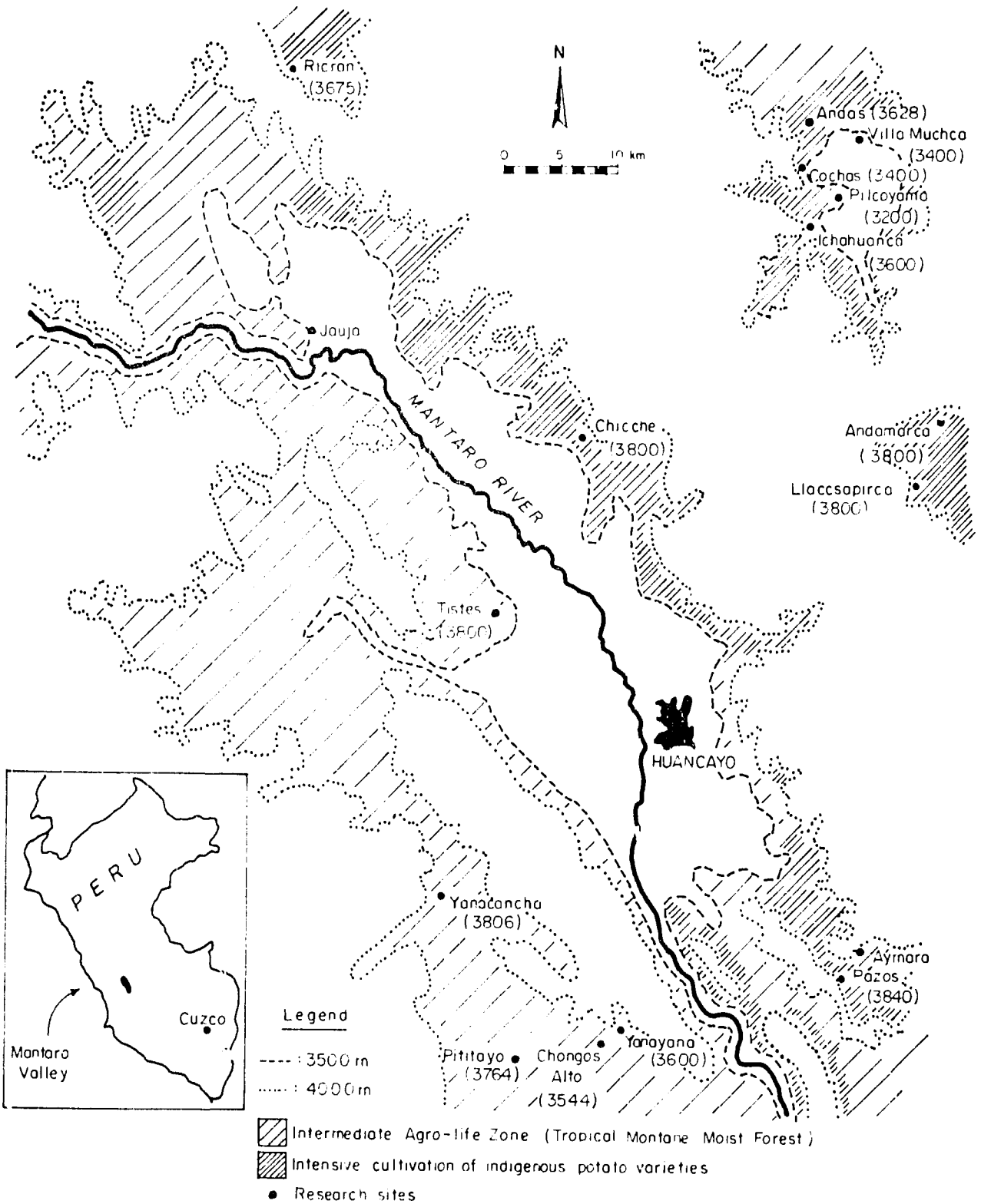
two zones. Between 3,600 and 3,900 meters non-bitter potatoes are produced, and above 3,900 meters bitter, frost-resistant potatoes are grown and converted into chuño by freeze-drying. Most households in this area produce both types of potatoes, as well as other Andean and European crops.

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 (Fig. 1). 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 (ONERN, 1976). This general pattern of vegetation is fragmented according to local differences in soils, exposure, slope and rainfall. Generally, as one moves westward from the central Mantaro and Vilcanota Valleys, rainfall becomes less, decreasing to 600 mm, and frost occurs earlier, in May or June, than to the east. 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, 1979).

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. The objective of this paper is to report on what appears to be traditional Andean patterns of identification, classification and distribution of primitive varieties in areas where subsistence production predominates. It is also concerned with the maintenance of native varieties by farmers who have the option of switching to improved varieties that have been diffused during the past three decades.

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 five 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 so that some were clustered into microregions in single river valleys while others were widely dispersed in different ecological and linguistic 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 four villages. Here fieldwork occurred in two periods, at planting and during the florescence of the potato fields (November and March).

Fig. 1. LOCATION OF AREAS OF POTATO CULTIVATION AND RESEARCH SITES IN MANTARO VALLEY REGION.



Tuber samples of native cultivars were treated in three fashions. First, a collection of 486 tubers, from four 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 comparable, augmenting 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 nine tuber characteristics and scored against a standard. Third, tubers were grouped according to local name, and tubers within groups were compared in two 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. The total sample contains 262 named varieties from the Mantaro region and 45 from the Vilcanota region.

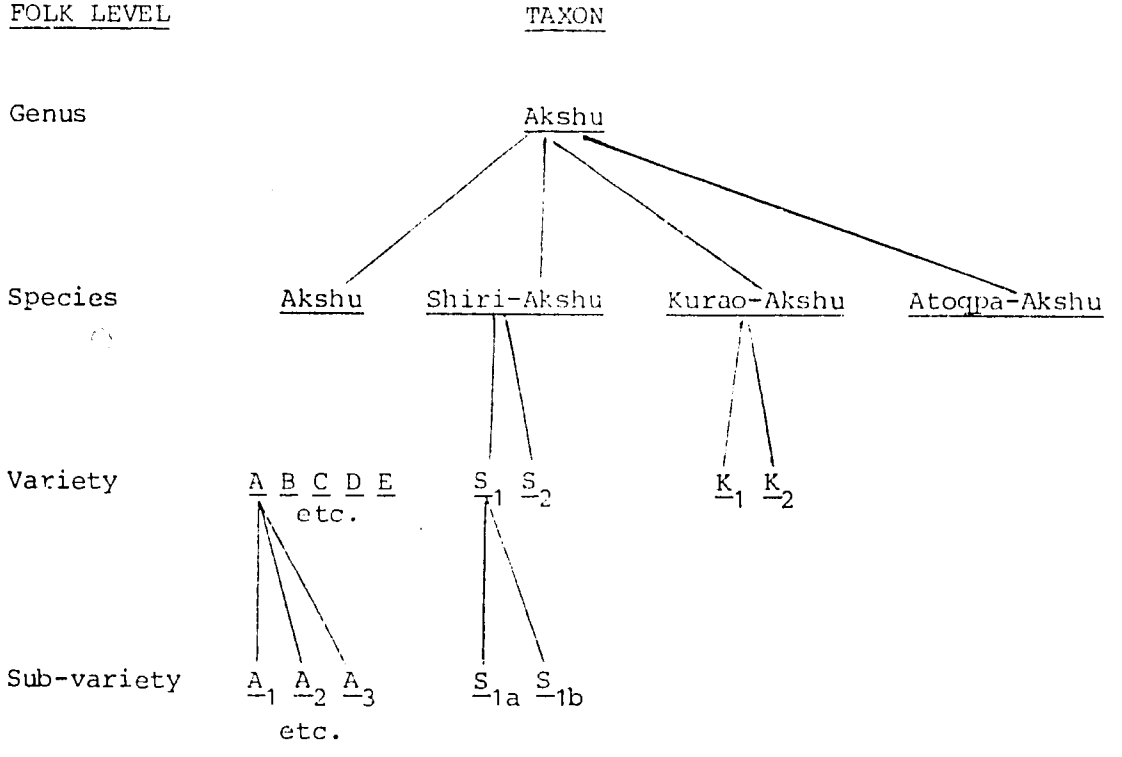
From January through March, when potato fields were in florescence, nineteen fields were mapped, eleven in the Mantaro region and eight in the Vilcanota region. Fields were chosen to reflect degrees of selection from highly heterogeneous to generally homogeneous plantings. Three different sampling strategies 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 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.

FOLK TAXONOMIES OF CULTIVATED POTATOES

The native classification of potatoes in highland Peru involves four levels arranged taxonomically, beginning at the folk generic level and descending to the sub-variety level (Fig. 2). 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 four distinct folk species, according to four criteria: (a) cultivation, (b) edibility, (c) processing, and (d) frost resistance. In the Mantaro region these four folk species are:

1. Akshu: cultivated non-bitter potatoes with little or no frost resistence.
2. Shiri-akshu: cultivated bitter potatoes which must be processed by freeze-drying to remove glycoalkaloids before eating; frost resistant.
3. Kurao-akshu: edible, semi-domesticated (uncultivated) potatoes found in mid-altitude maize fields; no processing required and not frost resistant.

Figure 2. Schematic diagram of the folk taxonomy of potatoes among Huanca-Quechua speakers (Mantaro region) of Peru.



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 Solanums are lumped into the atoqpa-akshu class; shiri-akshu is comprised of S. x juzepczukii and S. x curtilobum; and the other domesticated potato species grown in the area are grouped together as akshu. The botanical components of the semi-domesticate kurao-akshu have not been established, but they may be an 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 four. 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 verbalize on 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.

The fourth, and lowest, taxonomic level in the native classification is that of sub-variety. This is based on secondary tuber characteristics, principally variations in tuber color. Twenty percent of all varieties have

sub-varieties, varying from two to eight. Sub-varieties 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 cognition 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 shows, however, that the naming system is not random, especially on the local level.

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. The figures in this table report comparisons between tubers according to three 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 visually 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 three 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.

Table 1. Percentages of visually similar and electrophoretically identical tubers in like-named groups.

Spatial Level	COMPARISON			
	Visual		Electrophoresis	
	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

Beyond different farmer aptitudes in naming, variation in the native classification may be linked to three 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 2x 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 likely to hybridize with wild germ plasm and the latter 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 two 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 as such in such 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, 1975) and Mexico (Ugent, 1968) have

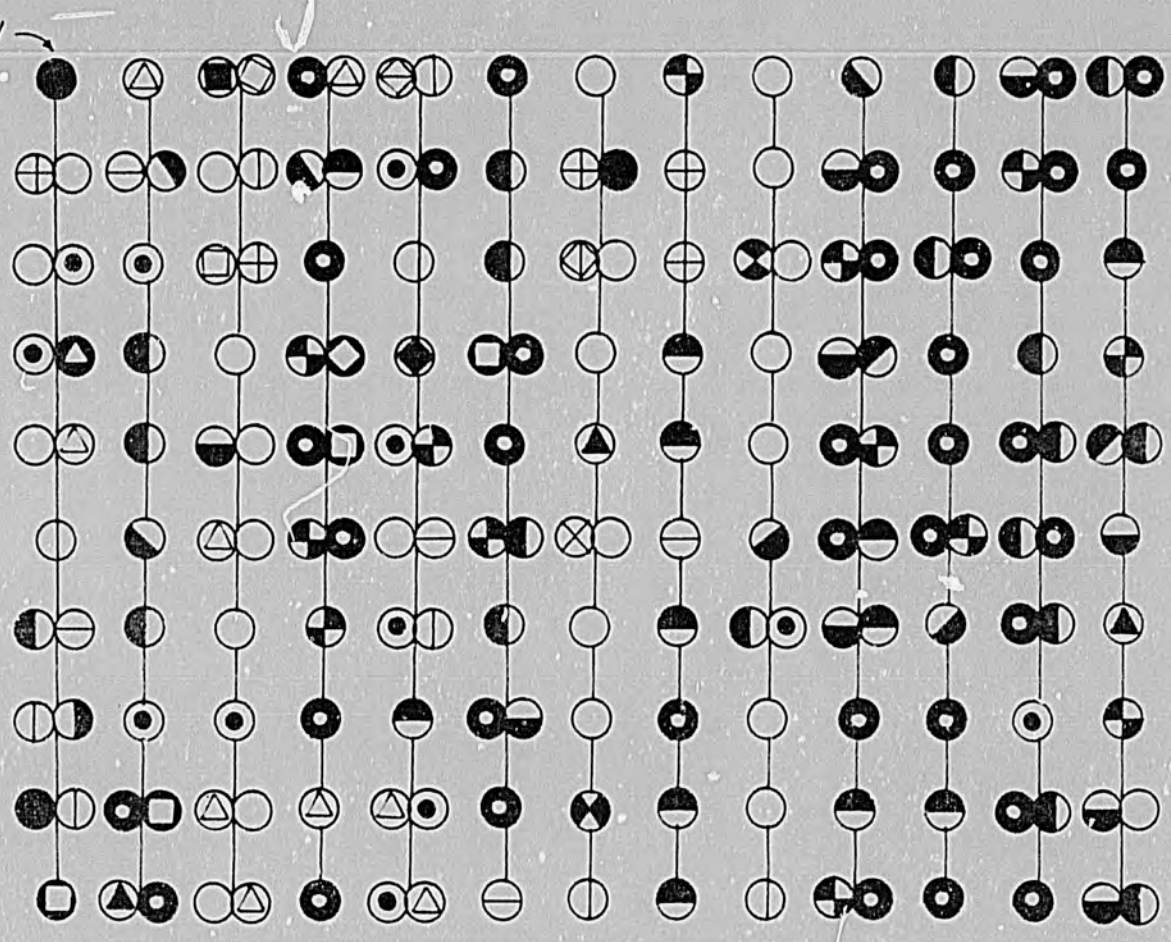
demonstrated field heterogeneity, our research indicates that the selection of ancestral varieties is more complex than previously thought. We found fields of all types of potato to be generally orderly. Rows were well kept, with relatively few weeds and little evidence of wild species within fields. 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 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 two kinds of fields. The first are fields where varieties are mixed and randomly planted. In the central highlands, such fields are referred to as chacra. 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 result is varietal heterogeneity within the field. Figure 3 depicts a field of this kind in the village of Umasbamba, north of Cuzco. This field was planted by an officer from the local religious hierarchy, its harvest intended for a fiesta. Forty-six named varieties were randomly planted in the field, with 2 or 3 clones frequently growing from a single planting. Following a traditional planting procedure (tikpa), seed tubers were dropped into a hole opened in untilled soil by the footplow. As many as five small tubers may be dropped into a single hole. After roughly six weeks, the sod around each clump is turned over and mounded against the plants and later worked with a short handled hoe. These fields are customarily planted in freshly fallowed land, using animal dung as fertilizer. The objective for planting heterogeneous fields is almost invariably for home consumption. The mixture of colors, textures, shapes, and flavors enchances a diet in which many meals consist of potatoes garnished with a hot pepper sauce. These varieties are also considered to retain palatability and viability as seed over many months of storage.

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

Fig. 3. TRANSECT OF NATIVE VARIETIES OF POTATO IN FIELD NEAR CHINCHERO, Cuzco Dept., alt. 3820 m.



KEY:

- tika boli (4x)
- muru boli (4x)
- puka boli (4x)
- kompis (4x)
- alka kompis (4x)
- puka kompis (4x)
- yurac kompis (4x)
- wayruru (4x)
- muru k'usi (4x)
- yana k'usi (4x)
- puka suyt'u (4x)
- simon suyt'u (4x)
- yana wakoto (4x)
- sogo wakoto (4x)
- q'ello wakoto (4x)
- olones (4x)
- puka wirajo (4x)
- muru wirajo (4x)
- yana wirajo (4x)
- alka wayatita (4x)
- puka wayatita (4x)
- yurac soncho (4x)
- espenqo tumera (4x)
- achancas papa (4x)
- chuchilio p'ayki (4x)
- renacimiento (4x)
- achancaras (4x)
- inkala (2x)
- montaro (4x)
- muru wamanero (3x)
- q'ello onko (4x)

of native varieties. Selection is by seed quality and by variety. It usually occurs at harvest when 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 (Phytophthora infestans) resistance. The development of roads, markets and urban centers in the Andean highlands encourages small farmers to market at least some of their crop. 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 of the fact that 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 (Ochoa, 1975b) and Jackson (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 Figure 4, 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 of fields surrounding this farmer's house shows, he practices a high degree of selection in the four fields below his house. Field 1 contains sections of 90% Murunki (subsp. andigena) separated by a thin corridor of 44% Mariva (tuberosum x 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 particularily 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. x curtilobum and S. x 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 two other fields, removed from his house, in this way. He is, however, atypical in not maintaining a heterogeneous chacra field.

The effectiveness of seed networks can be seen in Figure 5, a map of the dispersion of a single morphotype with the same name over a wide area in the Peruvian Andes. The potato shown here is the huayro, a culinary favorite in great demand in subsistence and commercial agriculture. The

Fig. 4. DIAGRAM OF A FARMER'S FIELDS PLANTED IN SELECTED NATIVE POTATO VARIETIES. Aymara, Huancavelica Dept., altitude 4050 m.

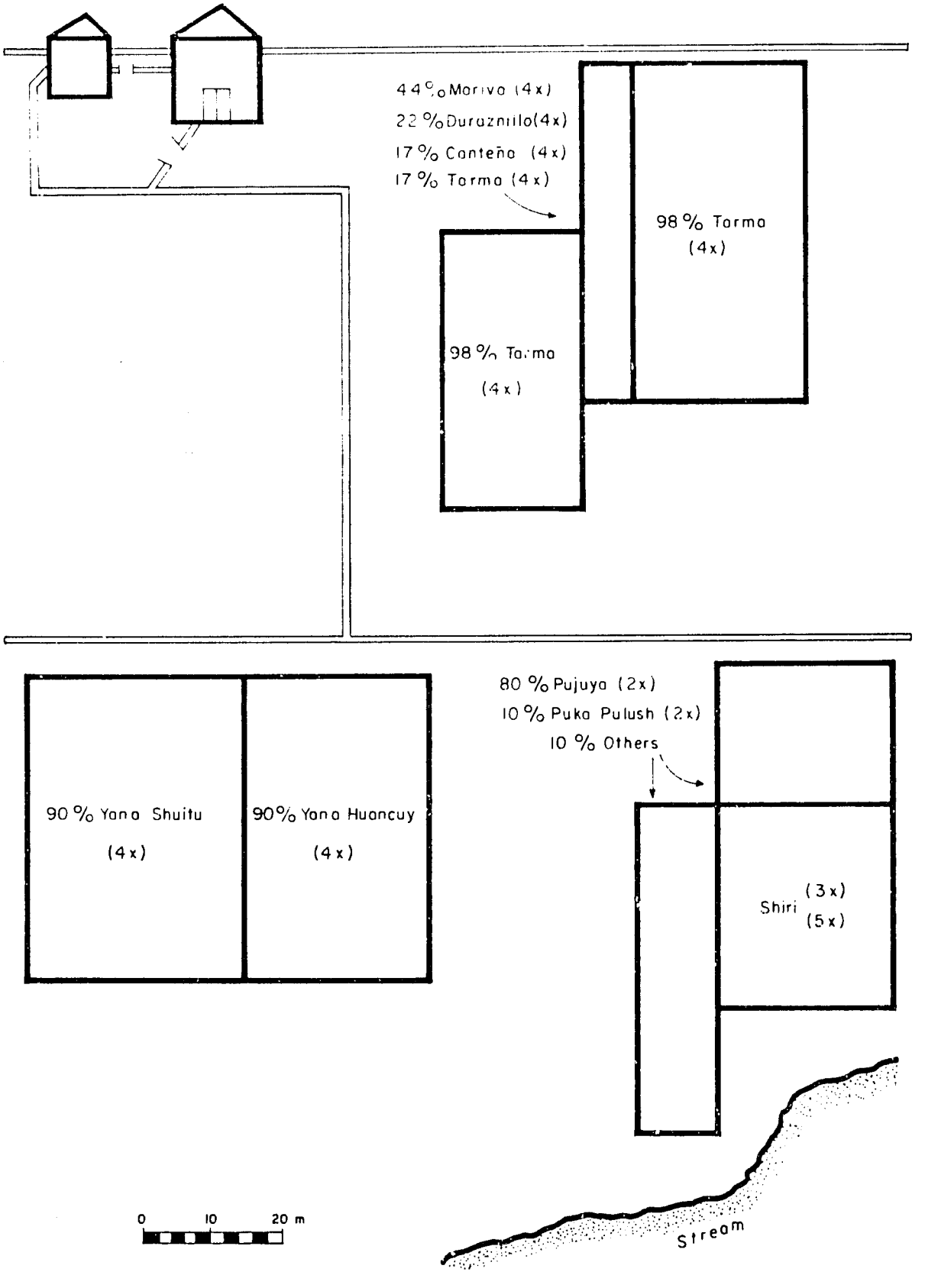


Fig. 5. DISTRIBUTION OF THE NAMED MORPHOTYPE "huayro" (S. x chaucha) IN PERU. (after Ochoa, 1975 b)

distribution shown here is by morphotype and name (Ochoa, 1975b). The "legitimate" huayro is a triploid (S. x chaucha) although many of the potatoes classified as huayro may, in fact, be other species. Our collections and electrophoretic analysis suggest that this name is a residual category of different varieties sharing rough morphological similarity. The clustering of this morphotype in the central Andes suggest that it is native to that part of Peru. There potatoes called huayro may be found in virtually every village and market. To the north and south, similar morphotypes of the same name are less common. It is possible that genetically similar tubers of different names are more widely dispersed, but the association of name and morphotype allow some approximation of seed networks which are dense over limited geographic regions.

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 1950's, 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 two or three times that of native varieties. This owes to their bred resistance, 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 criteria 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 two or three times a day, culinary appeal is essential. Improved potatoes are regarded as insipid, watery, palatable only in soups, fried, or to undiscriminating potato eaters; culinary inferiors to native potato varieties. The latter 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 and, therefore, bitter 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 one to three years. 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 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.

CONCLUSION

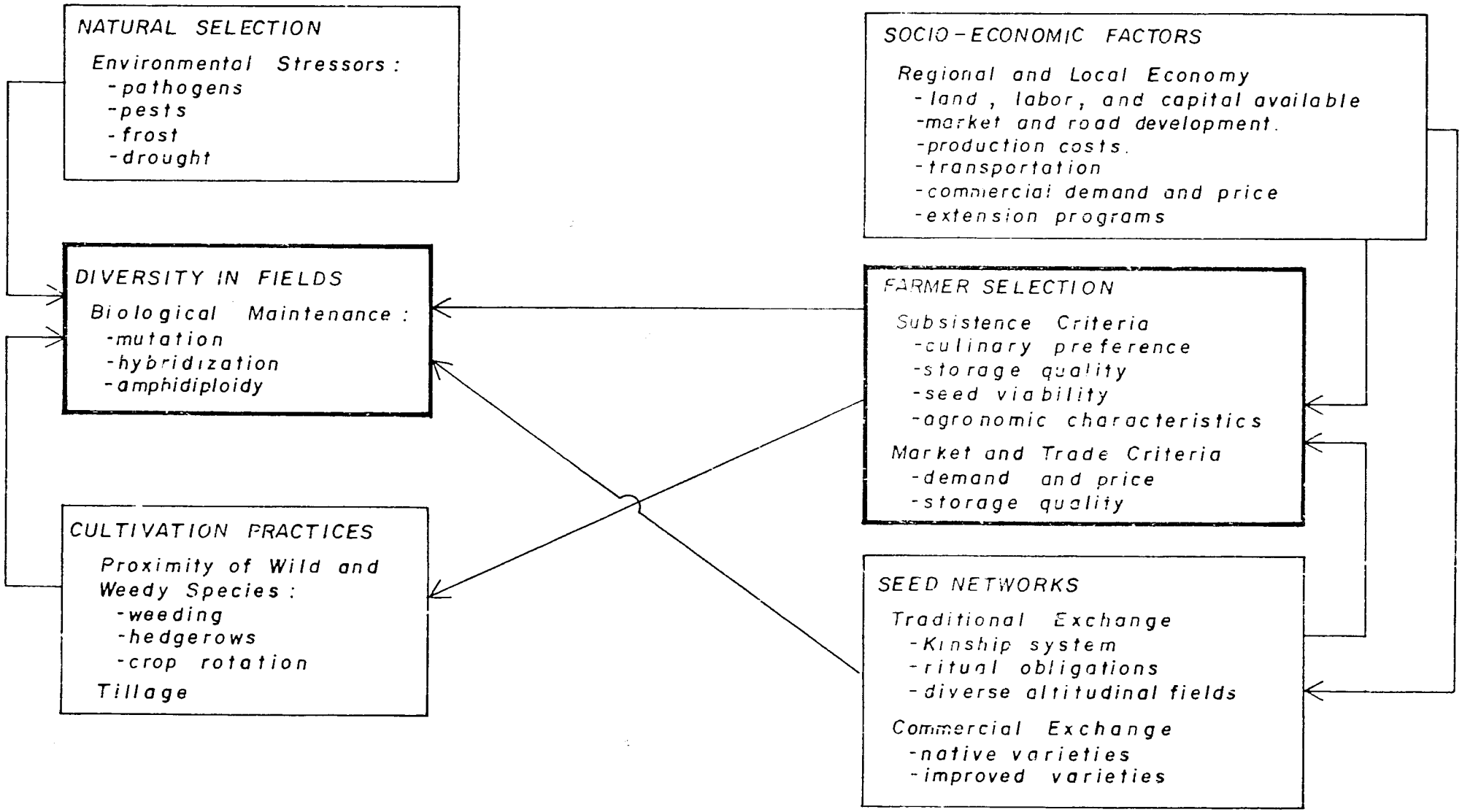
The primary components of Andean potato agriculture are summarized in Figure 6, a flow chart of the factors affecting the selection, maintenance and distribution of potato germ plasm in central Peru. This summary outlines the interaction of human and biological factors contributing to genetic diversity of potatoes in the area.

Botanists such as Iltis have suggested that native Andean potato fields are dynamic evolutionary systems (Jackson, 1977; Ugent, 1970). Inter-and intra-ploidy hybridization is made possible by the planting practices of Andean farmers reported here and elsewhere. This 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 plant 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 agricultural relying on hybrid varieties. The genetic erosion of native varieties is increasing at an alarming rate (Ochoa, 75a). 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.

Fig. 6. SUMMARY OF THE SELECTION AND MAINTENANCE OF POTATOES BY PERUVIAN HIGHLAND PEASANTS.



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