POTATO HARVESTING WITH A NEW CONCEPT IN BLADES

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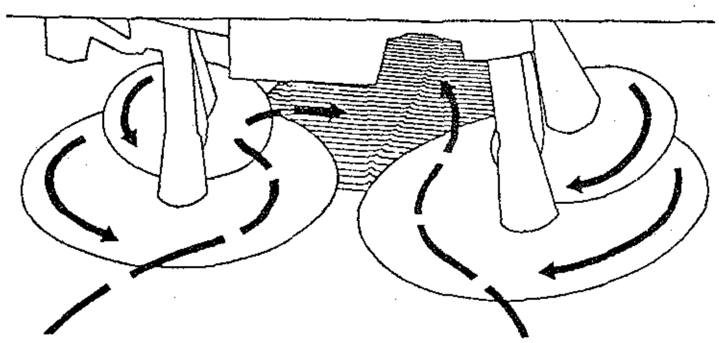
The first United States trials of the Scottish-invented rotary disc potato harvester blade confirmed its potential for improving both efficiency and quality in potato production. The new blade system substantially reduced tractor draft (drawbar pulling force) required to operate the harvester even in deep, difficult harvesting conditions; and at the same time it delivered 97 percent damage-free tubers or better to the harvester.

This article describes the disc blade system and discusses the 1983 Washington field experiments with it, blade adjustment effects on performance, relative power and draft requirements, operation in deep digging and heavy vines, tuber damage, and suggested design modifications.

THE DISC SYSTEM

The disc blade system (Figure 1) consists of two 3-foot diameter concave discs mounted side-by-side with their concave sides upward. The discs are attached to shafts which are powered to rotate toward each other. The blades are tilted forward at an attack angel of about 25 degrees, and they are tilted sideways, inward toward each other at a lateral tilt angle of 5 to 10 degrees. Thus they cut sideways into the potato hill and lift the soil and tubers toward the center of the two-row swath and up and back onto the primary chain. Each blade digs one row. The soil, tubers, and vines from each row are lifted from the large disc onto the primary chain by a smaller, powered disc mounted concave side down and positioned just above the rear half of each large disc. The disc system requires 20 to 30 hp from the pto.

Figure 1. Rotary disc potato harvester blade.



The whole idea of the rotary disc system is that rather than using tractor draft to force a fixed, flat blade under the tubers and using inefficient sliding motion to lift them onto the primary chain, a pto-powered rotating blade cuts below them and uses more efficient rotary motion to lift and place the tubers on the chain. In experiments at the Scottish Institute of Agricultural Engineering where the disc system was invented, the tractor draft requirement for the disc blade was as much as 80 percent less than that required for a conventional harvester blade (Hutchison and Fleming 1980). Also, since the discs lift the material as much as 15 inches,

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the front of the primary chain runs well above the soil level. Such positioning reduces stress, wear, and power requirement for that chain to the point that rubber covered chain could be economical for the primary as well as other chains on the harvester.

WASHINGTON FIELD TRIALS

The entire intent of our experiments was to investigate the operation of the disc blade system under Washington harvesting conditions, not to optimize the operation of the entire harvester. While some adjustments were made to other parts of the harvester and bruise samples were taken throughout the machine, the emphasis was on blade performance. Only blade performance is reported here.

The initial trials emphasized some of the differences between potato harvesting conditions in Scotland and in Washington. In the U.K. potatoes are ridged higher than in Washington, but the harvester blade depth is only about 2/3 of the way down to the bottom of the furrow. The U.K. soils hold the ridge shape over the growing season, and no irrigation is used. Vines are chopped before harvest. In Washington, the potato ridges are lower, the sprinkler irrigation tends to flatten them in the sandy soil, and the potatoes are planted deeper so that the harvester blade must dig to a depth that is below the furrow bottom. The vines are left intact until harvest.

Because we must dig deeper and handle more soil and vines than is done in the U.K., mounting the disc blades on the harvester in the same way as for Scottish conditions resulted in insufficient capacity for soil, vines, and tubers to flow through the blade assembly. In the black sands area west of Moses Lake (Road H at I-90) where the trials were conducted, the sandy soil tended to flow toward the outside edges of the main discs and to spill out, along with some tubers, at the edge of the swath. The vines tended to bunch up at the throat of the blade assembly between the two main blade shafts and eventually plugged the assembly.

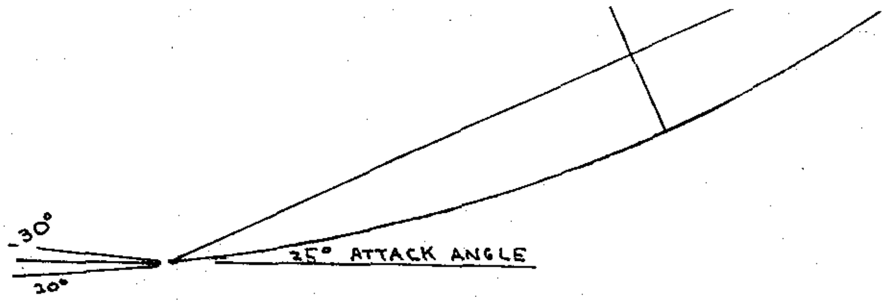
Adjustments made to improve blade performance included blade rotational speed, attack angle, lateral tilt angle, blade depth, blade lateral separation, the addition (and subsequent removal) of shielding to stop spillout at the outer edges of the blades, deletion of shielding between the main and cleaning disc mounting shafts, and the addition of angle irons welded along the main disc shafts to act as paddles to help move vines and soil through the assembly.

Widening the spacing of the discs was the best solution to all of the problems, particularly the plugging and spillout problems. The main discs were initially spaced with their edges less than one inch apart. Information supplied from Scotland cautioned that spacing them more than approximately 2.5 inches apart may result in spillout BETWEEN the blades. But note that that problem occurred where blade depth was less than the depth of the furrows. The lateral spacing of the blades was gradually increased in our trials until there were 9 inches between blades at a lateral tilt of 15 degrees. The result was elimination of machine plugging with no spillout between blades. Subsequent reduction of lateral tilt to 9 degrees resulted in a lateral spacing of 8.75 inches with the blades equally spaced to either side of the center of the harvester. The 8.75-inch lateral spacing resulted in good blade performance.

Addition of angle iron paddles to the disc shafts improved flow of material through the blade assembly and worked well in light vines. In heavy vines the paddles worked well when the blade was running at depth, but when it was lifted while running, the paddles quickly wrapped with vines and cleanout became necessary. An improved paddle arrangement that will not easily wrap with vines is needed.

Increasing the attack angle decreased the torque required to rotate the blades slightly, as also occurred in Scottish experiments. Greater attack angle seemed to cause the soil to pile up and plug the blade assembly more, and it increased spillout at the outer edges of the discs. Decreasing the attack angle to less than 25 degrees greatly increased the torque required to turn the discs because the curved part of the blade was then forced into the soil below the cutting edge. The optimum attack angle for the blades used appeared to be 25 degrees (Figure 2).

Figure 2. Disc blade profile.



Increasing the lateral tilt of the blades from 9 to 15 degrees did not reduce the spill-out problem, but it resulted in the outer edges of the discs running shallower which caused more tuber slicing. Increasing blade depth reduced slicing somewhat, but reducing the lateral tilt back to 9 degrees was the best solution to the slicing problem and resulted in less spillout rather than more.

Increasing blade rotational speed appeared to improve throughput early in the trials before the lateral spacing had been increased to 9 inches. However, after full width was reached, trials at varying engine speeds (and corresponding blade speeds) showed that small speed changes did not have a significant effect on flow of material through the blade system.

In very heavy vines, the straight colters on the harvester were replaced with dual concave angled colters with good success. The dual colters cut cleanly through the vines and reduced plugging and wrap problems. These colters were mounted on the colter frame at an expedient position and need to be remounted to get better alignment with the furrow. The colter frame lift links were replaced with lengths of chain so that the blade lift cylinder could lift the colters but could not apply downward pressure on them. These colters will pull themselves into the soil when they are allowed to float under only the weight of the colter mounting frame (on the Braco harvester used) and need little or no downward pressure. Excessive downward pressure only results in excessive colter wear and damage to colter bearings and spindles.

BRUISE DATA ANALYSIS RESULTS

Analysis of the first week's samples taken before the blades were properly adjusted showed that 7 out of 15 samples contained tubers with blade cuts. Total cut tuber weight was 4.8% of total sample weight. The bruise-free percentages were approximately 96.5 from the primary chain. We were able to operate the harvester with a 120 hp, 2-wheel drive John Deere 4250 tractor with 16.9 x 38 inch rear tires on moderately rolling terrain in the black sands area at up to 3.5 mph with no traction problems.

The sampling from the second week was more extensive and was preceeded by re-adjusting the blade lateral tilt from 15 to 9 degrees. The tractor used during these experiments was the John Deere model 4850. The experimental factors were two engine speeds and two tractor gears. Measurements included tuber bruise damage, cut tubers, and tuber size. These trials were made near Road H about 1 mile north of I-90. The tubers in that field were very deep and required that the blades go deep enough to leave 10 inches of loose soil behind the harvester. The results show the following:

Blade Cut Tubers:

Blade cuts were less than 1 percent (0.74% to be precise) in this trial. Comments from operators of conventional machines in the same field indicated that their machines were cutting more tubers.

Tuber Size:

The tubers in that field were often very large, but tuber damage proved to have no correlation with tuber size. Mean tuber weight in the samples ranged from 204 to 381 grams (7.2 to 13.4 ounces).

Black Spot and Shatter Bruise:

Averages for combined blade and primary chain damage (Table 1) show 96.5 to 99 percent damage-free tubers. The data indicate that engine speed had more to do with tuber damage than did tractor gear at this point in the harvester. This may have been because the primary chain was running a little fast for sandy soil (chain speed-to-ground speed ratios of 1.17 at 4 mph and 1.46 at 3 mph) and was thus very lightly loaded. The reduction of engine speed then reduced bruise by reducing chain speed and giving less bounce to the tubers.

Table 1. Bruise-free percentages for the primary chain related to Rpm, Gear:

Bruise-free means by gear:

Gear	Mean	Grouping*
3	97.734	A
4	97.929	A

Bruise-free means by rpm:

Rpm	Mean	Grouping*
1900	99.204	A
2150	96.508	B

* Means with same letter are not significantly different at the 5% level.

CONCLUSIONS

The combined results for the two week's sampling show that the tubers on the primary chain were 96.5 to 97.9 percent bruise-free; hence, tuber damage caused by the blades was nill. With the reduction in lateral tilt from 15 to 9 degrees, the blade cuts also became nil, so the conclusion is that with these adjustments the rotary disc blades operate essentially bruise-free, even in difficult, deep digging.

Although no direct measurements of draft requirement were made, observation of machine operation showed that draft requirement was considerably less than that for a conventional potato harvester. The real possibility exists that a smaller, less-expensive tractor could be used with this harvester than is normally used with a conventional machine in these conditions, with the result that the owner who doesn't need a larger tractor for other operations could save $20,000 to $50,000 in tractor cost by spending the additional $5,000 to $6,000 that a rotary disc blade system is estimated to cost.

FURTHER MACHINE MODIFICATIONS

Disc Enlargement:

Researchers in the U.K. added a flat steel edge to the large discs to increase clearance under the disc and to increase disc diameter to 42 inches for digging conditions in the southern part of the U. K. They used 25 deg. attack and 7 deg. lateral tilt angles. The larger blade may have advantages in Washington, too.

Disc Drive System:

The hydraulic system oil heated up to about 175 degrees after sustained operation, with a noticeable temperature increase when we had to increase the depth to 10 inches (below the top of the loose soil after the harvester had passed over). An oil cooler is needed in the hydraulic system. The hydraulic system also needs less restriction in the suction side because cavitation is a real problem when the oil is cold. The system must be run at idle for at least 10 minutes even on a morning in the 50 deg. temperature range before it is ready to harvest. A mechanical drive system instead of the hydraulic drive will likely be more economical and efficient in the long run and should be seriously considered. (Such a system with 42-inch blades was observed in operation in the U. K. in the fall of 1983 by Rudy Stetner and Henry Michael.)

Disc Bearings:

A different bearing with an integral, triple lip seal such as used on heavy-duty tandem discs might be more appropriate for the bottom bearings on the main discs. If possible, elimination of the bottom bearing would be a further improvement. Scottish researchers suggest that if we don't have shock load problems such as large stone, the bottom bearing might be eliminated.

Variable Speed Drive for Primary Chain:

A variable speed drive could be added to the primary chain to give the operator on-the-go control of soil loading in the harvester and thus provide easy adjustment for varying field conditions. This addition will be less expensive for a discblade harvester than for a conventional harvester, because the discs allow the primary chain to run up out of the soil where it requires much less power. The power requirement for the primary chain on the disc blade harvester was not measured. However, the power requirement was sufficiently smaller than on a conventional harvester that the top side of primary chain sagged between support rollers during harvesting. It is estimated that a 10 hp variable speed drive would be adequate (hydralic would be easiest) for a disc blade machine. (A harvester with a conventional blade requires about 30 horsepower to operate the primary chain.) Automatic control of primary speed could be accomplished with a little more expense by putting a load sensor in the support link for the front of the primary, independent of the disc blade supports, and adding an automatic control system.

REFERENCES

Hutchison, P. S. and J. Fleming. 1980. An investigation into the performance of a twin disc share for potato harvesters. Departmental Note SIN 286, SIAE, Bush Estate, Penicuik, Midlothian, Scotland, U. K.