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DIVERSITY, DISTRIBUTION AND PEASANT SELECTION OF INDIGENOUS POTATO VARIETIES IN THE MANTARO VALLEY, PERU: A BIOCULTURAL EVOLUTIONARY PROCESS

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DIVERSITY, DISTRIBUTION AND PEASANT SELECTION OF INDIGENOUS POTATO VARIETIES IN THE MANTARO VALLEY, PERU; A BIOCULTURAL EVOLUTIONARY PROCESS*

Heath J. Carney**

ABSTRACT

The native cultivation of potatoes in the Mantaro Valley, Peru was investigated. The frequency and distribution of native potatoes were examined at four levels: field, family, village and valley. In the fields sampled, a total of 77 varieties were named by peasants. The percentages of plants found, according to ploidy, was: 34.03% diploid (2n = 24), 9.14% triploid (2n = 36), 56.78% tetraploid (2n = 48) and 0.05% pentaploid (2n = 60). A mean of 14 cultivars/field was found (range = 24 cultivars/field, 6 cultivars/field minimum to 30 cultivars/field maximum).

An assessment is made of the relative importance of the principal factors involved in peasant selection: culinary quality, resistance to pathogens and yield. Biological and cultural factors contributing to the evolution and present-day diversity of native Andean potatoes are discussed. A model for the maintenance and amplification of the rich genetic base of potato varieties by Andean farmers is proposed.

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PAPAS NATIVAS EN EL VALLE DEL MANTARO, PERU:

EVOLUCION BIOLOGICA-CULTURAL

RESUMEN

Fue investigado el sistema nativo de producción de papa en el valle del Mantaro, Perú. Se tomaron en consideración la frecuencia y la distribución de papas nativas según cuatro niveles de análisis: Campo, familia, aldea y valle. En los campos incluídos en la muestra, los campesinos nombraron 77 variedades. En términos de poliploidismo se encontraron los siguientes porcentajes de plantas: 34.03% diploides (2n = 24), 9.14% triploides (2n = 36), 56.78% tetraploides (2n = 48), y 0.05% pentaploides (2n = 60). El promedio de variedades cultivadas por campo (v/c) fue de 14, con un intervalo de 24 v/c (6 v/c mínimo y 30 v/c máximo).

Se calculó la importancia relativa de tres factores principales relacionados con las selecciones (variedades cultivadas) hechas por los agricultores: calidad culinaria, resistencia a patógenos y rendimientos. Fueron discutidos los factores biológicos y culturales que influyen en la evolución y en la diversidad actual de las papas nativas andinas. Se propone un modelo para que los agricultores de los Andes mantengan y amplíen la copiosa base genética de las variedades nativas de papa.

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INTRODUCTION

Two lines of evidence indicate potatoes were first cultivated in the central Andes. Archeological remains dating back 4000 to 6000 years ago indicate the potato was first domesticated in the highlands of Bolivia and Peru, quite probably in the altiplano surrounding Lake Titicaca (Salaman 1949, Towle 1961). In addition, the richest gene pool of potatoes, estimated by geneticists and taxonomists at C.I.P. (Centro Internacional de la Papa) to be 4000 to 6000 varieties, is found in the central Andes. The Russian geneticist Vavilov was the first to assert that the cradle of domestication of a crop is characterized by the greatest genetic diversity of that crop. The Peruvian Andes, then, represent the center of domestication for the potato in the sense of Vavilov.

Potatoes are included in the section Tuberarium, genus _Solanum_. According to Hawkes (1963), cultivated potatoes of the Andes comprise seven species, ranging in ploidy from diploid (2n=24) to pentaploid (2n=60). By far the most ubiquitous subspecies is the tetraploid _Solanum tuberosum_ L., spp. _andigena_ (Juz. et Buk.) Hawkes. Also commonly found are the diploids _S. stenotonum_ spp. _stenotonum_ Juz. et Buk. and spp. _goniocalyx_ (juz. et Buk.) Hawkes, 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, the triploid _S._ x _juzepezukii_ Buk. and the pentaploid _S._ x _curtilobum_ Juz. et Buk. Another diploid, _S. ajanhuiri_ Juz. et Buk., is found only in southern Peru and northern Bolivia.

The potato is the staple of Andean highlands peasants. As such, it constitutes a vital component of native Andean agriculture. Previous studies of Andean potato agriculture have concentrated either on the actual biology of the potato or on the peasants cultivating the potato. Two principal types of studies have attempted to document the diversity and distribution of native potato cultivars in Peru. First, collecting expeditions have been organized, principally to collect germplasm for plant breeding. The first major explorations were made from 1926 to 1932 by Russians, particularly S.W. Juzepczuk, S.M. Bukasov, and N.I. Vavilov (Bukasov 1933). In 1939, E.K. Balls, J.G. Hawkes, and W.B. Gourlay collected both wild and cultivated potatoes in Peru and other Andean countries, and results of this expedition were later published by Hawkes (1944). During the late thirties, forties, and early fifties, C. Vargas (1949, 1956) collected extensively in southern Peru. Beginning in 1952, C. Ochoa (1955, 1958, 1964, 1965, 1975) made thorough collections in Peru. Since the fifties, Hawkes and Ochoa have been responsible for most of the major potato-collecting expeditions of wild and cultivated species in Peru.

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. Following the work of Ugent (1968) in Mexico, Jackson (1979) collected information on the actual frequency of indigenous cultivars in fields, and described practices associated with potato cultivation in the village Cuyo-Cuyo, located in southern Peru.

Neither collecting expeditions on a broad geographical scale nor small-scale ethnobotanical studies have been completely adequate in describing the frequency and distribution of native cultivars, or the selection processes of Andean agriculturalists. Jackson's study is based on a paucity of data. Less than two fields were sampled, and fewer than 500 plants were identified and mapped. The collecting explorations have not adequately covered the isolated areas where the greatest diversity of native cultivars is found. In part, this is because the optimum time for collection, the harvest, coincides with the rainy season. Exploration may be impeded considerably during this period.

Beginning August 1977, an interdisciplinary group of scientists conducted a year-long study of native Andean potato agriculture. The group was headed by Dr. Stephen Brush. Other social scientists included Alejandro Camino and Valentin Cusihuaman. The biologists included Dr. Zosimo Huaman, Wilman Galindez, and the author. It was thought that in combining the concepts and methodologies of natural and social scientists, a deeper understanding of native Andean potato agriculture could be reached.

Two principal objectives of the study were 1) to more thoroughly and accurately document the diversity and distribution of potato cultivars on an intermediate regional level and 2) to describe the identification, selection, and maintenance of potato varieties by peasants. This paper addresses the following question: what biological and cultural factors have contributed to the evolution and present-day diversity of native Andean potatoes? This is done by examining the frequency and distribution of native potatoes at four different levels: field, family, village and valley. In addition, a discussion of the selection process by natives is provided through an analysis of seed networks and ethnographic data. A model for the maintenance and amplification of the rich genetic base of potato varieties by native farmers is proposed.

STUDY AREA

The Mantaro Valley, located southeast of Lima in the southern part of the Department of Junin (Figure 1), was chosen as the study site for two reasons. First, areas of native potato cultivation were relatively accessible. Also, laboratory and greenhouse facilities were readily available at the International Potato Center field station in Huancayo.

Broad and flat compared to other Peruvian highland valleys, the Mantaro Valley is about 60 km. long, and varies in width from 2 to 24 km. Located approximately within 75-76° W and 11-13° S, it is flanked to the West by the Cordillera Occidental, and to the East by the Cordillera Central. In the valley, three ecological zones, ranging from 3,000 to 4,500 meters, predominate: Tropical Montane Dry Forest (Sierra) at 3,000 to 3,500 m., Tropical Montane Moist Forest (Sierra Alta) at 3,500 to 4,000 m., and Tropical Wet Subalpine Paramo (Puna Baja) at 4,000 to 4,500 m. (Holdridge 1967).

According to Mayer (1977), virtually all cultivation of native potato varieties occurs within the "Intermediate" agro-life zone, which roughly corresponds to the Tropical Montane Moist Forest at 3,500 to 4,000 meters (Figure 2). Geological information on the Mantaro Valley is poor: the western slopes of the valley consist largely of limestone while the eastern slopes are characterized by paleozoic igneous rock formations. The topsoils of the eastern slopes are considered more fertile, and it is on these soils that the majority of native cultivars are grown. The mean annual precipitation on the eastern slopes in this zone ranges from 100 to 160 cm. (39 to 62 inches). The mean annual temperature is 7.5° C (45.5° F), with a mean diurnal fluctuation of 17° C (31° F). The native potato varieties are, then, most apt to be cultivated on cool, moist slopes having relatively fertile soils at an altitude of 3,400 to 4,100 meters.

The potato is always cultivated by a household in combination with other cutlivars, and may be rotated with other crops on a given field. The other principal crops of the intermediate agro-life zone include barley (cebada - Hordeum vulgare), the tubers oca (Oxalis tuberosa Mol.), olluco (Ullucus tuberosus Lozano), and mashua (añu - Tropaelum tuberosum R. & P.), quinoa (Chenopodium Quinoa Wild.), and broad beans (haba - Vicia faba L.). Wheat (Triticum spp.) is also cultivated occasionally in this zone. Generally the fields are first prepared June and July, planted September to November, and harvested April through June. The annual agricultural cycle of Peruvian highlands farmers is discussed extensively in other publications (see Vargas 1948, Gade 1975, and Jackson 1979).

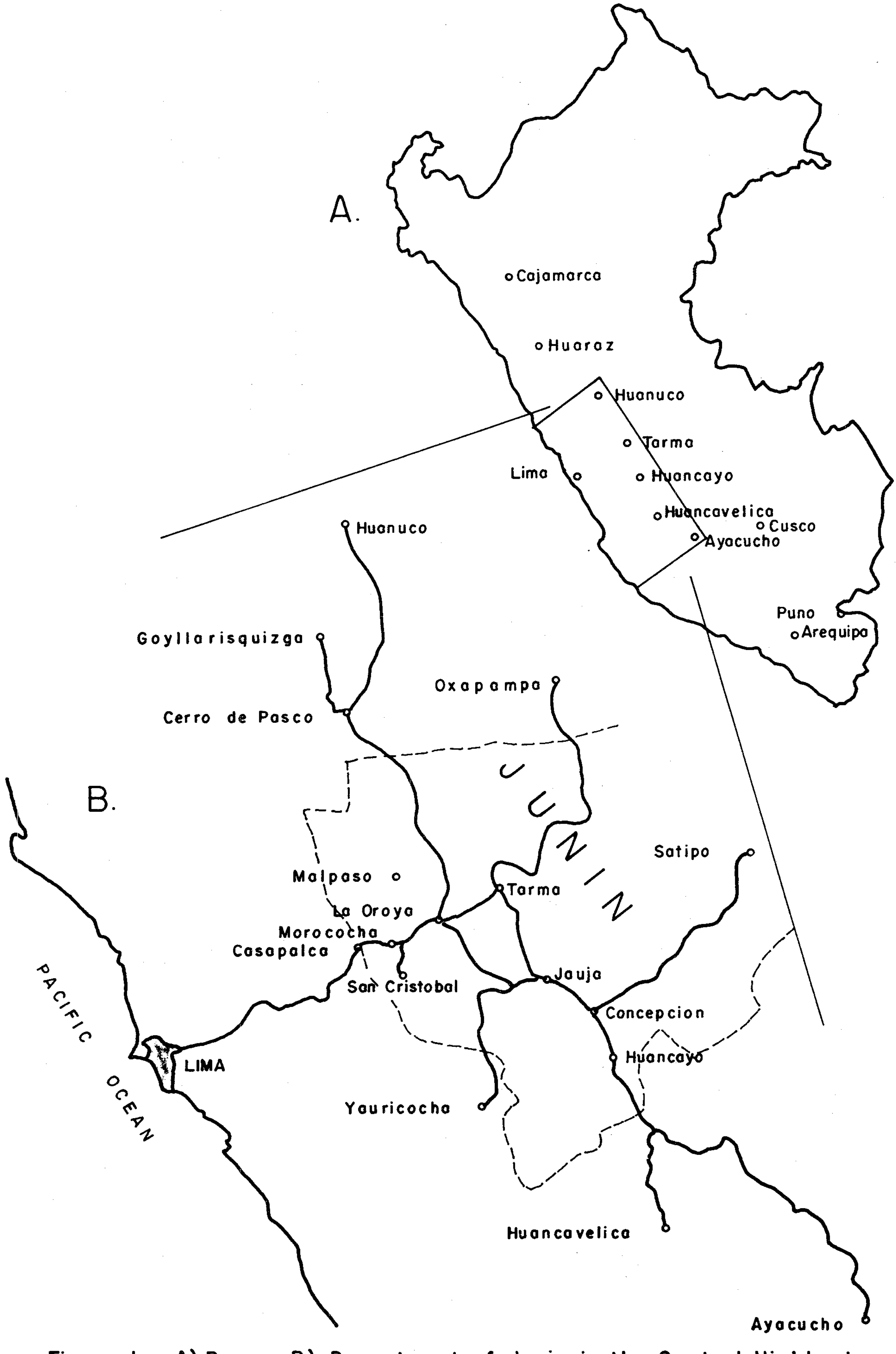


Figure I: A) Peru, B) Department of Junin in the Central Highlands.

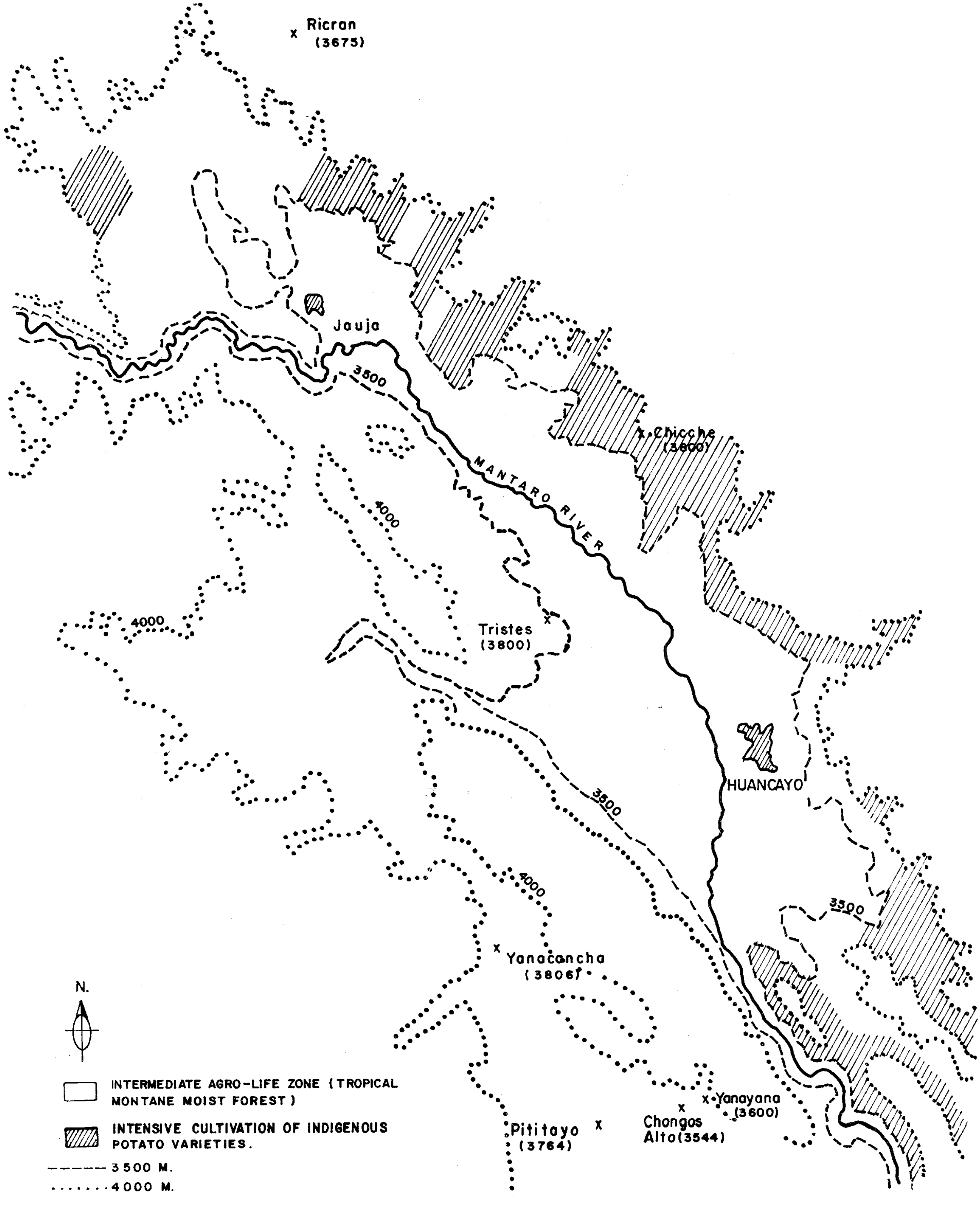


Figure 2: The Intermediate Agro-Life Zone and indigenous potato cultivation in the Mantaro Valley, Peru.

MATERIALS AND METHODS

During a two-month period beginning in late January, the first phase of the study, field mapping and identification of varieties, was completed. Fields were sampled while flowers were in bloom. Eleven fields were studied, using three different sampling strategies: 1) all plants, particularly in the smaller fields containing a great variety and mixture of clones; 2) transects - alternate rows, or every few rows, in the more homogeneous fields; and 3) quadrats, possibly combined with transects, especially in the larger fields, or groups of fields, where varieties appeared to be clustered. For all potato varieties encountered, the native name was noted, and characteristics of the cultivars were recorded using International Potato Center plant and tuber descriptors.

For varieties requiring ploidy-level determinations, two methods were used to count chromosomes. Somatic cell counts (mitosis) were taken from root tips. Stem cuttings were taken directly from the field, growth hormones were applied to the bases, and cuttings were then planted in coarse sand. Roots generally appeared after several weeks. Six roots (of different sizes) were collected from each cutting. These were placed in a 0.002 M solution of 8-hydroxyquinoline for 5 to 6 hours. The roots were then fixed in three parts 95% ethanol and one part glacial acetic acid. Counts were made using the squash method of Tarn (1967).

Counts were also made from pollen mother cells (meiosis). Buds of different sizes were taken directly from plants in the field and placed in Carnoy fixative at room temperature for 24 to 48 hours. These were refrigerated in the same solution for up to several weeks. The anthers were carefully dissected out, and counts were made using a modified squash preparation in aceto-carmine stain (Huaman n.d.).

During and after the harvest (May, June), the second phase of the study was completed. Tuber collections were taken to record varietal distribution on a regional level. An attempt was made to collect tubers in a given vicinity, either a village and its environs, or a cluster of villages. The localities sampled include: a) Cochas, Andas, Villa Muchca, Pilcoyama, and Ichahuanca, b) Andamarca and Llaccsapirca, c) Pazos and Aymara, d) Chongos Alto, Yanayana, and Pititayo, e) Yanacancha, f) Tistes, g) Chicche, and h) Ricran (see Figure 2). Tubers were collected from the field during the harvest, or from the storage bins in the farmer's homes. In two cases, tubers were taken by villagers to a predetermined site. In addition, questionnaires were administered to a) gain an understanding of varietal preference and selection by farmers and b) provide information on seed networks in the Mantaro Valley.

Electrophoresis work was carried out with many varieties to determine synonymy amongst tubers. The vertical slab method of Stegeman (1976) was used to separate soluble tuber proteins electrophoretically. Tubers weighing at least 20 grams were frozen at -20° C for at least 24 hours in polyethylene bags. They were then allowed to thaw at room temperature for 2 hours, and the sap of peeled tubers was expressed into a small beaker containing sulfite solution. The mixture was centrifuged for 30 minutes at 15,000 RPM, and the supernatant was carefully decanted and stored at -20°C. 8 or 10 samples were separated in each 6% acrylimide-bis-polymer gel using 500-600 V. and 50-60 mA. After separation, the proteins were stained with a comassie-blue solution. Only samples on the same gel were compared for synonymy. In several gels, duplicate samples were included to test for consistency of protein separation.

RESULTS AND DISCUSSION

Native plots.

Eleven fields were sampled, and a mean of 14 varieties was found per field. The frequency distribution according to ploidy level is 34.03% diploid, 9.14% triploid and 56.78% tetraploid and 0.05% pentaploid (Table 1). In all the fields sampled only two pentaploids were observed. The average number of varieties per field agree quite well with Jackson's findings. However, the ratio of diploids and triploids to tetraploids was much greater in these Mantaro Valley fields than in those studied by Jackson.

Table 1: Cumulative ploidy and cultivar frequencies for 11 fields sampled in the Mantaro Valley, Peru

Field N°	Cultivars per Field		2x	3x	4x	5x	Total Observation 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	15		1225	9	97	2	1333
8	11		5	-	391	-	396
9	5		-	-	217	-	217
10	30		82	18	486	-	586
11	18		14	16	273	-	303
			1437	386	2398	2	4223
		%	34.03	9.14	56.78	0.05	
Excluding Field 7:			212	377	2301	-	2890
		%	7.34	13.04	79.62		

Total number of cultivars found in field sampling: 77

Table 2: Pazos N° 1: cultivar and ploidy frequencies, field of Alejandro Chavez

Cultivar	Frequency	Percent
Akashlulu	1	0.171
Akaspashuyun	1	0.171
Amarilla	20	3.413
Callwash	14	2.389
Callwash negro	9	1.536
Camote	1	0.171
Chakchi palta	3	0.521
Duraznillo	16	2.730
Gaspar	11	1.877
Huayro	18	3.072
Ichipsa	1	0.171
Kanteña	17	2.901
Yana lima lima	18	3.072
Pukaluntush	130	22.184
Mishipsinghan	50	8.532
Murungush	56	9.556
Pepino plomo	2	0.341
Piña	9	1.536
Pujuya	23	3.925
Acco Shuito	29	4.949
Yana shuito	8	1.365
Tucu panahuin	91	15.529
Wakapa hallum	6	1.024
Wayquo	1	0.171
(no name)	3	0.512
Akalluipa pichun	2	0.341
Chichi shuito	1	0.171
Renacimiento	4	0.683
Sari papa	2	0.341
Valika	39	6.665
Total	586	100.000
Ploidy	Frequency	Percent
2x	82	13.993
3x	18	3.072
4x	486	82.935
	586	100.000

The number and distribution of cultivars in the fields studied varied considerably. Three types of fields, distinguished according to varietal diversity, are described below. At Pazos, a field containing 30 varieties and owned by Alejandro Chavez was sampled (Table 2). This type of field, termed chacro* contained a very large and random assortment of varieties. It is in these chacro fields, particularly that one may expect new genotypes to arise through hybridization and recombination.

A field having a more intermediate number of cultivars is that of Fortunato Quilca in Pazos (Table 3). 303 plants were observed, and 18 cultivars were found. 90% of the plants observed were tetraploid. Roughly equivalent numbers of diploids and triploids comprised the balance of the field sample.

Table 3: Pazos N° 2: cultivar and ploidy frequencies, field of Fortunato Quilca

Cultivar	Frequency	Percent
Amarilla	11	3.630
Amarilla larga	1	0.330
Caballo porenton	1	0.330
Callwash	23	7.591
Camote	1	0.330
Huacrash	1	0.330
Huayro	4	1.320
Kanteña	5	1.650
Yana lima lima	2	0.660
Murungush	13	4.290
Pepino plomo	2	0.660
Ranrahirca	1	0.330
Acco shuito	41	13.531
Yurac chuito	4	1.320
Huancavelica	2	0.660
Occa shuito	1	0.330
Yana mata	185	61.056
Yana palta shuito	5	1.650
Total	303	100.000

Ploidy	Frequency	Percent
2x	14	5.281
3x	16	4.620
4x	273	90.099
	303	100.000

* Chacro is a type of field recognized by peasants as having a large diversity of cultivars. It is therefore a type of chacra (a general term for field). I have made the above changes to avoid confusion.

A group of plots having a relatively low species diversity was that owned by Marcial Perez of Aymara. One field (field 7, Table 1) was atypical in that the diploid Pujuya (S. phureja) made up 80% of all plants. A number of bitter potatoes (both the triploid S. x juzepezukii Buk. and the pentaploid S. x curtilobum Juz. et Buk.) were also found. Marcial mentioned that Pujuya predominated because it is particularly tolerant to frosts. The unusual occurrence of the frost-resistant bitter potatoes (papa Shiri) in combination with the native "sweet" potatoes (papa de regalo) may also be explained by the fact that this field is located where frosts frequently occur.

The other fields of Marcial Perez were also characterized by a high degree of varietal homogeneity and segregation. One half of field two consisted of 90% Yana shuito (Solanum tuberosum L., spp. andigena), while the other half consisted of 90% Yana Huancay (also spp. andigena). The third field contained two sections of 98% Tarma murunki (spp. andigena) separated by a thin corridor containing 44% Mariva (spp. andigena) and 22% Duraznillo (spp. andigena). Marcial Perez maintained other fields in this way. For example, the majority of his Huayro (S. x chaucha) were grown in a field farther away from his home. The majority of his bitter potatoes were cultivated in yet another plot. This demonstrates his ability to discriminate intelligently between native cultivars.

In comparison with the fields studied by Jackson (1977) and Ugent (1968), native plots in the Mantaro Valley seem, generally, more orderly. Seed tubers of more than one variety were occasionally thrown into the same hole, but generally only one clone was observed growing per planting. Fields were generally kept free of weeds, and in only one case was a weedy Solanum variety observed growing in or around a plot. The diploid species Solanum bukasovii, termed "sapo" (frog) by the natives, was found between cultivated rows in the field of Adrian Figueroa, Chicche. However, our data do confirm that there is ample opportunity for intraploidy and interploidy hybridization and recombination.

Family level

Typically, nuclear families cultivated 3 to 5 chacras of potatoes comprising 1 to 3 hectares. Each family was found to cultivate and store 20 to 50 varieties of tubers. Thus, not all varieties were grown on a given plot. Indeed, most farmers observed simultaneously maintained three kinds of fields: 1) papa mejorada (modern hybrids, generally for the market), 2) papa de regalo (native varieties, mainly for home consumption), and 3) papa shiri (bitter potatoes, used to make chuño -- freeze-dried potato).

The plots of Jesus Quinto illustrate this cultivation pattern. In front of the house, close to the road, a large field of improved varieties was maintained. The predominant variety in this field was the tetraploid hybrid Renacimiento. Two fields, one to the side of the house, and another directly behind the house, contained 19 and 11 varieties of papa de regalo respectively. Farther up the slope, in the back of the house, a field of bitter potatoes, including both S. x juzepezukii and S. x curtilobum was cultivated.

Village and regional levels

Over 200 cultivars were collected in the Mantaro Valley region. The total number found in the field sampling was 77. Two principal types of tubers can be distinguished: 1) varieties cultivated in very restricted areas and 2) a cosmopolitan core group familiar to farmers of different parts of the valley. Cultivars in the latter group include Amarilla, Huayro, Ichipsa, Murungush, Piña, Shiri, and Tarmeña.

Members of this core group also comprise the predominant cultivars within fields. The dichotomy between local and cosmopolitan varieties suggests that new genotypes may arise regularly and independently in different parts of the valley, and that they may then be diffused through trade to other areas. If a given variety acceptable to peasants can tolerate a wide range of pathogens and environments, it becomes progressively more cosmopolitan through time.

But how may new genotypes be disseminated? Our ethnographic data reveal that three active and distinct seed networks occur in the Mantaro Valley. First, native tubers are traded and sold amongst peasants within the intermediate agro-life zone. These are generally exchanged as food or as seed for future planting. Also, exchange of improved varieties takes place between these farmers and commercial producers and merchants of the valley plain. Improved seed is bought by the peasants, cultivated, and then sold in major markets such as Huancayo and Jauja. Finally, improved seed is exchanged amongst commercial growers only. An infrequently-used network is the exchange of native varieties between farmers of the intermediate agro-life zone (Sierra Alta) and the people in the low agro-life zone (Sierra). Native varieties are occasionally sold in valley-floor markets, and these varieties are rarely brought from the Sierra to the Sierra Alta as food or seed.

Vertical slab electrophoresis was used to determine synonymy between folk names of the more cosmopolitan native varieties (synonymy = same clone). 206 samples were divided amongst 40 comparison groups of 2 to 8 samples. There was 86% synonymy between tubers of the same folk name or of different folk names referred by farmers as synonymous. In many instances, tubers of different names are known by the natives to refer to the same clone. Examples are Yana mata -- Papa viuda (S. x chaucha), Azul ciza -- Jaujina (spp. andigena), Huacrash -- Shukre (spp. andigena), and Gaspar -- Mishipsinghan (spp. andigena). Such naming can in part be explained by the fact that the different names refer to different aspects of a clone's morphology. For example, Yana mata refers to the dark color of the stem, while Papa viuda refers to the dark tuber.

In a number of residual groups, a given name refers to a number of clones. Examples are Huayro (S. x chaucha and S. tuberosum spp. andigena), and Murungush (generally spp. andigena). Oftentimes, these terms refer to general morphological characteristics of the tuber or plant which may easily apply to a range of clones.

Varietal selection by farmers

Varieties are generally distinguished by natives according to tuber characteristics. Evidence for this lies in the fact that a clone's folk name generally refers to some aspect of tuber morphology. For example, Moro callwash (spp. andigena), "weaver's shuttle", is long, flat, and dark. Chunchupañahuin (spp. andigena), "eyes of a jungle person", is dark and has white eyes. Kura pilingling (spp. andigena) "priest's ear", is flesh-toned and shaped not unlike an ear. Toromangia (spp. andigena), "rainbow", generally has polychromatic skin. Luchipamunduna (spp. andigena), "potato that makes the young bride cry", is particularly convoluted and hence difficult to prepare.

Clones are sometimes named according to actual plant characteristics. Examples are Azul wayta (spp. andigena), "blue flower", and Yana mata (S. x chaucha), "dark stem". However, only the most experienced farmers can be relied upon to make identifications according to such characteristics. It is interesting to note that scientists now consider tuber characteristics more diagnostic of a given clone than plant characteristics (Jackson 1977).

The major factors involved in native preference and selection include culinary quality, resistance to pathogens, and yield. Other factors include precocity and keeping quality in storage. Both Murungush (spp. andigena) and Canta (spp. andigena) are cultivated principally for their high yields. The diploid Pujuya (Solanum phureja) is maintained for its frost resistance and Okimacu (spp. andigena) is grown largely because of its resistance to late blight (Phytophthora infestans de Bary). The fact that the selection process by farmers involves a number of factors may in itself partially explain the maintenance of diverse tuber inventories by households.

Our questionnaires and other ethnographic data indicate that selection and maintenance of native varieties is based for the most part on culinary qualities. Understandably, the taste of a tuber is the first thing that will come to a farmer's mind while discussing the merits of a given clone. The varieties most preferred have a relatively high dry matter content, and are thus termed harinosa ("floury"). Varieties of the triploid Huayro yield poorly, and have a poor resistance to both late blight and frost. However, they are maintained for their excellent flavor. The diploid Amarilla (Solanum stenotonum, spp. goniocalyx) likewise has low yields, yet it is most commonly acknowledged as the best variety in the Mantaro Valley, due to its culinary quality. The tetraploid Kompis (spp. andigena) is the most common clone in the Vilcanota Valley. However, it has low yields and its deep eyes make preparation for eating troublesome. In addition, it is quite susceptible to both Phytophthora infestans de Bary and nematodes. Despite the fact that its "sweetness", Indians say, attracts worms (Gade 1975), it is clearly the favorite variety of peasants in the Vilcanota Valley due to its starchiness and taste.

Another clear indication that culinary qualities are the most important factors lies in the fact that natives cultivate the three fundamental crop types, papa mejorada, papa de regalo, and papa shiri, under different regimes, and for completely different reasons. Papa shiri are cultivated where frosts regularly occur so that <u>chuño</u> may be produced. Improved varieties require the application of pesticides and fertilizers and are cultivated only to be sold in the market. Native varieties, on the other hand, require no such expenditure, and are generally consumed rather than bartered or sold. In addition, improved varieties require more frequent seed replenishment and different seed networks.

Seed networks act as vectors for the distribution of preferred varieties selected on the basis of culinary qualities. Those varieties which are best able to cope with a variety of physical conditions such as soil, moisture, and temperature, as well as a variety of pathogens, become progressively more cosmopolitan. An appraisal of culinary quality is extremely subjective. A complex combination of factors including texture, flavor and starchiness may constitute a "favorable" variety for inclusion in a peasant inventory. Thus, a peasant may in part grow a variety of tubers because he enjoys a variety of flavors, textures, etc. This is particularly understandable when one considers that the traditional agriculture of highlands Indians included only a few other tubers and other crops in addition to potatoes. Surely, a variety of potatoes was a welcome relief from epicurian monotony.

<u>Model for the selection and maintenance of potatoes</u>

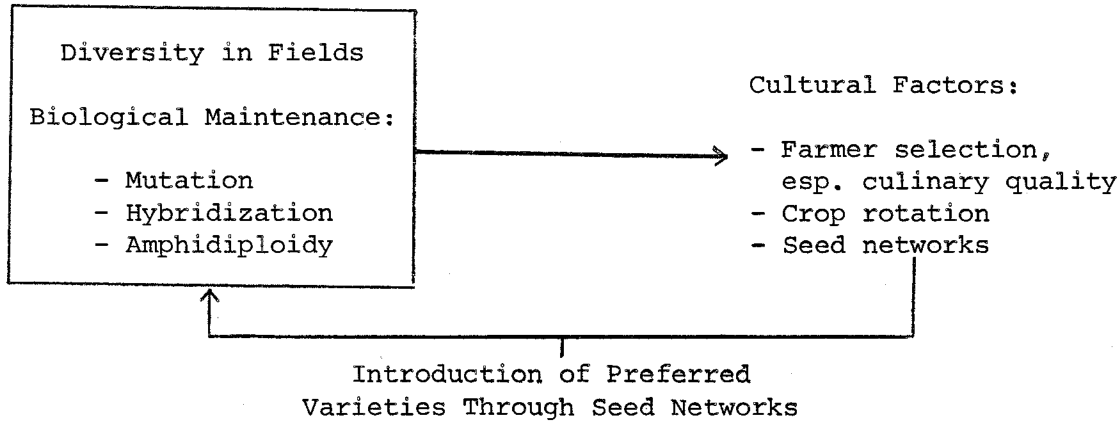
Let us now summarize how the biology of <u>Solanum</u> spp. and cultural practices of Peruvian peasants combine and result in the evolution of the cultivated Andean potato. The potato field is the basic unit within which the genetic diversity of cultivars is selected, maintained and amplified by natives. The singlemost striking aspect of Andean potato agriculture is the tremendous diversity of varieties maintained among and within fields. This is said to prevent any single pathogen (particularly viruses, bacteria, fungi or nematodes) from devastating the farmer's plot (Ugent 1968, Gade 1975). Biologically, the genetic diversity is maintained and amplified through mutation and hybridization. The latter occurs particularly between native cultivated varieties and results in the generation of new genotypes through recombination.

A number of cultural factors operate to influence the diversity and distribution of potato cultivars within and amongst fields. Peasants generally plant fields with a selected combination of varieties. A variety of factors enters into the selection process; the most important is culinary quality. The large number of factors entering into the selection process, as well as the subjective nature of the assessment of culinary quality, may in part explain the maintenance of large inventories by natives. These inventories in turn allow for a great deal of intraploidy and interploidy hybridization and recombination.

Crop rotation may be another cultural factor which contributes to the introduction of new genotypes. At Cuyo-Cuyo, Peru, a year of potato cultivation is followed by the planting of the tuber <u>oca</u>. During the <u>oca</u> harvest, potato tubers derived from sexually propagated true seed are collected along with the principal crop and subsequently used (Jackson 1979).

Finally, seed networks serve to diffuse preferred clones and thereby amplify the gene pools of individual fields. This process serves to accelerate hybridization and recombination. Figure 3 summarizes the biological anc cultural factors contributing to the ongoing evolution of cultivated Andean potatoes. It must be emphasized that Peruvian peasants are not consciously aware that they are generating new genotypes through their cultural practices. Nevertheless, these traits may be considered adaptive in that they help maintain the staple of the Andean highlands diet.

Figure 3: Diagramatic summary of the selection and maintenance of potatoes by Peruvian highlands peasants.



Other adaptive aspects of Andean potato cultivation include the following. Rows for the cultivars are either patterned diagonally or parallel in relation to the dip of the slope, depending on whether the priority is to prevent soil erosion or maintain adequate drainage. Hedgerows may surround fields to prevent erosion and help prevent intrusions by predators and pathogens. They are found especially in the eastern-facing slopes of the Cochas and Comas area where there is a very high mean annual precipitation. These hedgerows may also harbor wild varieties which cross with cultivated plants, birds which regulate insect populations, and insects which pollinate crops (Brush 1977). Predation is also prevented by planting the legume *tarwi* (*Lupinus mutabilis*) along the perimeter of potato plots. The high alkaloid content of the leafy part of the plant gives it an extremely bitter taste, thereby preventing the intrusion of cattle and sheep.

CONCLUSIONS

Native Andean potato cultivation constitutes a system in which the agricultural practices of peasants are inextricably bound to the maintenance and ongoing evolution of a tremendous variety of native cultivars. The potato fields themselves may be considered the basic spatial unit of evolution. Jackson (1977) refers to these plots as "dynamic evolutionary system(s)" and states that triploids in particular are dependent on man for survival. Higher levels of integration are the household, the village, and the region. At all these levels, biotic and cultural maintenance, selection, and exchange are taking place. This illustrates how the coevolution of man and plant may develop into a complex symbiotic relationship. Native Andean agriculturalists have developed a large inventory of native clones, and the maintenance of this diversity of varieties largely depends on their agricultural practices. The diversity of cultivars allows Peruvian highlands farmers to base their subsistence on this crop. The Peruvian botanist C. Vargas pays eloquent tribute to this man-plant interaction:

> "... Además se debe reconocer y agradecer que la conservación de la riqueza clonal de nuestras papas débese a la población nativa, pués ésta es la única que se empeña en cultivar la mayoría de variedades y formas de papas conocidas, conforme se puede evidenciar en las chacras de tales. (1949, p. 103).

Indications are, however, that this relationship is breaking down. In many areas, subsistence-oriented potato agriculture is being supplanted by commercial agriculture with hybrid varieties requiring pesticides and fertilizers. The genetic erosion of native varieties is increasing at an alarming rate, largely because hybrid varieties such as the _Renacimiento_ (spp. _andigena_) are being introduced into areas of traditional cultivation (Ochoa 1976). Northern Peru is the area hardest hit, and the diversity of native cultivars in the very cradle of potato cultivation, the altiplano of S. Peru and N. Bolivia, is being drastically reduced (Ochoa 1975, 1976). In the Mantaro Valley, peasants readily recalled varieties which are no longer cultivated. In Pazos and Aymara, such varieties as _Lucuma_, _Acaspa shullum_, _Sima tuna_, _Ebrida_, and _Maco_ are no longer cultivated. At the least, multidisciplinary information and materials, on a local and regional level, should be collected on native agricultural practices and the actual cultivars grown before the irreplaceable agricultural heritage of traditional Andean peasants, and the invaluable clonal richness of native potato varieties, is forever lost. Any efforts to preserve the diversity of native Andean potatoes must take into account the need to retain the agricultural practices which maintain these cultivars.

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