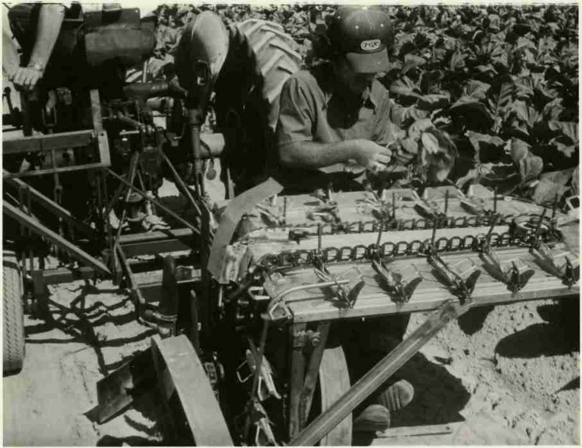

January 22, 1979

Mr. James Basselman
Publications Manager
American Society of Agricultural Engineers
2950 Niles Road
St. Joseph, Michigan 49085

Re: Development of a Transplanter with Multiple Loading Stations
MS # 445 by C.W. Suggs

Dear Jim:

I have checked the enclosed proofs and found only two minor mistakes which I have marked in red ink. There is also a mistake (my error on the manuscript submitted to you) in the references which shoul: be corrected. Correct the patent number even if you don't add the patent title.

I have asked our purchasing department to process an order for 200 reprints as indicated on the attached sheet. You should get a copy of the purchase order in a few weeks.

Thank you for making publication of this work possible.

Sincerely,

C.W. Suggs
Professor

CWS/bm

Enclosures

AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS

Howard F. McColly
Power & Machinery Editor
225 Kensington Road
East Lansing, MI 48823

June 5, 1978

To: C.W. Suggs
Re: ASAE Ms.# PM-230

The above referenced paper in final form has been forwarded to ASAE Publications Department for publication scheduling in the Transactions.

You will hear directly from ASAE as the article progresses in the publication process.

Thank you for finalizing this article. New orig. illustr. & ©TR Form were received.

Sincerely yours,

H. F. McColly

H. F. McColly, Division Editor
Power and Machinery Division

HFM/mkw

May 31, 1978

Professor Howard F. McColly
American Society of Agricultural Engineers
Power and Machinery Editor
225 Kensington Road
East Lansing, Michigan 48823

Dear Professor McColly:

I am returning herewith three revised copies of my paper entitled "Development of a Transplanter with Multiple Loading Stations" manuscript #PM 230. Comments of the two reviewers were pretty consistent so I was able to incorporate most of their suggestions.

I am enclosing a new set of prints of the figures as one of the figures was changed slightly. So, if you still have the set I sent in earlier please discard them and use the set enclosed.

If there are questions please contact me.

Sincerely,

C.W. Suggs
Professor

CWS/bm

Enclosure

NOTE-O-GRAM®
© THE DRAWING BOARD • BOX 505 • DALLAS, TEXAS

AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS
HOWARD F. McCOLLY
POWER & MACHINERY EDITOR
225 KENSINGTON ROAD • EAST LANSING, MICHIGAN 48823 • PHONE: 517 332-2385

MESSAGE	REPLY
TO Prof. C. W. Suggs ~~Agrl & Bio~~ Bio & Agr. Eng. Dept. North Carolina State University Box 5906 Raleigh, NC 27607	DATE
DATE May 12, 1978	
– Re: ASAE Ms. # PM-230	
Two very good reviews are enclosed for your use in finalizing the article. The third reviewer does not respond.	
Pls. return the finalized article as soon as you can satisfactorily complete it.	
BY H. F. McColly	SIGNED

AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS

Howard F. McColly
Power & Machinery Editor
225 Kensington Road
East Lansing, MI 48823

(517) 332-2385

May 12, 1978

RE: ASAE Ms. #PM-230

Dear Author:

We are pleased to tell you that your paper, listed above, has been reviewed for publication in TRANSACTIONS of the ASAE. We appreciate your contribution to the literature presented to ASAE for publication consideration.

Enclosed are the comments we received from technical reviewers. Since reviewers may disagree on recommendations, their comments are offered primarily as constructive criticism and are not considered binding.

Please make any revisions in the paper you deem advisable and return one copy of the final manuscript to me. This is your last opportunity to change the length of the paper. Upon receipt of your reply, including any desired revisions, we will schedule the paper in TRANSACTIONS of the ASAE. Please again refer to the sheet "Instructions to Authors for ASAE Publications," and note the notice referring to the new copyright law.

We should like your reply by your early convenience. If additional time is needed, please let us know.

Sincerely,

H. F. McColly

H. F. McColly, Division Editor
Power and Machinery Division

HFM:kc
encs: Review Evaluation Materials
Instructions to Authors
Copyright Transfer

Manuscript No. PM-230

Development of a Transplanter with
Multiple Loading Stations

C.W. Suggs

ABSTRACT

The multiple-loading feature significantly increased the operator's feeding speed because it allowed up to five plants to be fed into the mechanism before they are actually needed. Thus, during temporary feeding slowdowns due to tangled plants, etc., skips in the field do not occur. In addition to storage, the machine's plant acceptance time was increased from less than one second to several seconds. One operator on the machine with multiple loading stations could transplant at the same rate (about 70-80 plants/min) as two operators on a conventional one-row machine.

Development of a Transplanter with Multiple Loading Stations[1]

C.W. Suggs[2]

INTRODUCTION

In tobacco production, transplanting of the seedling from the plant-bed or greenhouse to the field requires a significant proportion of the total labor input to the crop. This is also true of many vegetable or truck crops. As harvest operations are mechanized, transplanting is likely to become the bottleneck limiting the number of acres which can be produced without hiring extra labor specifically for transplanting. This peak in the labor demand curve suggests that transplanter improvements which will reduce labor requirements are needed.

Efforts to field seed tobacco, and many other crops, have not been successful because the seeds during germination are sensitive to cold, wind and drying of the soil surface. This results in poor stands, nonuniform growth and low yield. In many areas growing seasons are not long enough to produce a crop unless the plants are started in a protected environment before the danger of frost is over.

Huang and Splinter (1968) have made significant progress in the development of a seedling production and automatic transplanting system in which seeds are placed and allowed to grow in a grid container which also becomes the "cartridge" which is loaded into the transplanter.

---

[1]Paper No. 5497 of the Journal Series of the North Carolina Agricultural Experiment Station, Raleigh, N.C. The use of trade names in this publication does not imply endorsement by the North Carolina Agricultural Experiment Station of the products named, nor criticism of similar ones not mentioned.

[2]Professor, Biological and Agricultural Engineering Department, North Carolina State University, Raleigh, N.C. 27650.

Another attempt at transplanting mechanization also involves a preloaded cartridge in a belt configuration (Roth, 1973). The belt is fed through the transplanter which mechanically removes the plant from the belt and places it in the ground. Unless mechanical means for loading the plants into the belt are developed, this system would simply transfer labor from one place in the system to another without actually eliminating any operations. This approach could also benefit from the concept of multiple loading stations.

Therefore, there is a need for labor reducing improvements on manually operated transplanters. These improved transplanters could be used until the Huang & Splinter type system described above becomes operational or until methods for mechanically singulating and feeding seedlings are developed and made commercially available.

This paper describes an improvement for a manually-fed transplanter. The modification consists of a series of plant retaining devices (clips or pockets) into which individual plants may be fed before they are actually required by the machine. Thus, plant feeding is simplified from a strictly paced operation to one in which considerable variation in instantaneous feeding rate may be tolerated. In fact, for short periods of time the operator may stop feeding plants without causing misses in the field as the machine transplants the seedlings already placed in the series of retaining devices.

REVIEW OF LITERATURE

Previous investigators (Splinter, et al., 1968, Splinter and Suggs, 1968, Splinter and Suggs, 1963) have described the relationships between planting rate, rejects, machine acceptance time, transplanter type, operator error and number of loading stations. It has been shown that the time needed to handle individual plants is not constant but has a skewed distribution, Figure 1. The handling time ranges from 0.4 to over 3.0 seconds per plant with a mean for the subjects observed of about 1 second per plant depending on the skill of the subject. For a conventional transplanter, since it does not have a reserve of plants already fed into the mechanism, a miss will occur any time plant handling time exceeds machine cycle time. That is, there is no way for the operator to get ahead of the task and when he gets behind plants will be missed. The shaded area in Figure 1 represents the proportion of plants which will be missed when transplanting at one plant per two seconds, that is, only half as fast as the mean handling rate.

When handling time is less than machine cycle time the difference cannot be utilized effectively as plants cannot be fed into the machine ahead of time. This time can, however, be used to arrange, straighten or untangle plants.

In transplanters with multiple loading stations we would expect feeding accuracy to improve because the time saved on the faster cycles can be utilized and the slower cycles can be accommodated by the storage of plants in the machine. Therefore, it should be possible to approach the operator's mean feeding rate and still maintain a very high feeding accuracy. Although no records of a multiple loading transplanter were found, a simulation study showed that significant improvements in feeding accuracy are realized as the number of loading stations is increased (Splinter and Suggs, 1968), Figure 2. This simulation work showed that feeding accuracy is improved, that is, errors or misses are reduced, as the number of loading stations is increased, Figure 3, up to about 5 or 6 stations after which little improvement is realized. Very large error reductions are possible in going from a single loading station to 5 or 6 stations.

TRANSPLANTER DESIGN

Recognizing that 5 or 6 loading stations were needed to optimize feeding rate the first design, Figure 4, utilized a cross feed belt fitted with divider strips 3 1/2 cm high at 5 cm intervals which formed plant pockets. This mechanism was constructed and attached to a Powell transplanter. The belt dropped the plants onto the plant tray which consisted of hinged spring loaded fingers which could fold back and allow the cam actuated plant hands to pass through the space and pick up the plants. Plants were placed in an open furrow when the arms rotated into their lowest position.

While this design optimized feeding rate, the transfer from the belt to the plant tray and planting hands caused problems. Most plants were transferred properly but some would hang on the belt or fall onto the near or far edges of the plant tray where they would be missed or improperly picked up by the planting hands.

In the second design, plant transfer was eliminated by causing the plant pockets (plant clips) to move from the loading area to a position directly over the open furrow, where the plants were released, Figures 5 and 6. This was accomplished by mounting the plant clips on a chain which is flexible in two planes. The chain is manufactured by Big Dutchman, Inc. for use on a poultry feeder. As the vertical strand of chain leaves the planting area it is turned sideways onto a table where the plants are loaded into the clips. The chain is then turned downward to the planting area. Clips, upside down as they leave the planting area, are turned upright as they approach the table. As they start down they are prevented from further rotation and closed to hold the plant until it reaches the lowest position where it opens and releases the plant in the furrow just before the soil is pressed around the plant roots.

The plant clips were riveted to a bracket which was welded or brazed to the chain. The rivet was left loose to form a pivot about which the clip could rotate. As the upside down clips approach the table a short crossarm on the clips contacts a stationary block which rotates the clip to the upright position. This position is maintained by allowing the crossarm to slide on the table. As the clip starts downward, a vertical pin on the clip contacts a guide which prevents further rotation.

TRANSPLANTER EVALUATION METHODS

Operating speed and percent errors were evaluated. Errors consisted of failing to place a plant in a clip (misses) or placing more than one plant in a clip (doubles, etc). Misses dominated errors to such an extent that the term "misses" was used interchangebly with "errors" and as such contains doubles, etc. Another term, feeding or operating accuracy was defined as 100% - error %.

During testing the operator (plant dropper) was given 30 tobacco plants about 6" to 8" long. He fed 6 of these into the available plant clips or receiving stations. Forward motion was then started and continued until all of the plants had been planted. A stopwatch was started when the first plant left the table and stopped when the last plant left. Misses, doubles and the number of unfilled plant clips available to the operator at the moment the last plant was placed into a clip were counted. These unfilled plant clips referred to as "lag" elsewhere in this paper, represents the degree to which the operator did not keep up with the transplanter.

Since they contained only 30 plants, the individual observations were not long enough to produce fatigue, but did allow the operator to approach steady-state. However, it was felt desirable to have a large number of short runs rather than a few long runs. Fatigue effects may have been present in the runs toward the end of each session. During a session of repeated 30 plant runs the fatigue state of the operators of the experimental transplanter and the conventional transplanters were probably not appreciably different.

Machine and operator speed in plant clips or plants per minute were calculated as follows:

Machine speed = plant clips/timed interval

= (30 + misses - doubles)/timed interval

Operator speed= plant clip filled/operator time

= (30 - 6 - doubles)/operator time

But operator time is not the same as the timed interval for determining machine speed.

$$\text{Operator time} = \text{timed interval}\left(\frac{\text{clips passing operator reference}}{\text{clips passing through machine}}\right)$$

For example, if the operator has all of the available clips (6) filling at the end of the run (no lag) and there are no misses or doubles, the operator time is 24/30 of the timed interval. The following expression accounts for misses, doubles and lag for the tests using 30 plants:

Operator time = time interval [(24 + misses - doubles + lag)/(30 + misses - doubles)]

It is easier to visualize the number of clips passing the operator if the reference is taken at the left end of the machine just past the sixth plant clip. The denominator of the expression is the same as used in the calculation of plant speed. Thus it can be seen that lag increases operator time, and therefore, decreases operator speed.

Performance tests were also run for comparative purposes on conventional transplanters having the same plant clip as the experimental unit. Test runs were 30 plants long and observations were made with both one and two operators feeding plants into the machine. Each of these transplanters had only one plant loading station.

RESULTS AND DISCUSSION

The first design involving the cross feed belt did not work well because of the lack of positive plant control during the transfer of plants to the plant tray. The design did, however, make it easier for the operator to feed plants into the machine. Because of the plant transfer problem this design did not appear to have commercial feasibility. Therefore, no performance data are included in this paper.

The second design utilizing chain mounted plant clips functioned well both with respect to the ease of feeding as well as the quality of the transplanting job. Some minor mechanical problems were encountered primarily in rotating the chain in the lateral direction and in maintaining the proper orientation of the clip. These problems were corrected during the course of the investigation.

Plant feeding speed for operators on the modified or experimental transplanter averaged 79.2 plants per minute with misses of 2.3%, Table 1. There is a slight learning trend evident as the rate increased from 76.2 plants per minute at the first test session to 79.4 plants per minute at the second session to 82.1 plants per minute at the third session.

Feeding rates for the conventional transplanter averaged 67.8 plants per minute with misses of 10.6%. In order to compare speeds, all of the rates were adjusted to 2% misses by means of the curve given in Figure 2 from Splinter and Suggs (1968) which plots the relationships between errors (misses) and operating rate. This error rate was selected as one which would be acceptable in virtually all field operations. When this adjustment is made the rates for the conventional transplanter becomes 54.4 and the experimental transplanter 78.9 or about 45% greater, Table 1.

Conventional one-row transplanters normally use two operators, with each operator feeding alternate plants into the machine. However, output rates do not double with addition of a second plant dropper. Observed planting rates of transplanters using two operators averaged 72.3 plants per minute or about 36 plants per operator per minute. One person on a conventional transplanter will plant about 70 to 75% as many plants as two people. There appears to be some interference between the two operators which reduces potential speed. A second very important factor is the increased speed of the plant clip and the reduction in the period of time in which the plant may be placed in the clip.

The most important comparison in the data is between the planting rate for the experimental transplanter with one operator, 79 plants per minute, and the conventional transplanter with two operators, 72 plants per minute. One operator on the experimental machine can transplant as many plants as the two operators normally used on a conventional machine.

SUMMARY AND CONCLUSIONS

An experimental transplanter fitted with several plants loading stations was found to result in significant increases in operating speed. The improved performance was due to the fact that the operator could feed plants into the loading stations before they were actually required by the machine. This backlog of plants could then be used by the machine whenever the operator's feeding rate was reduced for any reason for short periods of time.

It can be concluded that the experimental transplanter represents a significant improvement in transplanter feeding concepts. It was found that one operator on the experimental machine could perform at the same rate as two operators on a conventional one row machine.

REFERENCES

1. Huang, B.K. and W.E. Splinter. Development of an Automatic Transplanter. Trans. of ASAE 11(2):191-194, 197. 1968.

2. Roths, Herbert C.O. United States Patent #705,351. 1973.

3. Splinter, W.E., C.W. Suggs and J.F. Beeman. Mechanical Transplanting of Bright Leaf Tobacco Part VI. Effect of Transplanting Rate, Rejects and Machine Acceptance, Time on Operator Error. Tob. Sci. 12:208-215, 1968.

4. Splinter, W.E. and C.W. Suggs. Theoretical Model for Man-Machine System in Repetitive Loading Operation. Transactions of the ASAE, Vol. 11, No. 6, pp. 840, 841, 842 and 843. 1968.

5. Splinter, W.E. and C.W. Suggs. Simulation Studies of Human Errors in Multiple Loading Transplanting. ASAE Paper No. 63-150. 1963.

Table 1. Comparison of Modified Transplanter with Conventional Transplanter.

	Operator Speed Plants/Min	Misses %	Machine Speed Adjusted to 2% Misses
Modified Transplanter			
1 Operator			
1st Session	76.2	4.3	73.2
2nd Session	79.4	1.7	79.8
3rd Session	82.1	1.0	83.7
Mean	79.2	2.3	78.9
Conventional Transplanter			
1 Operator			
1st Session	68.4	12.4	53.4
2nd Session	67.4	8.8	55.4
Mean	67.8	10.6	54.4
Conventional Transplanter			
2 Operators			
Farm 1	36	3.2	70.2
Farm 2	38	3.0	74.4
Mean	34	3.1	72.3

TECHNICAL EVALUATION FORM
FOR TRANSACTIONS of the ASAE

Sheet No. 2

Note: This sheet will be returned to the author only if article is acceptable for publication. Reviewers may also make comments on manuscript.

Title of paper: Development of a Transplanter with Multiple Loading Stations

Author(s): C. W. Suggs

A. Points that must be changed in order to make manuscript acceptable for publication:

1. Could be more concise
2. Is Figures 1, 2, 3 needed — literature is cited

B. Suggestions for improving and/or condensing the manuscript:

1. See comments in manuscript for condensing
2. Consider deleting reference to Design #1 — which had functional problems and no data presented on performance
3. Later publish "long run performance" to evaluate "fatigue factor" — Not needed for this paper —

If you wish to be identified to the author, please print your name and address below.

Elmon Yoder
Dept of AE
Univ of Ky
Lexington 40506
606-257-1572

Manuscript No. Pm-230

Development of a Transplanter with
Multiple Loading Stations

C.W. Suggs

ABSTRACT

The multiple-loading feature significantly increased the operator's feeding speed because it allowed up to five plants to be fed into the mechanism before they are actually needed. Thus, during temporary feeding slowdowns due to tangled plants, etc., skips in the field do not occur. In addition to storage, the machine's plant acceptance time was increased from less than one second to several seconds. One operator on the machine with multiple loading stations could transplant at the same rate (about 70-80 plants/min) as two operators on a conventional one row machine.

~~Conventional machine being 1 row machine~~

Development of a Transplanter with Multiple Loading Stations[1]

C.W. Suggs[2]

INTRODUCTION

In tobacco production, transplanting of the seedling from the plantbed or greenhouse to the field requires a significant proportion of the total labor input to the crop. This is also true of many vegetable or truck crops. As harvest operations are mechanized, transplanting is likely to become the bottleneck limiting the number of acres which can be produced without hiring extra labor specifically for transplanting. This peak in the labor demand curve suggests that transplanter improvements which will reduce labor requirements are needed.

Efforts to field seed tobacco, and many other crops, have not been successul because the seeds during germination are sensitive to cold, wind and drying of the soil surface. [This results in poor stands, nonuniform growth and low yield. In many areas growing seasons are not long enough to produce a crop unless the plants are started in a protected environment before the danger of frost is over. These problems are the reasons that plantbeds or greenhouses are used to start plants in the first place and unless something can be done to alleviate the unfavorable early season conditions in the field it will continue to be necessary or desirable to transplant many crops.]

Could be more concise

Huang and Splinter (1968) have made significant progress in the development of a seedling production and automatic transplanting system in which seeds are placed and grown in a grid container which also becomes the "cartridge" which is loaded into the transplanter. While this system may have merit it does not appear applicable

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1 Paper No. 5497 of the Journal Series of the North Carolina Agricultural Experiment Station, Raleigh, N.C. The use of trade names in this publication does not imply endorsement by the North Carolina Agricultural Experiment Station of the products named, nor criticism of similar ones not mentioned.

2 Professor, Biological and Agricultural Engineering Department, North Carolina State University, Raleigh, N.C. 27607.

to farmers who do not have greenhouses and greenhouse expertise unless plants are available commercially at competetive prices. Sentence is rather rambling & clumsy

Another attempt at transplanting mechanization also involves a preloaded cartridge in a belt configuration (Roth, 1973). The belt is fed through the transplanter which mechanically removes the plant from the belt and places it in the ground. Unless mechanical means for loading the plants into the belt are developed, this system would simply transfer labor from one place in the system to another without actually eliminating any operations. (This approach could also benefit from the concept of multiple loading stations.) wording?

Therefore, there is a need for labor reducing improvements on manually operated transplanters. These improved transplanters could be used until the Huang & Splinter type system described above becomes operational or until methods for mechanically singulating and feeding seedlings are developed and made commercially availabe.

Introduction to here seems rather long, with some stuff that could be just as well deleted

This paper describes an improvement which was made to a manually-fed transplanter. The modification consists of a series of plant retaining devices (clips or pockets) into which individual plants may be fed before they are actually required by the machine. Thus, plant feeding is simplified from a strictly paced operation to one in which considerable variation in instantaneous feeding rate may be tolerated. [In fact, for short periods of time the operator may stop feeding plants or feed at a slow rate without causing misses in the field as the machine transplants the seedlings already placed in the series of retaining devices.]

Could delete?

REVIEW OF LITERATURE

Previous investigators (Splinter, et al., 1968, Splinter and Suggs, 1968, Splinter and Suggs, 1963) have described the relationships between planting rate, rejects, machine acceptance time, transplanter type, operator error and number of loading stations.

It has been shown that the time to handle individual plants is not constant but has a skewed distribution, Figure 1, with a mean for the subjects observed of about 1 second per plant depending on the skill of the subject. For a conventional transplanter, since it does not have a reserve of plants already fed into the mechanism, a miss will occur any time plant handling time exceeds machine cycle time. [That is, there is no way the operator can get ahead of the task and if he gets behind plants will be missed.] The shaded area in Figure 1 represents the proportion of plants which will be missed when transplanting at one plant per two seconds, that is only half as fast as the mean handling rate.

Needed?

When handling time is less than machine cycle time the difference cannot be utilized effectively as plants cannot be fed into the machine ahead of time. This time can, however, be used to arrange, straighten or untangle plants.

In transplanters with multiple loading stations we would expect feeding accuracy to improve because the time saved on the faster cycles can be utilized and the slower cycles can be accommodated by the storage of plants in the machine. Therefore, it should be possible to approach the operator's mean feeding rate and still maintain a very high feeding accuracy. Although no records of a multiple loading transplanter were found, a simulation study showed that significant improvements in feeding accuracy are realized as the number of loading stations is increased (Splinter and Suggs, 1968), Figure 2. This simulation work showed that feeding accuracy is improved, that is, errors or misses are reduced, as the number of loading stations is increased, Figure 3, up to about 5 or 6 stations after which little improvement is realized. Very large error reductions are possible in going from a single loading station to 5 or 6 stations.

Believe this could be more concisely stated.

See note next sheet

TRANSPLANTER DESIGN

Recognizing that 5 or 6 loading stations were needed to optimize feeding rate the first design, Figure 4, utilized a cross feed belt fitted with divider strips

1 1/2" tall at 2" intervals which formed plant pockets. This mechanism was constructed and attached to a Powell transplanter. The belt dropped the plants onto the plant tray which consisted of hinged spring loaded fingers which could fold back and allow the cam actuated plant hands to pass through the space and pick up the plants. Plants were placed in an open furrow when the arms rotated into their lowest position.

While this design optimized feeding rate, the transfer from the belt to the plant tray and planting hands caused problems. Most plants were transferred properly, but some would hang on the belt or fall onto the near or far edges of the plant tray where they would be missed or improperly picked up by the planting hands.

In the second design, plant transfer was eliminated by causing the plant pockets (plant clips) to move from the loading area to a position directly over the open furrow, where the plants were released, Figures 5 and 6. This was accomplished by mounting the plant clips on a chain which is flexible in two planes. The chain is manufactured by Big Dutchman, Inc. for use on a poultry feeder. As the vertical strand of chain leaves the planting area it is turned sideways onto a table where the plants are loaded into the clips. The chain is then turned downward to the planting area. Clips, upside down as they leave the planting area, are turned upright as they approach the table. As they start down they are prevented from further rotation and closed to hold the plant until it reaches the lowest position where it opens and releases the plant in the furrow just before the soil is pressed around the plant roots.

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Is it necessary to describe the first design in this paper, inasmuch as it was not operable to extent to record data of performance.

Fig 6 missing from this draft

TRANSPLANTER EVALUATION METHODS

Two related measures of performance were evaluated. These were operating speed and percent errors. Errors consisted of failing to place a plant in a clip (misses) or placing more than one plant in a clip (doubles, etc). Misses dominate errors to such an extent that the term "misses" is used interchangebly with "errors" and as such contains doubles, etc. Another term, feeding or operating accuracy is 100% - error %.

During testing the operator (plant dropper) was given 30 tobacco plants about 6" to 8" long. He fed 6 of these into the available plant clips or receiving stations. Forward motion was then started and continued until all of the plants had been planted. A stopwatch was started when the first plant left the table and stopped when the last plant left. Misses, doubles and the number of unfilled plant clips available to the operator at the moment the last plant was placed into a clip were counted. These unfilled plant clips referred to as "lag" elsewhere in this paper, represents the degree to which the operator did not keep up with the transplanter.

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= (30 + misses - doubles)/timed interval

Operator speed= plant clip filled/operator time

= (30 - 6 - doubles)/operator time

I do not follow logic here for removing "fatigue" effect from the test

Equation in middle of sentence ?

But operator time is not the same as the timed interval for determining machine speed,

$$\text{Operator time} = \text{timed interval} \left(\frac{\text{clips passing operator reference}}{\text{clips passing through machine}}\right)$$

If the operator has all of the available clips (6) filled at the end of the run (no lag) and there are no misses or doubles. The operator time is 24/30 of the timed interval. The following expression accounts for misses, doubles and lag:

$$\text{Operator time} = \text{timed interval} \left[(24 + \text{misses} - \text{doubles} + \text{lag})/(30 + \text{misses} - \text{doubles})\right]$$

It is easier to visualize the number of clips passing the operator if the reference is taken at the left end of the machine just past the sixth plant clip. The denominator of the expression is the same as used in the calculation of plant speed. Thus it can be seen that lag increases operator time and, therefore, decreases operator speed.

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Believe this could be more concise

RESULTS AND DISCUSSION

See note sheet 4

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Feeding rates for the conventional transplanter averaged 67.8 plants per minute with misses of 10.6%. In order to compare speeds, all of the rates were adjusted to 2% misses by means of the curve given in Figure 4 from Splinter and Suggs (1968) which plots the relationships between errors (misses) and operating rate. This error rate was selected as one which would be acceptable in virtually all field operations. When this adjustment is made the rates for the conventional transplanter becomes 54.4 and the experimental transplanter 78.9 or about 45% greater, Table 1.

Conventional transplanters normally use two operators. With each operator feeding alternate plants into the machine. However, output rates do not double with addition of a second plant dropper. Observed planting rates of transplanters using two operators averaged 72.3 plants per minute or about 36 plants per operator per minute. One person on a conventional transplanter will plant about 70 to 75% as many plants as two people. There appears to be some interference between the two operators which reduces potential speed. A second very important factor is the increased speed of the plant clip and the reduction in the period of time in which the plant may be placed in the clip.

The most important comparison in the data is between the planting rate for the experimental transplanter with one operator, 79 plants per minute, and the conventional transplanter with two operators, 72 plants per minute. One operator on the experimental machine can transplant as many plants as the two operators normally used on a conventional machine.

SUMMARY AND CONCLUSIONS

An experimental transplanter fitted with several plants loading stations was found to result in significant increases in operating speed. The improved performance was due to the fact that the operator could feed plants into the loading stations before they were actually required by the machine. This backlog of plants could then be used by the machine whenever the operator's feeding rate was reduced for any reason for short periods of time.

It can be concluded that the experimental transplanter represents a significant improvement in transplanter feeding concepts. It was found that one operator on the experimental machine could perform at the same rate as two operators on a conventional machine.

"Fatigue" factor was experimentally deleted by keeping test runs to only 30 plants. Seems that difference in fatigue factor between experimental machine and conventional transplanter would be of crucial interest. That is, I would anticipate the experimental machine would be less fatiguing to operate for extended duration --- and if so would be of great interest in ~~lot~~ evaluating field performance.

Charlie —

I have a great fascination for simple ideas that have usefulness. You have a real good idea here for a simple and inexpensive solution to improving transplanting.

Elmer

Table 1. Comparison of Modified Transplanter with Conventional Transplanter.

	Operator Speed Plants/Min	Misses %	Machine Speed Adjusted to 2% Misses
Modified Transplanter			
1 Operator			
1st Session	76.2	4.3	73.2
2nd Session	79.4	1.7	79.8
3rd Session	82.1	1.0	83.7
Mean	79.2	2.3	78.9
Conventional Transplanter			
1 Operator			
1st Session	68.4	12.4	53.4
2nd Session	67.4	8.8	55.4
Mean	67.8	10.6	54.4
Conventional Transplanter			
2 Operators			
Farm 1	36	3.2	70.2
Farm 2	38	3.0	74.4
Mean	34	3.1	72.3

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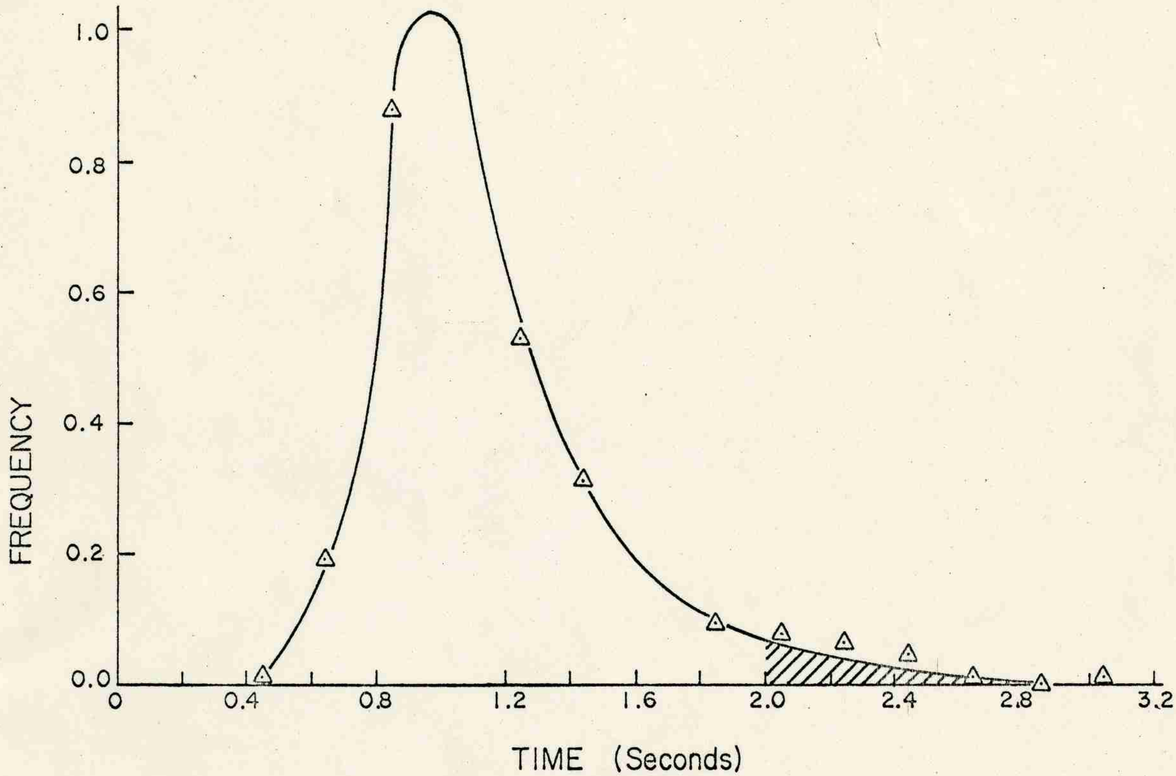

Fig. 1. Frequency distribution for feeding tobacco plants into a transplanter Splinter et al. 1963.

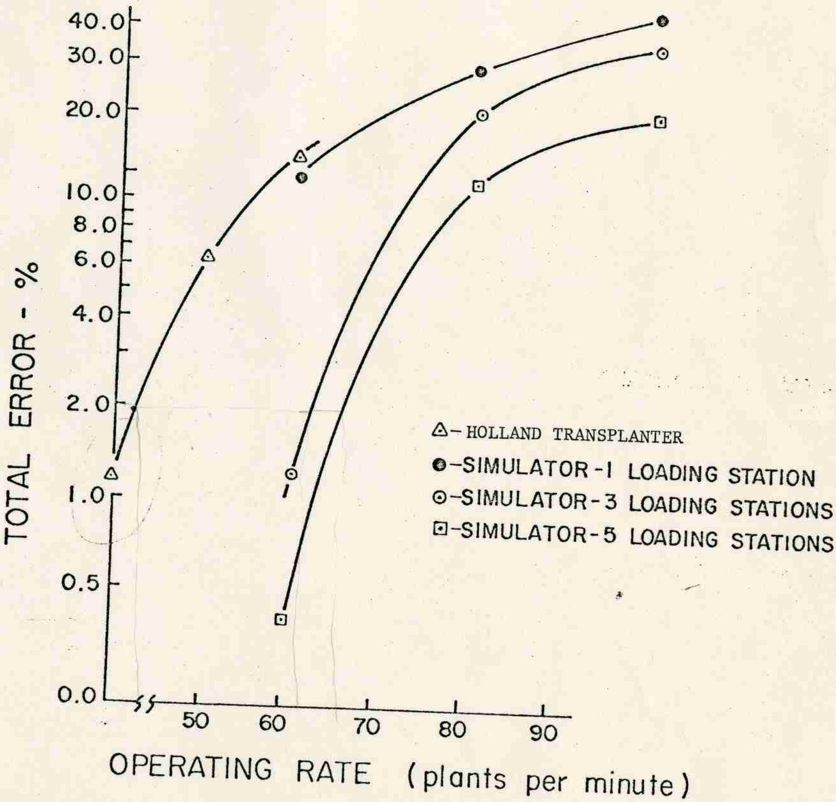

Fig. 2. Comparison of total errors versus operating speed for a field transplanter and a transplanting simulator using tobacco plants. Splinter and Suggs (1968).

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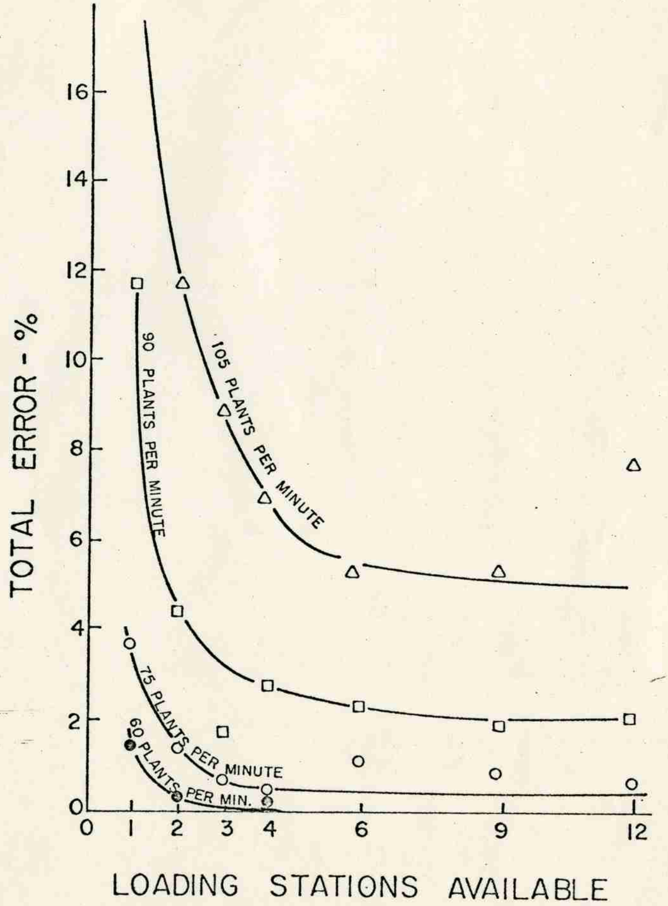

Fig. 3. Effect of number of loading stations on error at various operating speeds using simulated plants. (Splinter and Suggs, 1968).

Needed here?

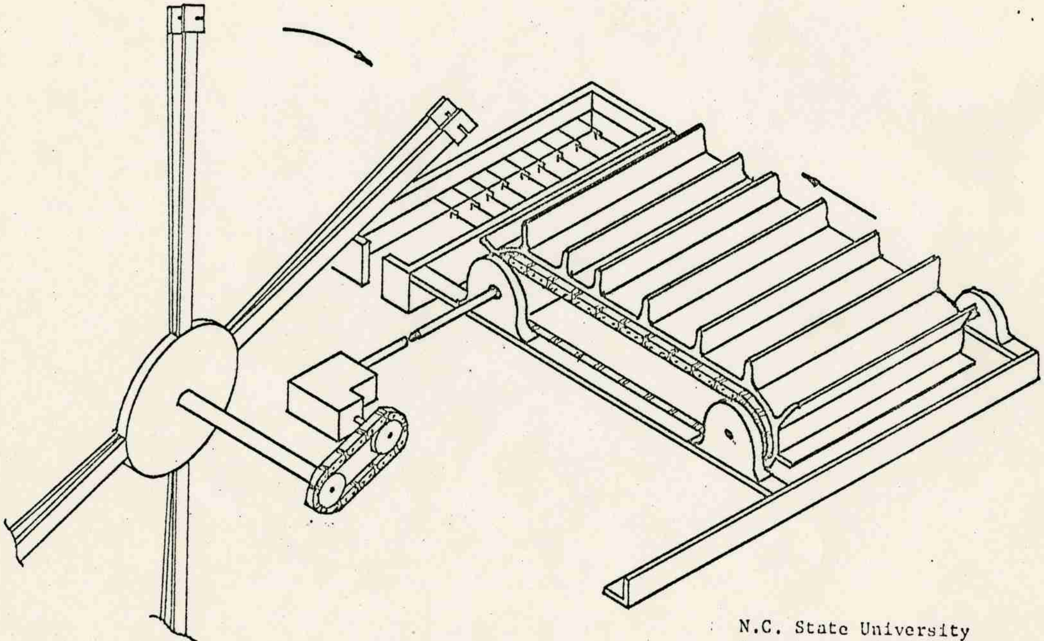

Figure 4. Multiple loading station transplanter utilizing cross belt and plant transfer.

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June 15, 1977

See note on sheet 4 regarding if the first design even needs any discussion in this paper.

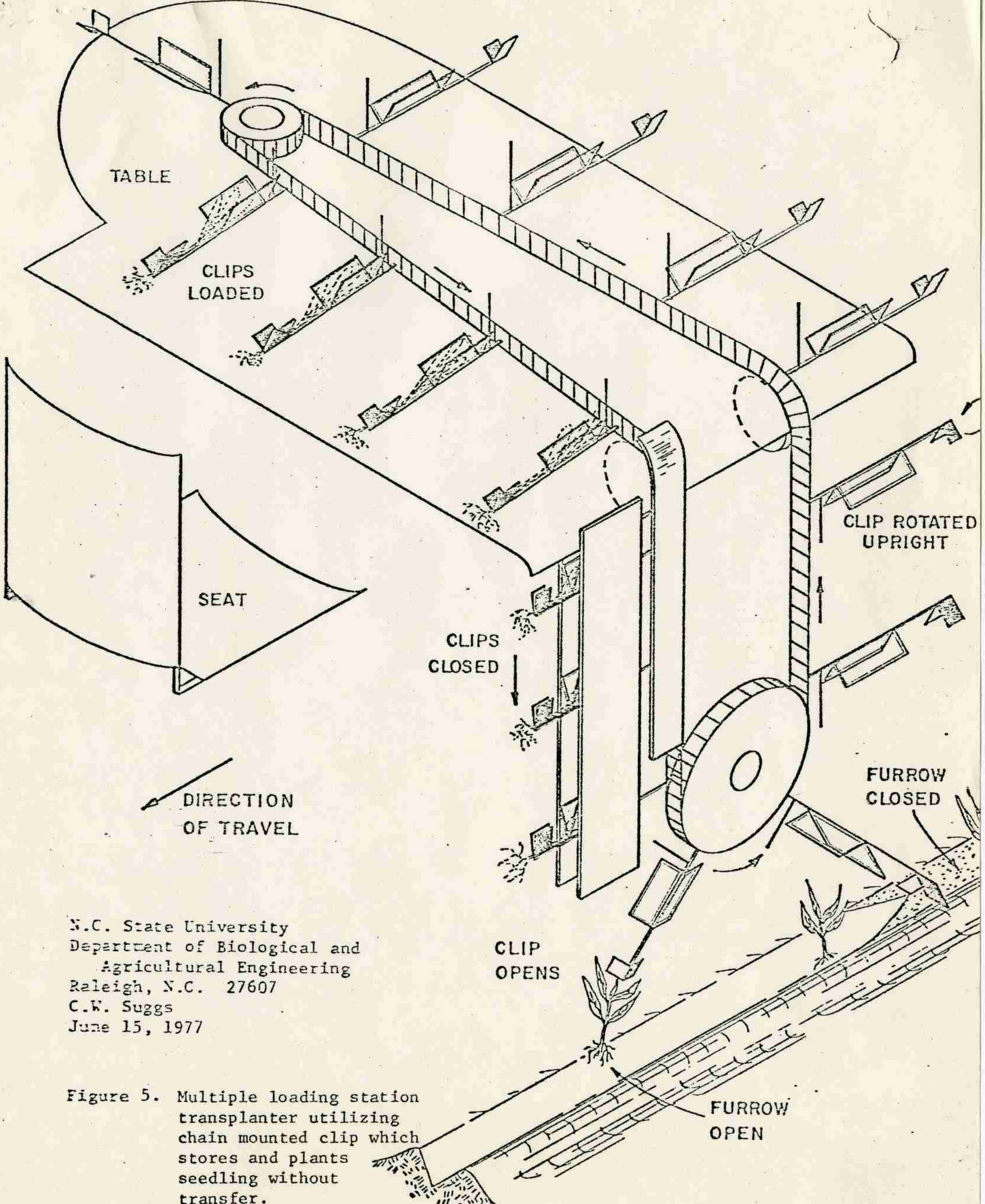

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Figure 5. Multiple loading station transplanter utilizing chain mounted clip which stores and plants seedling without transfer.

TECHNICAL EVALUATION FORM
FOR TRANSACTIONS of the ASAE

Sheet No. 2

Note: This sheet will be returned to the author only if article is acceptable for publication. Reviewers may also make comments on manuscript.

Title of paper: Development of a Transplanter with Multiple Loading Stations

Author(s): C. W. Suggs

A. Points that must be changed in order to make manuscript acceptable for publication:

1. Change units in SI units
2. Include Fig. 6. and correct reference to Fig. # in text. ✓

B. Suggestions for improving and/or condensing the manuscript:

1. You may use more descriptive captions in figures. See suggestions in ms.
2. You may label parts of the machine in figures as suggested in the ms.
3. At places the writing needs improvement for clarity - See ms.
4. If you can avoid using different words for the same item (eg. operator, subject, plant dropper are used for the same purpose) it may reduce confusion in the mind of reader. Other words need attention are, misses, error, lag, etc.

If you wish to be identified to the author, please print your name and address below.

It is a good paper and well written.

B. P. VERMA
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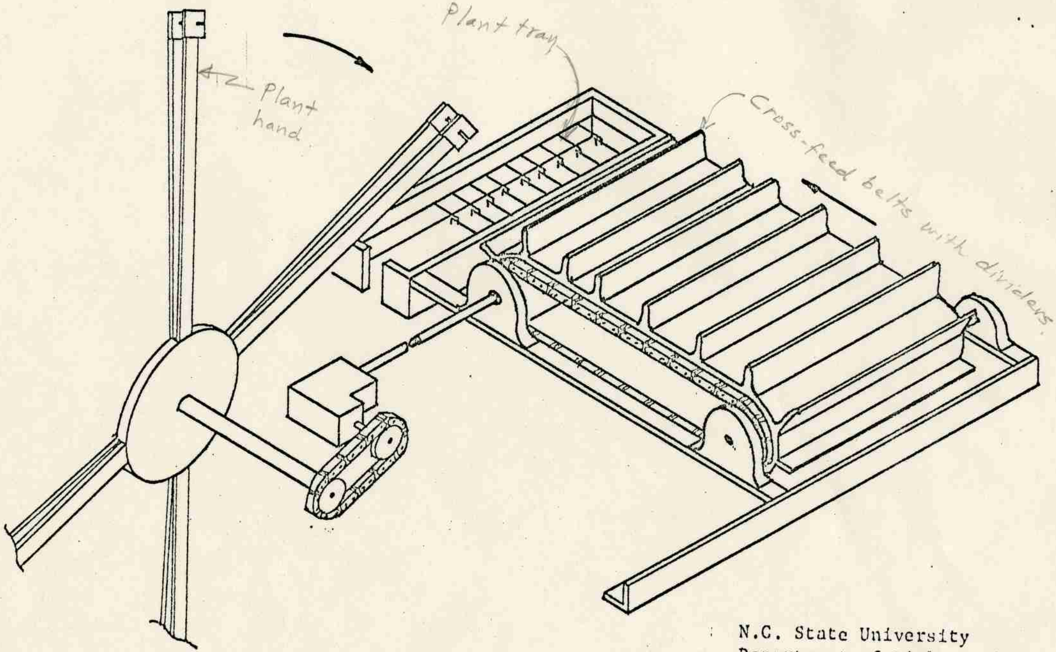

Figure 4. Multiple loading station transplanter utilizing cross belt and plant transfer.

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Manuscript No. PM-230

Suggestions by B.L. Vernon

Development of a Transplanter with
Multiple Loading Stations

C.W. Suggs

ABSTRACT

The multiple-loading feature significantly increased the operator's feeding speed because it allowed up to five plants to be fed into the mechanism before they are actually needed. Thus, during temporary feeding slowdowns due to tangled plants, etc., skips in the field do not occur. In addition to storage, the machine's plant acceptance time was increased from less than one second to several seconds. One operator on the machine with multiple loading stations could transplant at the same rate (about 70-80 plants/min) as two operators on a conventional one-row machine.

Development of a Transplanter with Multiple Loading Stations[1]

C.W. Suggs[2]

INTRODUCTION

In tobacco production, transplanting of the seedling from the plantbed or greenhouse to the field requires a significant proportion of the total labor input to the crop. This is also true of many vegetable or truck crops. As harvest operations are mechanized, transplanting is likely to become the bottleneck limiting the number of acres which can be produced without hiring extra labor specifically for transplanting. This peak in the labor demand curve suggests that transplanter improvements which will reduce labor requirements are needed.

Efforts to field seed tobacco, and many other crops, have not been successul because the seeds during germination are sensitive to cold, wind and drying of the soil surface. This results in poor stands, nonuniform growth and low yield. In many areas growing seasons are not long enough to produce a crop unless the plants are started in a protected environment before the danger of frost is over. ~~These problems are the reasons that plantbeds or greenhouses are used to start plants in the first place and unless something can be done to alleviate the unfavorable early season conditions in the field it will continue to be necessary or desirable to transplant many crops~~.

Huang and Splinter (1968) have made significant progress in the development of a seedling production and automatic transplanting system in which seeds are placed and allowed to grow in a grid container which also becomes the "cartridge" which is loaded into the transplanter. ~~While this system may have merit it does not appear applicable~~

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[1]Paper No. 5497 of the Journal Series of the North Carolina Agricultural Experiment Station, Raleigh, N.C. The use of trade names in this publication does not imply endorsement by the North Carolina Agricultural Experiment Station of the products named, nor criticism of similar ones not mentioned.

[2]Professor, Biological and Agricultural Engineering Department, North Carolina State University, Raleigh, N.C. 27607.

Suggs

Name on ea. p Hm

to farmers who do not have greenhouses and greenhouse expertise unless plants are available commercially at competetive prices.

Another attempt at transplanting mechanization also involves a preloaded cartridge in a belt configuration (Roth, 1973). The belt is fed through the transplanter which mechanically removes the plant from the belt and places it in the ground. Unless mechanical means for loading the plants into the belt are developed, this system would simply transfer labor from one place in the system to another without actually eliminating any operations. This approach could also benefit from the concept of multiple loading stations.

Therefore, there is a need for labor reducing improvements on manually operated transplanters. These improved transplanters could be used until the Huang & Splinter type system described above becomes operational or until methods for mechanically singulating and feeding seedlings are developed and made commercially availabe.

This paper describes an improvement which was made to for a manually-fed transplanter. The modification consists of a series of plant retaining devices (clips or pockets) into which individual plants may be fed before they are actually required by the machine. Thus, plant feeding is simplified from a strictly paced operation to one in which considerable variation in instantaneous feeding rate may be tolerated. In fact, for short periods of time the operator may stop feeding plants or feed at a slow slower rate without causing misses in the field as the machine transplants the seedlings already placed in the series of retaining devices.

REVIEW OF LITERATURE

Previous investigators (Splinter, et al., 1968, Splinter and Suggs, 1968, Splinter and Suggs, 1963) have described the relationships between planting rate, rejects, machine acceptance time, transplanter type, operator error and number of loading stations.

It has been shown that the time to handle individual plants is not constant but has a skewed distribution, Figure 1, with a mean for the subjects observed of about 1 second per plant depending on the skill of the subject. For a conventional transplanter, since it does not have a reserve of plants already fed into the mechanism, a miss will occur any time plant handling time exceeds machine cycle time. That is, there is no way the operator can get ahead of the task and if he gets behind plants will be missed. The shaded area in Figure 1 represents the proportion of plants which will be missed when transplanting at one plant per two seconds, that is only half as fast as the mean handling rate.

When handling time is less than machine cycle time the difference cannot be utilized effectively as plants cannot be fed into the machine ahead of time. This time can, however, be used to arrange, straighten or untangle plants.

In transplanters with multiple loading stations we would expect feeding accuracy to improve because the time saved on the faster cycles can be utilized and the slower cycles can be accommodated by the storage of plants in the machine. Therefore, it should be possible to approach the operator's mean feeding rate and still maintain a very high feeding accuracy. Although no records of a multiple loading transplanter were found, a simulation study showed that significant improvements in feeding accuracy are realized as the number of loading stations is increased (Splinter and Suggs, 1968), Figure 2. This simulation work showed that feeding accuracy is improved, that is, errors or misses are reduced, as the number of loading stations is increased, Figure 3, up to about 5 or 6 stations after which little improvement is realized. Very large error reductions are possible in going from a single loading station to 5 or 6 stations.

TRANSPLANTER DESIGN

Recognizing that 5 or 6 loading stations were needed to optimize feeding rate the first design, Figure 4, utilized a cross feed belt fitted with divider strips

Use SI units and English units in parentheses.

~~1 1/2" tall at 2"~~ 3 1/2 cm high at 5 cm intervals which formed plant pockets. This mechanism was constructed and attached to a Powell transplanter. The belt dropped the plants onto the plant tray which consisted of hinged spring loaded fingers which could fold back and allow the cam actuated plant hands to pass through the space and pick up the plants. Plants were placed in an open furrow when the arms rotated into their lowest position.

While this design optimized feeding rate, the transfer from the belt to the plant tray and planting hands caused problems. Most plants were transferred properly but some would hang on the belt or fall onto the near or far edges of the plant tray where they would be missed or improperly picked up by the planting hands.

In the second design, plant transfer was eliminated by causing the plant pockets (plant clips) to move from the loading area to a position directly over the open furrow, where the plants were released, Figures 5 and 6. This was accomplished by mounting the plant clips on a chain which is flexible in two planes. The chain is manufactured by Big Dutchman, Inc. for use on a poultry feeder. As the vertical strand of chain leaves the planting area it is turned sideways onto a table where the plants are loaded into the clips. The chain is then turned downward to the planting area. Clips, upside down as they leave the planting area, are turned upright as they approach the table. As they start down they are prevented from further rotation and closed to hold the plant until it reaches the lowest position where it opens and releases the plant in the furrow just before the soil is pressed around the plant roots.

Fig. 6 is not included with the paper.

The plant clips were riveted to a bracket which was welded or brazed to the chain. The rivet was left loose to form a pivot about which the clip could rotate. As the upside down clips approach the table a short crossarm on the clips contacts a stationary block which rotates the clip to the upright position. This position is maintained by allowing the crossarm to slide on the table. As the clip starts downward, a vertical pin on the clip contacts a guide which prevents further rotation.

~~* Footnote disclaiming endorsement recommendation~~

TRANSPLANTER EVALUATION METHODS

Two related measures of performance were evaluated. These were operating speed and percent errors. Errors consisted of failing to place a plant in a clip (misses) or placing more than one plant in a clip (doubles, etc). Misses dominate errors to such an extent that the term "misses" is used interchangebly with "errors" and as such contains doubles, etc. Another term, feeding or operating accuracy is 100% - error %.

During testing the operator (plant dropper) was given 30 tobacco plants about 6" to 8" long. He fed 6 of these into the available plant clips or receiving stations. Forward motion was then started and continued until all of the plants had been planted. A stopwatch was started when the first plant left the table and stopped when the last plant left. Misses, doubles and the number of unfilled plant clips available to the operator at the moment the last plant was placed into a clip were counted. These unfilled plant clips referred to as "lag" elsewhere in this paper, represents the degree to which the operator did not keep up with the transplanter.

The individual observations, since they contained only 30 plants, were not long enough to produce fatigue but did allow the operator to approach steady-state. However, it was felt desirable to have a large number of short runs rather than a few long runs. Fatigue effects may have been present in the runs toward the end of each session. During a session of repeated 30 plant runs the fatigue state of the operators of the experimental transplanter and the conventional transplanters were probably not appreciably different.

Machine and operator speed in plant clips or plants per minute were calculated as follows:

Machine speed = plant clips/timed interval

= (30 + misses - doubles)/timed interval

Operator speed= plant clip filled/operator time

= (30 - 6 - doubles)/operator time

But operator time is not the same as the timed interval for determining machine speed.

$$\text{Operator time} = \text{timed interval} \left(\frac{\text{clips passing operator reference}}{\text{clips passing through machine}}\right)$$

If the operator has all of the available clips (6) filled at the end of the run (no lag) and there are no misses or doubles, The operator time is 24/30 of the timed interval. The following expression accounts for misses, doubles and lag:

$$\text{Operator time} = \text{timed interval}\ [(24 + \text{misses} - \text{doubles} + \text{lag})/(30 + \text{misses} - \text{doubles})]$$

It is easier to visualize the number of clips passing the operator if the reference is taken at the left end of the machine just past the sixth plant clip. The denominator of the expression is the same as used in the calculation of plant speed. Thus it can be seen that lag increases operator time and, therefore, decreases operator speed.

Performance tests were also run for comparative purposes on conventional transplanters having the same plant clip as the experimental unit. Test runs were 30 plants long and observations were made with both one and two operators feeding plants into the machine. Each of these transplanters had only one plant loading station.

RESULTS AND DISCUSSION

The first design involving the cross feed belt did not work well because of the lack of positive plant control during the transfer of plants to the plant tray. The design did, however, make it easier for the operator to feed plants into the machine. Because of the plant transfer problem this design did not appear to have commercial feasibility. Therefore, no performance data are included in this paper.

The second design utilizing chain mounted plant clips functioned well both with respect to the ease of feeding as well as the quality of the transplanting job. Some minor mechanical problems were encountered primarily in rotating the chain in the lateral direction and in maintaining the proper orientation of the clip. These problems were rectified during the course of the investigation.

Plant feeding speed for operators on the modified or experimental transplanter averaged 79.2 plants per minute with misses of 2.3%, Table 1. There is a slight learning trend evident as the rate increased from 76.2 plants per minute at the first test session to 79.4 plants per minute at the second session to 82.1 plants per minute at the third session.

Feeding rates for the conventional transplanter averaged 67.8 plants per minute with misses of 10.6%. In order to compare speeds, all of the rates were adjusted to 2% misses by means of the curve given in Figure 4 from Splinter and Suggs (1968) which plots the relationships between errors (misses) and operating rate. This error rate was selected as one which would be acceptable in virtually all field operations. When this adjustment is made the rates for the conventional transplanter becomes 54.4 and the experimental transplanter 78.9 or about 45% greater, Table 1.

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It can be concluded that the experimental transplanter represents a significant improvement in transplanter feeding concepts. It was found that one operator on the experimental machine could perform at the same rate as two operators on a conventional machine.

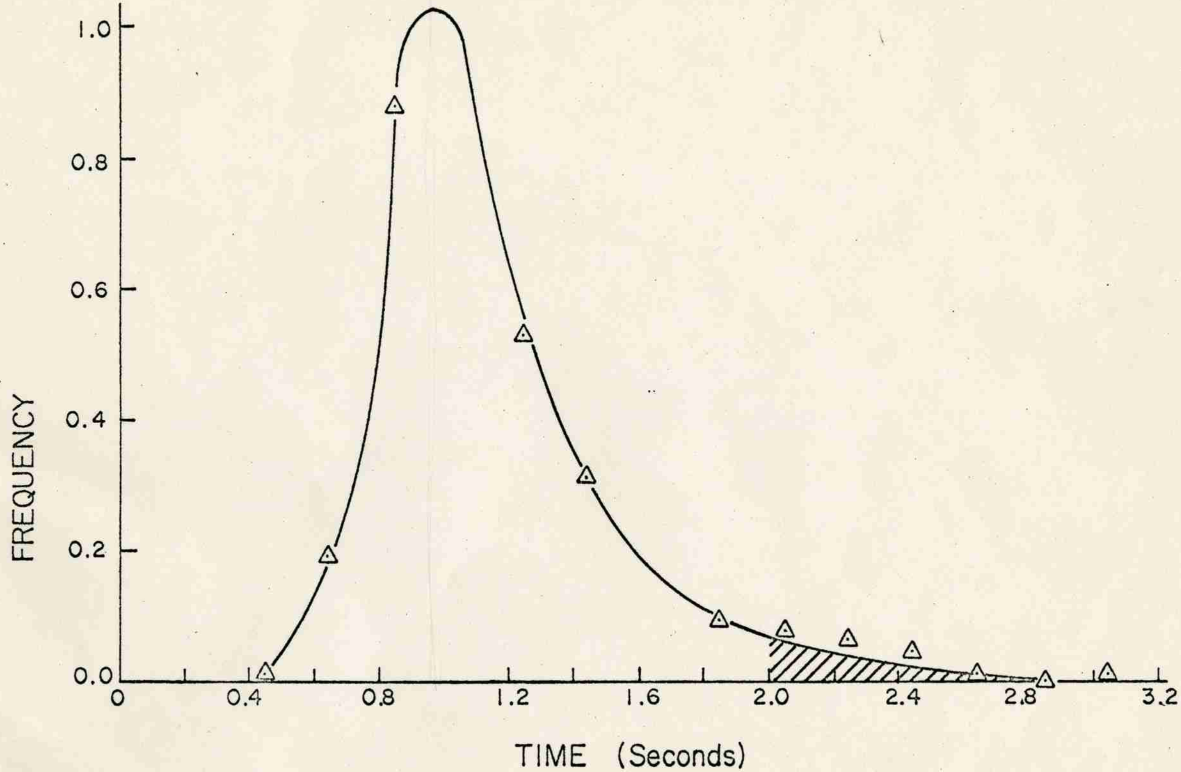


Fig. 1. Frequency distribution for feeding tobacco plants into a transplanter Splinter et al. 1963.
Shaded area shows the proportion of plants missed when transplanting at a rate of one plant per two seconds.

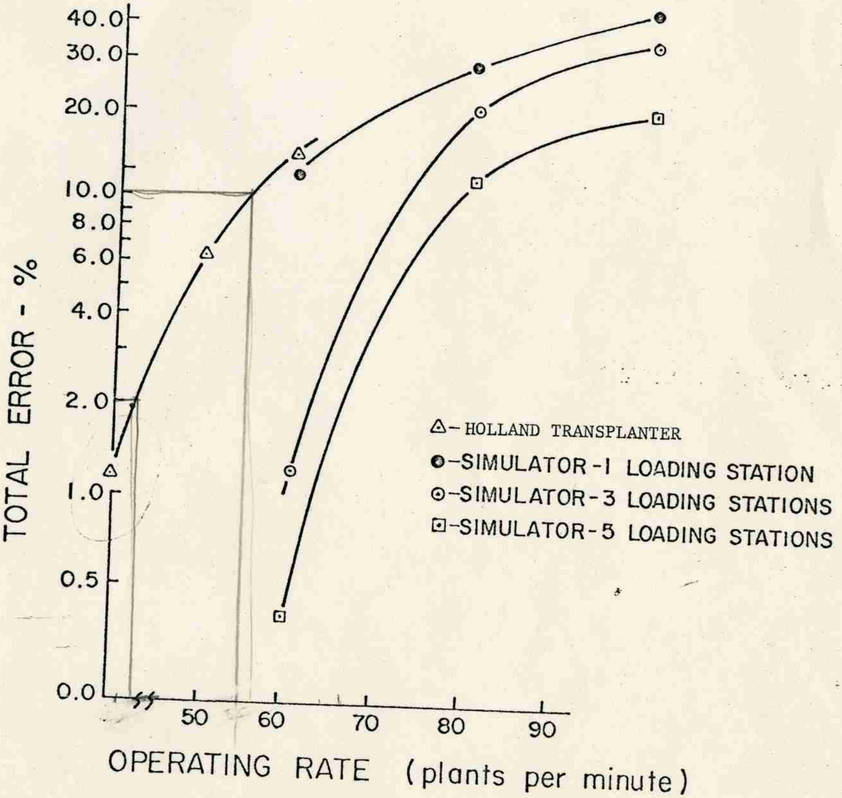


Fig. 2. Comparison of total errors versus operating speed for a field transplanter and a transplanting simulator using tobacco plants. Splinter and Suggs (1968).

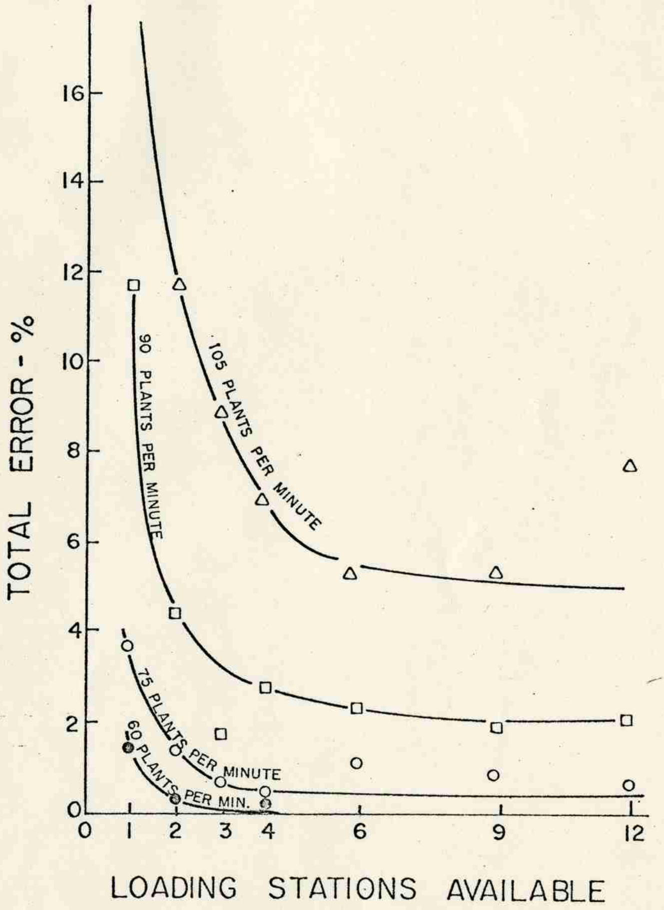
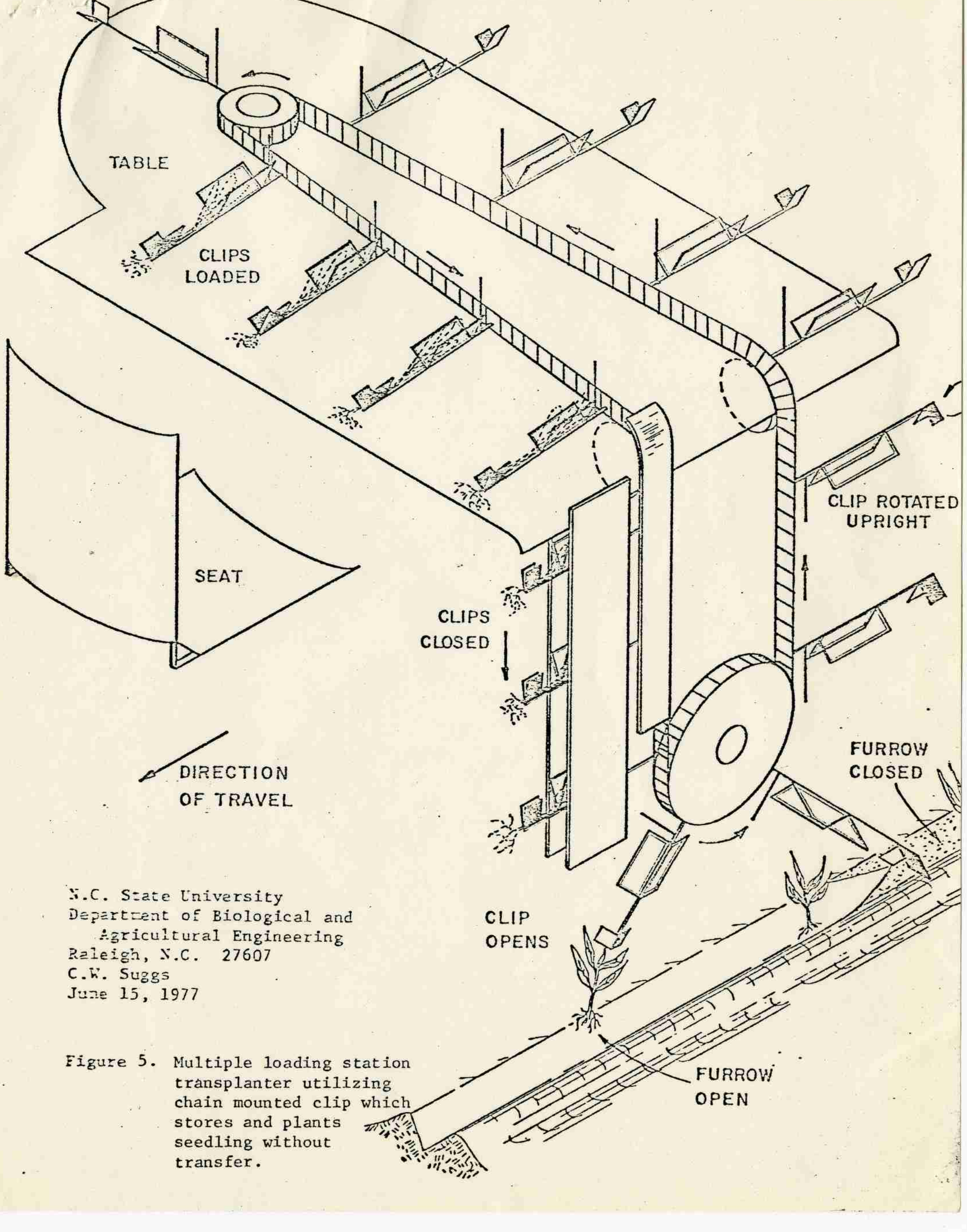


Fig. 3. Effect of number of loading stations on error at various operating speeds, ~~using simulated plants~~. (Splinter and Suggs, 1968).

~~a transplanting simulator.~~



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June 15, 1977

Figure 5. Multiple loading station transplanter utilizing chain mounted clip which stores and plants seedling without transfer.

Theoretical Model for Man-Machine System in Repetitive Loading Operation

W. E. Splinter and **C. W. Suggs**
Member ASAE   Member ASAE

The transplanting operation involves man and machine in a unique combination, in which the human operator must place and position a seedling at a particular point in space at exactly timed intervals. Errors in positioning or in timing cause stunted plants or skips which are unacceptable for later cultural operations, especially harvesting. Efficient use of man and machine requires that the equipment be operated at the highest rate possible within an allowable tolerance of stand uniformity.

Previous studies with tobacco transplants have shown that for every 1 percent reduction in stand due to skips there is a ½ percent reduction in yield (5)*. It was also found that the tendency for human operators to commit errors in transplanting (a) depended on how rigidly the operators were held to a timed sequence and (b) increased in an exponential manner with increased speed (4). In studies with a mechanical transplanter simulator, equations were developed relating operator error with rate of handling, number of rejects and machine acceptance time (6). Error prediction equations were developed for transplanting tobacco plants in field studies relating the percentage of skips, percentage of improperly set plants and total errors with transplanting speed.

The purpose of this study was to determine in greater detail the manner in which positioning and placement errors are related to certain transplanter design criteria and management decisions.

Operational Sequence in Transplanting

The operators work in pairs on most commercial transplanting equipment with one person working left-handed while the other works right-handed. Each operator must perform a sequence of tasks within a specific timed interval.

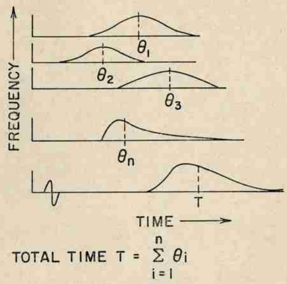

FIG. 1 Total time for a sequential operation is the sum of the times for each sequence.

For example, a sequence is outlined in Table 1., together with decision making and task time estimates obtained from McCormick (3). The number of decisions assumed for each decision point is given and each task is underlined. Where appropriate, the assumed transport distances are given.

From this example, we see that hand 1 performs a relatively simple task most of the time. However, every 10 to 20 plants, hand I must recycle to reload (steps 6 to 8) and the time required jumps to 1.7 sec for a person even after learning. Therefore, the loading cycle for hand 1 is the limiting factor for transplanting rate.

Hand 2 moves through a repetitive cycle every 1.6 sec. The times shown illustrate the common observation that errors are most frequent when the operator is still learning. At the cycle times shown, the limiting rate would be 35 plants per min for hand 1 and 37 plants per min for hand 2. These estimates are typical of normal field rates of transplanting where two operators work at rates of from 60 to 75 plants per min.

Effect of Rate of Operation on Errors

If each of the estimates given in Table I is realistic, it might appear that a transplanter should operate at zero errors up to a given speed. This, however, is not the case. Errors have been observed even where equipment was operated at 45 plants per min. The reason for this is that each subroutine has a population of times and the values shown represent only average times.

For any one operator cycle, the total time T will be the sum of the times for each subroutine (Θ_i) within the cycle, assuming each subroutine is independent. Fig. 1 shows this schematically. Each subroutine has a frequency distribution with time, and the total cycle time will therefore have a frequency distribution with the mean equal to the sum of the means of the individual subroutines.

Therefore, for any fixed machine cycle time t, the probability that an operator will commit an error will be the probability that the cycle time T for the operator is greater than t.

This may be written

$$P_E = \int_t^\infty f(T)\,dT \quad . \; . \; . \; . \; . \; . \; . \; . \quad [1]$$

where

P_E = probability for the operator to commit an error

$f(T)$ = some function of T.

To determine the functional nature of T, two subjects were allowed to drop wooden dowel pegs through a slot as rapidly as possible but without imposing any timing. The passage of each peg tripped a microswitch which actuated a pen on a strip chart.

The activity simulated transplanting in that the operators were required to obtain sublots of pegs from a tray with one hand and feed these pegs through the slot with the other.

The time interval between the passage of each consecutive peg was determined and a histogram showing the frequency distribution of times is shown in Fig. 2. The distribution is quite skewed. Using the method of moments (2), it was found that this distribution could best be described as a Pearson type III curve of the form

$$f(T) = f_o(T)\,\left(1 + \frac{T}{a}\right)^{b} e^{cT} \quad . \; [2]$$

where $f(T)$ is frequency of occurrence and $f_o(T)$, a, b and c are constants.

This form of the equation places the origin at the mode of the curve. Values for the mean $(\overline{T})$, standard deviation (s) and the constants for equation [2] are given in Table 2 for two subjects who were young college students and the calculated values are compared to the observed values of frequency in Fig. 2.

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The authors—W. E. SPLINTER and C. W. SUGGS—are professor and head, agricultural engineering department, University of Nebraska, Lincoln (formerly professor of agricultural engineering, North Carolina State University), and professor, biological and agricultural engineering department, North Carolina State University.

* Numbers in parentheses refer to the appended references.

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TABLE 1. TIME ESTIMATES FOR DECISIONS AND TASKS USED IN TRANSPLANTING
(Values estimated from McCormick, 1957)

Sequence I—Hand No. 1 Purpose: Acquisition of sublot of plants from plant tray	Time Required (Seconds) Inexperienced	 Experienced
Subroutine:		
1 Select sub area A_i for removal of plants from tray (three alternatives)	0.3	0.1
2 Vector hand 1 to tray, position hand facing downward, over A_i (40 cm movement)	0.6	0.5
3 Clamp hand about plants in A_1	0.1	0.1
4 Locate position, P, convenient to loading station (1 alternative)	0.2	
5 Vector hand 1 to P and rotate hand, palm up	0.6	0.6
	1.8	1.3
Sequence II—Hand No. 1		
Purpose: To serve as reservoir of plants near loading station. Some manipulation to select plant for hand 2		
Subroutine:		
6 Scan plants in hand and select plant to be set (three alternatives)	0.3	0.2
7 Index selected plant between thumb and fingers	0.3	0.2
8 Upon removal of plant repeat 6. If no plants in hand 1, repeat 1		
	0.6	0.6
Sequence III—Hand No. 2 (performed concurrently with Hand No. 1)		
Purpose: Place plant into machine		
Subroutine:		
9 Vector hand 2 to hand 1 palm downward (40 cm movement)	0.6	0.6
10 Grasp single plant	0.2	0.2
11 Locate loading station (one alternative)	0.3	
12 Vector hand 2 to loading station	0.6	0.6
13 Release plant	0.2	0.2
14 Repeat 9	1.9	1.6

If cycle time is plotted against the cumulative percentage of frequencies on log normal probability paper, a straight line results, except for a typical upturn in the lower percentage range as shown in Fig. 3. This indicates that frequency of handling data can also be treated without too much error as a log-normal distribution of the form (1)

$$f(T) = \frac{1}{T ln\sigma\sqrt{2\pi}} \exp\left[-\frac{1}{2}\frac{(lnT - ln\tau)^2}{ln\ \sigma}\right] \quad \ldots\ldots\ldots\ldots\ [3]$$

where τ = the number geometric mean estimated by

$$ln\tau = \frac{1}{N}\sum_{i=1}^{n} lnT_i \quad \ldots\ldots\ [4]$$

and σ = the number gometric standard deviation which is estimated by

$$ln\ \sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{n}(lnT - ln\tau)^2} \quad \ldots\ldots\ldots\ldots\ [5]$$

Values of the mean and standard deviation for the log-normal distribution may be estimated from the log-probability plot with reasonable accuracy (1).

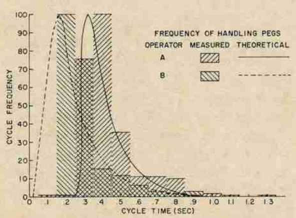

FIG. 2 Measured and calculated frequency distribution for handling wooden pegs for two operators.

The coded number gometric mean $\mu = ln\ \tau$ is estimated by determining the value of $f(T)$ at the 50 percent probability level. The coded number geometric standard deviation is estimated by

$$\sigma = ln\ \frac{1}{2}\left\{\frac{T_{50}}{T_{16}} + \frac{T_{84}}{T_{50}}\right\} \ldots\ [6]$$

where T_{16}, T_{50} and T_{84} are the times at the 16, 50 and 84 percent cumulative levels. The uncoded mean will be exp $(\mu + \frac{1}{2}\ \sigma^2)$ . . . . [7]

Values of the mean were calculated using equation [4] for each operator and were found to be 0.406 and 0.320 for operator A and B, respectively. Values were estimated directly from the curve using equation [7] and the uncoded means were found to be 0.378 and 0.255, respectively. Thus estimates of μ or σ taken from the log-normal plot may be convenient for estimating parameters but should not be used for efficient estimates.

The curve for $\int_t^\infty y_o \left\{1 + \frac{T}{a}\right\}^b e^{-cT} dt$

for operators A and B are shown in Fig. 4. The values of this integral for values of $t > 0.5$ plot nearly linearly on a semilog plot when plotted against cycle time $(60/T)$. Thus a rational explanation is available for the exponential increase in human error with increase in transplanting rate observed by Splinter and Suggs (4).

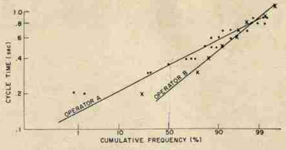

FIG. 3 Log normal plot of cycle time for the two distributions shown in Fig. 2.

Effect of Very High Operating Rates

A second test run was made with a simulator which carried pockets on a belt. The operators were required to drop pegs into a slot exposing only one pocket. The belt was operated at speeds of up to 240 pockets per min $(t=0.25)$. The percentage of errors averaged for the two subjects are plotted with a dashed line in Fig. 4. The fit is quite good at the tail of the curve, but the trend appears to deviate considerably at the higher belt speeds (lower values of t).

The reason for the departure is believed to be as follows: if the operation of the machine is such that the object may be placed in a loading station (pocket) independent of cycle time (as was the case with the belt simulator), then as cycle time decreases toward the mean value of the operator's time distribution (about 0.4 sec), the limiting factor will be the operator's ability to handle some number of objects per minute. This might be termed the steady-state rate of handling. The probability for errors will now increase linearly as cycle time decreases. This appears to be the case in Fig. 4 as shown by the dotted line.

Effect of Handling Tobacco Transplants

To compare the handling of actual transplants with the handling of wooden dowel pegs, operators were allowed to drop actual plants through a slot. Measurements of time intervals were made as before. Again the frequency curve of times for handling were skewed and the plot on log-probability paper was linear. The number geometric mean

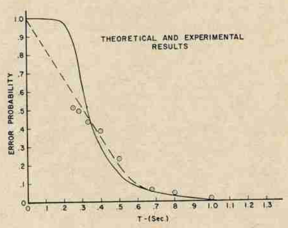

FIG. 4 Theoretical and measured errors averaged for two operators over a range of operating rates.

TABLE 2. CONSTANTS FOR THE FREQUENCY DISTRIBUTION EQUATION, PEARSON III ANALYSIS

Operator	a	b	c	$f_o(T)$	$\overline{T}$	s
A	0.659	0.598	0.907	108.4	0.426	1.393
B	1.240	−0.289	0.573	317.2	0.334	1.472

TABLE 3. CONSTANTS FOR THE FREQUENCY DISTRIBUTION EQUATION FOR HANDLING TOBACCO TRANSPLANTS, LOG-NORMAL ANALYSIS

Operator	τ(sec)	σ
B	0.83	1.651
C	0.84	1.571
D	0.94	1.617

and number geometric standard deviation were determined from the plots and are shown in Table 3. On the average it took about twice as long to handle transplants as wooden pegs.

Effect of Rejecting Undesirable Objects on Errors

It often happens that undesirable plants are found among the plants to be set. These may be rejected by the operator or placed in the machine for an error. If they are rejected, they quite often cause the operator to miss the next plant. The reason for this tendency to skip a plant following a reject is as follows:

The effect of selecting a reject in the transplanting operation will be to cause a random recycling of certain suboperations. In the example in Table I the reject would normally be dropped at subroutine 10 and the hand would have to recycle to 8 or possibly 3 if the reject plant was the last plant in the hand.

For a representative frequency distribution as shown in Fig. 4, it will be assumed that each recycling because of a reject will add one increment δ to the time probability distribution. Thus if the normal time for the sequence was T_1, a reject would add a time interval to T_1 giving a new cycle time T_2 and a higher probability that T_2 will be greater than t and result in a skip. Similarly two rejects in series would add a second δ resulting in a cycle time of T_3. Although the probability for rejects for the various sublots of plants is hypergeometrical (each sublot is subtracted from the initial population) the

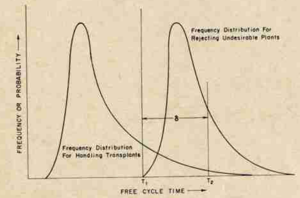

FIG. 5 Effect of a reject plant is to increase the time for that cycle by a time increment δ.

error will be small if the hand of objects is considered as part of the general population. Thus the probability for a single reject to appear will be $x(1-x)$ where x is the proportion of rejects in the total population. The probability for two rejects to appear consecutively will be $x \cdot x\ (1-x)$. Therefore, the total probability for error will be the probability for error without rejects plus the probability for error if there is one reject, etc., which may be written

$$P_E = (1-x)\int_\infty^{t} f(T) + (x)(1-x)\int_\infty^{t-\delta} f(T) + x^2(1-x)\int_\infty^{t-2\delta} f(T) + \ldots + x^n(1-x)\int_\infty^{t-n\delta} f(T) + \ldots \quad \ldots\ldots\ldots\ldots\ [8]$$

In a field situation, observation indicates an operator will tend to discard en masse rejects appearing in groups. Therefore, the first two terms of equation [8] should adequately describe the situation.

A test was run with two subjects using the single-station transplanting simulator (6) at 75 openings per min. The number of rejects in the population of wooden pegs was 0, 10 and 20 percent. The machine acceptance time for each opening was 50 percent of cycle time. (The simulator pocket was open 50 percent of the time).

Values calculated using the first two terms of equation [8] are compared with the experimental values in Fig. 6.

Effect of Machine Acceptance Time on Error

On most transplanters the operator has some short time period (t_a) within each cycle within which he must position the plant and release it. The ratio of the time within which the plant may be released to the machine to the total cycle time is defined as the machine acceptance-time ratio and is designated as α.

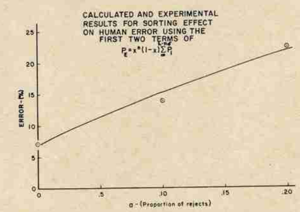

FIG. 6 Calculated and experimental results for errors caused by sorting out rejects.

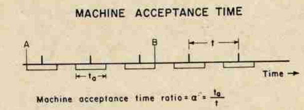

FIG. 7 Schematic for the time sequence for a mechanical transplanter. The mechanical hand will accept a plant only during the open period t_a.

Various transplanter designs result in different machine acceptance time ratios (4). It was observed that those machines having a greater machine acceptance-time ratio allowed the operator to work with fewer errors. The effect of machine acceptance-time ratio on errors can be understood more clearly by referring to Fig. 7. A series of cycles is shown with the period during which the machine will accept a plant shown as t_a. If an operator releases his plant at point A he will have a time period $t + \alpha t$ to place and release the next plant. If he releases his plant at B, he has only t seconds to obtain and release the next plant. Therefore, the effect of α is to increase, on the average, the available time within which the operator may make a successful fill with consequent reduction in probability of error, the greater the value of α, the lower the value of P_E.

Plotting the results reported by Splinter et al (6), where α was varied from 0.108 to 192, at 75 plants per minute

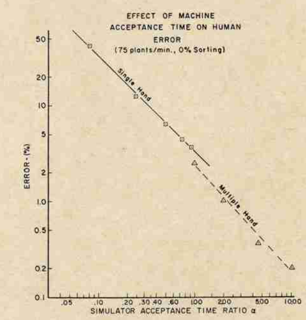

FIG. 8 Percentage errors versus operating-machine acceptance time for a single-hand simulator and for a multiple-hand transplanter simulator operated at 75 plants per min. Open time of 1,000 percent corresponds to ten pockets being available.

with 0 sorting, we obtain a linear relationship between P_E and α on log-log paper (Fig. 8). This may be closely approximated by the relationship

$$P_E = \frac{p}{\alpha^d} \qquad [9]$$

where p and d are constants.

For the single station simuulator $p = 0.032$ and $d = 1.03$.

To determine what happens if α is increased to values greater than unity, the belt simulator with a series of pockets was operated with from one to ten pockets exposed. Planting rate was 75 plants per min and there was no sorting. As shown in Fig. 8, the plot of P_E vs α remained linear on log-log paper as α was increased to 10. For the multiple loading station simulator $p = 0.024$ and $d = 1.12$. The constant p in this equation is the error probability where $\alpha = 1$ and can therefore be derived from the relationship shown in equation [1]. The constant d decreases linearly with

$$d = \frac{-2.7}{t} + 6.15 \qquad [10]$$

Discussion

The results of this study provide a rational explanation for the manner in which operators tend to commit errors in placing plants in a transplanter. The effect of transplanting speed (cycle rate) on errors has been shown to be the probability that the cycle time for the operator exceeds the fixed cycle time of the machine, as obtained from the cycle time distribution characteristic of the operator. Operators may therefore be characterized by determining the mean, standard deviation and skewness of their distribution function and their performance on a transplanter predicted. This approach could be used for predicting the expected operator error level for many industrial operations.

The effect of separating rejects has been explained on the basis of probability. A manager can use this information together with the allowable error level to determine what level of reject plants will be accepted from the plant beds.

Conclusions

1 The normal frequency for handling items tends to follow a relationship of the form $f(T) = f_o(T)(1 + \frac{T}{a})^b e^{cT}$ where $f_o(T)$ is the mode of the distribution, T is time and a, b and c are constants. The distribution may also be closely approximated by a log-normal distribution. The distribution is skewed having a mean on the order of 0.3 to 0.4 sec for operators working with wooden pegs, and 0.8 to 0.9 sec for operators working with transplants.

2 The probability for error at various cycle times t may be predicted from $P_E = \int_t^{\infty} f(T)\,dT$. This error-probability function may be approximated by an exponential relationship for levels of error acceptable for field transplanting operations.

3 The effect of sorting reject items from a population of plants may be determined from the relationship

$$P_E = x^n(1-x) \sum_{\infty}^{t-n\delta} f(T)$$

where x is the proportion of rejects and δ is a time increment caused by having to recycle after a reject. For normal transplanting it appears that the first two terms of the expansion is sufficient.

4 The effect of machine acceptance time on error probability may be expressed as $P_E = \frac{p}{\alpha^d}$ where α is the proportion of cycle time within which the machine will assume control of a plant, p is the error probability at $\alpha = 1$, and d is a function of cycle time.

References

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2 Elderton, W. P. Frequency curves and correlation. Harren Press, 1953.

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4 Splinter, W. E. and Suggs, C. W. Mechanical transplanting of bright-leaf tobacco, Part II. Effect of transplanter type and speed on operational skips. Tobacco Science 3:154-157, 1959.

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6 Splinter, W. E., Suggs, C. W., and Beeman, J. F. Mechanical transplanting of bright-leaf tobacco, Part VI. Effect of transplanting rate, rejects and machine acceptance time on operator error. Tobacco Science 12:208-215, 1968.

NORTH CAROLINA STATE UNIVERSITY | AT RALEIGH

SCHOOL OF AGRICULTURE AND LIFE SCIENCES

DEPARTMENT OF BIOLOGICAL AND AGRICULTURAL ENGINEERING
BOX 5906 ZIP 27607

December 16, 1977

Mr. James Basselman
Publications Manager
ASAE
2950 Niles Road
St. Joseph, Michigan 49085

Dear Mr. Basselman:

I have enclosed five copies of a paper entitled "Development of a Transplanter with Multiple Loading Stations" which I would like you to consider for publication in the Transactions of ASAE. In addition to the manuscripts which are complete with xerox copies of all the figures, I have enclosed photographic copies of the figures for printing purposes.

This work has not been published in any form elsewhere. However, I do hope to present it at the ASAE meeting in Utah this coming summer.

Sincerely,

C.W. Suggs

C.W. Suggs
Professor

CWS/bm

Enclosures

January 3, 1978

Dear Mr. Suggs:

For review purposes, please fill in the attached Manuscript Submission form and return to: Howard F. McColly, ASAE Power & Machinery Division Editor, 225 Kensington Rd., East Lansing, MI 48823. Thank you.

Sincerely,

Vivian Zeller

(Mrs.) Vivian Zeller
Editorial Assistant

AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS
P.O. Box 410
Saint Joseph, Michigan 49085

January 18, 1978
(Date)

TO: Name C.W. Suggs

Address Professor, Bio. & Agr. Engineering Dept., N.C. State Univ., PLO. Box 5906, Raleigh, NC 27607

FROM: Program Chairman Allen R. Rider

Division Power and Machinery

Address 216 Ag Hall, OSU
Stillwater, OK 74074

SUBJECT: **Notification of Paper Acceptance for 1978 Summer Meeting Program (Theme: "Engineering Vital Resources")**

It is indeed a pleasure for me to advise you that your paper:

Title: DEVELOPMENT OF A TRANSPLANTER WITH MULTIPLE LOADING STATIONS

Authorship: C. W. Suggs

has been accepted for presentation at the 1978 Summer Meeting of ASAE at Utah State University, Logan, Utah, June 27-30, 1978. If any changes or omissions in title or authorship are needed, **please advise me immediately**. For those who have not already submitted copies, a "1978 Summer Meeting Presentation Proposal Form" is enclosed which we request that you complete **now** and return to us so that your paper may be listed properly in the printed program which we will be developing soon.

If you cannot give this presentation PLEASE CALL ME IMMEDIATELY ABOUT CANCELLATION.

Enclosed are additional materials regarding ASAE policies and practices which we ask that you review carefully and **hold for further reference**. Forms referred to in the instructions but not enclosed with this mailing will be included in a February mailing from ASAE. Enclosures include: (1) Speaker Instructions for ASAE Meeting Programs, and (2) Information for Speakers (brochure).

In early February you will be asked by ASAE for your projection equipment requirements, for introductory information to be used by the presiding officer, and possibly for information for publicity purposes. They also will send you a draft copy of the session on which your presentation is scheduled and will give you further instructions, including the **ASAE paper number** assigned your presentation, ASAE standard cover page for technical papers, and registration information. In February ASAE also will send you information on how to submit manuscripts for possible publication by ASAE. Please comply with these requests so we may be of maximum help to you in connection with your presentation.

We **urge** you to confine your projection requirements to 2 x 2 slides if at all possible. If you cannot standardize to 2 x 2 equipment, however, specify your requirements on the request form (February), and we will make appropriate arrangements. We suggest that you bring your own Kodak carrousel tray if possible, particularly if you will be using a large number of slides.

Thank you for making this paper available and for your cooperation in following all instructions enclosed plus instructions to be mailed later by ASAE. Full compliance contributes to a smooth functioning meeting and reflects credit on you, your employer, and our profession.

Tentative date, time, and length assigned your presentation Wednesday, June 28, 1978

2:45 p.m. - 3:05 p.m. (20 minutes)

Session begins at 1:30 p.m. with Introductory Remarks.

1 - 4X5 print
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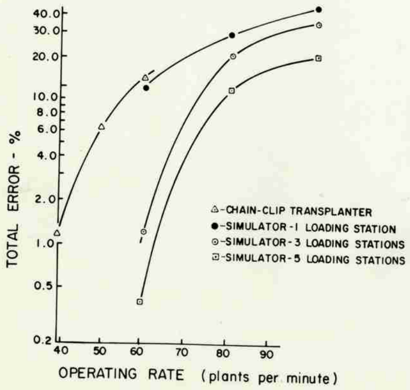
C.W. Suggs



Dear Mr. Suggs:

Reference: Ms. #PM-230

Thank you for submitting your article "Development of a Transplanter with Multiple Loading Stations"

for publication consideration. We are mailing it to the appropriate ASAE Division editor for review; you will hear directly from him concerning your article. All articles published in the TRANSACTIONS of the ASAE must be in SI units. If author prefers, dual dimensioning is permitted with customary units in parentheses. Any other exceptions must be approved by Division editors.

Sincerely,

Vivian Zeller

1/3/78

(Mrs.) Vivian Zeller
Editorial Assistant

econ-o-card

American Society of
Agricultural Engineers
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St. Joseph, Michigan 49085

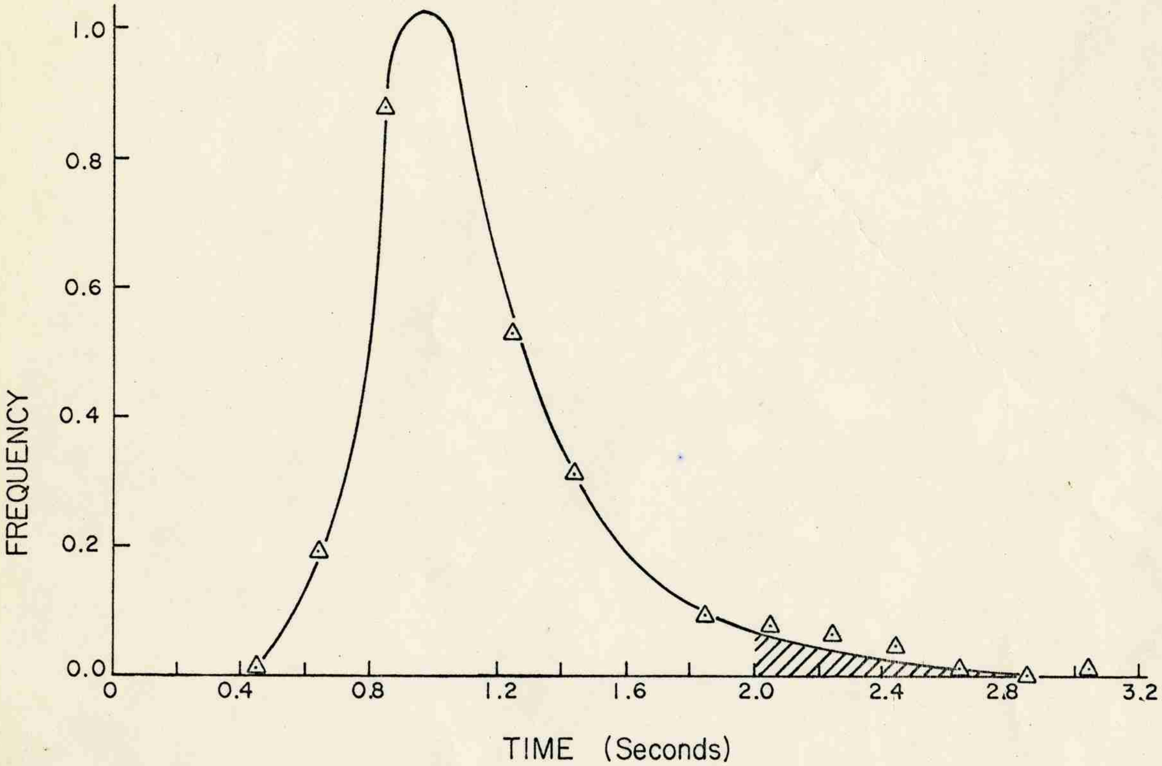


Fig. 1. Frequency distribution for feeding tobacco plants into a transplanter Splinter et al. 1963.

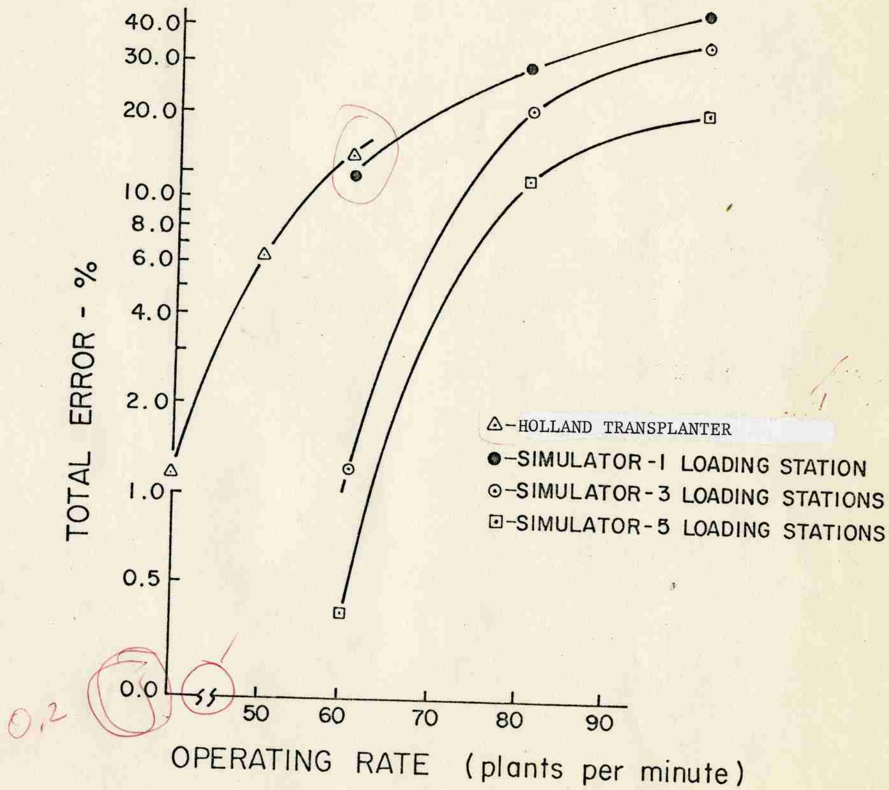
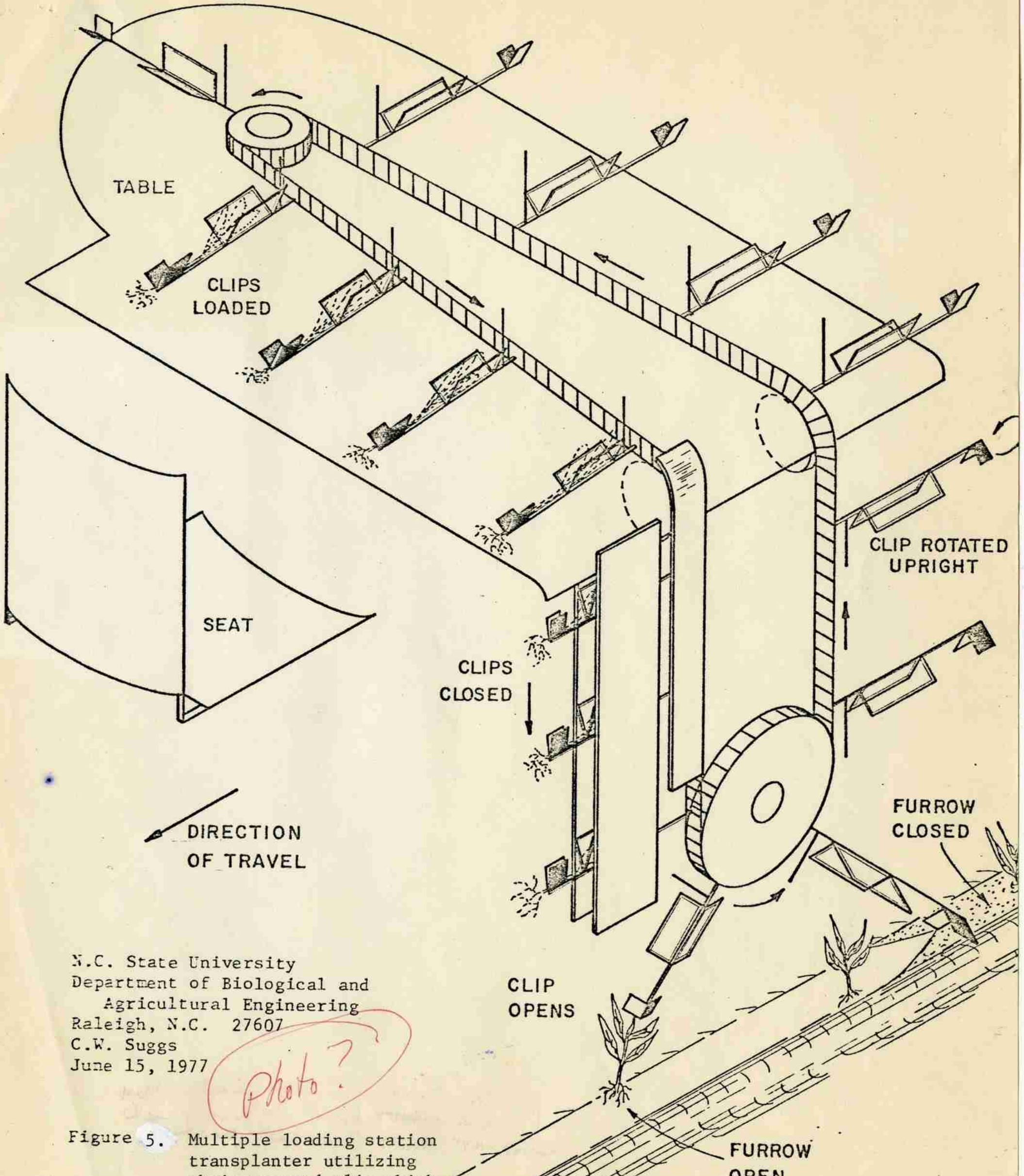


Fig. 2. Comparison of total errors versus operating speed for a field transplanter and a transplanting simulator using tobacco plants. Splinter and Suggs (1968).



N.C. State University
Department of Biological and
Agricultural Engineering
Raleigh, N.C. 27607
C.W. Suggs
June 15, 1977

Photo?

Figure 5. Multiple loading station transplanter utilizing chain mounted clip which stores and plants seedling without transfer.

December 16, 1977

Mr. James Basselman
Publications Manager
ASAE
2950 Niles Road
St. Joseph, Michigan 49085

Dear Mr. Basselman:

I have enclosed five copies of a paper entitled "Development of a Transplanter with Multiple Loading Stations" which I would like you to consider for publication in the Transactions of ASAE. In addition to the manuscripts which are complete with xerox copies of all the figures, I have enclosed photographic copies of the figures for printing purposes.

This work has not been published in any form elsewhere. However, I do hope to present it at the ASAE meeting in Utah this coming summer.

Sincerely,

C.W. Suggs
Professor

CWS/bm

Enclosures

Development of a Transplanter with Multiple Loading Stations

C.W. Suggs

ABSTRACT

The multiple-loading feature significantly increased the operator's feeding speed because it allowed up to five plants to be fed into the mechanism before they are actually needed. Thus, during temporary feeding slowdowns due to tangled plants, etc., skips in the field do not occur. In addition to storage, the machine's plant acceptance time was increased from less than one second to several seconds. One operator on the machine with multiple loading stations could transplant at the same rate (about 70-80 plants/min) as two operators on a conventional machine.

Senior Author's Copy

MEMORANDUM

To: Director of Research   Date: 12/2/77

From: F. J. Hassler (Name and Signature)   Head of: Biological and Agr'l Engineering

Manuscript: For approval X (enclose 3 copies of text; 1 copy of photos and graphs) For your information ____ (enclose 1 copy)

Title: Development of a Transplanter with Multiple Loading Stations

Author(s) C. W. Suggs

Recommended for publication as follows:

Station Technical Bulletin ____ Station Bulletin ____ Number of copies recommended ____

Journal Series article in Transactions of the ASAE (Name of Journal)

Note in ____ (Name of Journal)

Other ____

Contribution from Biological and Agricultural Engineering Department(s)

and U.S.D.A. ____; Other agencies: ____

It has been reviewed by a committee consisting of

E. C. Humphries   R. W. Watkins

R. P. Rohrbach Chm.

It has been approved by the following:

Departments: Biological and Agricultural Engineering

Other agencies: ____ Date: ____

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Action taken by Director:

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(2) Approved as Paper No. 5497 of the Journal Series.

(3) Manuscript returned to: ____

Comments: ____

Signed: George J. Fry   Date: 12-6-77
Director

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SCHOOL OF AGRICULTURE AND LIFE SCIENCES

DEPARTMENT OF BIOLOGICAL AND AGRICULTURAL ENGINEERING
BOX 5906 ZIP 27607

November 23, 1977

MEMO TO: Dr. F.J. Hassler

FROM: R.P. Rohrbach, Chairman RPR

SUBJECT: Manuscript Review

After careful review of the manuscript "Development of a Transplanter With Multiple Loading Stations" by C.W. Suggs, the committee judges and recommends the following:

1. Too much time (and space) is spent in the literature review in re-establishing the value of multiple loading stations as previously reported in the literature. Figures 1 thru 5 are also used primarily to support the idea that multiple loading stations are desirable. The review of literature should be condensed and focused on the body of literature which supports the development of the transplanter per se. [reduced to 1 d spaced page + 3 figures]

2. A good deal of reviewer confusion was experienced by the organization of the material in the Evaluation Section of the manuscript. The section should be re-written to include more clear and concise definitions of special terms such as "lag", "operator speed" etc. before giving examples. ✓

3. The validity of the conclusions would be strengthened by including some discussion on the effects of operator fatigue and the rational for tests with only 30 plants. ✓

4. The paper does in general contain material which should be published. The author has agreed to modify the manuscript in accordance with the above points after which the paper should be forwarded to the Station Director's office for further approval.

cc: E.G. Humphries, R.W. Watkins, and C.W. Suggs ✓

DEPARTMENT OF BIOLOGICAL AND AGRICULTURAL ENGINEERING

November 15, 1977

MEMORANDUM TO: R. P. Rohrbach, Chairman
E. G. Humphries
R. W. Watkins

FROM: F. J. Hassler FJH

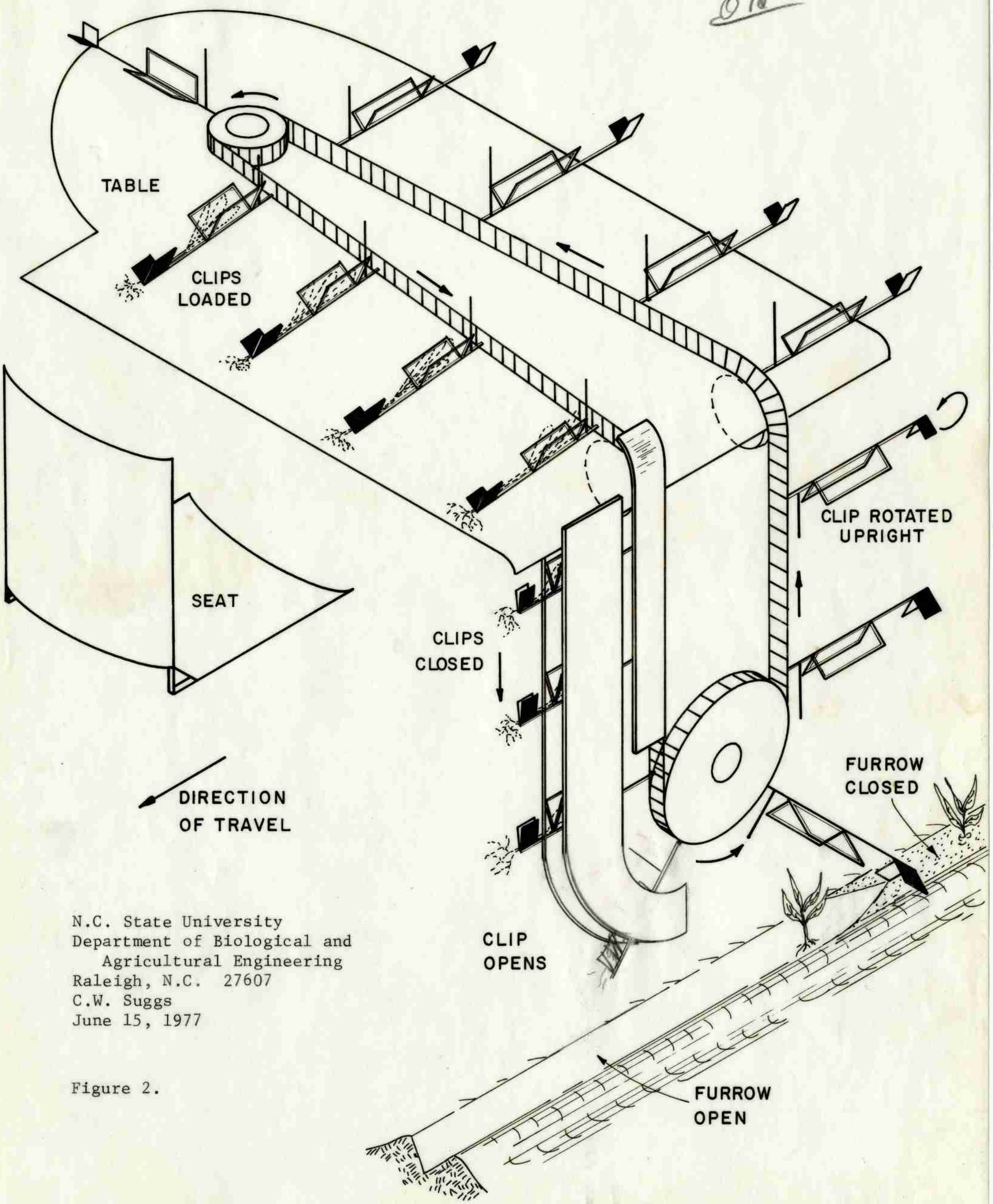
SUBJECT: Manuscript Review

Please accept my request for you to serve as a review committee for the attached copy of manuscript, "Development of a Transplanter with Multiple Loading Stations" by C. W. Suggs. The manuscript will be submitted to Transactions of the ASAE for publication.

You should work directly with the author in your review process if needed; I would like a response from the Chairman about the suitability of the manuscript for publication

encl.

cc: C. W. Suggs



N.C. State University
Department of Biological and
Agricultural Engineering
Raleigh, N.C. 27607
C.W. Suggs
June 15, 1977

Figure 2.

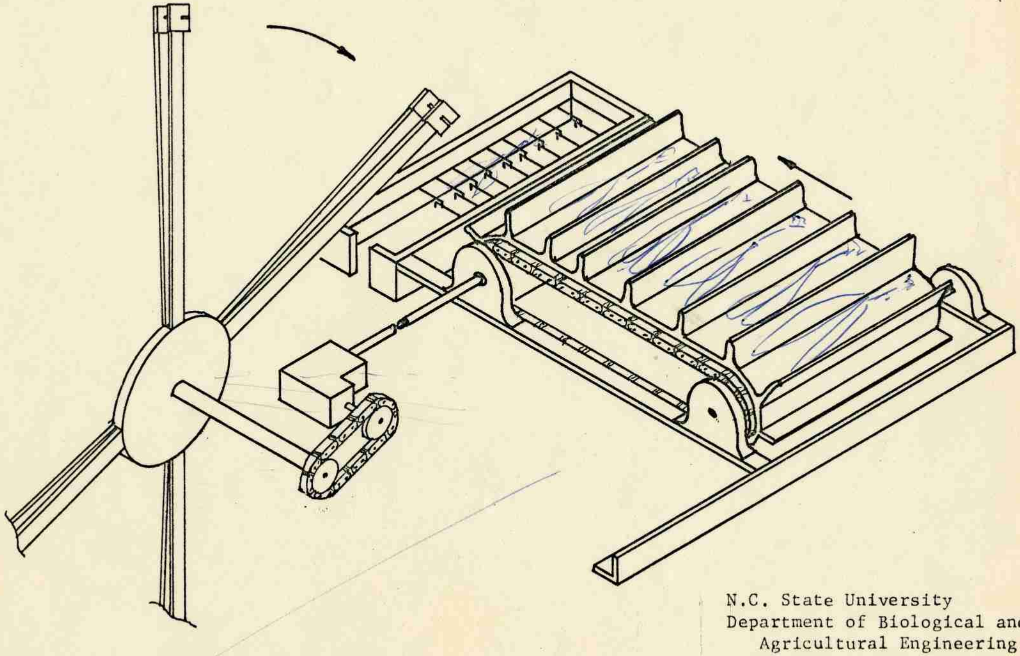


Figure 1.

N.C. State University
Department of Biological and
Agricultural Engineering
Raleigh, N.C. 27607
C.W. Suggs
June 15, 1977

August 16, 1977

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Translations Department
Beltsville, Maryland 20705

Dear Sir:

I would appreciate receiving English translations of the following articles:

1. Tobacco Planter According to Mechanization Bulgarian Tiutiun, Vol. 21(3) pg. 1-3, 1976.

2. Endeavor Toward Complete Tobacco Mechanization Bulgarian Tiutiun, Vol. 20(10) pg. 12-15, 1975.

3. About Problems with Mechanized Growing and Planting of Tobacco Seedlings, Vseeoiuznyi Nauchno-Issledovatel Skii Institut Tobaka i Makhorki imeni A.I. Mikoiana. Sbornik nauchno-Issledovatel skihh rabot. Vol. 163, pg. 16-22, 1974.

4. Study of Transplanting Machines with Automatic Feeding Systems, Farm Machinery, Vol. 12(2) pg. 57-70, 1975.

I shall look forward to hearing from you.

Sincerely,

C.W. Suggs
Professor

CWS/bm

Need 4 copies CWS

Nov 16-77 Master -

Development of a Transplanter with Multiple Loading Stations[1]

C.W. Suggs[2]

INTRODUCTION

In tobacco production, transplanting of the seedling from the plantbed or greenhouse to the field requires a significant proportion of the total labor input to the crop. This is also true of many vegetable or truck crops. As harvest operations are mechanized, transplanting is likely to become the bottleneck limiting the number of acres which can be produced without hiring extra labor specifically for transplanting. This peak in the labor demand curve suggests that transplanter improvements which will reduce labor requirements are needed.

Efforts to field seed tobacco, and many other crops, have not been successful because poor stands, nonuniform growth and low yield. The seeds during germination are sensitive to cold, wind and drying of the soil surface. (This results in ... In many areas growing seasons are not long enough to produce a crop unless the plants are started in a protected environment before the danger of frost is over. These problems are the reasons that plantbeds or greenhouses are used to start plants in the first place and unless something can be done to alleviate the unfavorable early season conditions in the field it will continue to be necessary or desirable to transplant many crops.

Huang and Splinter (1968) have made significant progress in the development of a seedling production and automatic transplanting system in which seed are placed and grown in a grid container which also becomes the "cartridge" which is loaded into

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[1] Paper No.________of the Journal Series of the North Carolina Agricultural Experiment Station, Raleigh, N.C. The use of trade names in this publication does not imply endorsement by the North Carolina Agricultural Experiment Station of the products named, nor criticism of similar ones not mentioned.

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the transplanter. While this system may have merit it does not appear applicable to farmers who do not have greenhouses and greenhouse expertise unless plants are available commercially at competetive prices.

Another attempt at transplanting mechanization also involves a preloaded cartridge in a belt configuration (Roth, 1973). The belt is fed through the transplanter which mechanically removes the plant from the belt and places it in the ground. Unless mechanical means for loading the plants into the belt are developed, this system would simply transfer labor from one place in the system to another without actually eliminating any operations. This approach could also benefit from the concept of multiple loading stations.

Therefore, there is a need for labor reducing improvements on manually operated transplanters. These improved transplanters could be used until the Huang & Splinter type system described above becomes operational or until methods for mechanically singulating and feeding seedlings are developed and made commercially available.

This paper describes an improvement which was made to a manually-fed transplanter. The modification consists of a series of plant retaining devices (clips or pockets) into which individual plants may be fed before they are actually required by the machine. Thus, plant feeding is simplified from a strictly paced operation to one in which considerable variation in instantaneous feeding rate may be tolerated. In fact, for short periods of time the operator may stop feeding plants or feed at a slow rate without causing misses in the field as the machine transplants the seedlings already placed in the series of retaining devices.

REVIEW OF LITERATURE

Previous investigators (Splinter, et al., 1968; Splinter and Suggs, 1968a; Splinter and Suggs, 1968b) have described the relationships between planting rate, rejects, machine acceptance time, transplanter type, operator error and number of loading stations. It has been shown (Splinter and Suggs, 1963) that the time to handle individual plants is not constant but has a skewed distribution, Figure 1, with a mean for the subjects observed of about 1 second per plant depending on the skill of the subject. For a conventional transplanter, since it does not have a reserve of plants already fed into the mechanism, a miss will occur any time plant handling time exceeds machine cycle time. That is, there is no way the operator can get ahead of the task and if he gets behind plants will be missed. The shaded area in Figure 1 represents the proportion of plants which will be missed when transplanting at one plant per two seconds, that is only half as fast as the mean handling rate.

When handling time is less than machine cycle time the difference cannot be utilized effectively as plants cannot be fed into the machine ahead of time. This time can, however, be used to arrange, straighten or untangle plants.

In conventional transplanters, that is, with only one loading station, the feeding accuracy at any transplanting speed can be predicted from the feeding distribution curve, Figure 2. If the horizontal axis is divided into integer multiples of the transplanting cycle time and the number of plants fed from each interval is N_1, $N_2 \ldots N_i$ then the co-responding number of machine cycles will be N_1, $2N_2 \ldots iN_i$ (6). This assumes that two or more machine cycles can be combined to form a single feeding cycle. Feeding accuracy in percent then is $(100)\ (N_1 + N_2 + \ldots + N_i)/(N_1 + 2N_2 + \ldots + iN_i)$. By changing cycle time and recalculating the above fraction, a curve of feeding accuracy versus transplanting speed can be determined, Figure 3. In this figure it can be seen that predicted and observed feeding accuracy are in reasonably close agreement.

In transplanters with multiple loading stations we would expect feeding accuracy to improve because the time saved on the faster cycles can be utilized and the slower cycles can be accommodated by the storage of plants in the machine. Therefore, it should be possible to approach the operator's mean feeding rate and still maintain a very high feeding accuracy. Although no records of a multiple loading transplanter were found, a simulation study showed that significant improvements in feeding accuracy are realized as the number of loading stations is increased (5), Figure 4. This simulation work showed that feeding accuracy is improved, that is, errors or misses are reduced, as the number of loading stations is increased, Figure 5, up to about 5 or 6 stations after which little improvement is realized. Very large error reductions are possible in going from a single loading station to 5 or 6 stations.

Transplanter Design

Recognizing that 5

Recognizing that 5 or 6 loading stations were needed to optimize feeding rate the first design, Figure 6, utilized a crossfeed belt fitted with divider strips 1 1/2" tall at 2" intervals which formed plant pockets. This mechanism was attached to a Powell transplanter. The belt dropped the plants onto the plant tray which consisted of hinged spring loaded fingers which could fold back and allow the cam actuated plant hands to pass through the space and pick up the plants. Plants were placed in an open furrow when the arms rotated into their lowest position.

While this design optimized feeding rate, the transfer from the belt to the plant tray and planting hands caused problems. Most plants were transferred properly but some would hang on the belt or fall onto the near or far edges of the plant tray where they would be missed or improperly picked up by the planting hands.

In the second design plant transfer was eliminated by causing the plant pockets (plant clips) to move from the loading area to a position directly over the open furrow, where the plants were released, Figure 7. This was accomplished by mounting the plant clips on a chain which is flexible in two planes, front to rear and side to side. As the vertical strand of chain leaves the planting area it is turned sideways onto a table where the plants are loaded into the clips. The chain is then turned downward to the planting area. Clips, upside down as they leave the planting area are turned upright as they approach the table. As they start downward they are prevented from further rotation and closed to hold the plant until it reaches the lowest position where it was opened and releases the plant in the furrow just before the soil was pressed around the plant roots.

The plant clips were riveted to a bracket which was welded or brazed to the chain. The rivet was left loose to form a pivot about which the clip could rotate. As the upside down clips approach the table a short crossarm on the clips contacts a stationary block which rotates the clip to the upright position. This position is maintained by allowing the crossarm to slide on the table. As the clip starts downward, a vertical pin on the clip contacts a guide which prevents further rotation.

TRANSPLANTER EVALUATION METHODS

Two related measures of performance were evaluated. These were operating speed and percent errors. Errors consisted of failing to place a plant in a clip (misses) or placing more than one plant in a clip (doubles, etc). Misses dominate errors to such an extent that the term "misses" is used interchangebly with "errors" and as such contains doubles, etc. Another term, feeding or operating accuracy is 100% - error %.

During testing the operator (plant dropper) was given 30 tobacco plants about 6" to 8" long. He fed 6 of these into the available plant clips or receiving stations. Forward motion was then started and continued until all of the plants had been planted. A stopwatch was started when the first plant left the table and stopped when the last plant left. Misses, doubles and the number of unfilled plant clips available to the operator at the moment the last plant was placed into a clip were counted. These unfilled plant clips referred to as "lag" elsewhere in this paper, represent the degree to which the operator did not keep up with the transplanter. ~~For example, if the transplanter speed is 60~~

The individual observations since they contained only 30 plants, were not long enough to produce fatigue but did allow the operator to approach steady-state. However, it was felt desirable to have a large number of short runs rather than a few long runs. Fatigue effects may have been present in the runs toward the end of each session. ~~These effects were hard to identify because~~ During a session of repeated 30 plant runs the fatigue state of the operators of the experimental transplanter and the conventional transplanters were probably not appreciably different.

Machine and operator speed in plant clips or plants per minute were calculated as follows:

Machine speed = plant clips/timed interval

= (30 + misses - doubles)/timed interval

Operator speed = plant clip filled/operator time

= (30 - 6 - doubles)/operator time

But operator time is not the same as the timed interval for determining machine speed. If the operator has all of the available clips loaded at the end of the run (no lag) and there are no misses or doubles the operator time is 24/30 of machine time. More generally the fraction is

Operator time = (machine time) [(24 + misses - doubles + lag)/(30 + misses - doubles)]

Thus it can be seen that lag causes this expression to increase but causes a decrease in operator speed as this expression is used in the donominator of the operator speed equation.

Performance tests were also run for comparative purposes on conventional transplanters having the same plant clip as the experimental unit. Test runs were 30 plants long and observations were made with both one and two operators feeding plants into the machine. Each of these trasplanters had only one plant loading station.

Results and Discussion

The first design involving the cross feed belt did not work well because of the lack of positive plant control during the transfer of plants to the plant tray. The design did, however, make it easier for the operator to feed plants into the machine. Because of the plant transfer problem this design did not appear to have commercial feasibility. Therefore, no performance data are included in this paper.

The second design utilizing chain mounted plant clips functioned well both with respect to the ease of feeding as well as the quality of the transplanting job. Some minor mechanical problems were encountered primarily in rotating the chain in the lateral

$$\text{Operator time} = \text{timed interval}\left(\frac{\text{Clips passing operator reference}}{\text{Clips passing through machine}}\right)$$

If the operator has all of the available clips (6) filled at the end of the run (no lag) and there are no misses or doubles the operator time is 24/30 of the timed interval. The following expression accounts for misses, doubles and lag:

$$\text{Operator time} = \text{timed interval}\left[(24 + \text{misses} - \text{doubles} + \text{lag})/(30 + \text{misses} - \text{doubles})\right]$$

It ~~may~~ it is easier to visualize the number of clips passing the operator if the reference is taken at the left end of the machine just past the sixth plant clip. The denominator of the expression is the same as used in the calculation of plant speed. Thus it can be seen that lag increases operator time and, therefore, decreases operator speed.

direction and in maintaining the proper orientation of the clip. These problems were rectified during the course of the investigation.

Plant feeding speed for operators on the modified or experimental transplanter averaged 79.2 plants per minute with misses of 2.3%, Table 1. There is a slight learning trend evident as the rate increased from 76.2 plants per minute at the first test session to 79.4 plants per minute at the second session to 82.1 plants per minute at the third session.

Feeding rates for the conventional transplanter averaged 67.8 plants per minute with misses of 10.6%. In order to compare speeds, all of the rates were adjusted to 2% misses by means of the curve given in Figure 4 from Splinter and Suggs (1968) which plots the relationships between errors (misses) and operating rate. This error rate was selected as one which would be acceptable in virtually all field operation. When this adjustment is made the rates for the conventional transplanter becomes 54.4 and the experimental transplanter 78.9 or about 45% greater, Table 1.

Conventional transplanters normally use two operators per row. With each operator feeding alternate plants into the machine. However, output rates do not double with addition of a second plant dropper. Observed planting rates of transplanters using two operators averaged 72.3 plants per minute or about 36 plants per operator per minute. One person on a conventional transplanter will plant about 70 to 75% as many plants as two people. There appears to be some interference between the two operators which reduces potential speed. A second very important factor is the increased speed of the plant clip and the reduction in the period of time in which the plant may be placed in the clip.

The most important comparison in the data is between the planting rate for the experimental transplanter with one operator, 79 plants per minute, and the conventional transplanter with two operators, 72 plants per minute. One operator on the experimental machine can transplant as many plants as the two operators normally used on a conventional machine.

Summary and Conclusions

all caps

An experimental transplanter fitted with several plants loading stations was found to result in significant increases in operating speed. The improved performance was due to the fact that the operator could feed plants into the loading stations before they were actually required by the machine. This backlog of plants could then be used by the machine whenever the operator's feeding rate was reduced for any reason for short periods of time.

It can be concluded that the experimental transplanter represents a significant improvement in transplanter feeding concepts. It was found that one operator on the experimental machine could perform at the same rate as two operators on a conventional machine.

Table 1. Comparison of Modified Transplanter with Conventional Transplanter.

	Operator Speed Plants/Min	Misses %	~~Speed~~ machine speed Adjusted to 2% Misses
Modified Transplanter			
1 Operator			
1st Session	76.2	4.3	73.2
2nd Session	79.4	1.7	79.8
3rd Session	82.1	1.0	83.7
Mean	79.2	2.3	78.9
Conventional Transplanter			
1 Operator			
1st Session	68.4	12.4	53.4
2nd Session	67.4	8.8	55.4
Mean	67.8	10.6	54.4
Conventional Transplanter			
2 Operators			
Farm 1	~~72/2~~ 36	3.2	70.2/2 35.1
Farm 2	~~76/2~~ 38	3.0	74.4/2
Mean	~~[illegible]~~ 34	3.1	72.3/2

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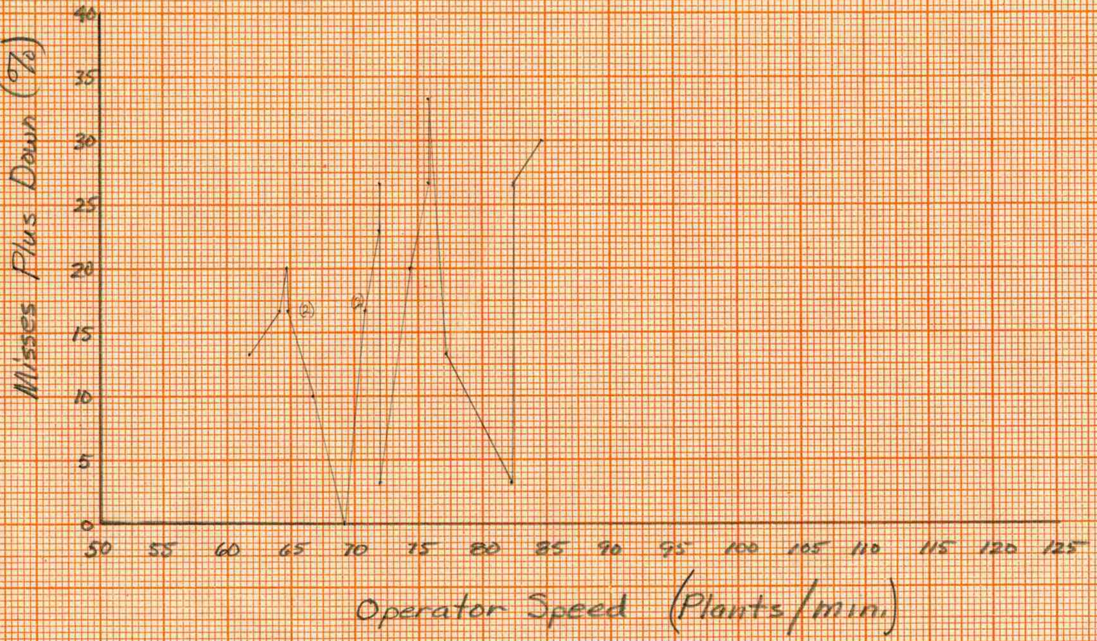
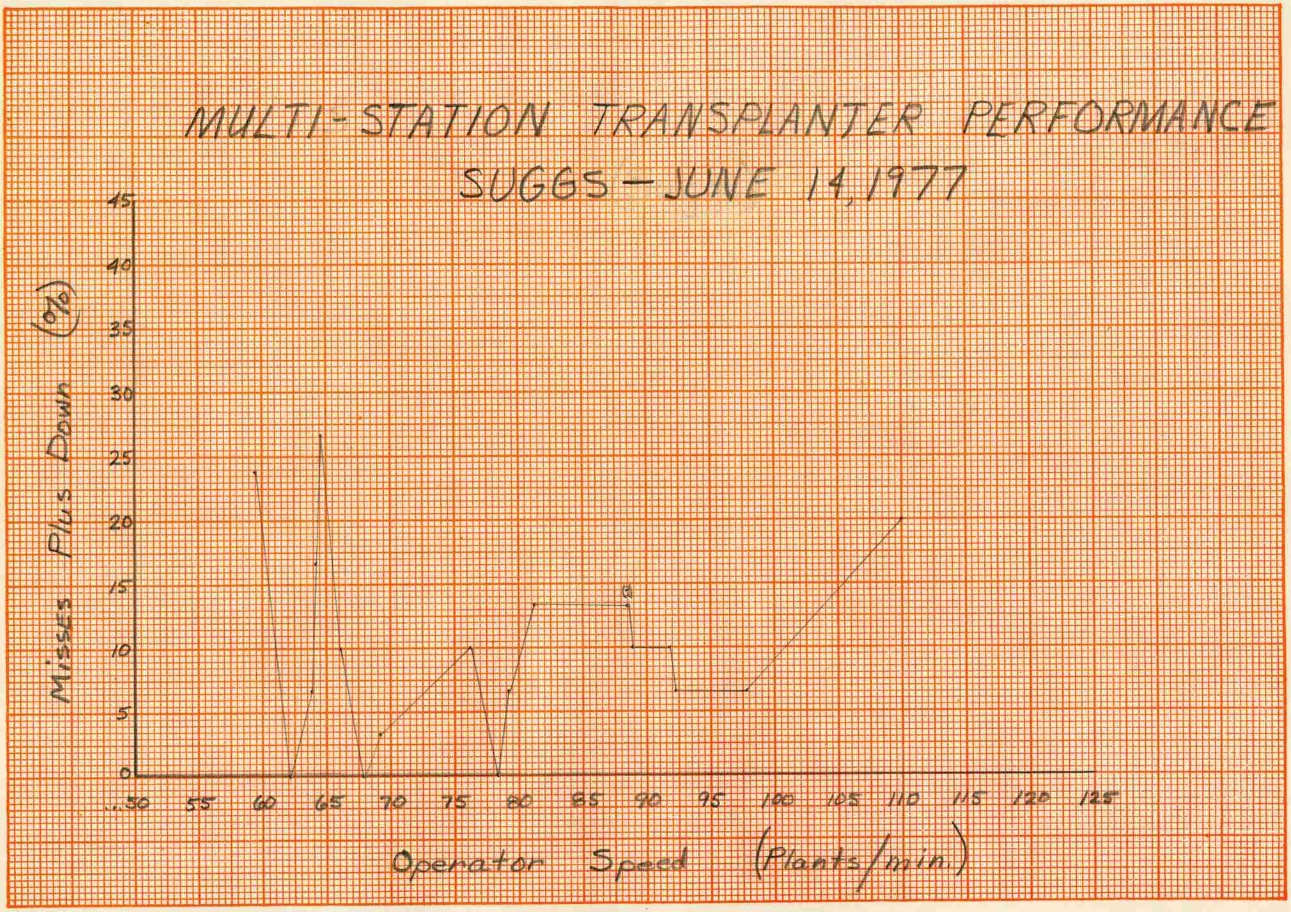
5 ~~7~~. Splinter, W.E. and C.W. Suggs. Simulation Studies of Human Errors in Multiple Loading Transplanting. ASAE Paper No. 63-150. 1963.

MULTI-STATION TRANSPLANTER PERFORMANCE

BRIGHT – JUNE 14, 1977

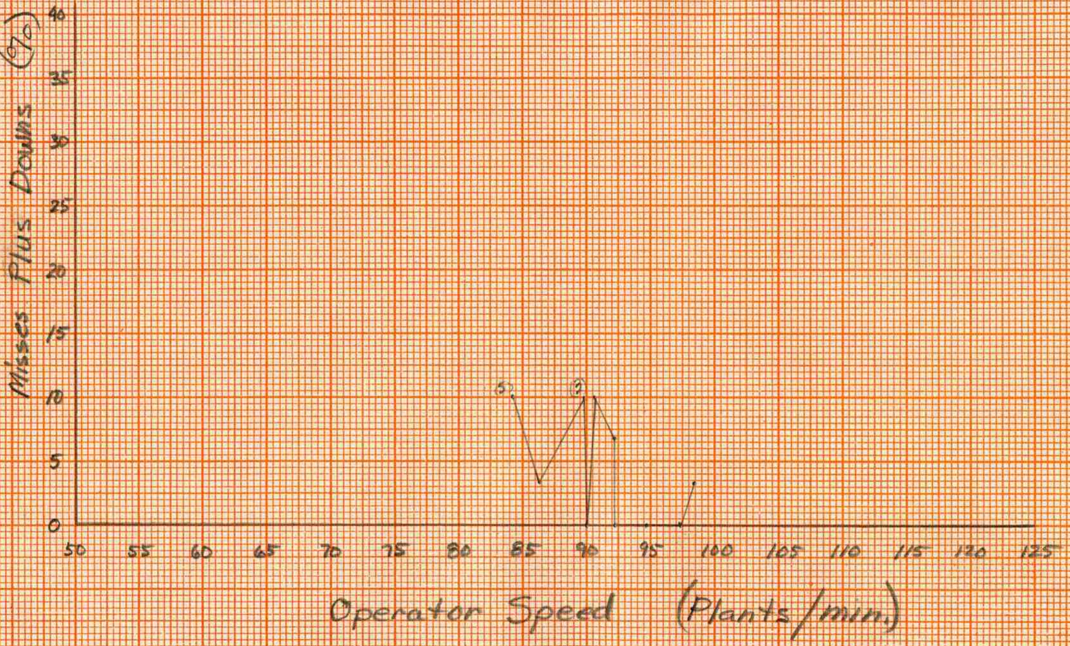




MULTI-STATION TRANSPLANTER PERFORMANCE
SUGGS - JUNE 14, 1977
Misses Plus Down (%)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
105
110
115
120
125
Operator Speed (Plants/min.)

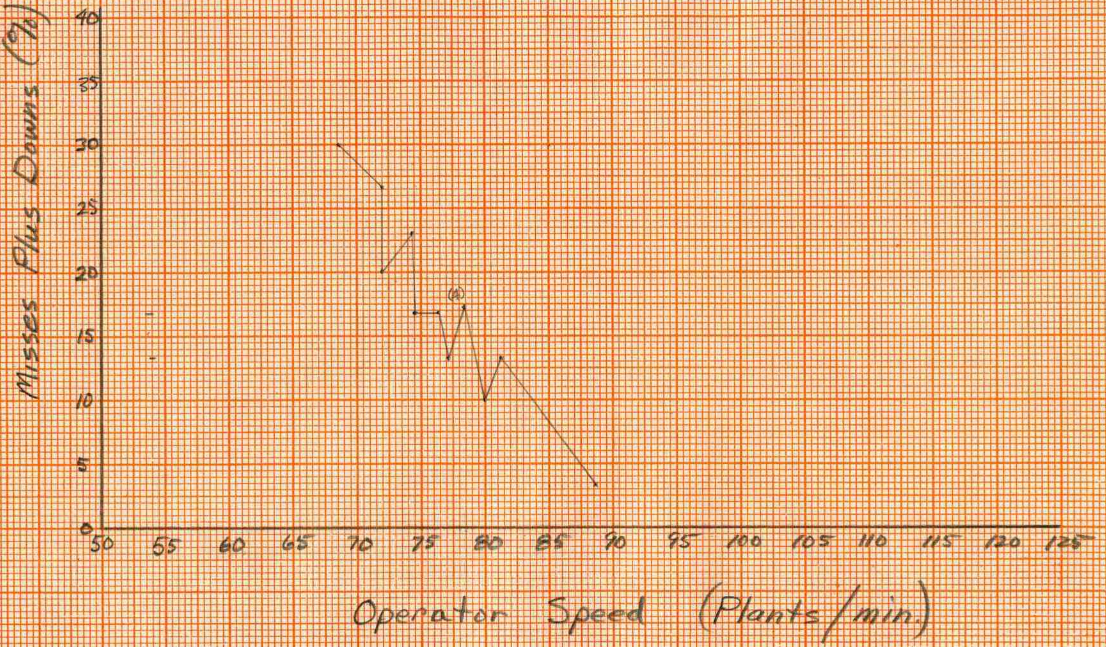
MULTI-STATION TRANSPLANTER PERFORMANCE

Suggs - June 16, 1977 - Topped Plants



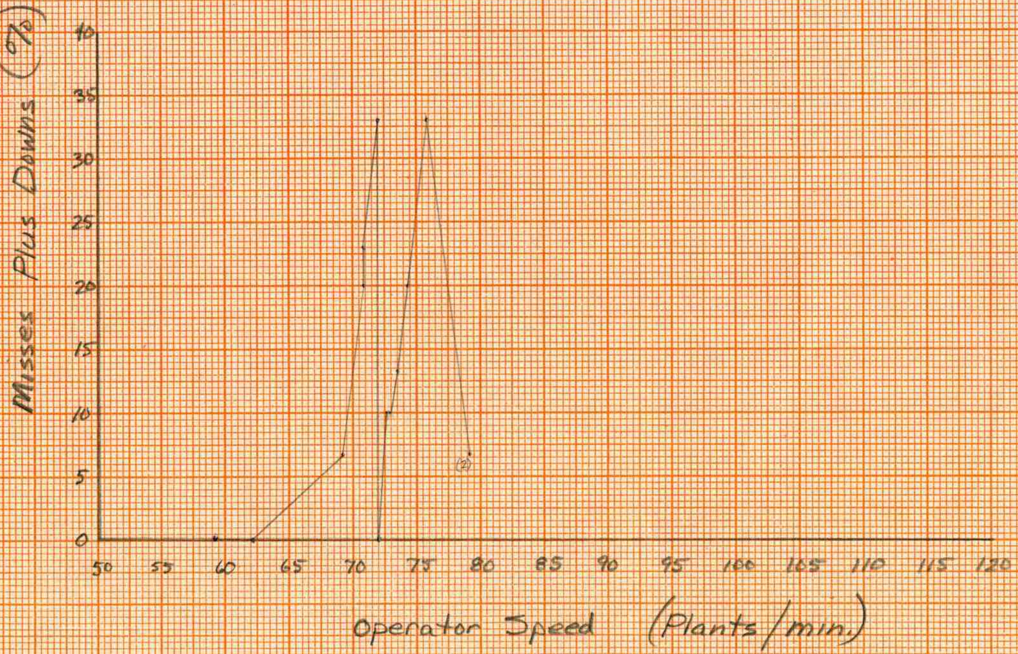
MULTI-STATION TRANSPLANTER PERFORMANCE

Bright - June 16, 1977 - Topped Plants



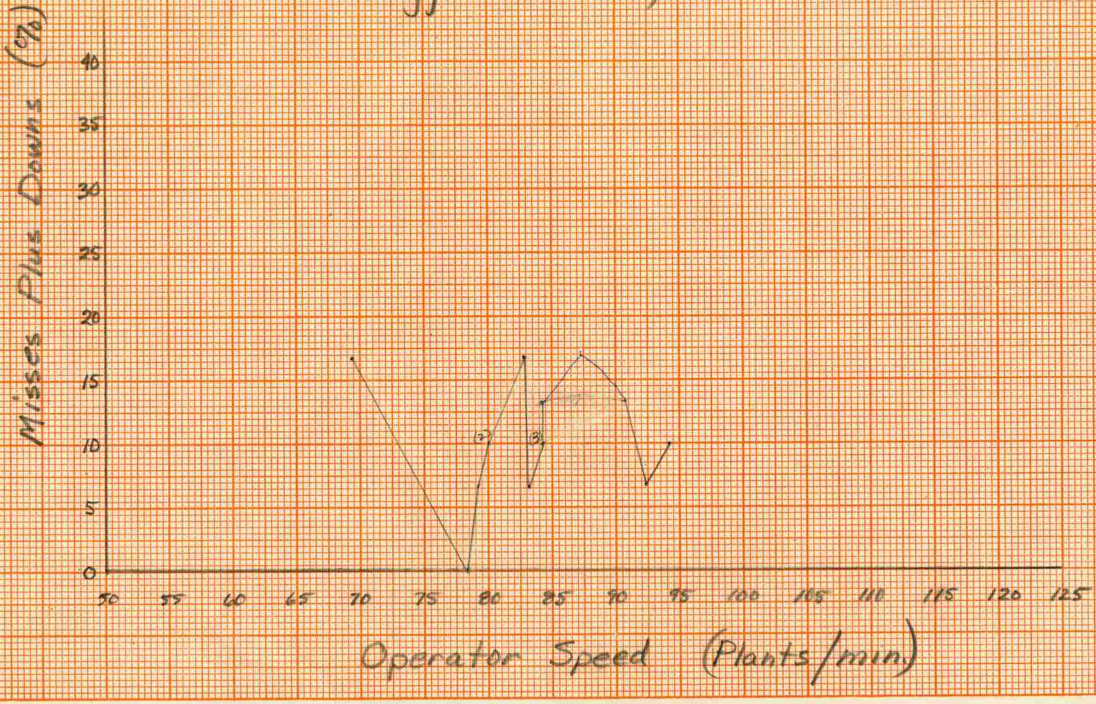
MULTI-STATION TRANSPLANTER PERFORMANCE

Bright – June 16, 1977 – Whole Plants



MULTI-STATION TRANSPLANTER PERFORMANCE

Suggs – June 16, 1977 – Whole Plants



Reg Transplanter % error

includes Fails

		55 0	
60	0, 3.3, 3.3, 0, 0, 0, 6.7	3.3, 0, 0, 3.3, 3.3, 0, 0.	1.6
65	0, 6.7 13.3, 0,	0, 0 6.7, 0, 3.3, 3.3, 13.3,	4.25
70	0, 13.3, 0, 10, 3.3, 3.8, 3.3	3.3, 3.3, 10, 10, 10, 3.3, 10, 10,	6.24
75	0, 10, 0, 3.3 13.3, 6.7,	3.3,	5.24
80	10, 33.3, 30,	6.7,	20.
85	30, 40,	20, 6.7, 26.7, 23.3,	24.45
90	20, 13.3	23.3,	18.87
95		13.3,	13.3
100			

X	Y
60	1.6
65	4.2
70	6.2
75	5.2
80	20
85	24.5
90	18.9
95	13.3

$\Sigma X = 620$ ΣY 93.9

$n = 8$ n 8

$\bar{X} = 77.5$ $\bar{y}$ 11.74 ΣXY 7840

$X^2 = 49100$

$CF = 48050$ ΣY^2 1620.03 C 7277.25

$\Sigma x^2 = 1050$ CF 1102.15 Σxy 562.75

Σy^2 517.88

$b = .53595$, $\hat{Y} =$ ~~.53595 +~~ $11.74 + .53595(X - 77.5)$

$= -29.794 + .53595X$

Reg. Transplantor

7 28

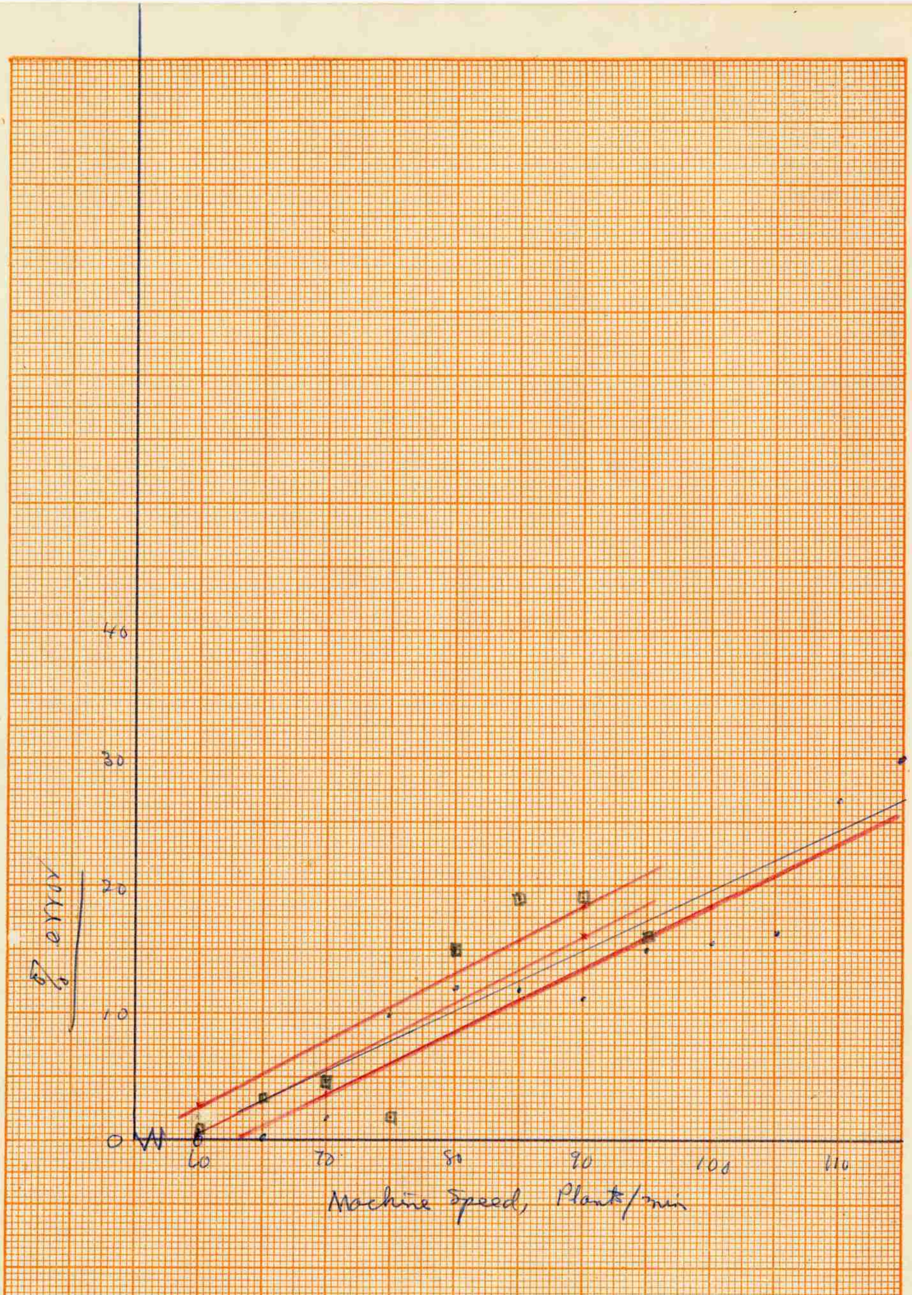
3.3

Bright	55 0 Suggs	
0, 0, 0, 0, 0, 0, 0, 3.3	0, 0, 0 3.3, 3.3 0, 0	.7
0, 3.3, 6.7, 0,	0, 0, 6.7, 0 3.3, 3.3, 13.3,	3.3
0, 10, 0, 6.7, 6.7, 0, 3.3,	3.3, 3.3, 6.7, 6.7, 10, 0, 6.7 6.7,	4.7
0, 0, 0, 0, 3.3, 6.7,	3.3,	
10, 20, 26.7,	3.3,	
30, 20	20, 3.3, 20, 20,	18.9
20, 13.3,	23.3	18.9
	13.3	13.3

Misses + doubles

Machine speed plants/min		June 16 untopped	June 16. topped	Misses + Doubles + Down	
57.5 - 62.5	60	0, 0,		0	% error
62.5 - 67.5	65		3		
67.5 - 72.5	70	4, 0, 0, 1, 2 1	2 0 .	0, 6.7, 0,	
72.5 - 77.5	75	0, 4, 0, 0 1	2 0 0 0	23.3, 10, 3.3, 10, 13.3, 3.3,	
82.5	80	0, 0, 0, 0 0 0 0	0 0 0 0 0 0	16.7, 16.7, 20, 16.7, 16.7, 0,	
87.5	85	0, 0 0 0 0 0 0	0 0 0 0 0 0	16.7, 16.7 26.7, 6.7, 10, 3.3	
92.5	90	0, 0	0 0 0 0 0 0 1 0	13.3	
97.5	95	0	0	23, 13.3, 20, 26.7,	
102.5	100		0 0	6.7 10, 26.7	
107.5	105			33.3, 6.7, 13.3, 10, 13.3, 13.3,	
112.5	110			26.7,	
	115			30	
117.5	120				
	125			125 - 20	

Machine speed	June 16 untopped	Misses plus Doubles plus Down	June 16 Topped	% error
57.5				
60	0, 0,	Av 0		
62.5				
65		0		
67.5				
70	0	0		
72.5				
75	6.7,	6.7	(100)	
77.5				
80	10, 0, 10,	6.7		
82.5				
85	16.7, 6.7, 6.7, 6.7, 13.3,	9.4		Av
87.5				
90	10, 6.7, 23, 20, 10,	13.9.	16.7, 0, 13, 16.7, 20, 10, 3.3, 0, 3.3	15.8
92.5				14.0 10, 10, 0
95	10, 20, 13.3, 10, 10,	12.7	16.7, 16.7, 16.7, 23, 26.7, 13.3, 10, 10, 10, 0, 16.7, 30	
97.5				
100	33, 16.7, 13.8, 6.7	17.6	10, 10, 10, 10, 6.7, 3.3	8.3
102.5				
105	33, 13.3, 10,	18.8		


% error
40
30
20
10
0
60
70
80
90
100
110
Machine Speed, Plants/min

~~Conventional - 76.6% plants/min = 70 with 16.6% Misses~~
~~83.7% with 9.7%~~
~~Overall - 76.9% 9.5%~~

Modified	op. speed		error
	79.4	Jun 16	1.7
	82.1	Jun 16	1.0
	76.2	Jun 14	4.3
overall	78.9		2.1

Conventional	op. speed		error	
✓	68.4	plants/min	12.4	% Misses
✓	67.4	"	8.8 %	
Overall	67.8	"	10.6 %	

corrected to 2.1% error This becomes 55.4 plants/min or

$$\frac{78.9 - 67.8}{67.8} = 16.4\% \text{ increase in speed}$$

79.6 % decrease in errors

with $\frac{78.9 - 55.4}{55.4} =$ ~~50.6~~ 42.4 % increase in transplanting speed

Correct the conventional to an error of 2.1% according to Fig 18 of Splinter & Suggs - Simulation - - . The rate would have to be decreased to 12 plants/min in order to bring the error down to 2% - That is 67.4 − 12 = 55.4 plants

Operator speed

Martin Σ 2311.5 = $\bar{x}$ = 92.46

June 16 - Av. of whole Plants Reid & Suggs 79.44 | - 25 observations

Σ = 2472.7 $\bar{x}$ = 95.10 " " Topped Plants - Reid & Suggs 82.06 | 26 observations

Σ = 3167.1 $\bar{x}$ = 90.48

June 14 Av. 2743.56 Reid & Suggs - 76.21 | — 36 observations 79.24 overall average

av - 92.68 — 14.5% Misses 78.4

Regular Transplanted

n = 15 - Σx = 1026.8 $\bar{x}$ = 68.45

n = 21 Σx = 1414.3 $\bar{x}$ = 67.35

36 2441.1 67.8 → 17% better

~~Regular Trans~~

40/50 = 80

n = 15 Σx 1148.7 $\bar{x}$ = 76.58 → 10.6% Misses

10/40, 10/50 n = 21 Σx = ~~1430.6~~ 1548.6 = ~~68.12~~ 73.74 8.7% Misses

2697.3 74.925 → 9.5% Misses

13/(30 x 25) = 13/750 = 1.7% Missed - 25 observations

35 x 30 = 1050

8/750 = 1.0% Missed - 26 observations

51, 36/67

32/1050 = 4.3% Missed 35 observations -

---

53 Regular Trans. Misses -

15, 30, 450 — 2380

Bright - 56/(30 x 15) = 12.4%

450, 630, 1080

Suggs - 56/(30 x 21) = 8.9%

36 x 30 = 1080

21, 30, 630

overall. 112/(30 x 36) = 112/1080 = 10.4% overall

% Error

X	Overall Y	1st Run	2nd Run	Con. Trans X	Con. Trans Y	Diff
60	0	0	0	60	.7	.7
65	0	0	0	65	3.3	3.3
70	1.7	2.2	0	70	4.7	3.0
75	10.0	10.6	6.7	75	1.9	-8.1
80	11.9	14.6	6.7	80	15.0	3.1
85	11.8	13.4	9.9	85	18.9	7.1
90	11.1	13.3	10.9	90	18.9	7.8
95	14.8	20.8	13.7	95	13.3	1.5
100	12.6	14.5	12.0			Total 18.4
105	16.2	15.0	18.8			
110	26.7	26.7				
115	30.	30				
120		~~20~~				
125		20				

n 10

~~X XY Φ Y~~

ΣX 925
n 10
$\bar{X}$ 92.5
ΣX^2 87625 ΣXY 14577 ΣY 146.8
CF 85562.5 CF 13579 n 10
Σx^2 2062.5 Σxy 998 $\bar{Y}$ 14.68
ΣY^2 2760.08
CF 2155.02
Σy^2 605.06

$b = \Sigma xy / \Sigma x^2 = .4839$

$\hat{Y} = 14.68 + .4839(X - 92.5)$

$\hat{Y} = -30.08 + .4839X$

$X^2 = 49100$ ΣY 76.7
$\Sigma X = 620$ $\bar{Y}$ 9.5875
$n = 8$ ΣY^2 1153.39
$\bar{X} = 77.5$ CF 735.36
CF = 48050
$\Sigma x^2 = 1050$ Σy^2 418.02875

b = .5283

$\Sigma XY =$ ~~4928.8~~ 6499

$C = \Sigma X \Sigma Y / n = 5944.25$

$\Sigma xy = 554.75$

$\hat{Y} =$ ~~[illegible]~~ $9.5875 + .5283(X - 77.5)$

$\hat{Y} = -31.36 + .5283X$

2 men on one row - conv. trans -

av. op speed - 57.45. n = 26.
av. error - 3.85 n = 26.
correcting to 2% error requires a reduction of 3 plants/min
This then becomes 57.45 - 3 = 54.45 plants/min

60p/m 30 sec

52

144.6

67.8
54.4
13.4

55.4
53.4
2|108.8
54.4

1.6
1.8
1.7

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September 8, 1977

Professor C. W. Suggs
Department of Biological
and Agricultural Engineering
North Carolina State University
Box 5906
Raleigh, North Carolina 27607

Dear Professor Suggs:

The four translations you requested in your letter of August 16 are not identified as being in our collection. Recently we have begun to file catalog cards showing the titles of articles translated, but most of the items in our translation file are by author only. If you can supply authors, I will be happy to make a second search for the material you need.

You understand, I am sure, that we do not have a translating service at the National Agricultural Library. Therefore, if they are not already on file here, I suggest you try the:

National Translation Center
John Crerar Library
35 West 33rd Street
Chicago, Ill. 60616

Sincerely,

Julia S. Merrill

JULIA MERRILL
Translations Officer