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ANIMAL-DRAWN IMPLEMENTS FOR SMALL FARMS IN MEXICO†

The dualistic pattern of Mexican agricultural development is clearly evident in the use of farm equipment. Use of tractors expanded rapidly on the large and relatively capital-intensive farms, particularly in northern Mexico, and the national stock of tractors rose from about 12,000 in 1954 to 171,000 in 1981.

In central and southern Mexico, however, millions of small farmers still rely on animal traction. The 1970 census of agriculture (the most recent data available), enumerated approximately 1.8 million animal-drawn plows. The number has probably not increased significantly since then, as many small farmers have turned to tractor-hire services.

It is not easy to compare animal and machine draft power because of the enormous diversity of animal-drawn implements. Nearly half of the plows counted in the 1970 census, for example, were unwieldy wooden Spanish plows, with steel used only to provide a point for the share. These devices are separated by several centuries from the efficient steel moldboard

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plows. Other animal-drawn implements are copies of nineteenth century North American designs. Disk harrows have not been manufactured for many years, and the International corn planter went out of production in 1983. However, small regional workshops continue to make batches of seeders for specific crops (for example, chile peppers in Oaxaca and Veracruz states). A reasonable estimate is that fifteen to twenty firms in Mexico are currently manufacturing animal-drawn equipment.

INCREASED EMPHASIS ON IMPROVED EQUIPMENT FOR SMALL FARMERS

Since the early 1970s, the Mexican government has manifested increasing concern about productivity and earnings of the small farm units that provide employment for most of the country's farm workforce, a workforce that still accounted for some 37 percent of the total labor force in 1980. To date, government investments in research, irrigation, and other types of rural infrastructure have benefited mainly a relatively capital-intensive subsector of large-scale farms that accounted for a large fraction of the rapid expansion of agricultural production during the 1950s and 1960s. Although it is now appreciated that there is a large potential for increasing agricultural production by raising the present low levels of productivity of the country's small farmers, Mexico's import-substitution strategy of industrialization and the preferential treatment of the large-scale subsector in agriculture has had serious negative consequences for the country's small-scale farmers (Cartas, 1987).

Mexico's continuing financial crisis and economic problems, especially its high rate of unemployment, have given added incentives to the use of animal-powered farm equipment that meets the realities of relative factor prices. At the same time, the large devaluation of the peso since 1982 and the continuing problem of servicing a foreign debt that is now well over US$100 billion have weakened the effective demand for advanced agricultural equipment such as combines and tractors. Domestic manufacture of tractors, for example, reached a peak of 18,880 in 1981. The tractor stock

They owe a great deal to the original six farmer collaborators (Ramón Alvirio, Rufino Marín, Gumersindo Rosado, Felipe Ruíz, Marco Martínez, and Lucindo Ruíz) and five manufacturers (Sergio Solorzano, Salvador Rodríguez, Raúl Rebolledo, Pepín Ortíz, and Leopold Mejía). They also wish to thank INIA researchers Alberto Rodríguez, David Moreno, and Javier Albarrán and Paul Rhode of the Agricultural History Center for invaluable assistance. Special mention must be made of Michael Richards and Peter Seager who helped with the analysis and Ciriaco Meza, a farmer who cheerfully tolerated a great number of on-farm equipment evaluation trials.

also peaked in that year at 170,995. In 1979 and again in 1980, Mexico imported nearly 20,000 tractors, but imports fell abruptly to less than 5,000 in 1981 and not quite 2,000 in 1982. Because of the reduction in both local manufacture and imports, the national stock of tractors fell to about 159,000 in 1983 (Gómez Jasso, 1984). In contrast, the devaluation has had much less effect on the cost of animal-drawn equipment that has a domestic content of almost 100 percent.

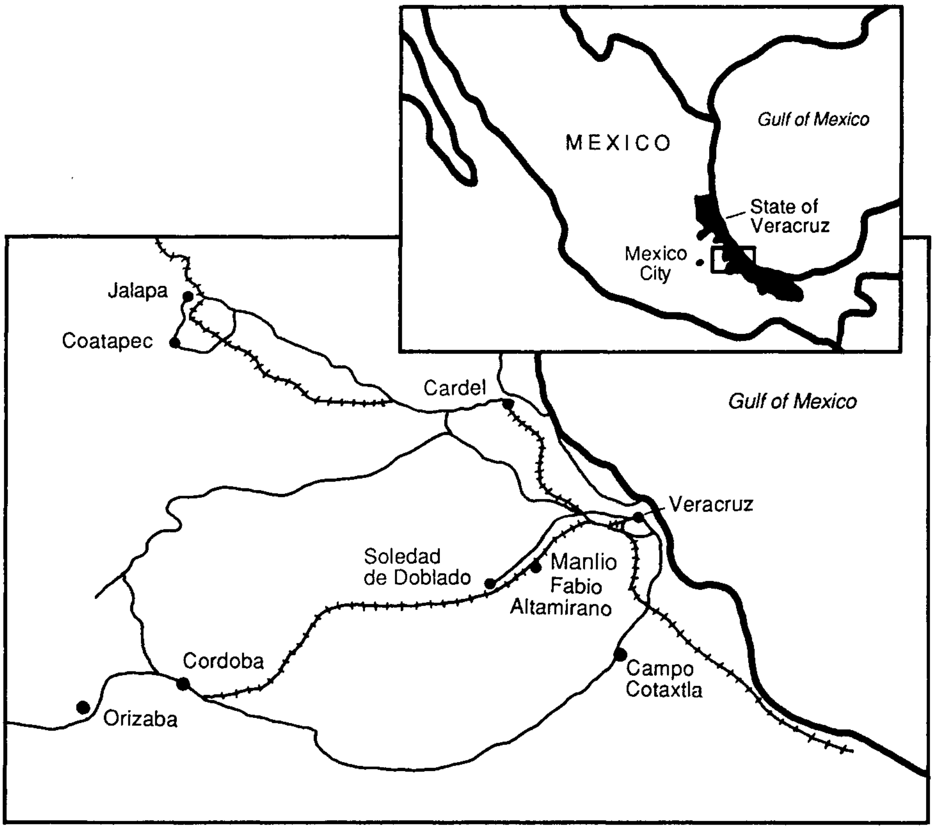
In the past, tractor services have been heavily subsidized by the government. However, the collapse of the oil boom and the need to curtail government expenditures have made the government less willing and less able to continue tractor subsidies. Whether large farmers and manufacturers of tractors, both of whom represent influential interest groups, will be able to persuade the government to continue the subsidy program remains to be seen.[1]

To the government's credit, however, in 1980 the National Agricultural Research Institute (INIA) initiated a program of research into agricultural engineering technologies designed to meet the needs of small farmers. The INIA program is located at the Cotaxtla regional experiment station for the semi-humid tropics in the state of Veracruz (Map 1). Small farmers in this region are typically dependent on animal (oxen) or human power for most fieldwork and transportation, although tractors may be used for plowing and disking. Data from the recent survey of small farmers suggest that roughly half of the farm households rely entirely on oxen draft power; the vast majority use draft oxen for part of the year, and almost all farms owned or had access to oxen or other animals.

The main body of the paper describes that INIA program and analyzes related activities to encourage local manufacture of promising implements. New options are now available to farmers because of recent improvements in the design of multipurpose tool bars, wheeled tool carriers, and disk harrows. The acid test of the economic worth of such equipment is whether or not the equipment's cost and productive characteristics make it in the self-interest of individual farmers to adopt it. The array of on-farm costs and revenues depends in large part on market forces, but they are also heavily influenced by government policies (for example, price controls, tractor subsidies, labor policies, export and import controls, credit policies). As noted earlier, such policies have greatly favored tractors and discriminated against animal-powered methods. An overvalued exchange rate and artificially low prices for diesel fuel have also made tractor-hire services attractive to farmers. While subsidized loans available from the Rural Credit Bank

[1] Subsidies are often justified on the basis of the technical efficiency of those capital-intensive technologies. But it is, of course, the *economic* efficiency of the alternatives that is relevant. See Binswanger (1978) and Johnston (1972).

Map 1.—The Republic of Mexico and Veracruz State with the Muncipalities of Manlio Fabio Altamirano and Soledad de Doblado



(Banrural) may be used to hire tractors, such loans are only now being considered for the purchase of inexpensive farm equipment. Under those circumstances, agricultural extension workers have given little attention to farm equipment innovations and often lack the knowledge required to advise farmers concerning animal-powered and other inexpensive equipment that could increase their productivity.

The research and development work of INIA's Agricultural Engineering and Mechanization Unit at Cotaxtla represents an exception to the general neglect of government support for farm equipment innovations. It is sometimes argued that this type of research and development should be left to private firms, citing their impressive record in developing farm equipment in North America and in Europe during the nineteenth and twentieth centuries. Many significant mechanical innovations were invented and developed by small rural machine shops working closely with local farmers. Large corporations then bought up the patents and undertook large-scale manufacture at a later stage. But even in the United States, blessed with its well-developed infrastructure and a large cadre of mechanics, blacksmiths, and inventors, there has been a significant role for government-sponsored mechanical research. Agricultural engineers at the land grant universities, for example, made significant contributions to the development of a wide variety of commercially successful agricultural equipment. Furthermore, field experiments and demonstrations sponsored by university and U.S. Department of Agriculture researchers helped persuade farmers to adopt new equipment and provided an invaluable bridge linking farmers, researchers, and manufacturers. The sort of feedback these researchers provided helped make manufacturers aware of farmer needs and thus accelerated the process of invention and technological diffusion.

THE INIA AGRICULTURAL ENGINEERING PROGRAM

A number of Latin American countries have undertaken programs to foster the use of animal-drawn equipment appropriate to the needs of small farmers, but the results have been disappointing. Such programs have generally failed to establish a close working relationship among researchers, farmers, and manufacturers to insure that the proposed equipment is cost-effective.

The agricultural engineering program of INIA has sought to overcome these shortcomings by working closely with both farmers and manufacturers. The interaction between the groups was facilitated by a joint on-farm evaluation of machine prototypes. The study carried out by INIA researchers focused on two municipalities: Manlio Fabio Altamirano and Soledad de Doblado, located 41 and 26 kilometers, respectively, to the southeast of Veracruz (Map 1). The agriculture in these areas is reasonably typical of the Mexican humid tropics, and farmers use animal traction, have access to tractors, and grow both rainfed and irrigated crops. After extensive interviews, six collaborating farmers were selected who resided in four *ejidos*.[2] Throughout a calendar year INIA researchers analyzed the daily agricultural activities of these six farmers to obtain information on labor inputs and production techniques. A later survey of 19 municipalities confirmed the representative nature of the sample (Cadena and Peña,

[2] Since the Mexican revolution, land reform has resulted in the creation of ejidos. Typically these are expropriated haciendas, owned by the federal government and divided into parcels farmed individually by each *ejidatario*.

1984). After the initial study the sample was expanded to a large number of farmers in different ejidos as collaborators in order to evaluate the different technologies and to obtain financial data.

Daily Analysis of Farming Activities

Throughout a complete year INIA investigators analyzed the labor use on the farms of the six initial collaborators, thus making it possible to identify peak periods of labor use. Raising labor productivity with machinery during these periods is a critical determinant of the financial rate of return to mechanization.

The method used to record the data is that described by Mann (1976), whereby the man-hours allocated to each task are noted with the work of the women and children adjusted to man-hour equivalents. The results are presented as a histogram. Table 1 offers an example of the weekly work sheets completed for each farming family. The table shows that on Friday the farmer's wife and son were counted as 0.5 of a man-equivalent each for the job of slashing with a machete; but the farmer's wife was counted as a full man-equivalent for corn winnowing on Saturday because her output per hour did not differ noticeably from the husband's.

During the year of the survey each of the farmers was visited at least once a week and during intensive work periods more frequently. The information indicated in Table 1 was recorded; the farmers' tools were used by the survey personnel; problems and possible solutions were discussed with the farmer, his family, and his neighbors.

Levels of Agricultural Mechanization

Table 2 gives an idea of the tasks, techniques, and equipment used by the small farmers. The government of the state of Veracruz maintains a fleet of 45 tractors to service the farms of 19 municipalities, including those of the present study. In the year of the survey (1981), only 26 of these tractors were serviceable. In addition, there are 136 tractors owned by ejidos in the two municipalities and about 50 privately owned machines. Most of these tractors are greatly underutilized due to maintenance problems and the lack of equipment needed to take advantage of their capacity.

The two municipalities have 1,462 pairs of working animals; the vast majority of these are oxen, but there are one or two teams that include bulls and cows, and some horses.

Tractors and draft animals are for the most part used to draw implements for plowing and weed control; Table 3 shows the relative importance of the two power sources in various operations on ejidos. Tractors accounted for practically half the plowing and all the disking, while animals performed

Table 1.—Sample Weekly Record Sheet: Activities and Labor Use: Farmer Gumersindo, El Sauce Ejido, Week No. 23, November 24–30, 1980

Day	Field code no.	Activity	Number of people	Man equivalents	Time taken (hours)	Man hours equivalent	Tools and animals
Monday	5	Harvesting corn	Gumersindo, assoc. farmer	2	8	16	Husking knife, baskets, donkey
Tuesday	5	Harvesting corn	Gumersindo, assoc. farmer	2	8	16	Husking knife, baskets, donkey
Wednesday	5	Harvesting corn	Gumersindo, assoc. farmer	2	8	16	Husking baskets, donkey
Thursday		Animal care	Gumersindo	1	1	1	—
Friday	3	Slashing for beans	Gumersindo	1	1	1	Machete
Friday	3	Slashing for beans	Gumersindo, wife, son	2	4	8	Machete
Friday	3	Sowing beans	Gumersindo wife	2	1	2	Ox team, plow, planting stick
Saturday		Animal care	Gumersindo	1	1	1	—
Saturday		Corn shelling	Gumersindo, wife, 4 daughters	3	1.5	4.5	Motorized corn sheller (evaluation)
Saturday		Corn winnowing	Gumersindo, wife	2	4	8	2 buckets
Sunday		Resting					

Table 2.—Agricultural Engineering Technologies
Used in Manlio Fabio Altamirano and Soledad de Doblado, 1981

Task	Available implements
Plowing	Tractor and moldboard or disk plow. Animal-drawn moldboard plow
Disking	Tractor and disk harrow. Animal-drawn disk harrow.
Ridging	Tractor and ridger. Animal-drawn ridger or moldboard plow.
Sowing	Corn: Manual with planting stick, cover by foot. Beans: Manual, continuous flow in furrow bottom, cover with tree branch harrow. Horticulture crops and papaya: Manual transplanting of seedlings from the nursery.
Slashing	Manual with machete.
Cultivating	Animal-drawn double tine or adjustable cultivator. Manual with long handled hoe.
Agrochemical application	Manual with knapsack sprayer for liquids or directly for solids.
Earthing up	Animal-drawn moldboard plow or ridger.
Irrigation	By siphons or sluice gates from canals. From tractor-drawn, trailer-mounted tanks delivering to hand-held hoses. Donkey-mounted tanks.
Corn bending	Manual with machete.
Harvesting	Corn: Manual with husking knife and basket. Lemon: Three-meter pole with hook at one end. Mango: Three-meter pole with basket at one end. Horticultural crops, beans, papaya: Manual.
Threshing and shelling	Corn: Manual with corn cob shelling board; mechanical sheller operated manually, by motor or by tractor. Beans: Manual beating of heaps of pods with sticks; with tractor running over the pods. Broom sorghum: Manual, scraping the seed head over a serrated knife; threshing cylinder driven by electric motor.
Winnowing	Manual using natural air currents.
Transport	Tractor and trailer; ox-drawn cart; baskets tied to donkeys and mules.
Storage	Corn: In the field on the bent-over stalks; in simple simple wooden cribs; in sealed galvanized steel tanks.

Table 2.–Agricultural Engineering Technologies
Used in Manlio Fabio Altamirano and Soledad de Doblado, 1981
(Continued)

Task	Available implements
Corn-grinding for tortilla dough	At the household level: Stone pestle and mortar; manual metal plate mill. At the community level: Electrically driven stone plate mill.
Water pumping	From deep wells: Electrically driven submerged pumps. From household wells: Bucket; manual lift pump.

Table 3.—The Relative Importance of Tractors and Animal Draft
in the Ejidal Agriculture of Manlio Altamirano
and Soledad de Doblado, 1981

	Percent of work done with:	
Task	Tractor	Animal draft
Plowing	47	53
Disking	97	3
Ridging	22	78
Cultivating	24	76
Earthing up	23	77

Source: Representatives of Units 2 and 14 of the SARH Rainfed Agricultural District No. 5.

more than 75 percent of the ridging, cultivating, and earthing up.[3]

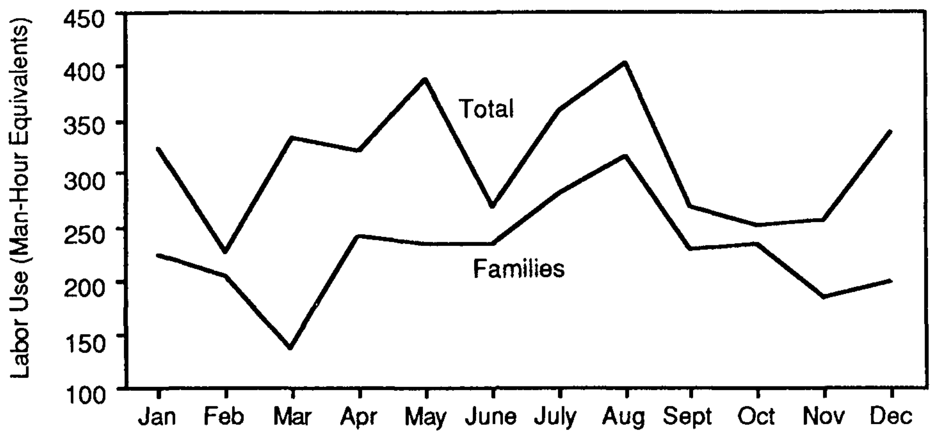
Labor Use

Chart 1 offers a summary of the monthly labor use for agricultural work; the figures are averages for the six farmers surveyed. The upper line shows the total labor usage and the lower one that supplied by the family. The monthly averages vary between 250 and 400 man-hour equivalents with an average of 315, which includes 28 percent hired labor.

Chart 1 shows that there are three periods of high labor usage—in May, August, and December/January. In May the high demand is due principally to weed control, irrigation (of papayas), and harvesting (of mangoes).

[3] For a more complete presentation of information on the details of crops, tasks, times, and implements, see Sims, Moreno, and Albarrán (1982).

Chart 1. Labor Use Per Month for an Average of Six Families



In August the most important activity is weed control in rain-fed corn. The December/January peak in labor demand is associated with the corn harvest.

The division of labor between the different tasks is summarized in Table 4. Harvesting demanded more time (29 percent) than any other activity. This is due mainly to fruit harvesting and to bending over the stalks of physiologically mature corn before harvesting the dry cobs.

Weed control starts with plowing and includes disking, slashing, cultivating, and earthing up. It occupies 23 percent of the farmers' time and, because timeliness in weed control is crucial to avoiding loss of yield, it is a priority area for improved labor productivity. The use of better cultivating tools would relieve a serious bottleneck, allowing the farmer to improve crop yields or to expand cultivated area.

While identifying the need for new agricultural technologies, weight was also given to the alleviation of unpleasant tasks that farmers performed grudgingly. Among the most unpleasant tasks are stripping broom sorghum, threshing beans, digging wells, and spraying. For example, crop spraying with the usual high volume knapsack sprayers is an extremely arduous task in the tropical climate because it requires about 400 liters of water per hectare. Use of controlled droplet application sprayers reduces the volume of liquid required to as little as 25 liters per hectare.

Table 4.—Percentages of the Total Annual Labor Employed in Different Tasks: Averages of Six Farmers in Central Veracruz State

Activity	Percent[a]	Activity	Percent[a]
Harvest[b]	29	Fence repairs	4
Land preparation, weed control[c]	23	Transport[d]	4
Planting[e]	9	Irrigation	3
Fertilizing	4	Shelling, threshing	3
Spraying[f]	4	Other	18
Annual labor requirement (man-hour equivalent)[g]			3,766
Area farmed (hectares)			8.5
Annual labor requirement per hectare (man-hour equivalent)			443

[a]The sum of the percentages does not equal 100 because of rounding off.

[b]Harvesting also includes bending the corn stalks at physiological maturity and uprooting bean plants.

[c]Land preparation and weed control includes plowing, disking, slashing, cultivating, earthing-up, and tree-felling.

[d]Transport includes transporting, producing, and stone clearing.

[e]Planting includes furrowing, sowing, planting out, and seed selection.

[f]Spraying includes applying fungicides, herbicides, insecticides, and foliar fertilizer.

[g]Man-hour equivalents take into account that women and children do not necessarily have the same output as men, although each activity differs in the amount of discrepancy. By observing the tasks and outputs of each class of worker the total labor requirements are reduced to man-hour equivalents.

INIA has developed a wide range of technologies designed to overcome identified problems of low labor productivity, unpleasant or unnecessary tasks, and underutilized resources is described elsewhere (Sims, 1984).

TWO ANIMAL-DRAWN IMPLEMENTS

This section deals with a subset of INIA-sponsored implements, the Yunticultor and the Multibarra, two animal-drawn implements for soil preparation, that have reached the stage of commercial manufacture.

The Yunticultor and the Multibarra are multipurpose tools that have not hitherto been sold in Mexico but which offer important advantages to the small farmer. Multipurpose tool bars permit the farmer to choose the tools he needs, or can afford, at any time and to add implements as conditions change. He only has to invest in a single chassis or tool frame. Instead of investing in, or hiring, a tractor for plowing and disking and then dealing with the subsequent weeding bottleneck, a farmer can purchase one implement that provides all of the tools needed for his crop production tasks.

The Yunticultor

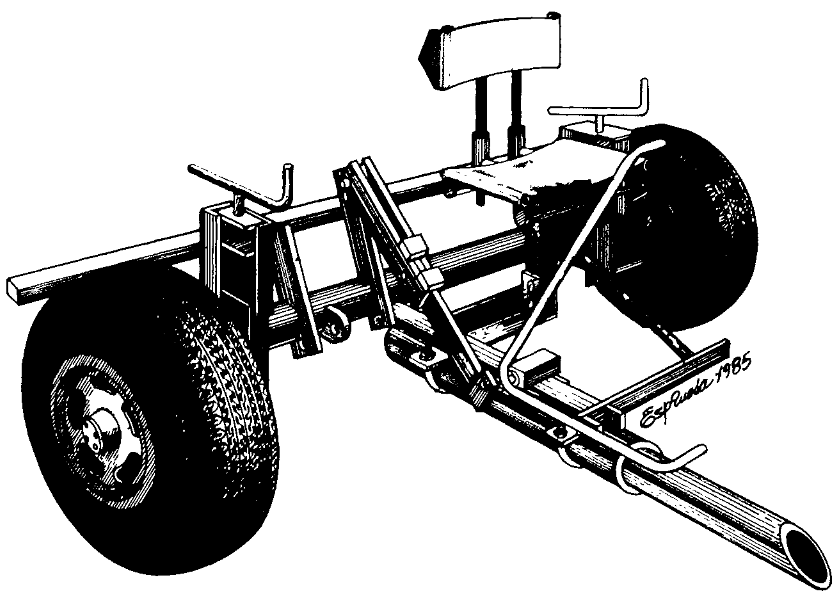
The Yunticultor (Figure 1) resulted from a request by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in India to the National Institute of Agricultural Engineering (NIAE) in Britain. The requirement was for a wheeled animal-drawn tool carrier capable of forming wide beds and able to work on them without compacting cultivated soil (Thierstein, 1983). Besides being able to carry tools to plow, furrow, cultivate, and earth up, the Yunticultor has a platform with a half-ton load carrying capacity. The Yunticultor is also designed so that the farmer can perform the various tasks while seated. In reviews of existing designs, various authors have reported the development of animal-drawn, wheeled tool bars in other countries (Goodenough Pumps, n.d.; Mouzon, 1975; Mexico, Universidad Autónoma Metropolitana, 1977; Willcocks, 1969). Kemp (1980), in a review of existing designs, concluded that apart from their high cost, all the machines incorporated one or more of the following defects: 1.) poor design of the implement lift system, which requires two operators to raise heavy implements; 2.) use of materials or manufacturing techniques unsuited to a program of local manufacture in developing countries; and 3.) inability to adjust implements on the move.

The NIAE engineers corrected these defects and designed a tool carrier to be hauled by a single pair of oxen, capable of plowing, ridging, sowing, cultivating, and earthing up, able to carry a one-ton capacity platform, and controlled by a single driver. In addition the tool carrier has a simple lift system with a locking mechanism to maintain the implements in position whether in or out of work.

The first Mexican prototype, known as the Yunticultor, was made in a commercial workshop in Veracruz in 1981. After field evaluations, INIA engineers made several modifications to suit the conditions of the Veracruz farmer. The technical characteristics of the machine and its use are fully described elsewhere (Sims, Moreno, and Albarrán, 1985).

The moldboard plows, ridging bodies, and disk harrow are each connected directly to the tool bar by means of specially designed clamps that do not require wrenches; they can be installed and removed with the aid of a six-inch length of half-inch-diameter steel rod. The cultivators are attached by similar clamps to a second bar that can articulate laterally about

Figure 1. The Basic Chassis of the Yunticultor



the tool bar. In this mode the Yunticultor must be controlled by a second man walking behind who uses a handle to guide between the plant rows.

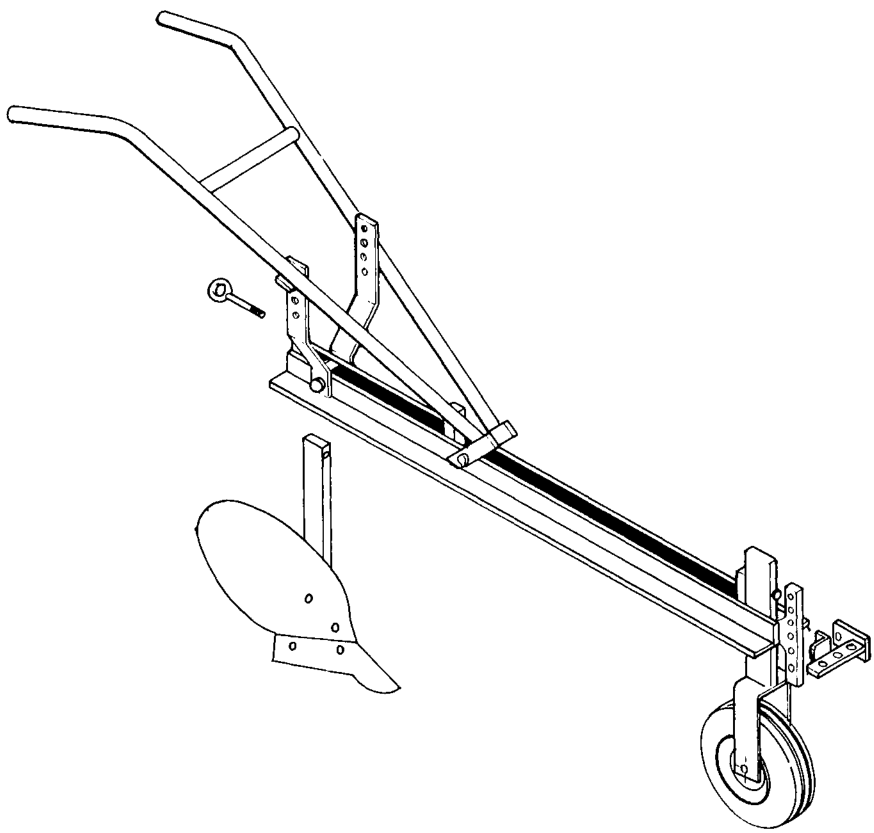
A major feature of the Yunticultor is its implement lift system; the double-lever lift allows the implements to be raised and lowered by the operator from his seat with minimal effort on his part. The adjustable lift linkage permits longitudinal leveling of the implements and so compensates for differences in the height of the ox yoke above the ground. In addition, each wheel can be adjusted to the depth of the tools and allow lateral leveling of the tool bar.

Development work is continuing on a crop sprayer, seeder-fertilizer units, and implements for reduced tillage (Camacho, 1983); these will be added in due course to the array of tools available. The Yunticultor with a full range of equipment presently sells for about US$1,000.

The Multibarra

The Multibarra (Figure 2) is a much simpler animal-drawn tool carrier that INIA engineers developed by adapting tool bars of British and French design. The Multibarra's frame has three spaces: two for receiving implement supports and one for the depth wheel. Also attached to the main frame is a single or double handle, and the vertical and horizontal hitch-point adjustments. Possible attachments include two sizes of moldboard plow, a ridger, a cultivator, and a seeder. Details of these are given by Sims, Albarrán, and Moreno (1986).

Figure 2.—The Multibarra with a Moldboard Plow



The farmer can interchange implements easily by removing a through bolt (again without need for wrenches) that clamps the implement support to the main frame. A further advantage is that two implements (for example, the ridger followed by the seeder) can be attached at the same time and so reduce the number of passes over the field. The Multibarra can be pulled by a single animal (mule, horse, or ox) or by a pair. A chain or rope connects the implement hitch point to the draft animal or animals.

Table 5.—Sequence of Operations, Implements Used, and Power Source Employed in Three Corn Systems

Task	Traditional system	Multibarra system	Yunticultor system
Plowing	Three-disk plow – tractor	Multibarra + moldboard plow – ox team	Yunticultor + 2 moldboard plows – ox team
Disking	Disk harrow – tractor	–	Yunticultor + disk harrow – ox team
Furrowing	Traditional moldboard plow – ox team	Multibarra + ridger	Yunticultor + 3 ridgers – ox team
Sowing	Pointed stick + seed basket – manual	+ seeder – ox team	Pointed stick + seed basket
Fertilizing	Fertilizer basket –manual	Fertilizer basket – manual	Fertilizer basket – manual
Cultivating	Two-tined cultivator – ox team	Multibarra + 3-tined cultivator – ox team	Yunticultor + cultivator – ox team
Earthing-up	Traditional moldboard plow – ox team	Multibarra + ridger – ox team	Yunticultor + 3 ridgers – ox team
Doubling over the canes	Machete – manual	Machete – manual	Machete – manual
Harvesting	Knife + basket – manual	Knife + basket – manual	Knife + basket – manual
Transport	Sacks – donkey	Sacks – donkey	Yunticultor + cart body + sacks – ox team

INIA is continuing its development work on the Multibarra in close collaboration with local manufacturers. New tool frames have been designed and are in the prototype stage. Further equipment being researched includes double-row seeders, seeder-fertilizer spreaders, and no-till seeders. The Multibarra tool package costs about US$200.

FINANCIAL ANALYSIS

In order to quantify the benefits to farmers of adopting the improved technologies, a financial comparison of three corn production systems was made (Sims, Moreno, and Albarrán, 1983): the first system uses a hired tractor for plowing and disking and primitive animal-powered equipment for other operations; the second system uses the Multibarra; and the third uses the Yunticultor. Table 5 lists the various operations performed with each system and the implements used. (See Appendix Tables 1, 2, and 3 for a summary of production costs for corn using the three systems.)[4] A summary of costs per hectare sown for each of the systems appears in Table 6. There were no significant differences in yields among the systems, so gross revenue per hectare was the same for all three methods. Thus, differences in net revenue were determined entirely by cost differences. Chart 2 shows the net benefit per hectare assuming a gross revenue of US$600 per hectare.[5]

These calculations use average data. Clearly, conditions vary for individual farms, but the results presented should nevertheless offer a good indication of the trade-offs faced by most farmers. It is common for trials with animal-powered equipment to be based on short periods of work and represent performance rates that could not be sustained by the draft animals for a normal working day. To avoid this problem performance rates were based on year-long observations showing actual day-to-day working conditions (Sims and Aragón, 1986).

It should also be noted that because competing technologies employ different ratios of fixed to variable costs, the relative advantage of one technology over another changes with farm sizes. Sharing or more intensive use of fixed capital would increase the relative cost effectiveness of a capital-intensive technology. In examining the relative cost effectiveness shown in Chart 2, it is clear that the Yunticultor system, not the tractor-based system, is the more capital-intensive method of production for farmers. The explanation for this paradox is straightforward: tractor services can be rented, so that for the farmer tractor costs are variable, not fixed.

Given these circumstances the Yunticultor becomes increasingly competitive with the tractor-based system as the area under cultivation in-

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[4] For more details see Sims, Moreno, and Albarrán (1983) and Sims (1988).

[5] Based on sample observations that showed an average yield of 4,000 kg of corn per hectare and a government-subsidized field price of $150 per ton.

Table 6.—Costs and Net Benefits per Hectare of Three Corn Production Systems*
(*U.S. dollars; at 15 percent interest rate*)

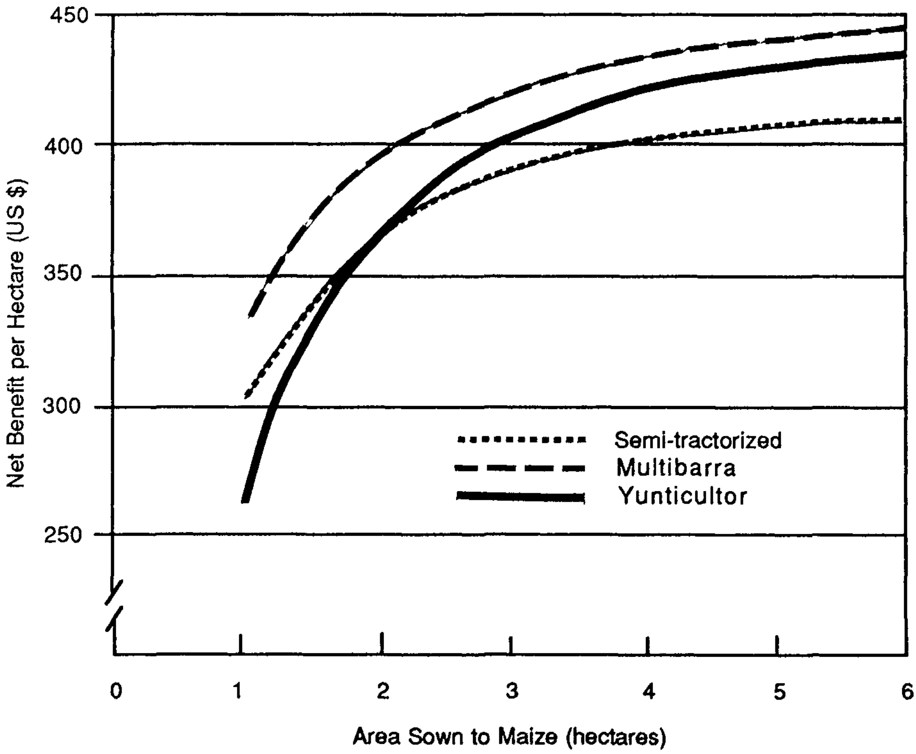
Production systems and costs	Area sown (hectares) 1	2	3	4	5	6
Semi-tractorized						
Fixed costs	130.7	65.4	43.6	32.7	26.0	21.8
Variable costs	168.6	168.6	168.6	168.6	168.6	168.6
Total costs	299.3	234.0	212.2	201.3	194.6	190.4
Net benefit	300.7	366.0	387.8	398.7	405.4	409.6
Multibarra						
Fixed costs	134.3	67.2	44.8	33.6	26.9	22.4
Variable costs	134.3	134.3	134.3	134.3	134.3	134.3
Total costs	268.6	201.5	179.1	167.9	161.2	156.7
Net benefit	331.4	398.5	420.9	432.1	438.8	443.3
Yunticultor						
Fixed costs	211.5	105.8	70.5	52.9	42.3	35.3
Variable costs	128.1	128.1	128.1	128.1	128.1	128.1
Total costs	339.6	233.9	198.6	181.0	170.4	163.4
Net benefit	260.4	366.1	401.4	419.0	429.6	436.6

*Assuming a yield of 4,000 kg/ha and a field price of US$150/ton giving a total revenue of US$600/ha.

creases. The calculations presented in Table 6 and underlying Chart 2 are based on assumptions that are relatively unfavorable to the Multibarra and Yunticultor. First, labor costs have been computed using the prevailing wage rate rather than the assumption that family labor was a fixed resource to the farmer. Second, for purposes of initial presentation a real rate of interest of 15 percent was taken as the appropriate indicator of the opportunity cost of capital.[6] Chart 2 clearly shows the Multibarra to be the preferred technology for all relevant production areas, and the Yunticultor dominates the semi-tractorized system on farms with more than two hectares sown in corn.

[6] In recent years the rate of inflation (60 percent or more) has often exceeded bank lending rates. Thus the real rate of interest for many borrowers with access to institutional credit has been negative. Most economic investigations for developed countries have settled on a real rate of interest between zero and 3 percent. Even in capital-scarce countries such as Mexico, a 15 percent real rate of interest is relatively high and thus biases the calculations against the Yunticultor system that is capital-intensive for the farmer (McKinnon, 1973, pp. 109, 115).

Chart 2.—Net Benefit Curves for Three Corn Production Systems
(Interest rate, 15 percent per year)



DIFFUSION PROBLEMS

To obtain an idea of the farmers' responses to the new implements and to identify possible constraints to commercial manufacturing, 26 small farmers and 18 manufacturers were interviewed (Jácome, Sims, and Seager, 1985).

Farmer Survey

The farmers expressed general appreciation of the technical advantages of the improved implements, but faced serious financial constraints due to low incomes and the lack of credit. In the study area, a typical small farm family may expect farm cash receipts to exceed cash outlays for production by only about US$500 to US$1000 per year.

In theory, credit has recently become available from the Banrural, but many farmers do not know how to obtain it. Others expressed a marked lack of confidence in the rural credit system and eschewed doing business with Banrural. Until 1987 no credit lines were available for the type of improved equipment that is being promoted. After considerable pressure, Banrural is now offering long-term credit repayable over five years at a subsidized interest rate of 32 percent. It remains to be seen how much, if any, of this credit will actually reach farmers.

Diffusion of the new farm tools has been retarded by the subsidization of tractor services. The government maintains tractor fleets for custom plowing and disking. The prices charged are typically 40 to 60 percent of the actual resource cost for plowing; the charges for disking are between 70 and 100 percent of the actual cost. The subsidized prices charged by the government naturally affect what private contractors can charge, tending to drive them from the market. The long-term effect has been that tractor rental services have become increasingly unreliable as operators find it difficult to service and replace their machines. Many farmers complained of the erratic service and have little confidence in the operator's ability to arrive on time and to do an acceptable job.

Manufacturer Survey

The INIA agricultural engineering program has had modest success in fostering the commercial manufacture of some of its prototypes. A factory in Ozumba in the state of Mexico, some 450 kilometers distant from Veracruz, has made and sold several hundred Multibarras and also makes the Yunticultor and the disk harrow when it receives orders. One manufacturer in Veracruz has been interested in the development of both the Yunticultor and the Multibarra and has made and sold several of each, but is more interested in developing new products than in producing large quantities of developed products. Finally, as of 1987, the Servicios Ejidales, a government-financed organization in Guadalupe, Zacatecas, was manufacturing 100 Yunticultors to be distributed by the government of Oaxaca.

To date the total commercial production is about 500 Multibarras and 100 Yunticultors; no local manufacturer in the Veracruz area has undertaken mass production of these implements. When interviewed, manufacturers expressed various financial concerns, and noted difficulties associated with technical ability, promotion, and marketing. Most manufacturers work exclusively to order, claiming that they are fearful of carrying large stocks in anticipation of future sales given today's austere economic climate. None of the manufacturers interviewed conducts any form of market survey, and many fear that small farmers would have trouble paying, which reduces their willingness to anticipate future sales.

Manufacturers did little to promote their products. Less than half advertised, and only 6 percent used the radio, which was considered to be the best means of reaching farmers because of a high illiteracy rate. There was no effort to promote their equipment at field demonstrations or at farm fairs. Up to 40 percent of the productive capacity of the factories was idle, in part because of a lack of diversification in the range of products being manufactured.[7]

Although the great durability of animal-drawn equipment is a major advantage for farmers, this characteristic limits replacement demand. All the manufacturers interviewed recognized the role that improved animal-drawn tools could play in increasing their product range and reducing idle productive capacity. But they always emphasized the problems of the low and insecure purchasing power of the prospective clientele in explaining why they failed to produce such equipment. In essence, they did perceive a market; it simply was not very lucrative in their estimation.

The technical problems associated with manufacturing the new equipment fall into three categories: availability of materials; knowledge of the fabrication techniques; and availability of the necessary equipment.

The material most difficult to obtain is carbon steel for the shares and disks of soil-moving parts. Distribution of carbon steel is controlled, and it is difficult for a small factory to acquire. There did not appear to be any supply problems with respect to other materials in Mexico.

Most manufacturers did not have the machine tools and other equipment needed to produce the implements, and many noted that uncertainty about the future may not justify investing in new equipment. The most important tools are presses for forming curved parts and ovens for heat-treating parts exposed to the abrasive action of the soil.

A majority of manufacturers were not familiar with the fabrication techniques required to produce agricultural implements. These manufacturers also failed to appreciate the importance of approach angles, smooth curves, and large clearances to allow soil and vegetation flow without surcharging the soil failure zone. The INIA engineers continue to provide instruction on these issues and advice on the design and use of jigs and fixtures to ensure uniformity and high quality in the finished product.

CONCLUSION

This research has important implications for Mexican officials struggling to find policies that will raise rural incomes and improve the quality of life in the farming communities of central and southern Mexico. One obvious possibility is to increase the utilization rate of the existing tractor stock and make tractor services more reliable. But the problems underlying the

[7] Follosco (1984) has emphasized that diversification is especially desirable in the case of farm machinery because of the seasonal nature and low volume of demand for each product.

inefficient use of tractors—particularly those owned by the government—are not easily overcome. Maintenance problems that idle many vehicles are a function of the difficulty in obtaining parts and the region's general level of economic development. In virtually all countries government tractor services have failed dismally to achieve a satisfactory utilization rate because government regulations and pricing policies fail to give operators sufficient incentive to do good and timely work. Another possibility is to take a serious look at promoting animal-drawn equipment.

Improving the quality of animal-drawn equipment is an attractive possibility where half of the farmers rely entirely on animal draft power and the rest depend on animals to a considerable extent. This study suggests that it may be economically more efficient for many farmers to use improved animal-drawn equipment than to hire tractors for plowing and disking. In much of rural Mexico, simple moldboard plows, ridgers, and cultivators represent significant technological improvements over the primitive Spanish plows still used by many farmers.

Because of normal uncertainty about the correct values of key parameters, the cost calculations for three corn production systems were repeated over a wide range of values. The conclusions are robust. Given any reasonable set of assumptions about key parameters such as interest rates and input costs, the Multibarra system was the least costly and most efficient method of production for all relevant farm sizes below 6 hectares. The tractor-based system was more efficient than the Yunticultor only on small farms, with the break-even area heavily dependent on interest rates. For real rates in the reasonable range up to 15 percent, the Yunticultor dominated the tractor on all farms planting more than 2 hectares of corn. These general results held for a wide variety of crop mixes common to the Veracruz region.

A small farmer could expect to reap substantial financial savings from adopting a Multibarra instead of employing the tractor-based system. A farmer cultivating 4 hectares of corn could expect cash savings of at least US$120 per year. At a cost of about US$200, the Multibarra offers a real rate of return of over 50 percent per year for small farmers working 4 or 5 hectares of corn.

Clearly, other factors may diminish the strength of these results. Tractors save on effort and can do the work much faster (provided that they show up when needed). But these issues did not seem to be a major concern of the farmers in the INIA survey. On the other hand, the prices of Yunticultors and Multibarras would undoubtedly fall if they could be produced in larger quantities. The Multibarras are being made in small batches and the Yunticultor is generally made for custom orders or in batches of two or three. All of the manufacturers in the survey were confident that they could achieve substantial unit cost savings by increasing output. The experience of small-scale industries elsewhere suggests that this is indeed a real possibility.

Furthermore, at the time of the survey, tractor prices were subsidized heavily by a variety of government programs. This suggests that the social savings of relying more extensively on animal-powered equipment would exceed the private benefits measured by present prices. Policies designed to encourage the manufacture of animal-drawn machines could increase the efficiency of resource use, help maintain rural employment, and raise rural incomes. In the small farmer economy of rural Mexico, the major impediments to diffusion could be lessened significantly by a modest infusion of credit to farmers earmarked for equipment purchases. The potential exists for large increases in the production of implements, and small-scale equipment manufacturers would undoubtedly respond rapidly to the demand that such a credit program would stimulate. Other steps might be considered to increase interaction between equipment manufacturers and farmers. The established makers of animal-drawn equipment that were interviewed had little or no direct contact with farmers to provide feedback, and there is no effort to promote equipment at the local level. Equipment fairs, demonstrations, contests, and prizes might be valuable for both farmers and manufacturers.

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Appendix Table 1.—Production Costs for Corn Semi-Tractorized System
(*U.S. dollars*)

Operation	Implement	Fixed costs per year				Variable costs per hectare		
		Depreciation	Interest[a]	Maintenance[b]	Animals	Labor	Maintenance[c]	Inputs
Plowing	Tractor, plow	—	—	—	—	—	—	17.1
Disking, 2 passes	Tractor, disks	—	—	—	—	—	—	20.0
Ridging	Oxen,	—	—	—	104.0	—	—	—
	moldboard plow	3.7	3.4	0.5	—	9.7	0.2	—
Sowing	Planting stick	—	—	—	—	9.8	—	13.1
Fertilizing (1)	Manual,	—	—	—	—	4.0	—	19.0
Cultivating	Oxen, two-	—	—	—	—	—	—	—
	tined cultivator	2.3	2.1	0.5	—	6.8	0.3	—
Fertilizing (2)	Manual	—	—	—	—	3.2	—	0.5
Earthing up	Oxen,	—	—	—	—	—	—	—
	moldboard plow	—	—	—	—	6.9	0.2	—
Cornstalk bending	Manual	—	—	—	—	3.8	—	—
Harvest	Manual,	—	—	—	—	30.0	—	—
	husking knife,	0.3	0.1	—	—	—	—	—
	baskets	1.0	0.2	—	—	—	—	—
Transport	Donkey,	—	—	—	1.6	16.0	—	—
	sacks	9.0	2.0	—	—		—	—
Totals			130.7				168.6	

[a]Interest rate at 15 percent.
[b]At 25 percent; includes repair.
[c]At 75 percent; includes repair.

Appendix Table 2.—Production Costs for Corn, Multibarra System
(*U.S. dollars*)

Operation	Implement	Fixed costs per year				Variable costs per hectare		
		Depreciation	Interest[a]	Maintenance[b]	Animals	Labor	Maintenance[c]	Inputs
Plowing	Multibarra,	Complete	6.8	Frame 0.3	104.0	15.8	Frame 0.1	—
	moldboard plow	Multibarra		Plow 0.4			Plow 0.3	
		7.4						
Ridging and	Multibarra,	—	—		—	7.7	Frame 0.1	13.1
planting	ridger,			Ridger 0.4			Ridger 0.2	
	planter			Planter 0.4			Planter 0.3	
Fertilizing (1)	Manual	—	—	—	—	4.0	—	19.0
Cultivating	Multibarra,	—	—	Cultivator 0.4	—	6.8	Frame 0.1	—
	cultivator						Cult. 0.3	
Fertilizing (2)	Manual	—	—	—	—	3.2	—	8.5
Earthing-up	Multibarra,	—	—	—	—	4.7	Frame 0.1	—
	ridger						Ridger 0.2	
Cornstalk	Manual	—	—	—	—	3.8	—	—
bending								
Harvest	Manual,	—	—	—	—	30.0	—	—
	husking knife	0.3	0.1	—	—			
	baskets	1.0	0.2	—	—			
Transport	Donkey,	—	—	—	1.6	16.0	—	—
	sacks	9.0	2.0	—	—			
Totals			134.3				134.3	

[a]Interest rate at 15 percent.
[b]At 25 percent; includes repair.
[c]At 75 percent; includes repair.

Appendix Table 3.—Production Costs for Corn, Yunticultor System
(*U.S. dollars*)

		Fixed costs per year				Variable costs per hectare		
Operation	Implement	Depreciation	Interest[a]	Maintenance[b]	Animals	Labor	Maintenance[c]	Inputs
Plowing	Yunticultor, 2 plows	Complete Yunticultor 45.0	41.3	5.3	104.0	15.8	Toolframe 0.1 Plows 0.7	—
Disking	Yunticultor, disks	—	—	—	—	5.2	Toolframe 0.1 Disks 1.0	—
Ridging	Yunticultor ridger	—	—	—	—	3.2	Toolframe 0.1 Ridgers 0.6	—
Planting	Planting stick	—	—	—	—	9.4	—	13.1
Fertilizing (1)	Manual	—	—	—	—	4.0	—	19.0
Cultivating	Yunticultor, cultivator	—	—	—	—	2.3	Toolframe 0.1 Cultivator 0.7	—
Fertilizing (2)	Manual	—	—	—	—	3.2	—	8.5
Earthing-up	Yunticultor, ridger	—	—	—	—	2.3	Toolframe 0.1 Ridgers 0.6	—
Cornstalk bending	Manual	—	—	—	—	3.8	—	—
Harvest	Manual, husking knife	0.3	0.1	—	—	30.0	—	—
	Baskets	1.0	0.2					
Transport	Yunticultor,	1.5	1.4	0.4	—	4.0	Toolframe 0.1	—
	platform, sacks	9.0	2.0	—			Platform 0.3	
Totals			211.5				128.1	

[a]Interest rate at 15 percent.
[b]At 25 percent; includes repair.
[c]At 75 percent; includes repair.