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Development of power tiller-operated soybean (*Glycine max*) harvester

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The most common method of harvesting soybean [*Glycine max* (L.) Merr.] crop is the manual harvesting using sickle. Shortage of labourers during harvesting period causes delay in the harvesting of the crop, as human energy of 150 to 200 man-hr/ha is normally required for harvesting and collection. To reduce the time and energy involved in harvesting, few tractor and power tiller-operated equipment mainly for harvesting of cereal crops have been developed by Devnani and Nag (1970), Chauhan (1973), Garg *et al.* (1984), Devnani and Pandey (1985) and Yadav and Yadav (1985). These equipment could not be tested for harvesting bunch-type crops like soybean, greengram (*Phasealus radiatus* L.) and blackgram (*P. mungo* L.).

Power tillers are very good source of farm power seedbed preparation, sowing and interculture operations (Varshney *et al.* 1995). The versatility of the power tiller can be increased if this power source is used for harvesting of crops. Power tillers being walking-type power source will have good manoeuvrability and require less headland during harvesting compared with tractor. Keeping this in view, a power tiller-operated harvester was designed and developed at the Central Institute of Agricultural Engineering, Bhopal, for harvesting soybean, gram (*Cicer arietinum* L.), greengram and similar crops.

Design criteria

The main considerations for an efficient soybean harvester include selection of suitable width, height and speed of cutterbar, reel for directing the crop to the cutterbar, provision for unloading the crop from the platform and power-transmission system. The width of the cutterbar should be such that harvester should be able to cover 3–4 rows of the soybean crop grown at a spacing of 45 cm or 30 to 35 cm. The power available from 8 to 10 HP power tillers is sufficient to operate this size of the cutterbar (Yadav and Yadav 1992). Height of the lowest pods of soybean crop varies from 10.0 cm to 13.0 cm from the ground surface. Therefore, the height of the cutterbar should be less than 10.0 cm from the ground surface for complete harvesting of the crop. The reel delivers the stalks to the cutting mechanism holding them upright during cutting and then delivers to the conveying or transport mechanism. The ratio of the speed of the reel and the forward speed of the harvester should be more than 1 for efficient operation of the machine (Klemin *et al.* 1995). The linear speed of the cutterbar should be such that there should not be shattering losses of grains and at the same time there should be thorough reaping of the plants. The recommended ratio of the linear speed of the cutterbar and forward speed of the power tiller should be 1.3–1.4 for proper cutting of the crop.

Since the harvested crop will be collected at fixed platform, it needs to be quickly removed for continuous harvesting operation without blocking the system. The simplest possible mode of removing the harvested crop is with the help of hand rake to dump the harvested crop in heaps on the ground for easy transportation from the field. The harvester should have an efficient and compact power-transmission system for the operation of the cutterbar and reel at desired speeds. The harvester should have suitable arrangement for disengaging power of the engine to the working components during the transport and turning of the machine at the ends. The arrangement should be simple and near to the operator for easy access.

Constructional features

Keeping in view the design criterion, a harvester suitable for 8 to 10 HP power tiller was designed and developed at the Central Institute of Agricultural Engineering, Bhopal, for harvesting soybean, gram, blackgram, greengram and similar types of crops. The harvester mainly consisted of a cutterbar, reel, platform, gauge roller, hitch plate, power-transmission system and dog clutch (Fig 1). The harvester was designed for mounting in the front part of the power tiller.

A 1.2 m size conventional cutterbar was used in the harvester. The stroke length of the cutter bar was 7.62 cm. Cutterbar speed of 0.8 to 2.0 m/sec has been recommended for efficient cutting of soybean crop (Yadav and Yadav 1985). A cutterbar speed of 800 strokes/min was found best for harvesting soybean crop. This speed of cutterbar was finalized after conducting trials at 5 speeds of 710, 760, 800,

*Short note

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855 and 906 strokes/min and studying the cutting behaviour of cutterbar. Considering the width of the cutterbar and quantity of harvested crop, a mild steel platform of 120 cm length and 55 cm width was mounted on the rear of cutterbar for collection of the harvested crop. An adjustable type reel of 100 cm length and 85 cm diameter was provided with 4 wooden slats of 100 cm × 9.5 cm × 1.5 cm size. The reel was designed to rotate at the speed of 0.98 m/sec. Provision has been made to adjust the reel 15 cm vertically and 10 cm horizontally. The lowest tip height of the reel was set at 7.0 cm from the ground level. The axis of the reel was set at 11 cm ahead of the cutterbar to give direction to the crop to be harvested. One gauge roller of 19 cm length and 11.5 cm diameter was provided below the hitch plate and back side of the machine. Provision was made to adjust the height of roller by 10 cm. A hitch plate of 30 cm × 19 cm × 1.2 cm was provided above the gauge roller for mounting the machine in the front part of the power tiller. Twentyfour holes of 12 mm diameter were made on the hitch plate to facilitate the harvester to be mounted with all popular makes of the power tillers. Power was transmitted

Fig 1 Power tiller operated soybean harvester

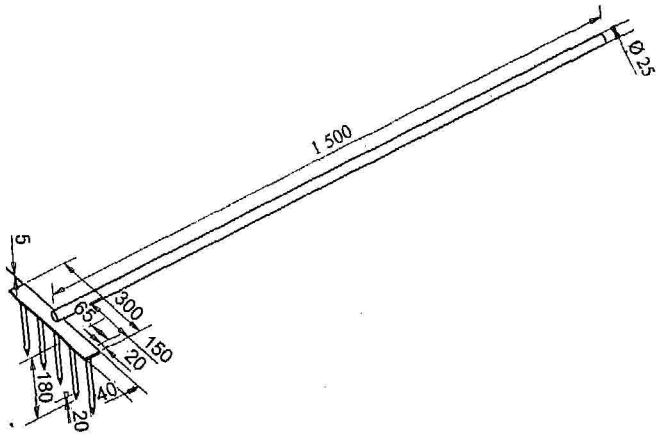

Fig 2 Manually operated hand-rake (all dimensions in mm)

Table 1 Field performance data of power tiller operated soybean harvester at 3 forward speeds

Parameter	I low gear	II low gear	III low gear
Area of plot harvested (m^2)	625	866	591
Time required (min)	35.0	33.0	16.0
Effective working width of machine (m)	1.20	1.20	1.20
Average speed of operation (m/sec)	0.28	0.43	0.69
Effective field capacity (ha/hr)	0.107	0.157	0.220
Average height of cut (stubble height) (cm)	7.89	7.89	7.89
Fuel consumption			
litres/hr	0.640	0.685	0.730
litres/ha	4.48	3.37	3.07
Pre-harvest losses (weight of grain on ground) (g/m^2)	18.88	18.88	18.88
Header loss(g/m^2)			
Weight of loose seed on ground	4.33	3.85	6.45
Weight of seeds from the pods fallen on ground	20.03	23.45	23.63
Weight of seeds from uncut pod 3 after harvesting	0.0	0.0	0.0
Total weight of seeds	24.36	27.30	30.08
Header loss (%)	2.80	4.30	5.74
Conveying loss			
Weight of loose seed and seed from the pods fallen out side the cut width of harvested area (g/m^2)	0.97	5.85	11.70
Conveying losses (%)	0.50	3.0	6.0
Total machine loss (%)	3.30	7.30	11.74
Saving in human energy over conventional system (man-h/ha)	109.3	115.3	118.9
Cost of harvesting			
Rs/hr	95.42	95.42	95.42
Rs/ha	891.00	608.00	433.00
Saving in cost of operation over conventional system (Rs/ha)	69.00	352.00	527.00
Operator's view (subjective), ease of operation	Easy	Manageable	Difficult

with the help of a V-belt from the engine pulley to the pulley of the input shaft (speed ratio 11:30) of the harvester. A dog clutch was provided near the pulley of the input shaft to engage or disengage the power of the engine of the power tiller.

A lever with grooved plate near the handle of the power tiller was provided to actuate the dog clutch. A set of bevel gears (speed ratio 11:16) was provided to operate the cutter bar at the designed speed. Since the reel was designed to operate at a speed of 0.98 m/sec a set of worm and gear (speed ratio 18:1) was used to transmit the power to the reel of the harvester.

A tilt angle of 6.5° was provided between the cutterbar and platform assembly for harvesting the crop close to the ground. A rake (Fig 2) was used to take out the harvested

crop conveyed on the platform.

The machine was tested in fairly levelled field for harvesting of soybean crop during the rainy season of 1997. The field evaluation was conducted as per RNAM Test Code considering only important parameters of crop, soil and machine. The soybean corp was also harvested with manual system of harvesting by using sickle in an area of 400 m^2.

Field testing of machine

The power tiller harvester was used for harvesting 'PK 472' soybean crop, sown at the row spacing of 30 cm during the rainy season. The average plant height was 60 cm and plant population at the time of harvesting was 30/m^2. Average number of pods/plant was 60, with lowest pod height of 12.7 cm. The diameter of the stem at cutting height was 7.1 mm. The average moisture content of grain and straw was 10.45 and 40.75% respectively. The average yield of the crop at 14% moisture content of grain was 2.01 tonnes/ha.

The power tiller soybean harvester was operated in the first low gear, second low gear and third low gear respectively. The effective field capacity of the machine during the operation in the first low, second low and third low gears was 0.107, 0.157 and 0.220 ha/hr respectively. The average forward speed of power tiller was 0.28, 0.43 and 0.69 m/sec in the first low, second low and third low gears respectively. The fuel consumption was minimum in the first low gear compared with that in the second and third low gears. The average height of cut of plants was 7.89 cm in all gear settings. Average pre-harvest loss was 18.88 g/m^2. The weight of loose grain found on ground surface after the operation was 4.33, 3.85 and 6.45 g/m^2 in first low, second low and third low gears respectively. The respective weight of grains form the cut pods fallen on the ground was 20.03, 23.45 and 23.63 g/m^2.

Since the harvester was able to harvest all the pods, the loss due to grains available from uncut pods after harvest was 0 in all test plots. Thus the total grain losses were 24.36, 27.30 and 30.08 g/m^2 in the first, second and third low gears respectively. This indicated that the total header losses were to the tune of 2.80, 4.30 and 5.74% in the first, second and thirds low gears respectively. Since it was easier to remove the harvested crop from the collection platform in lower gears, the conveying losses were minimum (0.5%) when the power tiller was operated in the first low gear. The conveying losses were 3.0 and 6.0% in the second and third low gears respectively. The total machine losses were 3.30, 7.3 and 11.74% in first low, second and third low gears respectively.

One operator for the operation of the power tiller and 1 labourer for taking out the harvested crop were required during testing of the machine. Total human energy of 18.7, 12.7 and 9.1 man-hr/ha were required for harvesting of the soybean crop in the first, second and third low gears respectively. The cost of using the power tiller-operated soybean harvester was worked out to be Rs 95.42/hr. Cost of harvesting the crop/ha was worked out to be Rs 891/ha, Rs 608/ha and Rs 433/ha respectively. As per opinion of the operator harvesting of the crop with harvester was easiest in the first gear but the operation was difficult in the third gear. However, the operation of power tiller was manageable in the second low gear.

Soybean corp was also harvested manually using local sickle. The average moisture contents of the grain and stem at the time of harvesting the crop was 10.45 and 38.75% respectively. The height of cut of the soybean plants varied form 5.0 to 9.0 cm. Pre-harvest loss was 18.88 g/m^2. The harvesting loss was 0.4% of the crop yield. The labour required for harvesting of the crop manually was 128 man-hr/ha. The labour charges were Rs 60/day and Rs 960/ha. Thus a saving of about 115 man-hr/ha could be achieved with the use of the machine in the second low gear over the traditional method of harvesting. The use of the machine for harvesting the soybean crop during the rainy season also saves the crop from the shattering losses since the crop can be harvested timely.

SUMMARY

One platform-type harvester with 1.2 m cutter bar suitable for 8 to 10 HP power tiller was developed at the Central Institute of Agricultural Engineering, Bhopal, for harvesting soybean [*Glycine max* (L.) Merr.], gram (*Cicer arietinum* L.), blackgram (*Phaseolus mungo* L.) and green gram (*P. radiatus* L.) crops etc. The harvester consisted of a cutter bar, reel, platform, gauge roller, hitch plate, power-transmission system and dog clutch. The harvester was evaluated to harvest soybean crop with an average moisture contents of grain and straw as 10.45 and 40.75% respectively. The effective fieled capacity of the machine was 0.157 ha/hr at the forward speed of 0.43 m/sec. The average height of cut of plants was 7.89 cm. The total machine losses including harversting and handling losses were 7.30%. There was a saving of about 115 man-hr/ha with the use of machine over traditional method of harvesting with sickle.

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