Table 1. The means of insect population and quantity of cassava chips damaged in different treatments (varieties).

| Varieties | Mean population of test insect | Mean quantity of chips damaged (g) |
|---|---|---|
| H-226 | 39.3 | 154.3 |
| H-1687 | 101.1 | 217.7 |
| H-165 | 85.0 | 209.3 |
| H-2304 | 64.0 | 147.0 |
| H-38 | 88.3 | 209.0 |
| H-3641 | 97.3 | 207.0 |
| H-312 | 99.3 | 201.0 |
| H-97 | 100.0 | 200.3 |
| H-2059 | 90.0 | 194.7 |
| H-1310 | 106.3 | 205.0 |

infests such crops as cassava, maize, pulses, ginger, and arecanut (Raghunath and Nair 1970). Though it is a serious pest of stored cassava chips, little work has so far been done on the extent of damage and the relative resistance/susceptibility of different cassava varieties. Raghunath and Nair (1970) reported that cassava is the preferred host material of the insect.

## Materials and Methods

Mass culture of *A. fasciculatus* on cassava was maintained in the laboratory from the inoculum obtained from the storehouse. Fresh sun-dried chips (250 g) of uniform size from each of the 10 hybrids were kept in thick polythene bags. Three identical samples were used in the experiment. Ten pairs of freshly emerged test insects were put into each bag for feeding and multiplication. The bags containing host material and test insects were dipped and kept in the laboratory for 45 days. The bags were then opened, and the number of adult beetles and the quantity of chips powdered were recorded. The data collected were subjected to analysis of variance.

## Results and Discussion

The data presented in Table 1 record the mean number of adult insects (from 39.3 of H-226 to 106.3 of H-1310) obtained and also the mean quantity of cassava chips powdered or damaged in each variety (147 g of H-2304 to 217.7 g of H1687) after 45 days. The quantity of chips damaged was usually directly proportional to the progeny increase in the test insects. The data indicate that H-226 and H-2304 are significantly superior to the other varieties in not promoting the population buildup of the pest.

There is also a significant difference between H-226 and H-2304 and H-226 has the highest resistance to this insect.

In quantity of chips damaged, all varieties except H-2304 and H-226 are susceptible and significantly inferior, but between these two there is no significant difference.

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# Utilization of Potatoes in the Tropics

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Research at the International Potato Center in Peru has demonstrated that excellent potato yields can be obtained under both intermediate- and low-elevation tropical environments. The potato clones that are well-adapted to these conditions mature quickly (65–90 days). This characteristic allows more flexibility to introduce the potato into current farm-

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ing systems in intermediate- and low-elevation tropical areas. The potential for high carbohydrate production plus the sizable amount of high-quality protein that the potato can produce in short time periods clearly indicates that it can play a very important role in diversifying and improving the nutritional status of many tropical areas.

The potato, indigenous to the tropical latitudes of the high Andes of South America, has travelled a circuitous route and undergone considerable change before returning to its original home. At this Center scientists are exploring its tremendous potential for adaptation to start it on a second world journey, this time in the lower elevations of the tropical and subtropical latitudes.

The Spanish seafarers who carried the potato to Europe made a greater contribution to mankind than those who carried gold and silver. When first introduced into Europe, the potato was poorly adapted to the long days of the temperate zone and was grown as a curiosity in botanical gardens. However, in the next century, through breeding and selection, its value was realized and production reached a peak in the nineteenth century (Salaman 1949).

The potato was classified as a crop of the temperate zone, primarily because of its adoption and use in Europe and North America. Its versatility permits it to be grown under very diverse environmental conditions. The "potato season" can be adjusted to the time of year which provides the most suitable temperature and moisture conditions. It is the most extensively cultivated "root crop" (293.72 million metric tons in 1974). It is grown in a very wide range of climatic zones in over 100 countries. In the Western Hemisphere, it is cultivated from Alaska down through Mexico, Panama, Colombia, Peru, to southern Chile. Because of its frost tolerance it thrives at altitudes too cold for maize. Adaptation to this wide range of environments was achieved by genetic alteration. It is now possible to define the characteristics that will promote its adaptation to tropical and subtropical environments where root crops are important sources of food.

Our results show that excellent yields in the San Ramon area can be produced in a tropical environment (Table 1). Yields as high as 2850 g /plant have been recorded. Some produced over 1000 g/plant in 90 days; one clone produced 1100 g/plant in 65 days. After testing similar cultivars South Korean workers are interested in 80-day potatoes in a multicrop sequence with rice. India is making a major effort to double potato production in the next 5 years. Kenya and the Cameroons are vigorously improving their potato programs. The potato is coming into its own in the tropics and has already gained considerable popularity, particularly among the affluent. However, too often the demand is satisfied by import, so it is essential that research be carried out to adapt the potato to the tropical environment. The addition of this very nutritious food item will help diversify the diet of a large segment of the world's fastest-growing populations.

The importance of potatoes in the early societies of South America and Europe is history. Langer (1963) attributes the European population explosion of the 18th Century to the introduction of the potato. Production from a small plot of ground provided sufficient food for a family and usually a surplus to sell. According to Salaman (1949) this made the industrial revolution possible.

Early South Americans were the first "potato processors." Chuño, probably the world's first freeze-dried food product, originated in the altiplano of Peru and Bolivia and reached its peak during the Inca regime. Ever since, the potato has been among the most reliable foods to ensure man's survival during periods of food shortages. Its use during wartime is well documented. Fresh potatoes are a durable food not easily destroyed by fire, either in the field or in storage.

Unfortunately, man is just relearning the exceptional value of dehydrated potatoes as a product to store, along with cereals, for periods of emergencies. Peare (1973) made a high quality concentrate with 33% protein by removing the large starch grains from potato flour. This Center has initiated research into storage and processing at the village level to preserve the potato for longer periods of time.

The potato is a succulent storage stem containing 70–80% water. This high water content must be considered when potatoes are compared to such foods as wheat, rice, or corn which are nearly dry. For instance, potatoes with 2–3% protein would appear inferior to rice with 7%. However, few cereals are eaten in their natural state. Rice when cooked and prepared for eating contains approximately 2% protein, very similar to potato. In a like

Table 1. Adaptation trial yields in 1974.

| Clone | San Ramon | | La Molina | |
|---|---|---|---|---|
| | Metric tons/ha | % solids | Metric tons/ha | % solids |
| 657A-5 | 60.06 | 20.1 | 51.97 | 21.0 |
| CGN69-1 | 49.33 | 20.2 | 46.20 | 22.1 |
| 69-47-2 | 43.89 | 20.9 | 49.00 | 21.1 |
| Antarqui | 39.50 | 16.6 | 40.59 | 20.0 |
| 72/Mast-164 | 35.97 | 21.1 | 29.86 | 22.2 |
| N512-50 | 35.64 | 21.6 | 30.03 | 19.8 |
| M1255-16 | 34.98 | 24.6 | 33.46 | 24.8 |

comparison bread contains 7–8%. This explains how great civilizations were built on potato, wheat, and rice as the staple foods.

The superiority of potato protein was reported by Kofranyi and Jekat (1967). In human bioassay with potato as the only source of protein, the daily requirement averaged 0.51 g protein/kg body weight. In rat-feeding trials Chang and Avery (1969) found the nutritive value of potato superior to that of rice. Jekat and Kofranyi (1970) demonstrated, by human bioassays, complementary effects of egg protein with potato, soybean, algae, rice, maize, bean, and wheat protein. The minimum protein requirement that maintained nitrogen balance was a mixture of 36% egg protein and 64% potato protein. In nitrogen balance studies, using adults as test individuals, potato protein proved to have the best nutritive value of all analyzed plant proteins, wheat flour, maize, rice, algae, soybean, and kidney bean protein (Kofranyi 1971, 1972). Kaldy (1972) calculated the number of people who could be supplied with protein per hectare per year from various crops, including potatoes (23.5 compared to 40.5 for soybean).

To meet present and especially future world food demands it is now recognized that emphasis must be placed on plants and plant products. Not only will it be necessary to improve on existing sources of food but new sources need to be explored. In the tropics the potato falls into the second category. The potato is one of the four most important food crops (the other three are wheat, rice, and maize).

In the assessment of any food crop, protein and energy must be considered together. The potato provides more of man's daily requirements of protein than energy. Protein cannot be used for growth or maintenance nor can it prevent the breakdown of tissue protein when the diet does not provide satisfactory quantities of other energy sources such as carbohydrates and fat. Since most human diets have an adequate protein–energy ratio the most practical solution to many food problems seems to be to supply more of the foods already consumed. While monotonous if consumed alone, most supply adequate proteins. When supplemented in a varied diet their total nutritional value will improve. With this in mind, we are studying the potato as a staple food, expecting it to be supplemented by animal or other plant products but serving as a major source of protein, carbohydrates, selected minerals and vitamins. In extending potatoes into the tropics the immediate objective is to increase production in the subtropics. Over half of the people of developing countries (more than 1000 million) live in climatic zones where the potato grows very well. A large portion of the population of countries normally considered tropical or subtropical such as Pakistan, Mexico, Brazil, and Tanzania live in areas where conditions of elevation or water modify the climate sufficiently for good potato production with the cultivars readily available today. Superior clones are rapidly becoming available as well (Table 2). The longer-term goal is to extend into the "true hot, humid, lowland tropics." This second objective will come with the development of genotypes adapted to these extreme conditions.

Potato culture in the subtropics and tropics will have to be modified to accommodate this new environment. Where potatoes have not been grown one can only anticipate problems such as season for planting, fertilization, disease, and pest management. The importance of these will be intensified where production is a year-round activity without frost or periods

Table 2. Yield of selected clones grown in 1975 (in La Molina).[a]

| Clone | Yield (kg/ha) | % solids | % protein[b] | RNV[c] |
|---|---|---|---|---|
| 5D 41-41 | 45870 | 34.3 | 8.1 | 68 |
| 3D 80-43 | 36102 | 33.8 | 7.5 | 66 |
| 5D 370-41 | 32109 | 25.5 | 15.5 | 73 |
| 3D 100-2 | 31878 | 30.9 | 6.9 | 83 |
| 3D 376-41 | 29700 | 25.7 | 11.3 | 75 |
| 3D 80-50 | 25047 | 30.9 | 10.8 | 85 |
| 3D 80-37 | 23628 | 30.8 | 7.6 | 66 |
| 3D 80-23 | 19734 | 36.3 | 4.9 | 74 |

[a]Courtesy Dr F. de la Puente.
[b]Protein = N × 625.
[c]RVN = Growth of *Streptoccocus zymogenes* as a percentage of casein.

of drought to decrease diseases and insects. Once production problems have been identified, seed programs can be initiated. In the early stages seed may have to be imported from traditional production areas. Also potatoes must "fit" established cropping systems. A potato, to complement total production per hectare in a multiple cropping scheme, provides the variation so necessary to many diets.

Potatoes from CIP's breeding programs are grown in Peru in a range of environments from Yurimaguas in the humid tropics to Puno in the altiplano to anticipate their adaptation to similar environments in other countries. Botanical seed and segregating tuber families are available for any potato program wishing to test them. Adaptation to the environment (yield and maturity) influences the production and food value of the potato. It would appear from recent studies that protein production parallels total yield per hectare and is strongly influenced by environment.

Yields, by tradition, have been reported on an area basis, i.e. hundredweight/acre or tons/hectare. In a temperate climate this was satisfactory as, for the most part, only one crop was produced each year. However, in the tropics where land can be cropped continuously, the time element becomes very important. It is misleading to compare the yield of a 90-day crop to the yield of a 300-day crop on a per hectare basis. For tropical agriculture, a more reasonable measure is yield per unit area per unit of time. Maturity as measured in temperate zones may not be essential. Production of a usable food product is the major criterion. With early-tuberizing cultivars, three to four crops are possible in one year tripling or quadrupling the yield per hectare and providing a continuous harvest to avoid storage problems. On this basis the potato outranks all of the major world food crops including corn, wheat, and rice. Only three short-season crops, soybeans, beans, and peas, outrank the potato in protein production per unit area per unit time. Growing potatoes in the tropics will necessitate major changes in the thinking of scientists from temperate regions as well as for the students of tropical countries trained in temperate regions.

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