REDUCING POTATO HARVESTER DAMAGE

by
R. E. Thornton, D. A. Smittle, and C. L. Peterson
Washington State University, Pullman, Washington

Financial loss from mechanical injury to potatoes during harvest costs Washington growers about 20 percent of their gross potato income. Loss occurs through lower potato prices, increased weight loss and decay during storage, and increased processing costs.

Types of Damage

Two types of potato damage result from impact: blackspot and shatter bruise. Blackspot appears as a relatively uniform discoloration of the damaged tissue when potatoes are peeled. A blackspot bruise usually does not penetrate deeper than 1/4 inch and usually does not rupture the potato skin. Shatter bruise appears as a fissure or a series of fissures with a discoloration at the fissure edge. Unlike blackspot, shatter bruise fissures may penetrate deeply into the tuber and usually break the skin of the tuber.

Methods of Bruise Detection

Methods of bruise detection include 1) treatment with a chemical solution (catechol) and, 2) peeling. The catechol treatment, applied to the outer surface of the potato, detects only bruises which cause a break in the surface cells. Blackspot bruises may be accompanied by a break in the skin, but usually they are not. Therefore, bruises detected by catechol are shatter bruises. With catechol treatment most blackspot bruising is overlooked.

Bruised potato tissue, whether associated with broken skin or not, will usually become discolored 12-24 hours after the bruise occurs. This discoloration can be seen when potatoes are peeled, and an evaluation of total bruise including both shatter bruise and blackspot can then be made.

Since the type of bruise detected by different methods of detection differs, there will be a difference in the bruise level found. The method of bruise detection used by a grower should be the same as that used by the buyer of his potatoes, especially if the potatoes are being sold on a contract that contains incentive and/or penalty provisions for bruise level. For determining total bruise the peeling method should be used. However, the catechol bruise detection method is especially useful in pinpointing where damage is occurring within a harvesting operation, since it indicates the occurrence of a severe impact.

Factors Influencing Bruise

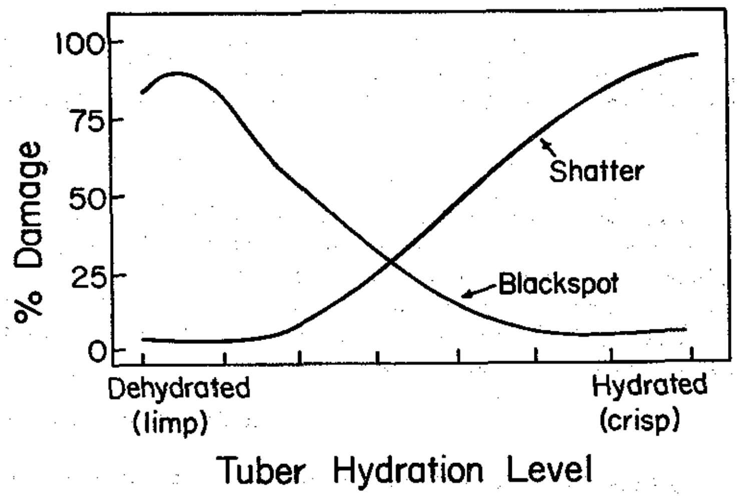
Four general factors determine the amount of bruise which occurs during harvest: soil condition, tuber condition, temperature, and harvester operation.

Soil Condition: The effect of soil condition at the time of harvest on amount of bruise is primarily the ease with which the potatoes can be separated from the soil. The ease of soil and tuber separation depends upon soil type, moisture and compaction. Heavy, compact soil and high soil moisture level cause separation of potatoes and soil to be more difficult. Soils that are medium to light in texture and mellow with good but not excessive moisture separate easily from potato tubers and require little or no shaking of harvester chains. Heavy, dry soil results in clod formation. Clods can increase damage to potatoes as they are carried through the harvester.

Tuber Condition: We do not completely understand the relationship between tuber condition and the likelihood that a tuber will damage. Cultural practices which have been shown to influence tuber condition include fertility level, irrigation practices, pest control practices and vine killing. Other factors undoubtedly are important. The four cultural practices listed all affect tuber hydration (the crispness of tubers).

Crisp potatoes are highly susceptible to shatter bruise and are quite resistant to blackspot. On the other hand, limp potatoes are resistant to shatter bruise and highly susceptible to blackspot. Figure 1 illustrates this relationship.

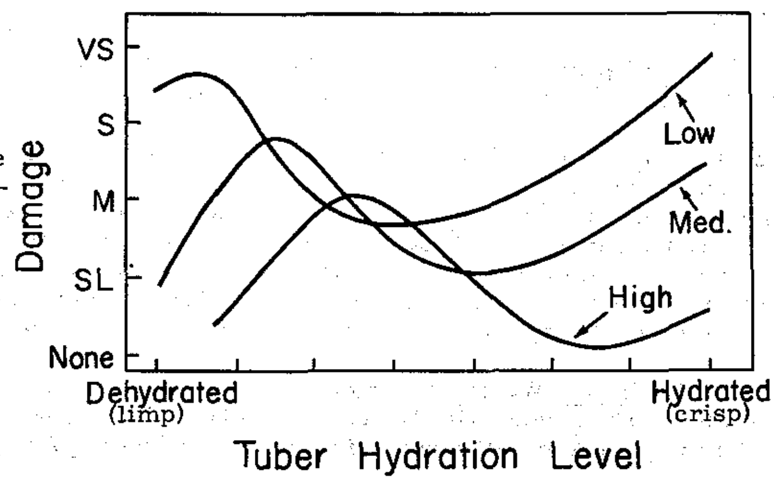
Figure 1: Effect of Tuber Hydration Level on Blackspot and Shatter Bruise (45-50°F)



The amount of both types of bruise changes as potatoes change from crisp to limp, but the change is not a straight line response. The condition desired for potatoes at harvest is one that results in the least amount of both shatter and blackspot bruising -- the lowest amount of total damage. However, at the present time there is no test that growers can use to determine when potatoes are in the least damage-prone condition. In addition, tubers in a given field are not all in the same condition.

Temperatures: The amount of total bruise which results from a harvester operation is not simply a matter of soil and tuber condition. The temperature of the tubers at harvest influences the amount of total damage and the point of lowest damage is at a different hydration level depending on the temperature of the tuber. (Figure 2) As a general rule, total damage increases as temperature decreases. Figure 2 shows that crisp potatoes will have a relatively low amount of total damage at 65-70°F and a high amount of total damage at 45-50°F. On the other hand, potatoes in a condition for lowest damage at 45-50°F are in a condition for highest damage at 65-70°F.

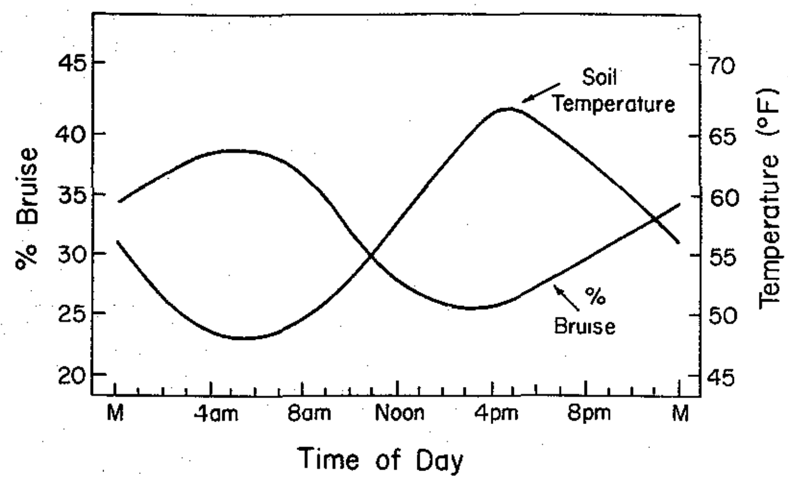
Figure 2: Effect of Tuber Temperature and Hydration Level on Damage Susceptibility



Influence of temperature on amount of damage to potatoes in a given condition is an important consideration in timing the harvest. The higher damage level associated with harvest at lower temperatures can be partially overcome by beginning the harvest earlier in the season. A small yield increase from delay of harvest may well be offset by an increased level of tuber damage from harvesting at low temperatures. The higher damage level during late-season harvest can be reduced by taking advantage of daily temperature fluctuations.

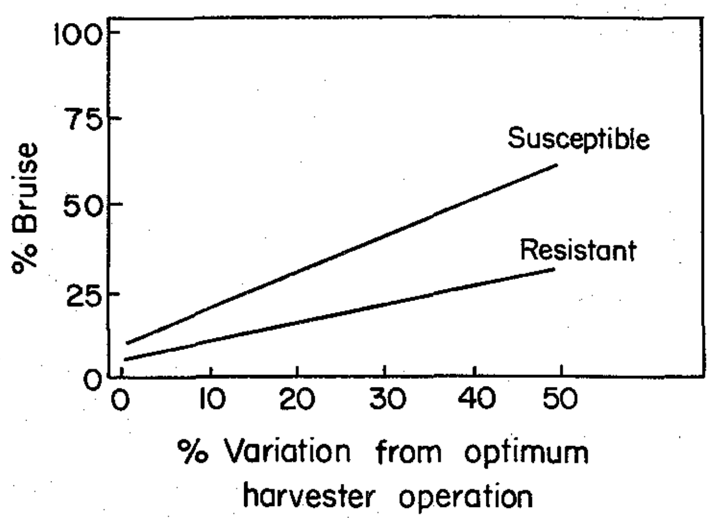
Bruise level is mugh higher during the morning than it is during the afternoon and evening because of warmer afternoon and evening temperatures (Figure 3). Therefore it would be advisable to harvest between 11:00 a.m. and 11:00 p.m. rather than during the traditional 7:00 a.m. to 7:00 p.m. harvest day. When temperature becomes quite low, damage levels may be reduced by shortening the daily harvest period to the warmest part of the day.

Figure 3: Daily Fluctuation in Soil Temperature and Tuber Damage



Harvester Operation: DAMAGE RESULTING FROM IMPROPER HARVESTER OPERATION IS IN ADDITION TO THE DAMAGE RESULTING FROM IMPROPER TUBER CONDITION AND TUBER TEMPERATURES. The effects of damage susceptibility and harvester operation on bruise are presented in Figure 4.

Figure 4: Effect of Damage Susceptibility and Harvester Operation on Bruise



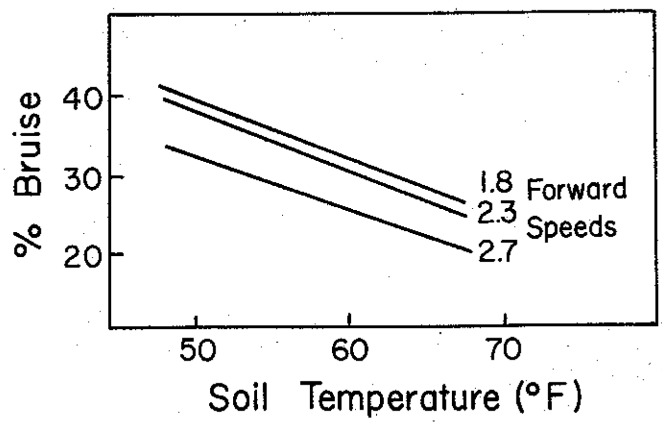
Damage is greater with more susceptible potatoes even with the best harvester operation procedures. Improper harvester operation increases bruising much more rapidly when potatoes are damage-susceptible. If the tuber condition and/or temperature is such that the damage susceptibility level is high, harvester adjustment is extremely critical; if the tuber condition and/or temperature is such that damage susceptibility is low, harvester adjustment will have less effect.

Traditionally, proper harvester operation has been based on two ideas: 1) a slower forward speed results in less bruising, and 2) the major portion of bruise damage occurs at the drops. Neither of these ideas is true enough to be a significant reason for operating a harvester in a certain manner.

Slowing down the forward speed of a harvester may actually INCREASE the amount of total bruise damage. During the 1971 Harvester Evaluation in Washington, harvesting 15 percent slower than the rate selected as optimum by harvester manufacturers increased total damage by 5 percent. Harvesting 21 percent faster than the supposed optimum rate increased total damage by only 1 percent.

In a study where chain speeds were constant, total damage increased as forward speed decreased at temperatures between 48°F and 68°F (Figure 5).

Figure 5: Effects of Forward Speed (mph) and Soil Temperature on Damage



Damage measurements taken at various points along the route of the tubers through the harvester show damage increased both at drops and while the potatoes were on the chains.

Damage at Drops	41%
Damage on Chains	33%

Because damage can occur at any point in the harvester operation, there is a need to take steps to control damage at every point. When the volume of material passing through the machine is equal to the capacity of each chain, excess movement of potatoes on the chains, amount of drop, and rollback (all major causes of damage) are reduced. Proper harvester operation then, is based on knowing the volume to be handled and relating the volume of material in the harvester at a given point to chain capacities.

Since the chain speed and forward speed must be coordinated so the volume of material handled is equal to the machine capacity at each point, the desired volume-to-capacity relationship can be expressed as a ratio of the chain speed to forward speed.

Potatoes and soil make up the material handled by the harvester (volume). On the primary and secondary chains most of the total volume is soil; therefore changes in potato yield do not appreciably affect the volume. This allows the ratio of primary and secondary chain speed to forward speed to be essentially the same for all potato yields. Factors that affect volume on these chains are soil type, soil moisture and soil compaction. These factors determine how easily the soil is separated from the tubers and lost from the chains.

The material (volume) on the remaining chains (rear cross, side elevator, and boom) consists mainly of potatoes. This volume then, is influenced greatly by change in per acre yield, making it necessary to increase the speed of these chains as yield increases. Harvester chain speed to forward speed ratios for heavy soils and various yields are presented in Table 1.

Table 1. Harvester Chain/Forward Speed Ratios for Heavy Soils

	Yield CWT/Acre						
	100*	200*	300*	400	500	600	700
Primary	1.05	1.05	1.05	1.05	1.05	1.05	1.05
Secondary	.68	.68	.68	.68	.68	.68	.68
Rear Cross	.20	.29	.38	.47	.56	.67	.76
Elevator	.18	.27	.36	.45	.54	.63	.72
Boom	.17	.24	.31	.38	.45	.53	.61

*The ratios at these yield levels have not been adequately tested and therefore must be considered theoretical values.

Light, sandy soils require different ratios than heavy soils. At a given forward speed the primary and secondary chain speeds should be slower than the ratios presented in Table 1. The slower chain speed compensates for the more rapid loss of soil volume on the primary and secondary chains in sandy soil. The adjusted ratios for sandy soils are presented in Table 2.

Table 2. Harvester Chain/Forward Speed Ratios for Sandy Soils

	Yield CWT/Acre						
	100*	200*	300*	400	500	600	700
Primary	.90	.90	.90	.90	.90	.90	.90
Secondary	.62	.62	.62	.62	.62	.62	.62
Rear Cross	.20	.29	.38	.47	.56	.67	.76
Elevator	.18	.27	.36	.45	.54	.63	.72
Boom	.17	.24	.31	.38	.45	.53	.61

*The ratios at these yield levels have not been adequately tested and therefore must be considered theoretical values.

Making Harvester Adjustments

Proper harvester adjustments require the following measurements and calculations: 1) Actual Forward and Chain Speed (mph), 2) Desired Chain Speed (mph), and 3) Percentage Change Needed.

Determining Actual Forward and Chain Speeds:

Forward Speed: The tractor speedometer does not give an accurate measure of forward speed due to slippage.

1. Measure tire circumference by marking a non-powered wheel with spray paint. Move the machine ahead so the wheel makes three full turns and measure the distance traveled. This divided by three gives the tire circumference.
2. Determine forward speed by timing the number of seconds needed to make five revolutions of the marked non-powered wheel. Divide the time by five to obtain seconds per revolution.
3. Calculate actual forward speed by using the above data with the Implement Speed Calculator (Appendix A) or in the following formula:

$$\text{Forward Speed (mph)} = \frac{\text{tire circumference (feet)}}{\text{seconds/revolution}} \times .68$$

Chain Speed:

1. Chain lengths can be determined simply by measuring the chains.
2. To determine seconds per revolution, mark a link of each chain with spray paint and time the revolutions with a stopwatch. The marks are more visible if made on a flight of flighted chains and on the ends of the links of the primary and secondary chain. Timing the primary, secondary and rear cross chains for five revolutions and dividing by five increases the accuracy of measurement.
3. The chain speed in mph is then determined by using the above data with the Chain Speed Calculator (Appendix B) or in the following formula:

$$\text{Chain Speed (mph)} = \frac{\text{chain length (feet)}}{\text{seconds/revolution}} \times .68$$

Determining Desired Chain Speeds:

The desired chain speeds can be taken from the table in Appendix C for the forward speeds and yields given. For yields and speeds not presented, the chain to forward speed ratio is obtained from Table 1 or 2 and used in the following formula to determine the desired chain speed:

$$\text{Desired Chain Speed} = \text{Forward Speed (mph)} \times \text{Chain Speed Ratio}$$

Determining Percentage Change Needed:

The percentage change needed to adjust the harvester from actual chain speed to desired chain speeds is found by using the following formula:

$$\text{\% change needed} = \frac{\text{desired chain speed} - \text{actual chain speed}}{\text{actual chain speed}} \times 100$$

Example: If the desired secondary chain speed is 1.6 mph and the actual chain speed is 2.0, the percentage change needed is:

$$\frac{1.6 - 2.0}{2.0} = \frac{-.4}{2.0} = -.2 \times 100 = -20\%$$

In this example the secondary chain speed must be reduced 20 percent to achieve the proper ratio of chain speed to forward speed. If the secondary chain is the only chain that is not in the correct ratio and if it has a 10-tooth drive sprocket, changing to an 8-tooth sprocket will be a 20 percent reduction and provide the correct ratio. If all chains are about 20 percent faster than needed, either slowing the chains 20 percent or increasing the forward speed 20 percent would result in the desired forward speed to chain speed ratio. The forward speed and chain speed information is being assembled into a slide rule that should be available from the Washington Potato Commission before the 1973 harvest season.

Results of Harvester Adjustments

Harvesters in commercial operations were evaluated to determine forward and chain speeds being used. These same machines were then changed to bring the actual chain speeds into alignment with the desired speeds. In every case the amount of damage after adjustment was lower than before. Amount of damage reduction obtained depended on how far the original operation was from the desired ratio. In no case did the adjustment require a decrease in the forward speed. All the data collected thus far shows that a slower rate of harvest is not required if the power unit is sufficiently large to give the chain speed to forward speed relationship needed. Results from adjusting three harvesters are presented in Table 3.

Table 3. Effect of Machine Adjustments

	Grower 1	Grower 2	Grower 3
% Bruise			
Before Adjustment	61	42	34
After Adjustment	36	21	23
$ Value/Acre of reduced bruise	150	120	50

The potatoes being harvested in all three of the commercial operations presented were being marketed on a processor contract that included a penalty for bruise and an incentive for bruise-free potatoes. On this contract each 1 percent bruise increased or decreased the price of the potatoes 1 cent/cwt. The yield was about 600 cwt per acre in each case.

The increase in net income to these growers from reduced bruise amounted to $50 to $150 per acre. In some cases the harvester adjustments doubled the net income from a potato crop. The time required to determine speeds and make harvester adjustments was less than two hours for each operation. The return for each hour devoted to harvester adjustment would be by far the most profitable effort of a potato grower during the entire growing and harvest season.

Summary

There are many aspects of the potato harvest operation that we do not understand, but a grower can reduce harvest damage by at least 50 percent if he will use the information available. An outline of procedures for harvesting potatoes with a low percentage of damage includes:

Cultural Practices

A. Properly implement fertilization, irrigation, pest control practices, and vine killing to provide uniform conditions throughout the field.
B. Condition soil to facilitate harvest through moisture control and avoiding compaction.

Temperature

A. Plan to complete harvest early. Small yield increases with delayed harvest may be negated by greater bruising from harvesting at low temperatures.
B. Shift daily harvest period to reduce damage.

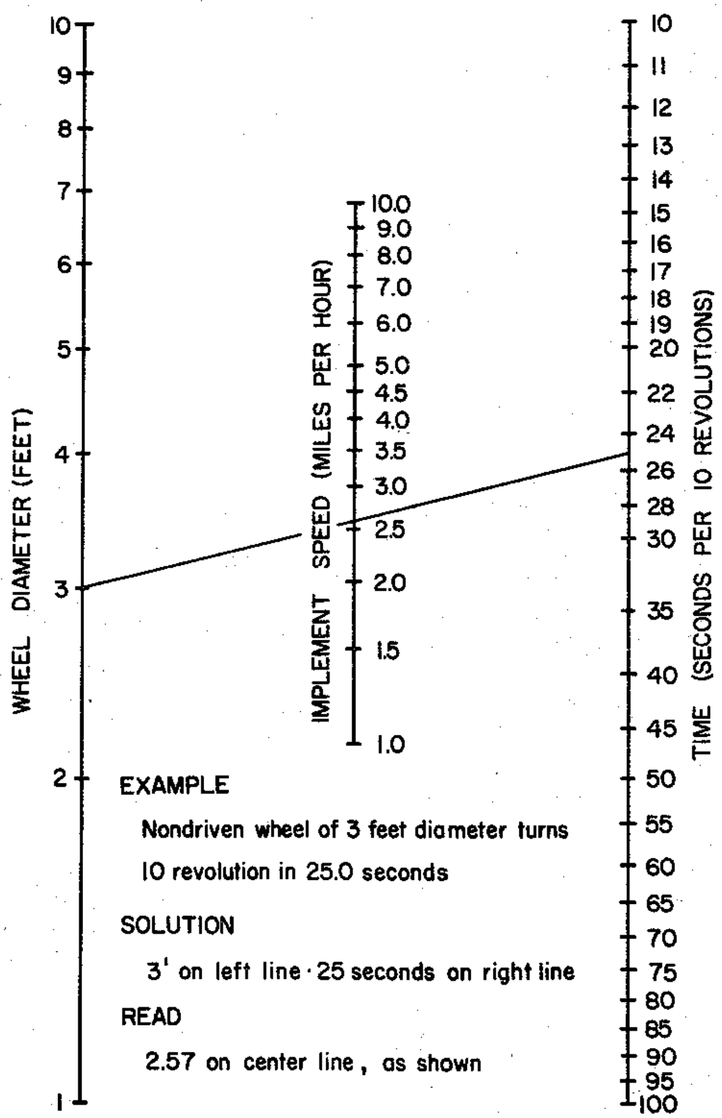
Harvester

A. Have enough power to give the chain/forward speed ratios desired. The overall rate of harvest is determined by the capacity of the power unit.
B. Adjust forward and chain speeds within the limit of the power unit so that the volume to be moved equals the capacity of each chain of the harvester.

Appendix A:

IMPLEMENT SPEED CALCULATOR

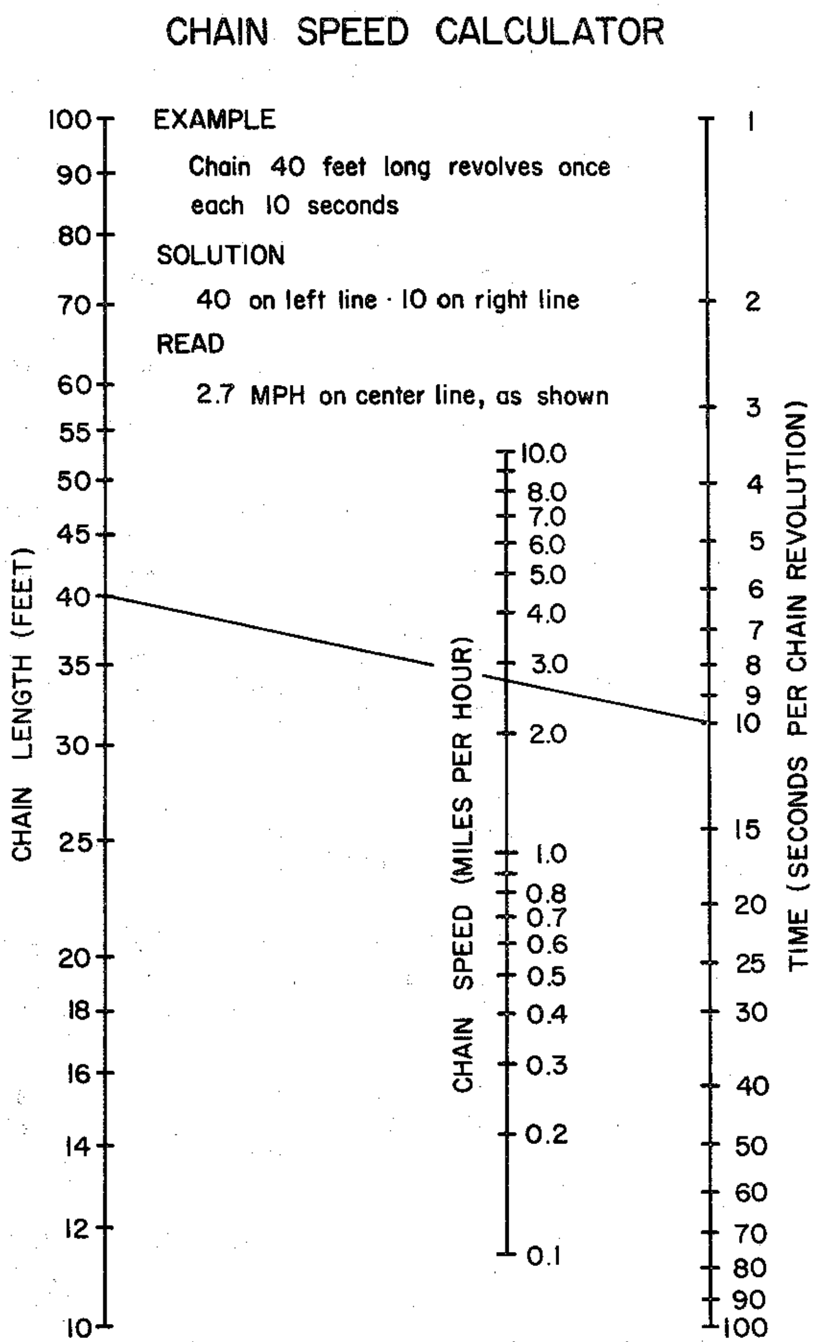
(NO SLIPPAGE ALLOWANCE)



Developed by:

C. L. Peterson, D.A. Smittle, and R.E. Thornton
Washington State University

Appendix B:



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Washington State University

Appendix C:

Harvester Operation Rates

Chain Speeds for Forward Speeds of

	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0
Heavy Soils								
Primary Chain	1.68	1.89	2.10	2.31	2.52	2.73	2.94	3.15
Secondary Chain	1.09	1.22	1.36	1.50	1.63	1.77	1.90	2.04
Light Soils								
Primary Chain	1.44	1.62	1.80	1.98	2.16	2.34	2.52	2.70
Secondary Chain	1.00	1.12	1.24	1.36	1.49	1.61	1.74	1.86
*100 CWT/Acre								
Rear cross	.32	.36	.40	.44	.48	.52	.56	.60
Elevator	.29	.32	.36	.40	.43	.47	.50	.54
Boom	.27	.31	.34	.37	.41	.44	.48	.51
*200 CWT/Acre								
Rear cross	.46	.52	.58	.64	.70	.75	.81	.87
Elevator	.29	.32	.36	.40	.43	.47	.50	.54
Boom	.27	.31	.34	.37	.41	.44	.48	.51
*300 CWT/Acre								
Rear cross	.61	.68	.76	.84	.91	.99	1.06	1.14
Elevator	.58	.65	.72	.79	.86	.94	1.01	1.08
Boom	.50	.56	.62	.68	.74	.81	.87	.93
400 CWT/Acre								
Rear cross	.75	.85	.94	1.03	1.13	1.22	1.32	1.41
Elevator	.72	.81	.90	.99	1.08	1.17	1.26	1.35
Boom	.61	.68	.76	.84	.91	.98	1.06	1.14
500 CWT/Acre								
Rear cross	.90	1.01	1.12	1.23	1.34	1.46	1.57	1.68
Elevator	.86	.97	1.08	1.19	1.30	1.40	1.51	1.62
Boom	.72	.81	.90	.99	1.08	1.17	1.26	1.35
600 CWT/Acre								
Rear cross	1.07	1.21	1.34	1.47	1.61	1.74	1.88	2.01
Elevator	1.01	1.13	1.26	1.39	1.51	1.64	1.76	1.89
Boom	.85	.95	1.06	1.17	1.27	1.38	1.48	1.59
700 CWT/Acre								
Rear cross	1.22	1.37	1.52	1.67	1.82	1.98	2.13	2.28
Elevator	1.15	1.30	1.44	1.58	1.73	1.87	2.02	2.16
Boom	.98	1.10	1.22	1.34	1.46	1.59	1.71	1.83

*The ratios of these yield levels have not been adequately tested therefore must be considered theoretical values.

developed by:
D.A. Smittle, R.E. Thornton, and C.L. Peterson
Washington State University