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Row-crop Machinery Capacity as Influenced by Field Conditions

Agricultural Experiment Station
AUBURN UNIVERSITY
E. V. Smith, Director
Auburn, Alabama

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Row-crop Machinery Capacity as Influenced by Field Conditions

E. S. RENOLL, *Associate Professor of Agricultural Engineering*

THE APPLICATION OF MACHINES to agricultural production has been one of the outstanding developments in American agriculture during the past century *(2)*.

Since farm machinery is so vital to agriculture, it is important that it be used to the best possible advantage *(4)*. This is particularly true for new and improved machines currently on the market *(2)*. These machines are faster, more efficient, and larger with greater capacity. Every machine should be used to take advantage of these built-in improvements *(9)*.

Farm machinery is seldom engaged in productive work 100 per cent of the field time. Many delays occur that result in lost time *(6,7)*. The amount of time lost in any operation will vary greatly from field to field and farm to farm *(10)*. Time spent in making field adjustments or repairs, adding seed, fertilizer, chemicals, or water, and turning at row ends results in lost time that reduces acres-per-hour capacity of the machine *(5,8)*.

Lost time for typical farm machines may range from 10 per cent for an 8-ft. tandem disk harrow to as much as 50 per cent for a 12-ft. combine *(1,3)*.

A 3-bottom plow might have 20 per cent lost time, whereas a 4-row planter equipped with a fertilizer and pre-emergence spray attachment may have as much as 60 per cent. Time studies of a 2-row cottonpicker indicate that nonproductive time for this machine can run as high as 35 per cent.

At least two items play a very important part in field machine capacity. One is machine management. Management involves such items as machine speed selection, labor force used, when and where the machine is used, flow of material to and away from the machine, and state of repair or condition of the machine. The second involves physical condition of the field. This includes field size and shape, topography, row length and arrangement, terrace layout, row-end turning space, and surface condition in the turn area.

EXPERIMENTAL PROCEDURE

The study was conducted over an 8-year period. The early parts of the study were conducted on the North Auburn Teaching Farm on Piedmont soil. The last 4 years of the study were conducted on the Marvyn Research Farm on Lower Coastal Plain soil. Both of these farms are units of the Agricultural Experiment Station.

Machines used for the study included conventional row-crop machines that are available to farmers. These included 1-row, 2-row, and 4-row machines. A 12-row sprayer was used in part of the study.

Machine operators were typical of those found on farms in this part of Alabama. Each could operate all of the machines and each also had considerable experience.

Various field conditions were available for the study. Fields ranging in size from 1.2 acres to 48 acres with rows from 200 to 1,500 feet in length were used. These fields involved conventional terraces, parallel terraces, and no terraces. The fields had various geometric shapes.

Data from the study were obtained by time-record methods. This involved a stopwatch for obtaining short-time records and a clock for long-time records. In some cases a self-recording clock was attached to the tractor or implement to aid in obtaining a time-use record.

ROW-END TURNING

Machinery time used for turning at row ends is in many cases an important part of the total machine field time. Turning pattern used will influence time needed per turn. The amount of space for the turn will influence time needed and pattern used during the turn. Surface condition of the turn area will also influence turning time. Rocks, ditches, stumps, and other foreign material in the turn area will increase turning time.

Turning Time

Time spent turning the tractor in row-crop operations may amount to 20 per cent of the total field time, Table 1. Any reduction in this time will increase machine capacity.

TABLE 1. FIELD LAYOUT AND CULTIVATOR OPERATION 2-ROW CULTIVATOR

Field	Machine capacity	Turning time
	Acres/hour	*Pct.*
A	2.3	20
B	2.9	3

Time needed to complete a single turn in row-crop work depends mainly on width of available turning space and ground surface condition in the turning area. A narrow space that requires backing the tractor or machine will increase turning time. Turning on rough area will result in a longer time. Examples of turning time are given in Table 2.

TABLE 2. COMPARISON OF TURNING TIME FOR SMOOTH AND ROUGH GROUND CONDITIONS IN FOUR DIFFERENT FIELDS

Field operation	Turning time		Increase in turning time
	Smooth	Rough	
	Sec.	*Sec.*	*Pct.*
Cultivating	14.8	18.0	22
Cultivating	18.6	20.8	12
Sidedressing	20.4	26.3	29
Sidedressing	26.0	29.0	11

Turning Space and Pattern

Width of turning area will usually dictate the type of turning pattern. The least turning time required is usually when turning space is large enough for the tractor to make an easy semicircle turn. A narrow turning space will require a longer time.

Some common patterns used to turn tractors doing row-crop work are shown in Figures 1, 2, and 3. The turning space in Figure 1 is wide enough for an easy, normal turn. In Figure 2, the turn space is too narrow for turning the tractor without backing. This pattern requires 50 per cent more time than the normal turn. The turning pattern in Figure 3 is used in fields having no turning space at row ends. This type turn may more than double the normal turning time.

Turning Space Needs

Turning space needed for tractor mounted cultivators and planters is somewhat a function of the front wheel arrangement

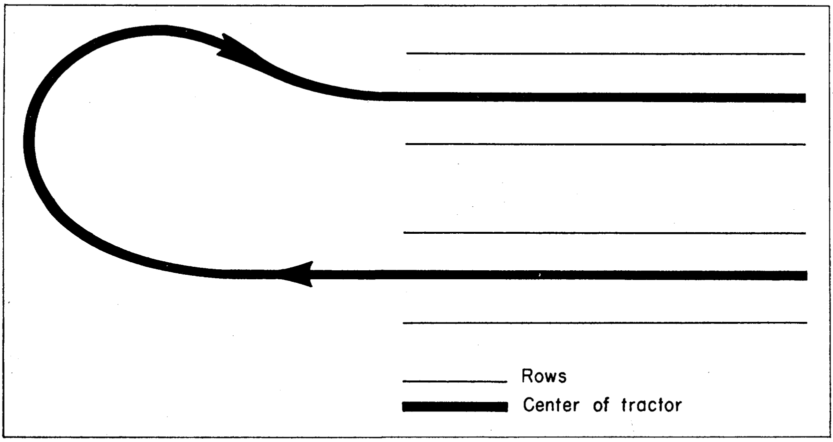

FIG. 1. Normal turning pattern with wide turning space.

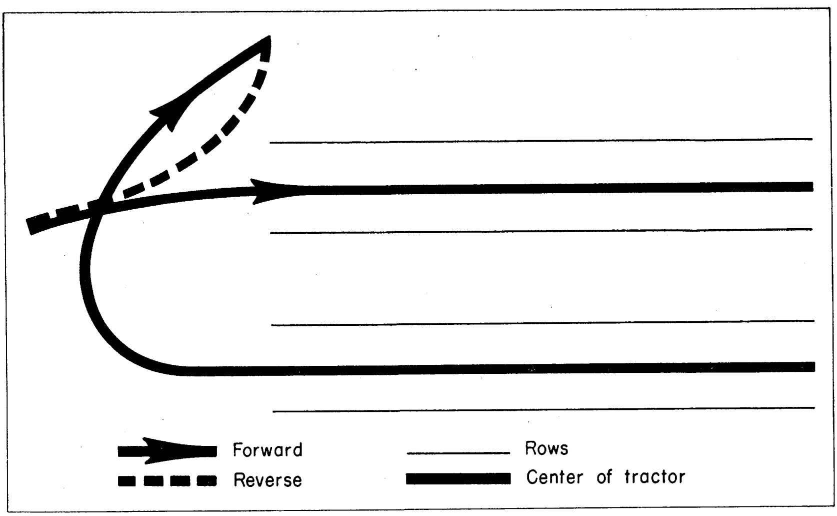

FIG. 2. Turning pattern when turning space is too narrow.

of the tractor. Space needed for a semicircle turn for a tricycle tractor is less than for a wide-wheel tractor. Minimum turning space should be 2½ times the length of the tractor for the tricycle tractor and 3½ times for the wide-wheel. The minimum turning space suggested for large row-crop machines such as combines and cottonpickers is twice the length of the machine.

Turning-Area Surface Condition

Rough ground, rocks, ditches, or other obstructions in the turn-

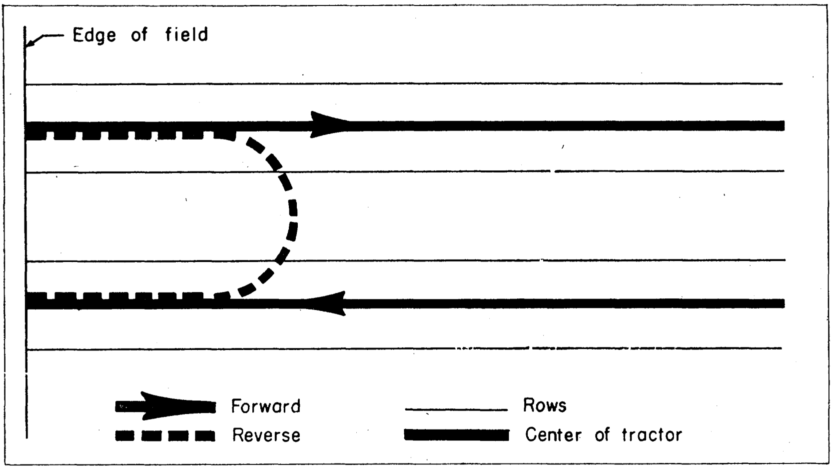

FIG. 3. Turning pattern where no space is available at row ends.

ing area will increase turning time. Table 2 shows the influence of smooth and rough turning area on turning time. Table 3 shows typical turning time for five different turning-area conditions.

TABLE 3. TYPICAL ROW-END TURNING TIME FOR DIFFERENT CONDITIONS

Implement	Smooth field turn area	Rough turn area	Sloping turn area	Terrace turn area	Good road turn
	Sec.	*Sec.*	*Sec.*	*Sec.*	*Sec.*
4-row planter	13.2	17.6	14.0	18.0	12.5
2-row planter	12.3	14.6	13.2	15.0	12.0
4-row cultivator	12.0	16.1	12.3	15.4	10.2
2-row cultivator	11.6	12.9	12.7	13.1	12.1
1-row picker	16.2	21.3	18.3	18.6	17.1
2-row picker	17.7	23.5	20.0	19.0	18.2

Turning on a smooth field surface or a good field road appears to require minimum turning time. A turning area that is rough, sloping, or involves a terrace requires more time. This increase in turning can be considerable and in the case of the 4-row cultivator in Table 3 represents an increase of 58 per cent.

ROW LENGTH

Row length will influence capacity of row-crop machines. Row length, per cent turning time, and down-the-row speed are interrelated. A change in any of these will cause a change in machine capacity. The number of terraces and terrace arrangement in a field will influence row arrangement. Row arrangement in turn will affect row length.

Turning Time Per Acre

Turning time at row ends can seriously influence acre-per-hour capacity of machines. The total time used per acre for turning is influenced by the number of rows per acre. As row length increases the time spent in turning decreases and machine capacity increases.

Row Speed

Down-the-row speed also influences per cent turning time. At 1 m.p.h. in 700-foot rows, a 4-row cultivator using 15 sec. per turn would have 4 per cent turning time while at 5 m.p.h. it would have nearly 13 per cent. As farm machinery becomes larger and operating speeds become faster, time spent turning becomes increasingly important. The relationship of row length, operating speed, and per cent turning time is shown in Figure 4.

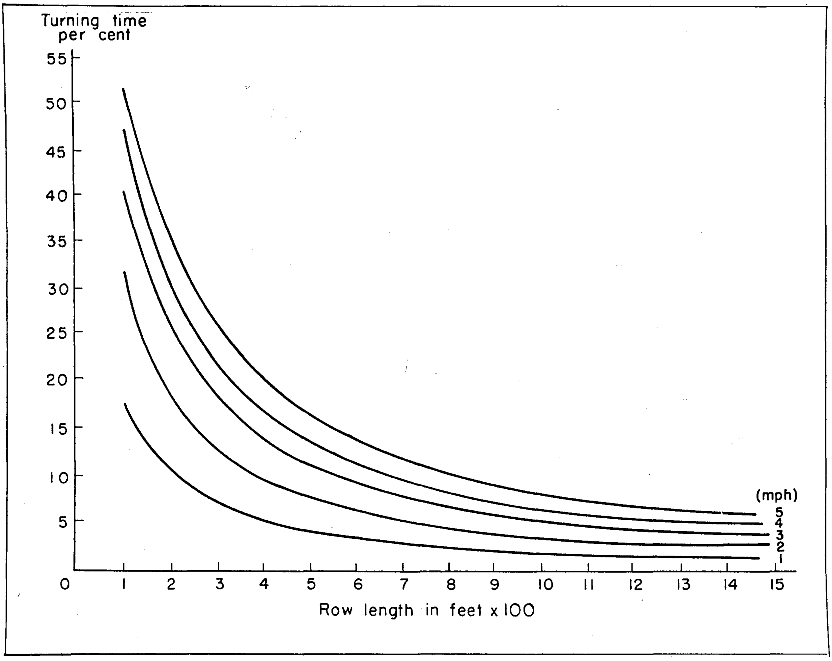

FIG. 4. Speed of operation, field row length, and per cent of time spent turning are interrelated.

Minimum Row Length

Field studies of machines indicate that a turning time of less than 5 per cent of the total field time is rather difficult to obtain, but that values between 5 and 10 per cent are frequently obtained. If per cent turning time is to be held to a reasonable level, less than 10 per cent, field rows need to have some minimum length. Table 4 shows the minimum row lengths needed for five different operating speeds and two levels of turning time.

TABLE 4. MINIMUM ROW LENGTH FOR 7 AND 10 PER CENT TURNING TIME WITH A 4-ROW MACHINE*

Speed	Minimum row length needed	
	7 per cent turning time	10 per cent turning time
M.p.h.	*Ft.*	*Ft.*
1	280	190
2	540	360
3	740	520
4	920	680
5	1,080	840

* Turning time of 15 sec. per turn and 40-in. rows.

Machine Width

Row length and machine width influence per cent of total field time spent turning, Figure 5. A 2-row cultivator operating at 5 m.p.h. in 600-foot rows would have 10 per cent turning time while a 4-row cultivator at the same speed in the same row length would have 14 per cent. In 400-foot rows the turning time would be 14 per cent for the 2-row machine and 21 per cent for the 4-row. For a 2-row cultivator having a turning time of 10 per cent the minimum row length is 600 feet. For a 4-row cultivator having the same per cent turning time the minimum row length would be 840 feet. Row length and field size should increase as machines become wider. When changing from 4-row to 6-row machines for example, serious consideration should be given to ways of increasing row length and field size for these wider machines.

Terrace and Row Arrangement

Field row length is influenced by terraces and other soil-conserving structures. The number of terraces and terrace layout influence row arrangement and length. Terraces also influence acre-per-hour capacity of farm machines. Table 5 presents data for a 4-row cultivator operating in areas without terraces, with parallel terraces, and with nonparallel terraces. Per cent turning

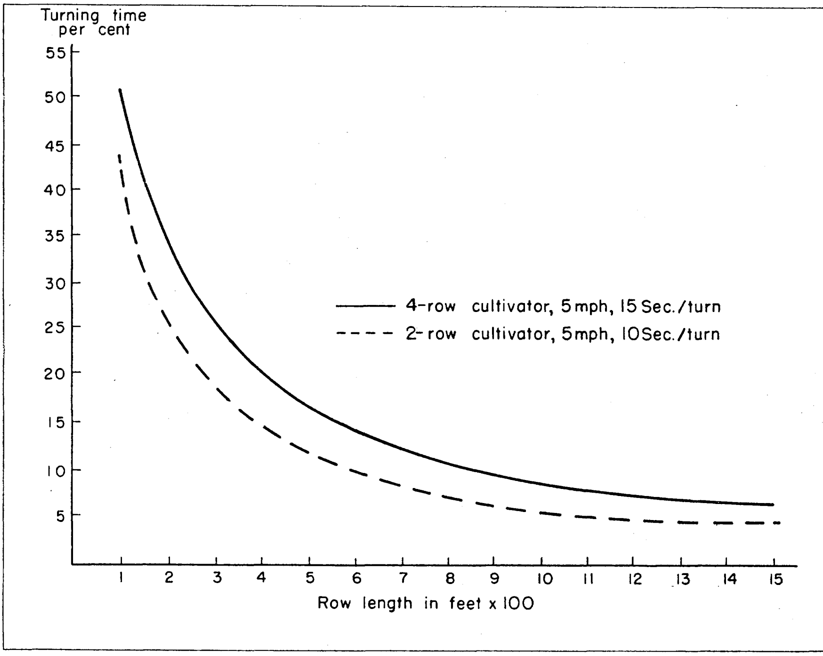

FIG. 5. Machine width, field row length, and per cent of time spent turning are interrelated.

TABLE 5. FOUR-ROW CULTIVATOR CAPACITY FOR THREE FIELD CONDITIONS

	Effective cult. cap.*	Row end turning time	Field length	Av. speed
	Acres/hr.	*Pct.*	*Ft.*	*M.p.h.*
Nonparallel terraces	5.0	14.0	1,250	4.0
Parallel terraces	6.4	8.0	1,175	4.5
Without terraces	7.6	8.0	1,125	5.3

* Capacity determined for actual time spent in the field. Includes all field stops and adjustments. Does not include daily tractor service, changing cultivator sweeps, or lubrication.

time is highest for the nonparallel terrace area. This area also has the lowest average speed and lowest effective cultivator capacity. Terracing of row-crop land is a good conservation practice, but from the standpoint of machine capacity, parallel terraces should be used where practical. In fields where conventional terraces must be used, consideration should be given to terrace arrangement and field use to minimize short rows between terraces.

FIELD SIZE AND SHAPE

Field size and shape will influence machine capacity. Field size and shape also determine row length. Small fields are usually less efficient for machinery use than are large fields.

Field Shape

The geometric shape of the field can influence row length. This is clearly shown in Figure 6. The fields in Figure 6 are the same size, the only difference being the geometric shape.

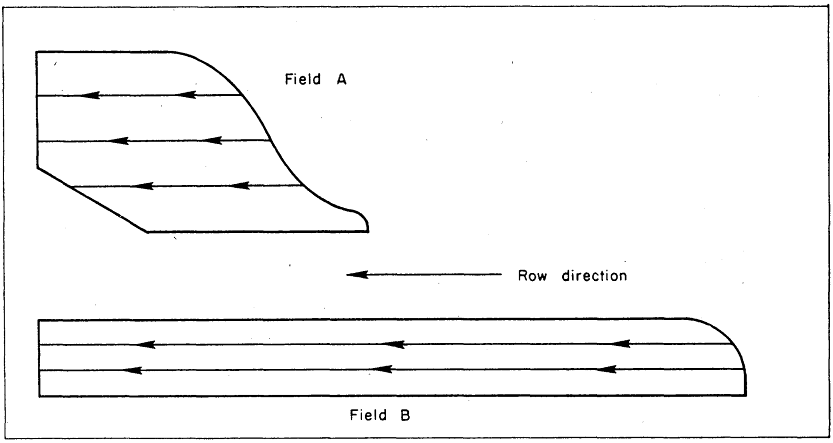

FIG. 6. These fields contain the same area but shape determines row length and therefore influences machine efficiency.

The importance of field shape is shown in Table 1. The data in Table 1 were obtained from a comparison of the two fields to show the relationship of row layout, row length, field size, field machine efficiency, and machine capacity.

All operations on the two fields were identical, including driver, tractor, cultivator, and speed of operation. Neither field had any operation time loss except that used for turning at row ends.

Field A was irregular in shape with the longest row being 400 feet. The shortest row was 165 feet long. Field B was long and narrow. The row length averaged 1,050 feet, the longest and the shortest rows being 1,060 and 1,000 feet.

Machine capacity in field B was 0.6 acre per hour greater than in field A. The long rows in field B account for the increase in capacity from 2.3 to 2.9 acres per hour.

The importance of field shape is shown in a study of the operating time and capacity of a 4-row cultivator operating on two fields. Each field contained 10 acres. One field was square and had rows 660 feet long. The cultivator operating at 4 m.p.h. in this field had a capacity of 5.7 acres per hour. The other field was rectangular in shape and had rows 1,300 feet in length. The 4-row cultivator operating in this field at 4 m.p.h. had a capacity of 6.2 acres per hour.

Field Machine Efficiency

Field machine efficiency is a term used to indicate how well a field is adapted for machinery use. The term "field machine efficiency" is used to show the relationship between turning time and productive field time. Productive field time for a planting operation would include only the actual time spent planting; time for filling hoppers, adjustments, and other like items is not included. It is expressed as a percentage.

A field with a field machine efficiency of 90 per cent would have 10 minutes of turning time and 90 minutes of productive field time. The influence of row length on field machine efficiency is shown in Table 6.

TABLE 6. FIELD MACHINE EFFICIENCY

Operation	Row length	Field machine efficiency
	Ft.	*Pct.*
Cultivating	500	90
Cultivating	850	95
Insect spraying	500	82
Insect spraying	850	85

If field machine efficiency values for field operations are to be useful in future planning of field size, it is necessary that one field machine efficiency study be made for each field on the farm. This would involve keeping a time record for all activities associated with this one specific field operation. Such a time record might look like the following:

EXAMPLE OF A TIME RECORD FOR PLANTING A 10-ACRE FIELD

Item		Time
		Min.
A. Total field time		175
B. Support functions time (Not including turning)		83
Adding fertilizer and seed	38	
Adding chemicals and water	29	
Adjustment time	12	
Other down time	4	
C. Turning time		12

Total field time in the above example includes all of the time, from start to finish, required to plant the 10-acre field.

Field machine efficiency (FME) for the field in the example can be calculated from the following formula.

$$\text{FME} = \frac{A - B - C}{A - B} \times 100$$

Items A, B, and C in the formula are the same as the three parts listed in the sample time record.

For the planting example used, field machine efficiency is obtained by substitution:

$$\text{FME} = \frac{175 - 83 - 12}{175 - 83} \times 100 = 87\%$$

After values for each field have been determined, comparisons of field machine efficiency for the fields can be made. Fields with the lowest efficiencies should be considered for changes to increase row length or reduce turning time.

The field machine efficiency values obtained in this study indicate that a field which has a high machine efficiency value for one machine will also tend to have high values for other machines.

Consolidating Fields

Combining several small fields into a large one can result in increased machine efficiency. As an example, fields 1 and 2 were originally operated as small separate fields with short rows. Time records were kept for machine operations on these fields. The fields were later consolidated into a large field which resulted in an increase in row length.

Fields 1 and 2 had field machine efficiency values for insect control of 83 and 84 per cent, respectively, when operated as separate fields. When combined into one large field the efficiency increased to 91 per cent. For cultivation, the field machine efficiency for the two separate fields was 84 and 80 per cent and increased to 90 per cent when the two were combined into a single field. This increase in efficiency is directly related to row length increase.

SUMMARY

Time spent in turning at row ends for row-crop operations will materially influence machine capacity. Minimum turning time results when the turn area is smooth and wide enough to allow an easy semicircle turn. Rough or narrow turn areas can increase

turning time as much as 50 per cent. For a 4-row cultivator this could mean a decrease of .3 acre per hour.

Fields with long rows are more efficient for machinery use than fields with short rows. Row lengths should be long enough to have field machine efficiencies of 90 per cent or better. Terraces tend to reduce efficiency of machine operations. Fields without terraces are more efficient for machine use than fields with terraces. Parallel terrace fields are more efficient than conventional terrace fields. Recommended minimum average row length is influenced by machine width and ground speed. For example, a 4-row cultivator operating in 40-inch rows at 4 m.p.h. should have minimum row length of 680 feet. If the speed is 5 m.p.h. the length should be 840 feet.

The physical shape along with row layout of the field has much to do with machinery efficiency. Long narrow fields with long rows are more efficient than short narrow fields. Field size also is related to field machinery efficiency. Small fields usually have short rows and are inefficient for machine use. Combining small fields into larger fields can materially increase field machine capacity. Field machine efficiency values for a specific operation on a specific field are not very useful in predicting actual values for other machines on that same field. However, if field machine efficiency values are obtained for several fields by using the same machine operation on these fields, then the field machine efficiency values tend to indicate the efficiency of each field for machine use.

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APPENDIX

Calculating Machine Capacity

The following methods are commonly used to determine machine capacity in acres per hour:

Method I. Simple method used to get a quick approximation.

$$C = \frac{W \times S}{10}$$

C = Capacity in acres per hour
W = Machine width in feet
S = Ground speed of machine in m.p.h.

This method allows for 17.5 per cent nonproductive and down time.

Example: 4-row-cultivator, 40-in. rows
Speed – 5 m.p.h.

$$\text{Machine width} = \frac{4 \times 40\text{-in.}}{12} = 13.3 \text{ feet}$$

$$\frac{13.3 \text{ ft.} \times 5 \text{ m.p.h.}}{10} = 5.6 \text{ acres/hour}$$

Method II. A more accurate method of predicting acres per hour.

$$C = \frac{5280 \times S \times W \times E}{43{,}560 \times 100} = \frac{SWE}{825}$$

C = Capacity in acres per hour
S = Ground speed in m.p.h.
W = Width of machine in feet
E = Field efficiency in per cent (Typical values for field efficiency can be found in Appendix Table 1.)

Example: 4-row planter, 40-in. rows
Speed – 4 m.p.h.
Width – 13.3 feet
Efficiency – 70 per cent

$$\frac{4 \times 13.3 \times 70}{825} = 4.6 \text{ acres/hour}$$

Calculating Speed in Miles Per Hour

The following methods can be used to calculate speed of operation in miles per hour:

Method I. Use when speed in feet per minute is known.

$$\frac{F \times 11.4}{1000} = M$$

M = Speed in miles per hour
F = Feet traveled in one minute

Example: Cultivator travels 264 feet in one minute

$$\frac{264 \times 11.4}{1000} = 3.0 \text{ miles per hour}$$

The values in Appendix Table 4 were compiled in this way.

Method II. Use when time in seconds to cover a distance of 100 feet is known.

$$\frac{68.5}{T} = M$$

M = Speed in miles per hour
T = Time in seconds to travel 100 feet

Example: Planter travels 100 feet in 20 seconds

$$\frac{68.5}{20} = 3.4 \text{ miles per hour}$$

The values in Appendix Table 5 were compiled in this way.

APPENDIX TABLE 1. COMMON FIELD MACHINE EFFICIENCY VALUES FOR ROW CROP MACHINES

Operation	Average values field efficiency*
	Pct.
Plowing	75-85
Harrowing	80-90
Harrowing and chemical application	65-75
Planting (seed and fertilizer) 2-row	60-70
Planting (seed, fertilizer, chemicals) 2-row	50-60
Planting (seed and fertilizer) 4-row	55-65
Planting (seed, fertilizer, chemicals) 4-row	50-60
Cultivating 2-row	80-90
Cultivating 4-row	80-90
Picking cotton (spindle machine) 1-row	65-75
Picking cotton (spindle machine) 2-row	65-75
Picking corn 2-row	55-65
Picking corn 4-row	55-65
Combining	60-70

* Values are based on average ground speed for the operation and for row lengths of 1,000 feet. Rows longer than 1,000 feet would be more efficient, while rows less than 1,000 feet would be less efficient.

APPENDIX TABLE 2. ROWS PER ACRE FOR COMMON LENGTHS AND ROW SPACING

Row length	Row spacing				
	48 in.	44 in.	40 in.	36 in.	32 in.
Ft.	*Rows/acre*	*Rows/acre*	*Rows/acre*	*Rows/acre*	*Rows/acre*
400	27.3	29.7	32.9	36.3	40.8
600	18.2	19.7	21.8	24.2	27.4
800	13.6	14.8	16.4	18.2	20.4
1,000	10.8	12.0	13.0	14.5	16.4
1,200	9.1	9.6	10.6	12.1	13.2
1,400	7.8	8.4	9.2	10.3	11.4
1,600	6.8	7.4	8.1	9.1	10.1
1,800	6.0	6.5	7.2	8.0	9.0
2,000	5.4	5.9	6.5	7.2	8.2

APPENDIX TABLE 3. TYPICAL SPEED FOR SOME ROW CROP MACHINES

Operation	Rate
	M.p.h.
Plowing	3.5-5.0
Disk harrowing	3.5-5.0
Planting	3.0-5.0
Rotary hoeing	5.0-8.0
Flame cultivating	1.5-3.0
Sweep cultivating	
First cultivation	1.5-3.0
Later cultivation	3.0-5.0
Corn picking	2.5-3.5
Combining	2.5-3.5
Cotton picking (spindle machine)	1.5-2.5
Spraying (insect)	3.0-6.0

APPENDIX TABLE 4. CONVERSION TABLE FEET PER MINUTE AND MILES PER HOUR

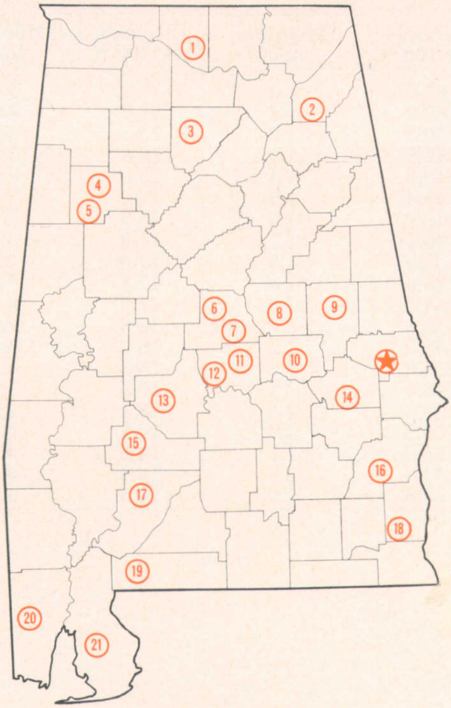
Feet per minute	Miles per hour	Feet per minute	Miles per hour	Feet per minute	Miles per hour
176	2.0	361	4.1	535	6.1
185	2.1	370	4.2	543	6.2
194	2.2	379	4.3	552	6.3
202	2.3	387	4.4	561	6.4
211	2.4	396	4.5	570	6.5
220	2.5	405	4.6	578	6.6
229	2.6	414	4.7	588	6.7
237	2.7	422	4.8	596	6.8
246	2.8	431	4.9	605	6.9
255	2.9	440	5.0	614	7.0
264	3.0	449	5.1	622	7.1
273	3.1	458	5.2	631	7.2
282	3.2	468	5.3	640	7.3
292	3.3	476	5.4	649	7.4
299	3.4	484	5.5	658	7.5
308	3.5	493	5.6	666	7.6
317	3.6	502	5.7	675	7.7
325	3.7	510	5.8	684	7.8
334	3.8	519	5.9	693	7.9
343	3.9	528	6.0	702	8.0
352	4.0				

Appendix Table 5. Conversion Table Seconds Per 100 Feet and Miles Per Hour

Seconds per 100 ft.	Miles per hour	Seconds per 100 ft.	Miles per hour	Seconds per 100 ft.	Miles per hour
69.0	1.0	22.7	3.0	13.6	5.0
62.0	1.1	22.0	3.1	13.3	5.1
56.8	1.2	21.3	3.2	13.1	5.2
52.5	1.3	20.6	3.3	12.9	5.3
48.6	1.4	20.0	3.4	12.6	5.4
45.4	1.5	19.5	3.5	12.4	5.5
42.6	1.6	18.9	3.6	12.2	5.6
40.1	1.7	18.4	3.7	12.0	5.7
37.9	1.8	17.9	3.8	11.8	5.8
35.9	1.9	17.5	3.9	11.6	5.9
34.1	2.0	17.0	4.0	11.4	6.0
32.3	2.1	16.6	4.1	11.2	6.1
31.0	2.2	16.2	4.2	11.0	6.2
29.6	2.3	15.8	4.3	10.9	6.3
28.4	2.4	15.5	4.4	10.7	6.4
27.3	2.5	15.1	4.5	10.5	6.5
26.2	2.6	14.8	4.6		
25.3	2.7	14.5	4.7		
24.3	2.8	14.2	4.8		
23.5	2.9	13.9	4.9		

AGRICULTURAL EXPERIMENT STATION SYSTEM OF ALABAMA'S LAND-GRANT UNIVERSITY

With an agricultural research unit in every major soil area, Auburn University serves the needs of field crop, livestock, forestry, and horticultural producers in each region in Alabama. Every citizen of the State has a stake in this research program, since any advantage from new and more economical ways of producing and handling farm products directly benefits the consuming public.



Research Unit Identification

★ Main Agricultural Experiment Station, Auburn.

1. Tennessee Valley Substation, Belle Mina.
2. Sand Mountain Substation, Crossville.
3. North Alabama Horticulture Substation, Cullman.
4. Upper Coastal Plain Substation, Winfield.
5. Forestry Unit, Fayette County.
6. Thorsby Foundation Seed Stocks Farm, Thorsby.
7. Chilton Area Horticulture Substation, Clanton.
8. Forestry Unit, Coosa County.
9. Piedmont Substation, Camp Hill.
10. Plant Breeding Unit, Tallassee.
11. Forestry Unit, Autauga County.
12. Prattville Experiment Field, Prattville.
13. Black Belt Substation, Marion Junction.
14. Tuskegee Experiment Field, Tuskegee.
15. Lower Coastal Plain Substation, Camden.
16. Forestry Unit, Barbour County.
17. Monroeville Experiment Field, Monroeville.
18. Wiregrass Substation, Headland.
19. Brewton Experiment Field, Brewton.
20. Ornamental Horticulture Field Station, Spring Hill.
21. Gulf Coast Substation, Fairhope.