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Prediction of Labor Requirement and Cost of Pick-up Type Pulse Crop Harvester for Soybean and Red Bean Harvesting

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Abstract

Purpose: This study was carried out to evaluate the labor requirement and the cost-reducing effects of the pick-up type pulse crop harvester compared with those of conventional harvesting for soybeans and red beans. **Methods:** The labor requirement and the cost to gather, thresh, and clean for conventional harvesting operations were surveyed; those for the pick-up type pulse crop harvester were estimated for soybeans and red beans. The annual capacity of the harvester and the break-even area of the two harvesting methods were also estimated. **Results:** For soybean harvesting, the labor requirement of 0.57 hour-persons/10 a for the pick-up type pulse crop harvester reflects a 91.9% reduction in the labor requirement of 7.00 hour-persons/10 a for conventional harvesting. Machinery costs of 51,300 won/10 a for the harvester were estimated for an annual harvesting area of 52.5 ha/year, representing a reduction of 33.3% from the 78,700 won/10 a cost of conventional harvesting. A break-even area of 28.4 ha was estimated for the two harvestings. For red bean harvesting, the labor requirement of 0.57 hour-persons/10 a for the harvester reflects a 92.6% reduction in the labor requirement of 7.66 hour-persons/10 a for conventional harvesting. For an annual harvesting area of 52.5 ha/year, annual capacity of 52.5 ha/year and machinery costs of 51,700 won/10 a were estimated for the harvester, reflecting a reduction of 44.7% in the cost of 93,500 won/10 a for conventional harvesting. A break-even area of 23.1 ha was estimated for the two harvestings. A governmental subsidy for purchasing the harvester could contribute to reducing the break-even area and harvesting costs. **Conclusions:** The pick-up type pulse crop harvester for soybean and red bean harvesting could reduce the labor requirement and costs of conventional harvesting, and a governmental subsidy for purchasing the harvester will improve the economics of the harvester for efficient mechanical harvesting.

Keywords: Labor requirement and cost analysis, Pick-up type pulse crop harvester, Soybean and red bean harvesting

Introduction

Because pulse crops such as soybeans and red beans are being recognized as health foods and alternatives to rice, their cropping area and supply have increased recently in Korea. However, conventional harvesting methods involving hand cutting, field drying, threshing with a thresher attached to a tractor or power tiller, separating, and cleaning using a stationary cleaner are labor intensive given shortages in rural labor. Labor time of 21.7 hours/10 a is required for bean harvesting, which represents 44% of the total labor time for cultivating operations (Hong at al., 2003). Mechanical harvesting is needed to reduce labor requirements and to save harvesting costs.

During the past several decades, many researchers developed various types of bean harvesters, such as cutters, threshers, and pull-type or self-propelled combines. Most studies focused on improving machine performance and efficiency to maximize the quantity and quality of the grain. Various cutting, gathering, conveying, threshing, separating, and cleaning mechanisms to reduce grain loss, grain damage, material-other-than grain (MOG) in grain, and power requirements have been researched

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(Dunn et al., 1973; Fayz et al. 1979; Fernando at al., 2004; Fernando at al., 2005; Mesquita at al., 1979; Mesquita at al., 2005; Nave et al., 1972; Nave et al., Newbery at al., 1980; 1975; Williams et al., 1973; Williamson et al., 1976). A comparison of harvesting methods (McColly, 1958) and machinery selection for bean production using economic analysis (Al-Soboh, 1986) were also carried out. Domestic research on the development of a bean combine harvester has been done (Hong at al., 2003). The bean combine harvester showed field capacity of 27.0 a/hour and could save 97% of labor requirements and 88% of harvesting costs compared with the conventional harvesting method.

In Korea, the conventional harvesting method for pulse crops involves hand cutting, field drying, threshing with a thresher attached to a tractor or power tiller, separating, and cleaning with a stationary cleaner. Although direct mechanical harvesting using a combine harvester to reduce labor requirements and costs is necessary, such harvesting is in the beginning stage. The imported combine harvesters that utilize bean attachments, including cylinder reduction drivers, screens, and other parts, display too much loss and damage to grains for farmers. Because most pulse crop varieties are not suitable for direct combining, and most farmers grow more than one crop that needs early harvesting to prepare for subsequent crop operations, most pulse crops are cut by hand and dried in the field for two to three days. Therefore, a combine harvester that can pick up, convey, thresh, separate, and clean the cut and field-dried pulse crops is needed to reduce the labor requirement and the cost of conventional harvesting.

This research is part of a major project to develop a pick-up type pulse crop harvester. An experimental pick-up type pulse crop harvester was designed and manufactured. The purpose of this study is to evaluate the labor requirement and cost-reducing effects of harvesting using the pick-up type pulse crop harvester compared with that of conventional harvesting for soybeans and red beans.

Materials and Methods

Surveys on conventional harvesting

The pick-up type pulse crop harvester can pick up, convey, thresh, separate, and clean cut and field-dried pulse crops. The types of equipment and machines used and their field capacities, number of workers, time required for operation, cost analysis items for gathering, threshing, and cleaning operations in conventional harvesting were investigated using representative farms in Muan County for soybeans and in Chunan County for red beans. Conventional harvesting labor requirements and costs were analyzed. Table 1 describes the machines used in conventional harvesting.

Pick-up type pulse crop harvester

As part of a major project to develop a pick-up type pulse crop harvester, an experimental harvester was designed and manufactured. Figure 1 provides an overview of the harvester, and Table 2 describes its specifications and features.

The main parts of the harvester are a 45-kW diesel engine, an HST transmission, a crawler drive, an operation and control device, a pick-up device, an auger and chain conveyor, two transversely located cylinders and a concave,

Figure 1. Overview of pick-up type pulse crop harvester.

Table 1. Machines used in conventional harvesting

Crop	Operation	Machine
Soybean	Gathering	Manpower
	Threshing	Moving bean thresher attached to the 7.5 kW power tiller
	Cleaning	Stationary 4 kW bean cleaner
Red bean	Gathering	Manpower
	Threshing	Moving bean thresher attached to the 60 kW tractor
	Cleaning	Stationary 4 kW bean cleaner (same as soybean cleaner)

Table 2. Specifications of pick-up type pulse crop harvester

Item	Specifications
Engine type and power	Diesel, 45 kW/2, 800 rpm
Type of travel device	Crawler, HST transmission
Travel speed	Field: forward 0–1.5 m/s, reverse 0–1.5 m/s Road: forward 0–2.5 m/s, reverse 0–2.5 m/s
Gathering device	Pick-up type, pick-up width of 100 cm
Type of feeder	Auger and chain conveyors
Threshing device	Two threshing drums 420 mm and 320 mm in diameter
Separating and cleaning device	Air blow fan, vibrating straw walker, grain pan, and grain sieve
Tailings and grain discharge devices	Horizontal: auger; vertical: bucket elevator
Grain tank and discharging devices	Capacity: 600 L; hydraulic discharge height control
Estimated field capacity	35 a/h

Table 3. Symbols, their descriptions, estimate values assigned, and basic equations for cost analysis

Symbol	Description	Estimated values or basic equation for cost analysis
PP	Purchase price (thousand won)	Thresher attached to power tiller (TAP): 3,500 (soybean) Thresher attached to tractor (TAT): 1,890 (red bean) Stationary cleaner (SC): 15,500 (soybean and red bean) Pick-up type pulse crop harvester (PH): 90,000
SP	Salvage price (thousand won)	10% of purchase price of machine
L	Machine life (years)	TAP: 8, TAT: 8, SC: 8, PH: 6
DC	Depreciation cost (thousand won/year)	DC = (PP − SP) / L
IR	Interest rate (%/year)	3
IC	Interest cost (thousand won/year)	IC = (PP + SP) / 2 * IR
RM	Repairs and maintenance costs (thousand won/year)	5% of purchase price of machine
IS	Insurance and shelter costs (thousand won/year)	1% of purchase price of machine
AFC	Annual fixed costs (thousand won/year)	AFC = DC + IC + RM + IS
LC	Labor cost (thousand won/hour)	Muan County (soybean): man–12.0, woman–8.0 Chunan County (red bean): man–12.5, woman–6.25 Driver of PH: 1.5 times that of man
MP	Machine power (kW)	TAP: 7.5 kW, TAT: 7.5 kW, SC: 4 kW, PH: 45 kW
SFC	Specific fuel consumption (l/kWh)	All machines: 0.25 l/kWh
FP	Fuel price (thousand won/l)	Fuel (diesel): 1.060
FC	Costs of fuel and oil or electric energy (thousand won/hour)	FC = MP * SFC * FP * 1.15, (assuming oil cost as 15% of fuel cost) Electric: FC = MP * 0.0392, (excluding basic charge of 1,150 won/kW)
AFR	Annual fixed costs rate (%/year)	25% of purchase price
AUT	Annual use time of machine (hours/year)	Power tiller: 500, tractor: 1,000
DM	Cost of driving machine (thousand won/hour)	DM = PP * AFR / AUT
OPH	Operating costs per hour (thousand won/hour)	OPH = LC + FC + DM

a vibrating straw walker, a grain pan, grain sieves, a tailings auger and bucket elevator, a grain discharge plate and bucket elevator, a grain tank, and so on.

The harvester shows a pick-up width of 100 cm, field speed range of 0–1.5 m/s, and estimated field capacity of 35 a/hour.

Costs analysis

The costs of the gathering, threshing, separating and cleaning operations for conventional harvesting and machinery were compared with the costs associated with the pick-up type pulse harvester.

The machinery costs for the pick-up type pulse harvester

and for the bean thresher and cleaner used in conventional harvesting, excluding timeliness costs, were calculated. Table 3 indicates the symbols and their descriptions, and the basic equations used for the cost analysis. For both conventional harvesting and the pick-up type pulse crop harvester, costs change as annual harvesting area increases for soybeans and red beans. The break-even area—the area for which the annual costs of the two harvesting systems are the same—was also analyzed regardless of whether or not a government subsidy for purchasing the harvester is provided.

Results and Discussion

Labor requirement and annual capacity

Table 4 describes the labor requirements of conventional harvesting and the pick-up type pulse crop harvester for soybeans and red beans.

Conventional harvesting labor requirements of 7.00 hour-persons/10 a for soybeans and 7.66 hour-persons/10 a for red beans were investigated, and those for 0.57 hour-persons/10 a for the pick-up type pulse crop harvester for both crops were estimated. The harvester was found to reduce the labor requirement by 91.9% for soybeans and by 92.6% for red beans, respectively, compared with conventional harvesting.

The field capacity of the harvester was estimated at 35 a/hour and the machine can harvest various cut and dried pulse crops from the middle of October to late November in Korea. Assuming an actual harvesting time of 6 hours/day, 25 annual harvesting days per year, and actual harvesting time of 150 hours/year, annual harvester capacity was predicted to be 52.5 ha/year.

Table 4. Labor requirements of conventional and pick-up type pulse crop harvester for soybeans and red beans

Crop	Item	Conventional harvesting			Pick-up type pulse crop harvester
		Gathering (manpower)	Threshing (thresher)	Cleaning (cleaner)	
Soy bean	No. of workers (person)	2	2	1	2
	Capacity (a/h)	5.0	10.0	10.0	35
	Labor requirement (hour-persons/10 a)	4.00	2.00	1.00	0.57
			7.00		
	Ratio to conventional harvesting (%)		100		8.1
Red bean	No. of workers (person)	5	3	2	2
	Capacity (a/h)	16.7	9.5	13.3	35
	Labor requirement (hour-persons/10 a)	3.00	3.16	1.50	0.57
			7.66		
	Ratio to conventional harvesting (%)		100		7.4

Table 5. Costs of conventional harvesting and pick-up type pulse crop harvester for soybeans

Crop	Item		Conventional harvesting			Pick-up type pulse crop harvester
			Gathering (manpower)	Threshing (thresher)	Cleaning (cleaner)	
Soy bean	AFC (thousand won/year)	DC	-	394.0	1,744.0	13,500.0
		RM	-	175.0	775.0	4,500.0
		IC	-	58.0	256.0	1,485.0
		IS		35.0	15.5	900.0
		others	-	-	4.6	-
		Total		3,457.1		20,385.0
	OPH (thousand won/hour)	LC	16.0	24.0	12.0	30.0
		FC	-	2.3	0.2	13.7
		DM	-	1.6	-	-
		Total		56.1 (72,100 won/10 a)		43.7 (12,500 won/10 a)

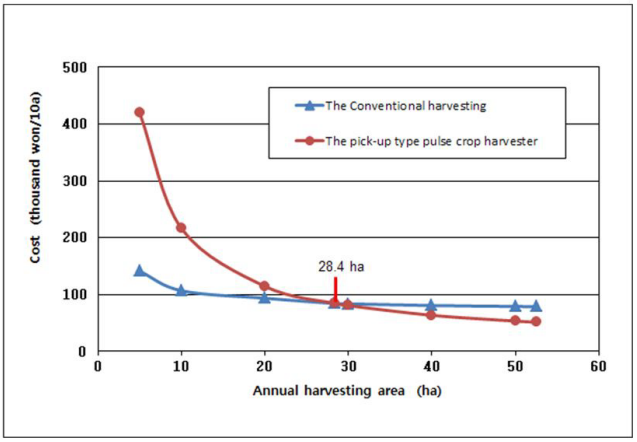

Figure 2. Changes in costs per 10 a based on annual harvesting area increases for soybean.

Costs of soybean harvesting

Table 5 shows the cost details for conventional harvesting and the pick-up type pulse crop harvester for soybeans. Annual fixed costs of 20,385,000 won/year and operating costs of 43,700 won/hour (12,500 won/10 a) were estimated for the pick-up type pulse crop harvester. For conventional harvesting, annual fixed costs and operating costs were 3,457,100 won/year and 56,100 won/hour (72,100 won/10 a), respectively. Therefore, the harvester's annual fixed costs and operating costs are approximately 5.9 times and 0.8 times that of conventional harvesting, respectively.

Figure 2 shows the increases in the cost per 10 a for an annual harvesting area for conventional harvesting and the pick-up type pulse crop harvester. For an annual harvesting area of 52.5 ha/year, the harvester's estimated machinery costs were 51,300 won/10, representing a decline of 33.3% from the conventional harvesting cost of 78,700 won/10 a. For the two harvesting systems, the break-even area was 28.4 ha and the corresponding estimated cost was 84,300 won/10 a.

Costs of red bean harvesting

Table 6 shows the cost details for conventional harvesting and the pick-up type pulse crop harvester. Annual fixed costs of 20,385,000 won/year and operating costs of 45,000 won/hour (12,900 won/10 a) were estimated for the pick-up type pulse crop harvester. For conventional harvesting, annual fixed costs and operating costs were 3,152,700 won/year and 103,800 won/hour (87,500 thousand won/10 a), respectively. Therefore, the harvester's annual fixed costs and operating costs are approximately 6.5 times and 0.4 times that of conventional harvesting.

Figure 3 shows the changes in costs per 10 a for conventional harvesting and the pick-up type pulse crop harvester on the basis of annual harvesting area increases. Machinery costs of 51,700 won/10 a for the harvester were estimated for an annual harvesting area of 52.5 ha/year, which reflects a reduction of 44.7% from the cost of conventional harvesting of 93,500 won/10 a. A break-even area of 23.1 ha and cost of 101,100 won/10 a for that area were estimated for the two harvesting systems.

Improvement of economics

Supplying the combine harvester for pulse crops to farmers requires government assistant because its purchase price is too high for most farmers with small farmland

Table 6. Costs of conventional harvesting and pick-up type pulse crop harvester for red beans

Crop	Item		Conventional harvesting			Pick-up type pulse crop harvester
			Gathering (manpower)	Threshing (thresher)	Cleaning (cleaner)	
Red bean	AFC (thousand won/year)	DC	-	213.0	1,744.0	13,500.0
		RM	-	94.5	775.0	4,500.0
		IC	-	31.2	256.0	1,485.0
		IS		18.9	15.5	900.0
		others	-	-	4.6	-
		Total		3,152.7		20,385.0
	OPH (thousand won/hour)	LC	31.3	37.5	25	31.3
		FC	-	2.3	0.2	13.7
		DM	-	7.5	-	-
		Total	103.8 (87.5 thousand won/10 a)			45.0 (12.9 thousand won/10 a)

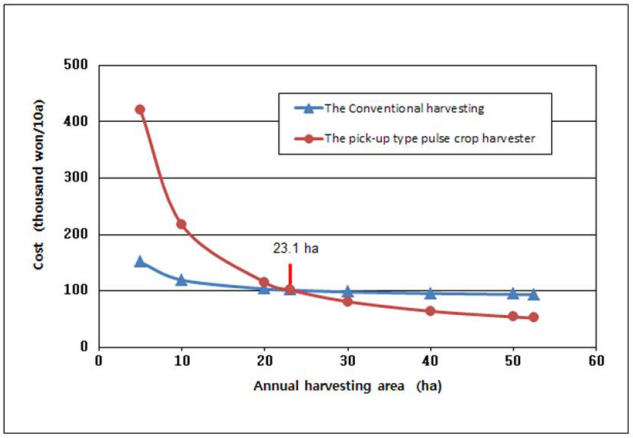

Figure 3. Changes in costs per 10 a for annual harvesting area increases for red beans.

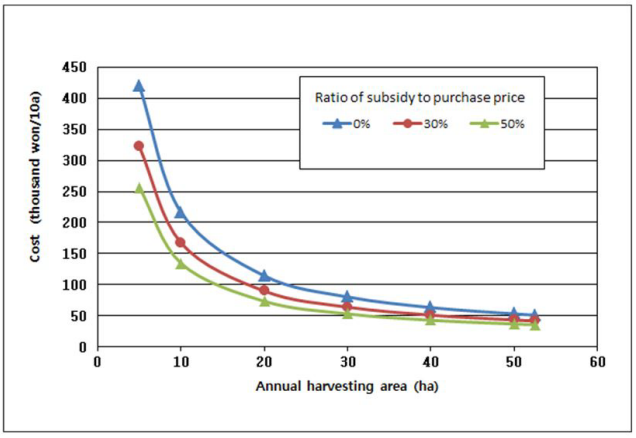

Figure 5. Changes in costs per 10 a of the pick-up type pulse crop harvester when a government subsidy is and is not provided to purchase the harvester for soybean harvesting.

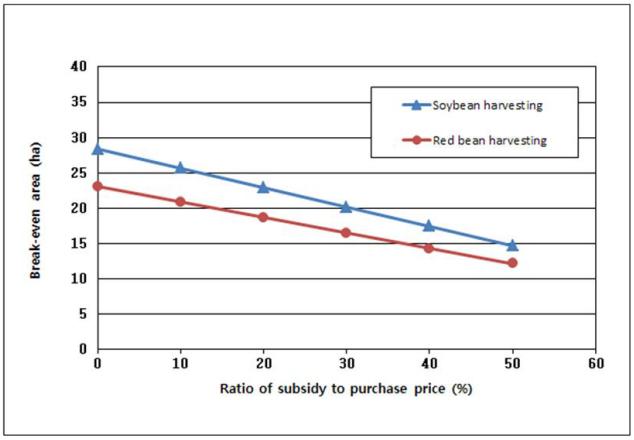

Figure 4. Changes in break-even areas for soybean and red bean harvesting assuming government subsidies are provided for purchasing the harvester.

and because the harvester market is too small for most manufacturers to produce the harvester in Korea. One assistance program provides subsidies for purchasing the machines. Figure 4 shows the changes in the break-even areas for soybean and red bean harvesting when a government subsidy for purchasing the harvester is provided. Accordingly, break-even areas between conventional harvesting and the harvester system decrease linearly as the ratio of government subsidy to harvester purchase price increases. Break-even areas for soybean harvesting changed from 28.4 ha to 20.2 ha and 14.7 ha at subsidy ratios of 30% and 50%, respectively. For red bean harvesting, these break-even areas changed from 23.1 ha to 16.5 ha and 12.1 ha at subsidy ratios of 30% and 50%, respectively.

Figure 5 shows the changes in costs per 10 a of the harvester based on the annual harvesting area at subsidy ratios of 0%, 30%, and 50% for soybean harvesting. Although the differences in the costs per 10 a for the 0%, 30%, and 50% subsidy ratios decrease as the annual harvesting area increases, the cost of 42,000 won/10 a at a subsidy ratio of 30% and the cost of 35,800 won/10 a at a subsidy ratio of 50% were reduced by 18.1% and 30.2%, respectively, for an annual harvesting area of 52.5 ha/year compared with the case of no subsidy and a cost of 51,300 won/10 a.

For red bean harvesting, the costs per 10 a of the harvester were almost the same as shown in Figures 2 and 3. Similar results were estimated.

Therefore, a governmental subsidy for purchasing the harvester could contribute to reducing the break-even area, and harvesting costs and are expected to improve the economics of the pick-up type pulse crop harvester for efficient mechanical harvesting of pulse crops. If possible, increasing the subsidies for farmers is desirable to reduce harvesting costs and to enable manufacturers to easily supply the machine.

Conclusions

The labor requirement and the economic feasibility of the pick-up type pulse crop harvester compared with that of conventional harvesting were estimated for soybean and red bean harvesting. This study found that the pick-up type pulse crop harvester is able to reduce the labor requirement and the costs associated with conventional harvesting, and a government subsidy provided to purchase

the harvester improves the economics of the machinery for efficient mechanical harvesting of pulse crops.

Conflict of Interest

The authors have no conflicting financial or other interests.

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