TECHNOLOGY DEVELOPMENT PROCESS AND EXPERIENCES ON SMALL FARM MECHANIZATION IN TAIWAN

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ABSTRACT

In Taiwan, the progress of agricultural mechanization, along with automation, has been significant in the past 30 years. The production of rice, the main crop, has been fully mechanized from preparing the land, to transplanting, spraying, harvesting, and drying. Planting other crops such as vegetables is also mechanized. Although the majority of farmlands is small, the degree of their mechanization is as high as 98%. A variety of locally manufactured innovative farm machinery has struck a growing market share in Taiwan and overseas, particularly in Japan. These products, which used to be patterned after Japanese designs whose capacities were modified to suit local needs, are discussed in this paper.

Key words: Agricultural mechanization, automation, farm machinery,

INTRODUCTION

In Taiwan, agricultural mechanization from preparing the land to seedling nursing, transplanting, spraying, harvesting, and drying has been highly developed over the past three decades. In paddy production, for example, the level of mechanization has reached such a highly significant status that most of the farm operations are done using a variety of farm machinery. Land preparation is done by tractors with mounted rotary tillers; the nursed seedlings are planted by transplanters; and the grown rice in the field is harvested by self-propelled combines.

Aside from the machines for paddy production, the upland-crop harvesting machines for corn and sorghum were also locally developed to meet the government policy on the diversification of paddy field. Ear corn pickers, dehuskers, and shellers; soybean harvesters; and sorghum combines have also been working very well for small farm practices.

The automation technique, along with sensing devices and automatic controls, is also being applied on the existing production system to enhance production efficiency. Many efforts, including examining production cost and techniques, have been taken in the past ten years to increase the earnings of each farming family. The automation on agricultural production, livestock, fishery, transportation, and trading has been in progress and has gained a promising success.

The e-farmer was also conceptually formed and framed to facilitate the sale of farming products over the Internet. All these give a prosperous picture of Taiwan agriculture.

LAND PREPARATIONS

Power Tillers

The walking power-tillers from the 1950s were once the main power for land preparations in Taiwan but they only lasted for two decades or so as tractors of all sizes imported from Japan and Europe prevailed on the domestic market in recent years (Fon 1995). Owing to keen competitions in both domestic and foreign markets, the local manufacturers hardly survived, and so they shifted their product...
lines to the smaller managing tillers. At present, a small quantity in sizes of 10-15 hp is still used in certain fragmented areas, but most of them are Japanese models.

**Tractors**

The tractors have replaced the farm power, dominating Taiwan agriculture since 1980. Transactions for use are usually through the custom service or a job hiring organized by certain farmers who usually own large farmlands. Therefore, through the custom services, most of the small farmers are able to handle their farm operations on time without the need to purchase or own any tractor and related equipment (Taiwan Provincial Government 1988).

The size of tractors ranges from 40 hp to 150 hp, depending on the type of practice. However, a size of more than 150 hp is also likely to be found working in some fragmented field as a keen competition between groups of contractors is going up. The range of 150–180 hp is being used in dry land areas and those of 60–80 hp for wet land. The 40-50-hp tractors are sufficient for common farm work. However, it is believed that the larger the tractor, the quicker and more efficiently the job is done. For land preparations, tractors are equipped with rotary tillers, which can pulverize the top soil layer of 10-20 cm in depth. Experts say that the structure of the soil is likely to be destroyed if the soil is not plowed once every three years.

Tractor safety is another concern as accidents occur yearly. Even traffic rules have forbidden tractor-driving on the highway, as there have been some casualties because of illegal driving. According to the law, farmers should join the training course and obtain a license before driving their own tractors. But the rule is not quite seriously put into effect.

**Managing Tiller**

Managing tiller is a kind of walking garden tractor, which helps in soil pulverizing, furrowing, and weeding, with a limited capacity, while plants are growing. It is a mini-power tiller but is quite suitable for vegetable and flower growers. The tiller, which stirs but not turns the soil near the plant at a depth of 7-8 cm, consumes less power than power tillers do. Its power ranges from 2 hp to 5 hp, depending on the crops cultivated. The precision and accuracy of work, however, are an important factor in the success of a tiller’s operation, as long as it does not damage the plants around.

This machine, through its rotating blades in a horizontal axis, can both cut and blend the soil aggregates. The blades may have types like pick-up crawls, spring crawls, chopper knives, and L-shaped knives, some of which, however, can also be used to mix composts.
The tiller with a mono wheel (Fig. 1) is the simplest, which usually cultivates the fields for vegetables, flowers, tobaccos, peas, and teas. It works well in soil loosening, weeding, furrow opening, and cultivating. The one with dual wheels (Fig. 2) is also used when stability is concerned during operations. Operations like seed planting, fertilizer spreading, and transporting are also possible using the tiller power frame by engaging its appropriate attachments (Fig. 3).

RICE NURSERY CENTERS

Working Cycle

Seedling nursing is a pre-procedure for both hand and machine transplanting. Standard nursing procedure is a must to have a successful operation for the machine transplanting or rice transplanter. The nursing operations include seed selection, germination, tray accommodation, sowing mechanism, and seedling hardening. A rice nursery center (RNC), basically consisting of a working area and hardening fields, is a factory that houses the necessary operations in a time sequence.

The events taking place in a typical RNC is shown in Fig 4. From left, the immersed seeds, pulverized soil, fertilizers, and empty trays are concurrently supplied to the seeding line at one end. The finished trays, covered with uniform seeds, come out from the other end and are sent to the conditioning room for preemergence treatments for two or three days. Then, these trays are sent out via a transport mechanism to the hardening field for greening, which takes about 20 days. The grown seedlings will grow like a mat (Fig. 5) and can be rolled in a pack of three for later shipping. The empty trays need to be collected, cleaned, and sterilized before re-use in the next cycle (Chiu & Fon 1998).

Working Area

Fig. 6 depicts a typical working area for rice nursery centers that supply seedlings for a 100-ha scale. The work area, 24 m x 9.5 m, is allocated for most of the materials and equipment, including nursery trays, soil medium, rice hulls, and fertilizers. The building is made of steel truss with an eave height of 2.8 m (Fig. 7).
Fig. 8 shows a typical seeding line, consisting of a tray discharger, a soaking tank, a soil refilling tank, a seeding device, a sprayer, a pulverizing equipment, and a tray stacker, as well as the main conveyor. Empty trays, 60 cm x 30 cm x 3 cm (Fig. 9), are stacked by hand on the cartridge of a discharger and removed via the main conveyor. As the trays move along the conveyor, each takes a soil medium from the soil tank, seeds from the seeding device, water from the sprayer, and soil cover from the soil tank again. The finished trays with seeds will then be stacked on a pile, three in one, and removed by another conveyor. The handling speed reaches 2,000 trays an hour.

The seeded trays are stacked again on top of a pallet, which holds 240 trays each and is moving toward the stack area, where the ambient atmosphere is kept warm and humid (or under a plastic cover) to enhance the further germination of the seeds for three
Fig. 6. Layout of the work area for a unit.

Fig. 7. Side view of a steel truss structure for the work area.
Fig. 8. The operation events occurring in a seeding process.

Fig. 9. The size of a nursery tray.

Fig. 10. Tray-stacking carried out by workers.
to five days (Chiu & Fon 1997, 1998). After sprouting, all trays will be unstacked and relocated to the hardening field for acclimatization for another 15-20 days (Fig. 10).

Pallets (Fig. 11) have long been used for automatic material transportation and handling (Banjing 1996, Fu 1994, Wang 1996, Taiwan Pallet Company 1999, Tien 1998, Liu and Hsiao 1997). However, pallets, categorized into two sizes – 1,280 cm x 1,280 cm and 1,280 cm x 640 cm – are becoming the common platform for stacked-tray operations in nursery centers. The large one can hold 240 trays in eight piles while the small one can hold 120 trays in four piles. The loaded pallets can be fork-lifted to the germination area. As germination completes, the whole pallet of trays is lifted again to the inlet of the conveyor, where the seeded trays are unpacked and individually sent to the acclimatization fields for hardening.

An average RNC can supply seedlings for about 200 ha. Fully automatic seedling lines equipped to connect the flow of trays and tray-unloading machines working on a
transporting gantry are developed to help arrange the trays in a field for the seedlings to be hardened (Fig. 12). The hardened seedlings with trays can also be automatically retrieved back via the same system. These trays would be laid down on the acclimatization fields for hardening and future growing (Chiu et al. 1998).

**Rice Transplanter**

To fulfill the need for mechanical transplanting, the seedlings should be raised to standard sizes during the nursery stage. The seedlings should sit firmly on the seedling box of the transplanter, where the transplanting arm and finger mechanism is able to grasp two or three seedlings at a time and dig them into the soil.

A constant transplanting depth is maintained by using both the wheels running on the plow sole and the float, which runs on the paddy field surface.

The first single-row power transplanter was introduced in Taiwan from Japan in 1967. Ten years later, some local companies worked out two- and four-row models. In 1981, the four-row, Japanese-made transplanter dominated the domestic market, replacing the local ones. Then there came the six-row type with a driver seat (Fig 13). At present, with only very few using direct seeding, almost all the rice fields in Taiwan employ the transplanting method. The degree of mechanization for rice transplanting is greater than 99%.

**Rice Combine**

Rice combine is a complicated mechanism that functions cutting, holding, threshing, separating, and packaging in one consistent process. The harvested rice can be stored in bags or in a temporary tank, where the unloading auger is equipped for a direct unloading to a standby truck. The first rice

Fig. 13. The 6-row riding-type transplanter in operation.

Fig. 14. Rice combines in Taiwan.
combine appeared in 1970 and domestic manufacturers have tried to work out similar ones, but failed. All are Japanese models (Fig. 14). As the degree of mechanization reaches 99%, no one is likely to see any hand-harvesting in the field. The new versions usually are four to five rows, equipped with a comfortable riding seat, a storage tank, and an auger conveyor. Their power ranges from 80 hp to 90 hp.

Many custom services, usually mobile, own not only tractors for land preparation, but also rice transplanters and rice combines. During harvest season, they travel from south to north, from county to county, and work day and night to maximize machine usage. They arrange service deals through phone calls and deliver their services according to the prearranged schedule. If they can harvest 100 ha a year, for both crops, their one-year earnings are enough to pay back their loans completely.

**Rice-drying Center**

Mechanical drying started in 1960 and was widely accepted in 1970. The box-type portable dryer first entered the market. Five years later, the circulating-type dryers, which dry the grains while keeping them circulating inside, came to the picture and replaced the box-type for their ability to dry uniformly. In 1985, the government set a new policy to subsidize the purchase of circulating-type dryers and to install drying centers at farmers’ associations (FAs). Since then, the circulating types have dominated the drying process.

Although a few farmers still favored sun-drying in the beginning, they finally found that the local FAs provided better services than ever. In 1995, more and more FAs installed their own rice-drying centers (Fig. 15) to serve nearby farmers who directly bring wet grain from the harvested field. Farmers benefit by getting the equivalent payback at the dumping pit. In Taiwan, 77 FAs now own their drying centers, with daily drying capacities ranging from 60 t to 300 t.

The dryer manufacturers in Taiwan were all small at the early stage. Usually, they borrowed Japanese design and enlarged its capacities to meet the local needs. The capacities of earlier models were 1.8 t, 3.2 t, 4.8 t, and 6 t, mostly made according to Japanese specifications. The early types are already obsolete and newer designs of 10 t, 12 t, 20 t, 24 t, and 30 t in capacities are now in the market. The greatest advantage of these is that large units can save space, a critical consideration for the dryer installation. New products with rice husk burner are also becoming popular, as oil prices have been going up. These products are also exported to Japan and some other South Asian countries.

In Taiwan, the dryers can only be used twice a year during the harvest seasons, where

Fig. 15. Rice-drying centers.
each season only lasts one month or so. Although the dryers are idle most of the time, most FAs who intend to business rice packs are willing to own a drying center so that not only can they control the source of paddy, but may also be able to serve their farmer-members.

DEVELOPMENT OF MACHINES FOR UPLAND CROPS

Grain Drills

Grain drills are the attachments mounted on a tractor to plant corn, peanuts, sorghum, and soybeans (Fig. 16). With multiple lines, these are capable of planting 4 ha/day, depending on the seed varieties. Fertilizer applicator, furrow listers, or add-on functions combined are common attachments to perform no-till practices.

Planters employing precision vacuum mechanisms with adjustable row width up to 45 cm and a workload of 3.4 ha/day are also available. Inside, the seed plate that regulates the size of seeds is easy to switch back and forth for different seeds.

For the greenhouse system, the vegetable seeder and transplanter of two rows work successfully on 128-pot seedling trays, with the help of two operators. Being half-automatic, this transplanter can be employed for all kinds of vegetable seedlings.

Harvesting Machines

Harvesting machines for corn, soybeans, and peanuts are of the same principle but are likely different for each crop. In general, the western...
combines are too large to fit small fields.

**Corn sheller and pickers.** To avoid breakage in harvesting wet corn, a tractor-driven, axial-flow corn sheller would be the answer. This sheller, with little adjustments on the threshing drum, can thresh both ear corns and sorghum heads (Fig. 17).

**Peanut harvester.** Two local companies have successfully manufactured a stalk-holding-type peanut harvester. The basic functions work by pulling up the peanut plants and then holding them to the place for threshing, separating, and cleaning. The daily capacity is around 0.8 ha (Fig. 18).

**Soybean combine.** Soybean combine is a crawler type that uses the main frame of rice combine. Its functions include cutting, threshing, separating, and packaging. The working capacity is about 1 ha /day.

**AUTOMATION SYSTEM IN AGRICULTURE**

Automation techniques have been applied to agricultural works. It is a combination of computer-controlled means and mechanization through an optimizing process. To accelerate the pace of modernization in agriculture and cut down the farm labor, the government initiated many automation programs on agricultural production, livestock production, fishery operation, and agricultural transportation and services for a period of ten years since 1991 (Fon 1997).

The automation in agricultural production includes pesticide-spraying application, postharvest processing, seedling production system, greenhouse cultivation, gantry loading, and handling systems for rice seedlings. Plant factory systems might be the final form to combine some of the above-mentioned features and become an integrated system, such as bean sprout production, field cultivation, and greenhouse managing systems. It has been proven successful in a microclimate control, especially on the vegetable and flower productions.

The automation related to seedling production of flowers has three categories, namely, the seedling nursery, cut flower, and plant flowers. All these products are grown in a controlled environment or in an equipped greenhouse to facilitate mass production.

Vacuum seeding technique has been widely used in growing vegetable seedlings of which seeds are small. Some growers imported facilities like medium mixers, automatic potting machines, and control units from the Netherlands for modifications.

For the seeding in a greenhouse system, the vacuum device with picking needles has been widely employed to separate seed kernels (Fig. 19). It is suitable for the greenhouse system to prepare the seeded trays. The working rate may exceed 200 trays an hour. Some local manufacturers have it modified by using two rows of needles to speed up the seeding rate.

Besides being hardware-wise, farming operations can also be incorporated with information techniques. The e-farmer is another concept to promote the sale of farm products on the Internet. Many platforms are available in networking to sell high-quality products such as packed rice, processed food, and fish goods. It becomes another channel to share product information. All these give a prosperous picture of Taiwan agriculture.
CONCLUSION

The agriculture in Taiwan has reached a very high degree of mechanization, which is up to 98%. As custom hiring services and seedling nursing systems are widely used, both are keys to promoting agricultural mechanization.

The dryer manufacturers in Taiwan own high technology and have their capability of producing competitive products. New products with rice husk burner are also becoming popular, as oil price is going up recently. These products are also exported.

The mini-power tillers are other innovative products that can earn more market shares both in the domestic sector and abroad. The versatility of designs can meet the needs of work for small farmers.

In the future, more incentives for quality farming are required to attract more youths to be involved in agriculture. In the past, field crop production could only be done on the open field in a toilsome manner, while the greenhouse system, which originated from the Netherlands and Japan, is a prosperous enterprise that might draw more people to engage in. From the viewpoint of production, the greenhouse products are of high yields, good-quality produce, weatherproof management, and high profitability, providing farmers a brighter future.

ACKNOWLEDGMENTS

The author wishes to thank Mr. Min-Zen Lin, officer at COA, for supplying current information on agricultural mechanization in Taiwan.

REFERENCES