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SOME EFFECTS *of* MANAGEMENT *on* CAPACITY *and* EFFICIENCY *of* FARM MACHINES

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Some Effects of Management on Capacity and Efficiency of Farm Machines

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FARM MACHINERY manufacturers are continually improving their machines and, in so doing, making them larger, more complex, and more expensive. If these new machines are to make their maximum contribution to agricultural production, they must be used effectively and efficiently to take advantage of the built-in improvements. Efficient use means getting maximum machine capacity at minimum per unit cost, and timely operation is necessary for effective machine use.

The acreage a machine can handle in an hour is influenced by many factors, as reported in an earlier Auburn University Agricultural Experiment Station bulletin.[1] Included are machine factors, field factors, and management factors. Management factors and field factors are interrelated since management controls certain aspects relating to the fields. For example, management has some control over field size, row arrangement, soil conservation practices used, conditions in the turn-row area, and even whether the field is to be planted.

Management also controls the flow of materials for a farm machine. Materials flow for farm machinery is essentially of two types. One is the flow of material to the machine, such as seed or fertilizer to a planter. The other type involves the flow of material away from the machine, such as cotton from a cottonpicker.

A study to show the effect of some management decisions on machine field efficiency and capacity was conducted as part of continuing research in farm machinery use.

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[1] RENOLL, E. S. 1969. Crop Machinery Capacity as Influenced by Field Conditions. Auburn Univ. (Ala.) Agr. Exp. Sta. Bull. 395.

GENERAL TEST CONDITIONS

The study was conducted during a 3-year period at the Agricultural Engineering Research Unit near Marvyn, in the Lower Coastal Plains area. Field sizes ranged from 3.5 to 48.0 acres, with rows 200 to 1,500 feet in length. The fields had various geometric shapes and included parallel terraces, conventional terraces, and no terraces.

Machines used during the study were conventional row-crop machines commonly available to farmers. These included 1-row, 2-row, and 4-row machines.

Machine operators could be described as typical of those on farms in this area of Alabama. Each operator had considerable experience and could operate all of the machines involved.

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.

MATERIALS HANDLING MANAGEMENT

Economic utilization of farm machinery depends to a large extent on the flow of materials for these machines. The importance of this material flow can be seen in a planting study. In this study the water for chemical spray was handled by two different methods:

Method A. Water for the preemergence chemical was transported in 55-gallon drums on a large truck. The planter tanks were filled by gravity flow from the drums on the truck.

Method B. Water for the preemergence chemical was transported in a water-tank trailer and was transferred to the planter tanks with a small gasoline engine and pump.

All planting operations were identical except method of handling water. The preemergence chemical was applied in 10 gallons of water per acre.

The gravity flow system used in method A required 2.88 minutes per acre to handle the water, but method B's pump system took only 1.03 minutes per acre, Table 1. This is a reduction of 64 per cent. Capacity of the planter in this study showed an increase from 3.4 to 3.9 acres per hour by shifting from method A to method B for water handling. This amounted to an increase of 5 acres for a 10-hour day. Thus, materials flow to a machine can greatly influence its capacity.

TABLE 1. COMPARISON OF TWO METHODS OF HANDLING WATER FOR A PREEMERGENCE SPRAYER USED ON A 4-ROW PLANTER

Description	Time per acre, average	Planter capacity per hour
	Minutes	*Acres*
Method A		
Water stored in 55-gallon drums and fed to planter tanks by gravity	2.88	3.4
Method B		
Water stored in tank trailer and fed to planter tanks by power pump	1.03	3.9

MACHINE OPERATION MANAGEMENT

Management of machine operations can have significant influences on machine field capacity and efficiency, as illustrated by results from two studies.

The first study, of a cotton planting operation, examines two specific segments – adjustment time and other down time – of the total time to plant an acre.

Planter 1 had much more adjustment time than planter 2, Table 2. This difference might have resulted from several causes. Supervision of planter preparation and adjustment prior to going to the field may have been lax and allowed the planter to go to the field incorrectly adjusted. Soil and seedbed conditions may have been such that frequent adjustment was necessary for satisfactory planting. Regardless of the reason, adjustment time for planter 1 needs to be reduced to make this operation more efficient. Planter 1 also had more down time than planter 2. Management should examine the operation of planter 1 to determine causes of this down time and then take steps to reduce it. The lower adjustment and down time of planter 2 increased its capacity by 0.3 acre per hour over planter 1.

The importance of machinery management is also shown by data from a study of two cottonpickers. Time to harvest an acre of cotton was 53.0 and 47.2 minutes. This variation is related to machine management, Table 3.

TABLE 2. INFLUENCE OF ADJUSTMENT AND OTHER DOWN TIME ON THE CAPACITY OF A 4-ROW PLANTER

Planter	Average adjustment time per acre	Average down time per acre	Planter capacity per hour
	Minutes	*Minutes*	*Acres*
1	1.18	.75	3.4
2	.43	.35	3.7

TABLE 3. TIME IN MINUTES TO HARVEST AN ACRE OF COTTON BY TWO DIFFERENT MACHINES AND OPERATORS

Item	Harvesting time	
	Operator X	Operator Y
	Minutes	*Minutes*
Total time	53.0	47.2
Turn at row ends	2.6	1.2
Dump basket	4.6	4.3
Clean machine	2.3	2.1
Idle travel	1.1	0.3
Travel to and from wagon	3.6	2.7
Pack basket	2.1	.0
Other down time	0.7	0.6
Actual picking	36.0	36.0

Travel time to and from the wagon to dump the basket depends on wagon placement. Operator X used 3.6 minutes per acre going to and from the wagon while operator Y used 2.7 minutes, reflecting the greater travel distance for operator X.

Time spent turning at row ends can be influenced by machine management. For example, the field picking pattern used by a 1-row cottonpicker affects time spent in turning. Some operators prefer to skip several rows when turning at row ends rather than to use a tight turn and harvest the next adjacent row. Thus, machine operating patterns and turning patterns affect total turn time. The importance of planning field layout, row arrangement, and field end turning to obtain maximum machine capacity is indicated by data in Table 3. Operator Y used 1.2 minutes per acre for turning and 0.3 minute per acre idle travel time, as compared with 2.6 and 1.1 minutes per acre, respectively, for operator X.

For some machines, especially cottonpickers, management of certain machine operations is very important. For example, the time used in packing the basket by operator X was 2.1 minutes per acre but operator Y used no time for this purpose. Basket packing becomes necessary when the basket fills before the machine reaches the row end. Determining exactly how many full-length rows are needed to completely fill the basket is not easy, but this factor is worthy of consideration when laying out fields.

FIELD MANAGEMENT

Past research has shown that machine capacity can vary with fields, and row arrangement appears to be one reason for this variation. Row arrangement is a function of many things, including field size, field slope, soil conditions, and soil conservation

TABLE 4. INFLUENCE OF TWO TERRACING SYSTEMS ON CULTIVATOR CAPACITY ON THE SAME FIELD

Item	System differences	
	T9	T4
Number of terraces	9	4
Cultivated acres	52	46*
Total time for 1 cultivation, hours	9.62	7.50
Turning time, hours	1.30	.72
Adjustment and idle time, hours	.80	.33
Efficiency of total cultivation operation, per cent	78.0	86.0
Acres per hour	5.6	6.1

* Only 46 acres planted because of change in cropping practices. Did not result from terrace changes.

practices. The influence of terrace arrangement on machinery use was studied as part of this research.

Two nonparallel terracing systems were used on the same field. The first system of nine terraces (designated T9) was used for several years and was later replaced with an experimental four-terrace system (T4).

Capacity of the 4-row cultivator went from 5.6 acres per hour on T9 with nine terraces to 6.1 acres per hour on T4 with four terraces, Table 4. This increase in capacity resulted from several conditions. Turning time was reduced from 1.3 to 0.72 hours for the entire field when the terrace system was changed and many short rows were eliminated.

Elimination of short rows also reduced adjustment and idle time. The terrace channel frequently served as the turn area for the short rows. Turning on these terraces not only increased turning time but frequently resulted in the cultivator sweeps being knocked out of adjustment by digging into the terrace. Cultivating the short rows increased idle time since the operator frequently had to double back to the edge of the field to get on the next long rows. Efficiency of the total cultivation operation on T9 and T4 was 78 and 86 per cent, respectively.

The alterations in terrace and row arrangement also were reflected in the planting operation. Turning time for a 4-row planter was 15.1 per cent on T9 and only 6.7 per cent on T4. Time actually spent placing seed in the ground increased from 46 per cent for T9 to 56 per cent for the T4 system.

In recent years, some interest has been expressed in planting rows across terraces rather than parallel to them. This method of row arrangement should result in increased average row length, especially in fields using nonparallel terraces.

A row arrangement study was conducted in 1967 and 1968 on an 18.5-acre field having a 3 per cent slope. The field contained five broad-base terraces, including both parallel and nonparallel. There were two nonparallel terrace intervals of varying width. In 1967 the field was planted in a conventional row arrangement with rows running parallel to the terraces. This resulted in short point rows in the nonparallel terrace intervals. In 1968 the rows were arranged parallel to one edge of the field and at right angles to direction of the major field slope. In this arrangement many of the rows crossed the terraces, with angle of row crossing at the terrace ranging from 5 degrees to 80 degrees.

The field was planted with a 4-row trailing planter and cultivated with a 4-row mounted cultivator. A 12-row sprayer was used for insecticide application. Harvesting was done with a 1-row cottonpicker. The physical layout of the field in 1967 and in 1968, including row lengths and number, turns and turning conditions, and terraces is shown in Table 5.

The following items are important when comparing the 1967 row arrangement to the one used in 1968:

1. The number of rows in the field was reduced from 320 to 264 without any change in acreage.
2. Rows less than entire field length were reduced from 172 to 56 in number.
3. Rows in the longest length group increased from 100 to 124.
4. Turns inside the field were eliminated; all turns were made at field edge in 1968.

TABLE 5. PHYSICAL ROW LAYOUT OF A FIELD WHEN USING TWO DIFFERENT ROW ARRANGEMENTS

Item	First year	Second year
Acres	18.4	18.5
Terrace intervals	4	4
Parallel	2	2
Nonparallel	2	2
Rows of each length, number		
100-300 feet	88	16
300-500 feet	44	36
500-700 feet	20	32
700-900 feet	12	24
900-1,100 feet	56	32
1,100-1,320 feet	100	124
Row distribution		
Rows entire length of field, number	148	208
Short rows (less than field length), number	172	56
Total rows in field, number	320	264
Type row end turns		
Turning at field edge, number	512	528
Turning within field, number	88	0
Terrace turn within field, number	40	0

5. The number of rows 500 feet or shorter decreased from 132 to 52.

6. The number of rows 900 feet or longer did not change, each having 156.

The relative efficiency of the 1968 row arrangement for machinery use, as compared to the 1967 arrangement, for some specific field operations is summarized as follows:

1. Row end turn condition was improved since all turns were at field edge.

2. For 4-row equipment, the number of turns for one complete field coverage was reduced from 80 to 66.

3. Total time spent turning while planting the field (4-row planter) was reduced from 18.2 minutes to 14.3 minutes, a 21 per cent reduction.

4. Total time spent turning while cultivating (4-row cultivator) for each cultivation was reduced from 16.6 minutes to 13.2 minutes, for a 20 per cent time saving.

5. Total time spent turning while picking cotton (1-row machine) was reduced 17 per cent, from 179.6 minutes to 149.5 minutes.

6. In view of the improved turning conditions and the reduction in total turns, wear on the tractor and fatigue of the operator should be less for the 1968 row arrangement.

In some soil types and during wet weather conditions, rows planted across terraces might present some machinery and soil erosion problems. In this 1968 study, however, no machinery problems were encountered with a 4-row planter and cultivator, a 12-row insect sprayer, and a 1-row cottonpicker. There did not appear to be any unusual problems in obtaining a crop stand and there were no unusual erosion problems or terrace breaks. This study is not to suggest that rows planted across terraces will always be satisfactory, but rather to suggest that this is another method for consideration when planning row arrangement for maximum row length.

FIELD MACHINE INDEX

Efficient machinery utilization is related to row length. Large fields are usually better suited to machinery use than small fields. Long-row fields are more efficient for machine use than short-row fields. Research on the relationship between machinery effectiveness and row length has produced a procedure that is useful in

TABLE 6. TIME FOR EACH SEGMENT OF CULTIVATION OPERATION

Segment of operation	Time required
	Minutes
A. Total time to cultivate field	195
B. Total support functions time (not including turning)	12
C. Total time turning	17

measuring this relationship. The heart of this procedure is called "field machine index."

The term field machine index is used to indicate how well suited a specific field is for machinery use. A field with a field machine index of 95 is better adapted to machine use than a field with an index of 85. An index of 100 is maximum.

To calculate field machine index for a specific field, certain basic information is needed. Using a cultivator operation as an example, the following information is needed:

A. Total time to cultivate the field.

B. Total support functions time, other than turning.

C. Total time spent turning at row ends.

All times are expressed in minutes. Item B includes time for such support functions as sweep adjustment and all other "down" time. Item C, the total time spent turning at row end while cultivating the field, can be obtained by timing each turn and then adding together all turns. Another method would be to time a number of turns to get an average time per turn, and then multiply by the number of turns for the entire field. This latter system assumes that turning conditions for the entire field are essentially the same. Data from such a study, Table 6, are used in the following way to calculate field machine index (FMI).

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

$$\text{FMI} = \frac{195 - 12 - 17}{195 - 12} \times 100 = 91$$

Field machine efficiency can be determined for each field on the farm, using similar information for a common machine for each of the fields. After index values have been determined, comparison and study of individual fields can begin.

SUMMARY AND CONCLUSIONS

Effect of specific management decisions on farm machinery capacity and efficiency was measured. The acre-per-hour capacity of a machine is influenced by machine factors, field factors, and management factors. Results from this study show that field factors and management factors are strongly interrelated.

The flow of material to the farm machine or away from it influences machine capacity. The capacity of a 4-row planter increased from 3.4 to 3.9 acres per hour when methods of handling water for chemical spray were improved.

Excessive adjustment time and other down time were shown to decrease the capacity of a 4-row planter by as much as 0.3 acre per hour. Thus, reasonable supervision of the planting operation and proper adjustment of the planter could pay dividends in increased planter capacity.

Cottonpicker capacity was influenced by management or operator decisions made while the machine was in operation. Time spent dumping and cleaning the picker, travelling to and from the dump wagon, packing the basket, and for other nonproductive items varied in the study. Time spent for some specific individual items varied by more than 300 per cent between pickers.

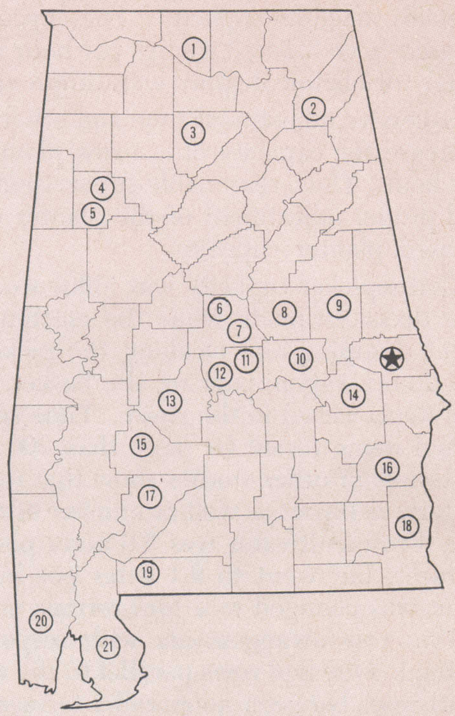
Results of other studies show that machine capacity is affected by terrace layout as well as number of terraces per acre. Capacity of a 4-row cultivator was 5.6 acres per hour in a field with nine terraces, but went to 6.1 acres per hour when terrace arrangement was changed to a four-terrace one.

Two row arrangements with respect to terrace layout were studied. One had rows parallel to the terraces and included some short rows between nonparallel terraces. The other arrangement had long rows the length of the field that crossed over the terraces. In this study the latter row arrangement was superior and resulted in a 21 per cent reduction in turning time during planting and a 20 per cent reduction in turning time for each cultivation. Also, turning time for a 1-row cottonpicker during harvest was reduced 17 per cent.

Efficient machine utilization is related to field row length. Large fields are usually better adapted to machinery use than small fields. A field machine index (FMI) concept was presented that is used to indicate how well adapted a specific field is for machinery use. This concept uses turning time, support functions time, and total field operation time to determine a FMI value for each field. Values go up to a maximum of 100, which indicates maximum efficiency. Fields best adapted for machinery use can thus be selected by comparing FMI values for the individual fields. Fields with low values can be identified and studied for possible ways to make them more efficient for machinery use.

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.