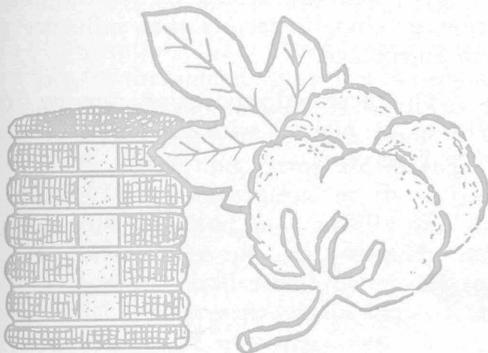


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the Effects of Certain

PRECISION PRACTICES

on the Efficiency
of Cotton Production

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SUMMARY

A careful evaluation of the conventional system of field crop production indicates that a tremendous potential for increasing production efficiency exists by overcoming or minimizing the following deficiencies:

(1) Normal yields are less than 70 percent of the potential yield in many fields because of variations in production among individual rows and areas within the fields.

(2) More than 50 percent of the plants in a typical cotton field will bear less than 25 percent of the total yield.

(3) Non-uniform growth and plant development, particularly during the early part of the season, reduce the effectiveness and efficiency of many of the cultural operations.

(4) The overall efficiency of the harvesting operation is reduced by the non-uniform rate of maturity among the plants along the rows and among the rows which will either result in a delayed harvest for the major portion of the fruit or the harvest of a high moisture product.

Investigations and analysis of present production procedures indicate that many of the factors that influence the variables can be related directly to the performance and operational characteristics of machine components. The lack of a means of maintaining precise control over the movements and operational characteristics of the principal soil-working components is one of the basic problems. Nonuniformity of seed placement combined with the micro-environments to which the seed are exposed during the germination and emergence periods are principal factors contributing to variability in emergence, growth, maturity and yields.

Department of Agricultural Engineering field experiments have shown that it is feasible to establish and maintain precision control surfaces that can be used by properly designed sensing and controlling devices to maintain precise control over the movements of the implements in the vertical and horizontal planes. The following operational characteristics of the machine components and equipment indicate increases in efficiency and effectiveness that can be achieved:

(1) From 50 to 100 percent reduction in soil movement in field operations with an overall increase in efficiency and effectiveness of soil working tools.

(2) More precise control over seed placement in the vertical and lateral planes within the intended seed zone.

(3) Significant increase in speed and capacity.

(4) Significant reduction in power requirements.

(5) Establishment and maintenance of more favorable environmental conditions required for germination and growth of the planted crop.

Crop response to the new approach has been indicated by the following:

(1) Increased uniformity in rate of emergence.

(2) Increased total emergence.

(3) Increased rate and uniformity of growth and maturity.

(4) Reduced sensitivity of the planting operation to climatic factors that influence germination and emergence.

(5) Increased production, ranging from 13.8 percent to 44 percent with an overall average increase of 28.2 percent.

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MECHANIZED EQUIPMENT HAS PLAYED a major role in achieving the high degree of efficiency which is now realized in field crop production. The most obvious contribution of mechanization to the overall efficiency has been the dramatic reduction of labor requirements. Practically all phases of crop production have been mechanized. That is, most of the functions formerly performed by hand labor and animal-powered equipment are now being accomplished with high-capacity motorized equipment and chemicals.

Since most operations have been mechanized, the obvious trends for the immediate future to combat the steadily rising cost of labor will be in the development and use of larger equipment with higher capacities. Unless the fields and farms are sufficient in size to permit efficient operation of the larger units, additional cost involved may nullify the intended savings. The success of past research and developments has greatly diminished potentials for increasing the efficiency of present production systems through the development of new machines.

This bulletin reports research developments of the Department of Agricultural Engineering at A&M on a fresh approach to field crop production. Cotton has been used as the principal test crop. However, the system should be adaptable to most major field crops. The intensive investigation and analysis of the conventional production system defines and illustrates some of the major recurring problems in using machines.

The new approach is based on the principle that a machine is limited in its performance only by the skill of the operator or the control plane which it is designed to follow, regardless of the refinement or precision encompassed in the machine. The manufacturing industry has been successful in revolutionizing many of the production systems by applying this principle. In most cases, where the process has been automated with a machine following a precision reference plane or pattern, the quality and the quantity of the products are normally superior to those produced with similar equipment controlled and operated by skilled labor. In order for the machines to operate effectively as independent units, some type of guidance or control mechanism must be established—such as a reference plane, track, program or template. A high degree of precision must be incorporated in the control mechanism,

Lambert H. Wilkes and Price Hobgood*

which in turn, determines the uniformity and accuracy of the machine.

Research in the Brazos River Valley near College Station has dealt with the establishment and maintenance of precision control surfaces for use in field operations. Implements have been developed to utilize the potentials this approach offers. Control surfaces have been highly effective in providing precise control over critical movements in the vertical and lateral planes. In addition to the precision that has been obtained, a significant increase in crop productivity has resulted.

ANALYSIS OF THE CONVENTIONAL PRODUCTION SYSTEM

A critical examination of the current production system reveals that most of the practices and equipment have evolved from those employed when animals were used as the chief source of power. Land preparation, planting and cultivation procedures and equipment are basically the same. Much of the human energy and all of the animal power have been replaced with mechanical energy. Equipment and procedures have been modified to function at higher speeds, which modern tractors can obtain. Larger power units have also made it possible, in many instances, to combine several functions into one operation.

In mechanizing field crop production, many of the machines have retained their basic operating principles. During the era of animal power, the operator was responsible for the performance of a single unit. As more power has become available, his responsibility has increased, according to the number of rows the power unit can handle. These responsibilities add to those required in operating the tractor or power unit.

In field operations, there are two distinct planes in which the movements of the implements are involved. These include the vertical and horizontal planes. The effectiveness of most functions of

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machines depends on the machine components being held at a relative and constant position in the two planes to a selected reference while in operation. Normal references used in field operations include the soil surface, prepared furrows or seedbeds and the planted crop.

The lateral position of the machine components in the horizontal plane depends entirely upon the operator's skill while the equipment is moving. Previously prepared furrows or ridges and the planted crop are normally used as the reference by the operator to steer the tractor. Individual row components in a multiple-row machine are mounted in fixed positions laterally along tool bars, which the tractor supports. This arrangement causes the entire machine to function as a rigid unit in the horizontal plane. The effectiveness of practically all operations—including cultivation, flaming, chemical and fertilizer applications and harvesting—depends upon the operator to maintain the operating component of the machine in a fixed position relative to the crop. In many cases, the effectiveness and resulting efficiency of field operations can be increased by maintaining closer tolerances than most operators can maintain.

Position of the machine components in the vertical plane is normally maintained at a selected distance from the soil surface. Position of the components, with respect to depth of penetration or height above the surface, is normally sensed and controlled through the tractor wheels, gage wheels on tool bars or small gage wheels on individual row components. Precise control over the relative position is also important in all cultural practices, including cultivating, chemical and fertilizer applications and harvesting. Although the principles of sensing and controlling the vertical movements of the components are sound,



Figure 1. These are lister-formed seedbeds before planting. Typical variations in sizes and shapes among the rows, along with the rough, irregular surface, prevent using precision planting and production techniques.

conventional land preparation and cultural practices do not permit effective use of the system. In many field operations, such as with sweep cultivators, variations of surface profiles make it necessary to select and use greater penetration depths than normally required. This is to insure that the components are effective in all parts of the field.

Rate of travel is also a major factor in the efficiency and effectiveness of the machines. Speed is critical in operations where chemical, seed and fertilizer applications are involved. Travel speed also affects the effectiveness of the tillage implements, such as the cultivator. Most tractors are equipped with adequate governing systems to maintain speeds the operator selects. One of the principal factors that determines the selected speed is the operator's ability and skill.

Land Preparation

Field crops in the humid areas of Texas are normally planted on raised seedbeds to provide drainage away from the seed in case of excessive rains after planting. This method is generally referred to as "bed planting." The seedbeds are formed with listers or row disks several months before planting, so that the normal spring rainfall will provide sufficient moisture in the soil for germination and emergence. Although the listed beds have been satisfactory in providing the desired environment for the planted seed, profiles of most seedbeds cannot be used effectively as control planes for implements. A typical field which has been prepared for planting is shown in Figure 1. The beds appear to be relatively uniform in shape and size. However, measurements taken at random locations in a typical field have shown that cross-sectional dimensions, including height and width, may vary as much as 50 percent. These dimensions along a single row have been found to vary as much as 4 to 6 inches in different sections of a field. These irregularities are often further aggravated by tillage operations for controlling weeds that occur on the beds before planting. Although the uniformity of the profiles may be improved by operating the bedding equipment more carefully, the rounded profile and the loose soil on the surface have not satisfactorily provided the precision needed in most operations.

Planting

A typical planter, which has been used extensively for planting on the listed beds, appears in Figure 2. Most of the planters used in multiple row machines are suspended through flexible linkages from tool bars attached to the tractor. A large wheel on each planter operates on the convex surface of the beds and helps control vertical movements of the individual planters. Immediately behind the gauge wheel is a wide sweep, which removes loose, dry soil from the crest of the beds and establishes a new and lower elevation and profile.

Because of nonuniformity of the bed profiles,

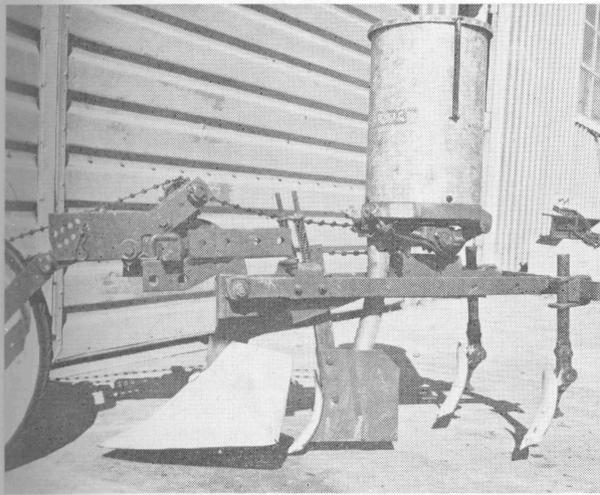


Figure 2. The conventional row-crop planter used for planting on listed seedbeds uses a large sweep to remove loose dry soil from the crest of the listed beds. Amount of soil removed by the sweep is determined by the depth of moist soil required for germination and emergence of the planted seed. A chisel type furrow opener forms the seed trench. Chisel covering shovels provide the moist covering soil.

the depth to moist soil from the surface varies considerably. Since it is not practical to compensate for the varying depths of dry soils, maximum depths are usually selected so that all seed are placed in moist soil. This removes more soil than necessary in most areas of the field and causes principal components of the planter, including the furrow opener and covering device, to operate in high moisture soil.

Planting depth is determined from the new surface the sweep establishes. The furrow opener is adjusted to the desired planting depth and is secured in a fixed position relative to the sweep. Small chisels operating on each side of the seed furrow provide moist covering soil for the seed.

Several problems related to seed placement in the soil have not been solved in the mechanization process. Although some improvements have been obtained with other devices for forming the seed furrow in the conventional planting system, these have not been great enough to overcome the practical aspects of the chisel type opener. As with most tillage implements, moisture content and soil type severely affect the performance of the opener. Scouring in wet and sticky soils is the most difficult problem with all openers. It is difficult to form a clearly defined seed trench. Measurements taken at random locations within a field have shown that the cross-sectional dimensions of a seed furrow are often 50 to 75 percent greater than the opener.

An intensive study of seed furrows created by the conventional planting system has shown immense variation in seed distribution and in the resulting environment to which the seed are exposed. In addition to the scatter within the planting zone, the distance of this zone to the surface of the covering soil (effective planting depth) has varied as much as

1 inch in different areas of the field. Bulk density of the soil in the seed zone, which has been used to indicate intimacy of contact between the soil and seed, has varied as much as 78 percent. Soil temperatures to which the seed are exposed are also an apparent variable that causes nonuniform emergence. Seed scatter in the vertical plane, coupled with variable depths of the seed zone along the row, results in the seed depth range of 1 to 3 inches. Temperatures may vary as much as 1° F. to 3° F. between the two depths. Soil samples in the seed zone have shown that moisture content of the soil has been relatively uniform and apparently is not a critical factor in the conventional planting system.

Large press wheels usually compact the surface of the beds after planting. Compacting the covering soil retards the drying rate and improves to some extent the soil-to-seed relationship. Extra large drum-type rollers are also used in some instances to improve the surface profile of the beds to help subsequent cultural operations.

Post-emergence Operations

Many cultural operations depend on the success of the planting operation and surface profiles. Most common to all crops is mechanical cultivation. Other practices include application of herbicide, flame, fertilizers and insecticides. For maximum effectiveness in most of these operations, a high degree of control should be exercised. Many of the herbicides are applied as directed sprays to minimize possible crop damage. The same principle applies to the use of flame cultivation to control weeds among crop plants along the drill. The maximum potential and extensive use of many of the new practices have been handicapped by the lack of uniform surfaces, Figure 3.



Figure 3. Non-uniformity of the listed seedbeds, combined with the lack of a suitable means of controlling the vertical and lateral movements of the planters, results in extremely irregular row profiles. The effectiveness of early-season cultivation is severely reduced because it is difficult to select an ideal setting of the cultivators to compensate for the variations in profiles among the rows.

The only practical means of accomplishing the post-planting operations in a field without uniform surfaces is to rely on the operator's skill. Speed and effectiveness of the operation are severely affected while the plants are small. Where the row profiles have been destroyed, elevated sections of the rows are normally reconstructed by gradually moving the soil to the base of the plants with cultivating implements. In most areas a depressed area between the rows for channeling irrigation water and for drainage, in case of excessive rains, is needed.

Crop Response

Difficulty in maintaining positive control over the functions of conventional production machines often relates to the uniformity of emergence of plants, rate of growth, maturity and production among individual rows and plants within a field. Variations in plant emergence among consecutive rows that often occur are shown in Figure 4. Rows from which the emergence data were obtained were planted with a four-row machine. The two areas were selected in the field along the same rows to illustrate how the performance of planters may vary in different sections of the field. Usually, no established pattern of variability exists among the rows. This makes it difficult to detect the exact causes.

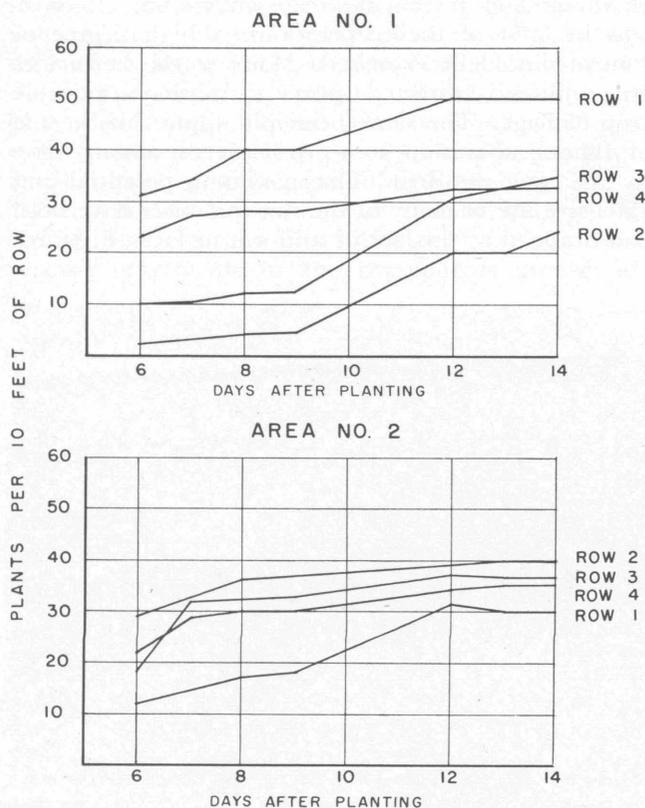


Figure 4. Variations in the performance of conventional planters is illustrated by plant emergence patterns. The data were taken from the same four rows in two areas of a field. These variations stem basically from the performance of the opening and covering devices, which the moisture content and soil type influence.

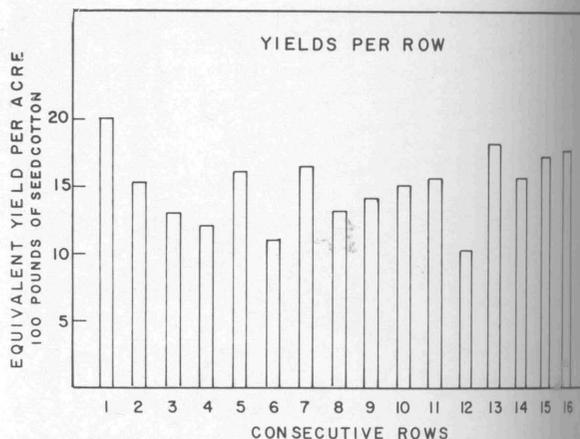


Figure 5. Graph shows typical variations in yields among rows of cotton. The difference in maximum and minimum yields has varied as much as 100 percent. Variations are attributed to uniformity of emergence and final stands in different sections of the row. These data indicate that the potential yields could be increased by approximately 35 percent by obtaining uniform production among the rows.

Yield data from individual rows also reflect a significant variation in equipment performance. Cotton yields obtained from consecutive rows, Figure 5, have shown that production from the rows may vary as much as 100 percent in some areas of the field. Difference in yield is partly because of variation in plant populations along the row.

Another important variable measured in cotton fields is the productivity range among the plants. Other factors, in addition to planting and production practices, could influence the plant growth and fruiting habits. The productivity range among plants determined by the number of bolls per plant in a typical cotton field is shown in Figure 6. As many as 7.4

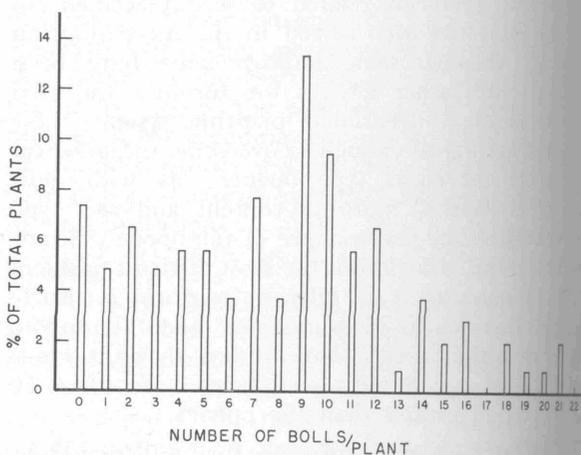


Figure 6. Productivity among cotton plants varies significantly within a given stand or field. Variations do not appear to be related to varietal characteristics, since similar trends have been recorded in several cotton varieties. Plants that produced eight bolls or less represented approximately 50 percent of the total population. The yield from this portion of the stand represented only 24 percent of the total.

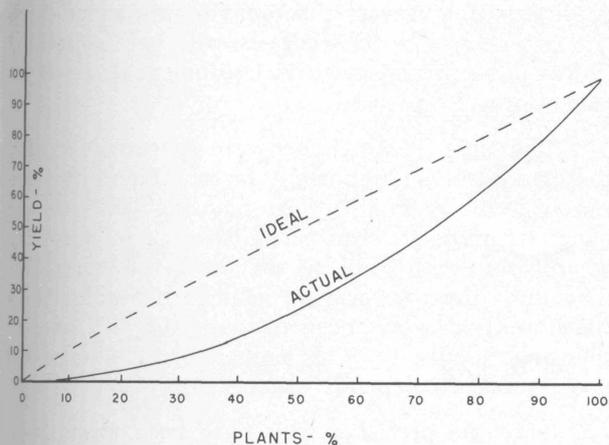


Figure 7. Percent of yield, as distributed among the plants under actual field conditions, contrasts with an ideal stand, in which total yield is distributed uniformly among the plants.

percent of the plants produced no fruit at all. Plants that produced eight bolls or less represented 49.9 percent of the total plants. However, the yield from this portion of the stand represented only 23.8 percent of the total yield. Actual distribution of the total yield among the plants is contrasted to an ideal stand in which the yield is distributed uniformly among the plants in Figure 7. Identifying factors that cause the low or non-productive plants, which would either improve the productive capacity or be eliminated in the seed stage before planting, has a tremendous potential for increasing production efficiency. It should be emphasized that the low producing plants, as well as the low producing area of the field, received the same cultural treatments during the production season as the more productive plants and areas.

DEVELOPMENT AND CONSTRUCTION OF PRECISION CONTROL SURFACES

The initial phase of this research was for obtaining more precise control over the planting depth. As the research progressed, approaches and techniques used in obtaining precision in the planting were also adapted to other cultural operations.

In developing an overall system, special consideration was given to the following objectives: (1) developing and maintaining uniform surfaces to control vertical and lateral movements of the implements; (2) developing control surfaces which exhibit the precision that is expected and required by machines utilizing the surface; and (3) developing row profiles which provide the environment required for germination, emergence and growth of planted crops in humid areas.

The fields in which this research was conducted had been prepared with listed beds formed in the conventional manner. Several methods and machines were used in the initial stages of the research to establish a flat, smooth surface on the crest of the

listed beds. Equipment included drum-type roller, bed planes (drags) and conditioners. In some fields with uniform listed beds, using bed conditioners followed by the drum-type rollers provided a satisfactory surface on the beds for adapting precise planting techniques, when compared with conventional planting equipment and practices. Although flat surfaces formed this way were satisfactory in some instances for controlling planting depth, the beds did not provide suitable surfaces which could be used for controlling lateral movements of the planter and other implements.

Forming Precision Shaped Seedbeds

The most effective control surfaces were obtained with precision formed or shaped seedbeds. The Department of Agricultural Engineering designed a bedshaper, Figure 8, for listed beds in the humid areas. This was because commercial shapers were not available in the area. "Bedshaping" has been associated with a wide variety of bed-forming equipment. However, in this research, it refers to forming seedbeds with precise dimensions in the horizontal and vertical planes. The implement used in forming the beds is basically a leveling and molding device, which creates the desired profiles with smooth surfaces. Forward components of the shaper accumulate soil from the high points along the sides and tops of the listed beds. Soil which is accumulated is then deposited in the low sections along the row, establishing beds with uniform profiles throughout the field.

Several operational characteristics to be considered for successfully using this equipment in soils in the humid areas have been established. Listed



Figure 8. The two-row precision bedshaper was designed and built at A&M. Four-row shapers have been constructed and used in a wide variety of soil types. A dry soil mulch is necessary in the heavy clay soils to prevent moist soil from coming in contact with the shaper.

beds must be relatively uniform in height and shape. The shaper can compensate for variations of 3 to 4 inches in height and width for distances 10 to 15 feet along the row. One of the principal problems encountered was scouring in heavy soils. Using drum rollers in heavy soils immediately ahead of the shaper to reduce the bed height reduced this problem in most cases. The generation of a loose, dry soil mulch over the listed beds with mechanical equipment has been necessary in some fields to reduce the scouring problem and to help operate the shaper properly. A way to adjust the pitch or attitude at which a shaper is operated must be available, since this feature can be critical in moist soils. Adjusting the top link in a standard three-point hitch system was suitable.

Design of the shaper determines desired shapes of the row profiles, including height, width and slopes of the beds. Much experimentation with various configurations showed that most listed beds contained sufficient soil to form a bed 4 to 5 inches high and 20 inches wide. The 20-inch horizontal surface has been adequate for maintaining precise control over the movements of the implements in the vertical plane during planting and other production operations. Height of the precision beds was adequate for maintaining lateral stability of the production implements.

Precision shaped seedbeds have been formed with the A&M bedshaper in several soil types, including Lufkin Fine Sandy Loam near College Station; the Miller Clay and Norwood Silt Loam in the Brazos River Valley; and the Houston Clay in the Blackland areas of Texas. The beds have been highly effective in providing the desired control surfaces for planting and the various cultural operations. It should be

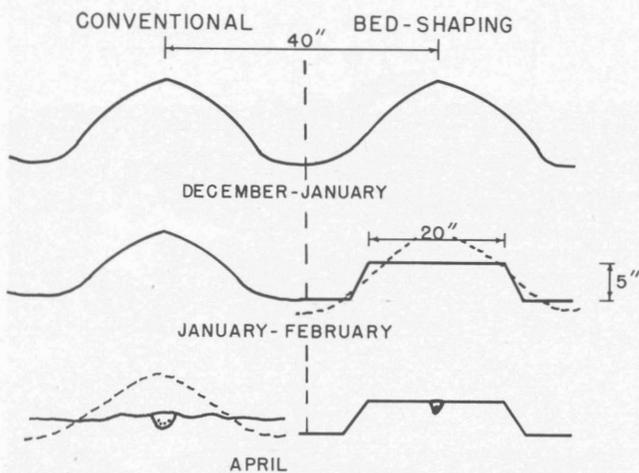


Figure 9. The conventional planting system is compared schematically with the precision system. Research shows that the beds should be shaped in enough time before planting, so that normal rains will provide the moisture required for planting. Moisture must be available at a uniform depth from the surface at planting time. A precision depth planter should be used on the shaped bed to realize the maximum potentials of the system.

emphasized, however, that maximum potentials of the precision shaped seedbeds will not be realized unless planters and cultural equipment designed for this approach are used.

The time at which beds are shaped in relation to planting is an important factor. Equipment employed to maintain a uniform planting depth requires adequate moisture for germination and emergence at uniform depth from the surface of the shaped bed. The most practical way to achieve this objective in the humid areas has been to shape the beds prior to planting, Figure 9. The time interval between the two operations depends upon the expected rainfall.

Once the precision beds have been formed, soil in the intended seed zone should not be disturbed. Preplant weed control should be accomplished with soil-incorporated herbicides, flaming or herbicidal oils. The firm, undisturbed surface must support the planters and provide positive control over the planting depth. The dry surface also minimizes the scouring problem with the furrow openers, enabling the openers to form a precision shaped seed furrow.

Precision-depth Planting

The need for greater precision in planting has been demonstrated in some basic studies, which involved the effects of certain micro-environmental factors upon germination and emergence of planted seed. These factors include soil temperature, moisture and intimacy of contact between the seed and soil. The principal problem in these studies has been relating laboratory findings to field results because of varied conditions that often occur among the rows, as well as along a given row, in different field sections.

This research has chiefly tried to obtain greater precision in seed placement in lateral and vertical planes of the seed zone. No efforts have been devoted to longitudinal seed placement, since ungraded commercial seed were used in the research.

A planter was designed and constructed to utilize the top surface of the precision-shaped beds as the reference plane to maintain precise control over the penetration depth of the furrow opener, Figure 10. Two semi-pneumatic gauge wheels were selected as the depth control mechanism. Gauge wheels were placed as close to the opener as practical for immediate response to surface variations.

The seed furrow opener is the most vital component of the planter. After the seed have been metered from planter hoppers, they are allowed to free-fall into the soil. The shape or configuration of the furrow is, therefore, the chief factor that controls lateral and vertical seed displacement in the intended placement zone. Field evaluations with several types of openers show that the design of the opener, along with its ability to scour in moist soils, are the principal factors that govern the furrow shape.

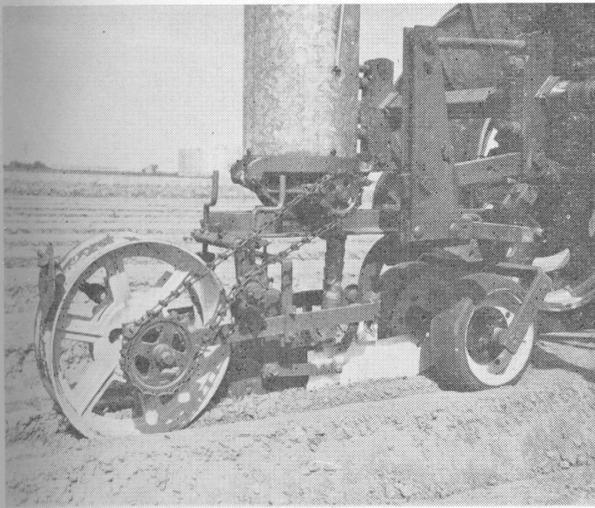


Figure 10. A precision-depth planter was designed and constructed for precision-shaped seedbeds. Only the furrow opener penetrates or disturbs the soil. Penetration depth is controlled by gauge wheels adjacent to the modified runner opener. A seed press wheel may be used to press the seed into the moist soil to improve the relationship between the soil and the seed. An open-center press wheel is used to cover the seed. A piece of abrasion resistant plastic on the trailing edge prevents moist clay soils from sticking to the opener.

Relative effectiveness of three types of openers in forming seed furrows on precision shaped beds are illustrated in Figure 11 by resulting seed distribution patterns. Furrows formed by the standard chisel opener resulted in only 33.3 percent of the seed deposited in the desired zone. The double disk opener provided good seed control in the vertical

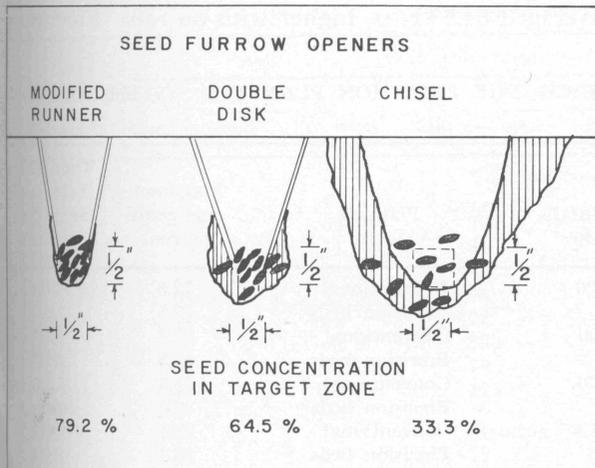


Figure 11. Design and operational characteristics of seed furrow openers in various soil types are principal factors that determine seed distribution in the horizontal and vertical planes in the seed furrow. When operating on pre-shaped seedbeds, the modified runner opener gave the highest seed concentration within the intended planting zone. Poorest concentration was obtained with the chisel opener. Field emergence of cotton reflected little differences between the modified opener and the disk openers, even though the seed were scattered more in the lateral plane.

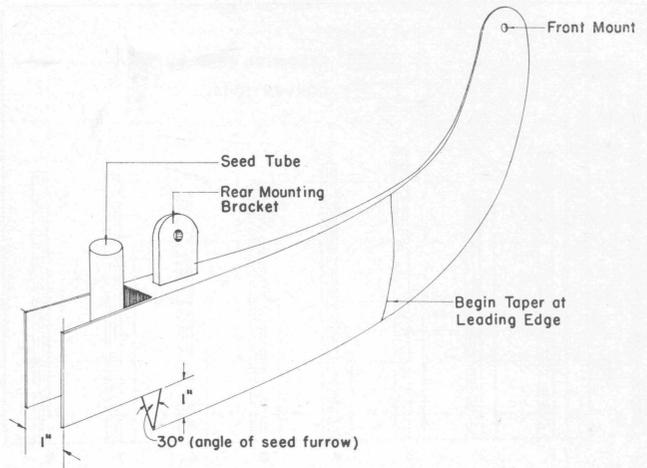


Figure 12. Diagram illustrates principal construction features of the modified, runner-type furrow opener. The shape of the opener was designed to act as a sliding wedge to minimize soil disturbance and to form a firm "V"-shaped trench. The point of the wedge started at the leading edge of the opener and expanded gradually to the trailing edge.

plane. The seed, however, were scattered over a 1-inch lateral span. Approximately 65 percent of the seed were located in the intended zone. The highest degree of uniformity was obtained with the modified runner opener. Approximately 80 percent of the seed were concentrated in a cross sectional area of $\frac{1}{2}$ inch square. The modified opener, Figure 12, moves like a sliding wedge in the soil, forming a "V"-shaped furrow. An open center press wheel easily closes the furrow after the seed have been deposited. Seed press wheels pressed the soil around the seed to retard the loss of moisture and obtain positive contact between the soil and seed. This attachment was used effectively with the modified and double disk furrow openers. It was not effective with the chisel opener.

Evaluations of Planting Methods

The precision-depth planting system has been evaluated in field experiments to test procedures and equipment against the principal variables that normally affect the performance of the equipment and crop being planted. Variables included soil types, soil temperatures and rainfall following planting. In each field experiment, the conventional planting system was included for comparison. Such factors as seeding rate, seed quality and variety, planting depth and operating speed were the same for the two planting methods. Performance of the planted crop has been used as the main indicator to evaluate the planting system. Measurements of micro-environmental conditions in the seed zone were made where feasible.

Emergence

Plant counts were made at periodic intervals during the emergence period to evaluate effects of

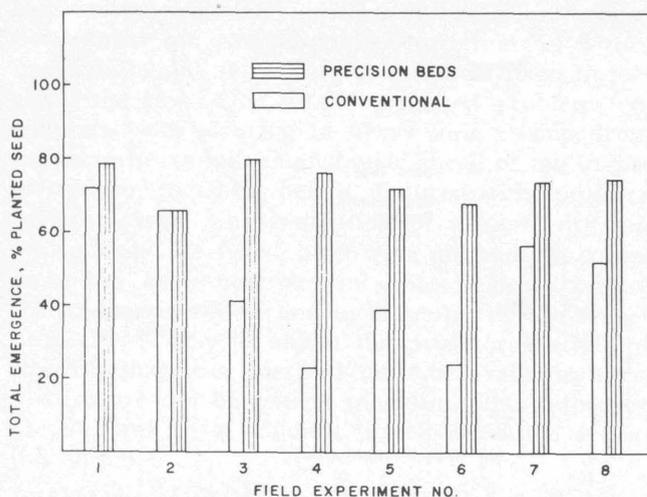


Figure 13. Effects of planting methods on total emergence of cotton are shown. Soil types, minimum soil temperatures and rainfall conditions encountered in each experiment are summarized in Table 1. Overall average emergence was 74.4 percent for cotton planted on precision beds with the precision depth planter, as compared with 46 percent with the conventional planter.

planting methods on rates of emergence and total emergence. Plant emergence data have been expressed as percent of planted seed. Effects of the two planting systems on maximum plant emergence in eight of the field experiments are given in Table 1 and presented graphically in Figure 13. Principal variables, including soil types, minimum soil temperatures and rainfall, during the emergence period for each of the experiments are given, Table 1. Typical emergence patterns obtained with the two planting systems under different climatic conditions are illustrated in Figures 14 and 15. Maximum plant emergence obtained with the conventional planting system

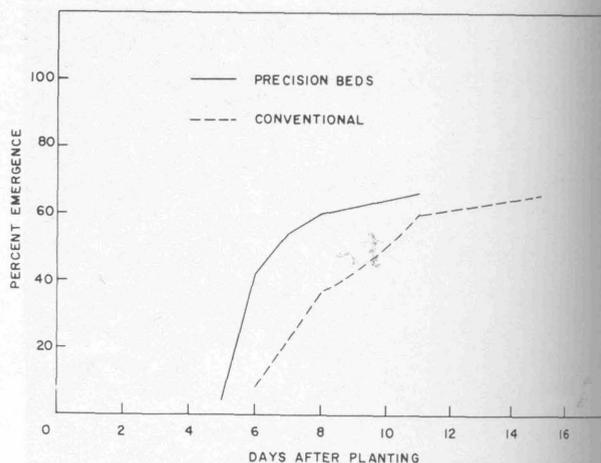


Figure 14. Graph shows emergence rate of cotton as affected by the two planting systems when the average of the daily minimum temperatures at seed depth was 64.5° F. with no rain during the germination emergence period. Although total emergence was equal, the emergence rate was greater in the pre-shaped precision beds.

ranged from 23.4 percent to 72.6 percent. Under the same climatic conditions and soil types, maximum emergence ranged from 67.3 percent to 80 percent with the precision-depth planter on shaped beds. Overall average emergence of the eight plantings was 46 percent of the planted seed with the conventional planter, as compared with 74.4 percent for the precision planting system. The greatest differences between the two systems were obtained in the experiments where low soil temperatures and rain occurred during the emergence period. Total emergence data reflected little differences between planting methods where the minimum soil temperature averaged 64.5° F. or higher with no rain. Emergence

TABLE 1. A SUMMARY OF THE FIELD EXPERIMENT IN WHICH THE PRECISION PLANTING SYSTEM WAS COMPARED WITH THE CONVENTIONAL PLANTING SYSTEM

Field experiment no.	Year	Soil type	Soil temperature °F ¹	Rainfall inches ²	Planting system	Maximum emergence percent	Total Yields Pounds of seedcotton per acre
1	1964	Norwood Silt Loam	66.4	.00	Conventional	72.6	913
					Precision beds	79.3	1200
2	1965	Norwood Silt Loam	63.5	.00	Conventional	67.8	2986
					Precision beds	67.3	3400
3	1966	Norwood Silt Loam	58.2	.76	Conventional	41.3	1225
					Precision beds	80.0	1550
4	1966	Norwood Silt Loam	59.4	4.12	Conventional	23.4	1535
					Precision beds	78.4	2024
5	1966	Miller Clay	58.2	.75	Conventional	39.0	1475
					Precision beds	72.4	2135
6	1966	Houston Clay		1.25	Conventional	24.2	
					Precision beds	68.4	
7	1967	Norwood Silt Loam	61.2	.45	Conventional	57.2	1220
					Precision beds	74.5	1685
8	1967	Miller Clay	62.5	.55	Conventional	52.5	
					Precision beds	74.7	

¹Average of the minimum daily soil temperature at 2-inch depth during the germination and emergence period.

²Total rainfall during the first 5 days after planting.

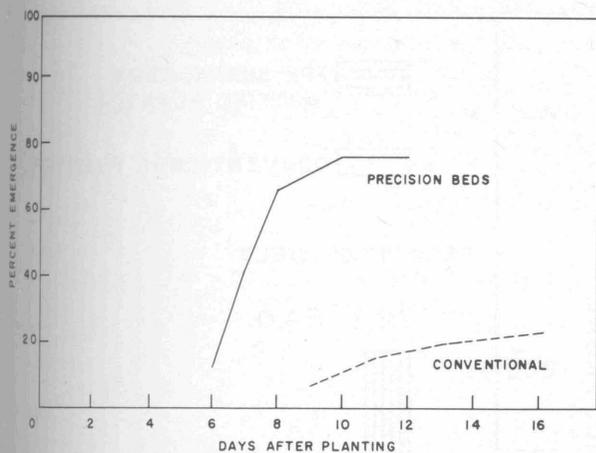


Figure 15. Emergence rate of cotton appears as affected by the two planting systems, when minimum daily soil temperatures averaged 62° F. during the emergence period. Total rainfall was approximately 3 inches during the germination period. Soil crusting caused significant reduction in rates and total emergence of cotton planted with the conventional planter.

rates were faster, however, with the precision system in all experiments, even under favorable climatic conditions.

Soil Temperature

Increased effectiveness of the new planting system is attributed to the improved micro-environmental conditions into which the seed were introduced. Precise control over the vertical movement of the seed furrow opener results in uniform planting depth. This, combined with the high seed concentration

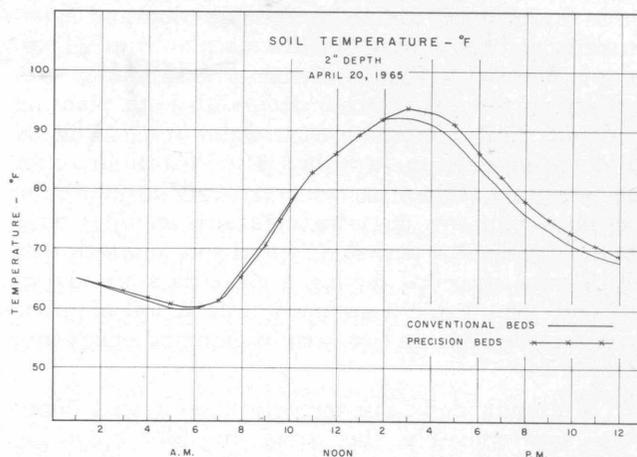


Figure 16. Soil temperatures were recorded on an hourly basis at the 2-inch depth in the conventional and precision seedbeds after planting. Temperatures indicated that a greater amount of radiant energy was absorbed and retained in the precision shaped beds, when compared with the conventional beds.

within the planting zone, as in Figure 11, exposes more seed to the same micro-environment within the seed furrow. The precision seed trench also permits more intimate contact between the seed and soil, which, in turn, increases the absorption rate of heat and moisture.

The increase in radiant energy absorbed by soil in precision beds, as compared with conventional beds, has been a major factor in the effectiveness of the new planting system when soil temperatures are a limiting factor. Soil temperature records were kept

TABLE 2. SOIL TEMPERATURES DURING TWO 8-DAY PERIODS RECORDED IN THE CONVENTIONAL AND PRECISION BEDS DURING THE 1965 PLANTING SEASON IN THE BRAZOS RIVER VALLEY

Date	Soil temperatures — °F — 2-inch depth							
	Minimum		Maximum		Average ¹		Degree-Hours Per Day ²	
	Conventional	Precision	Conventional	Precision	Conventional	Precision	Conventional	Precision
Planting No. 1. March 27, 1965								
March 27	47	45	71	75	59.0	60.1	27	55
March 28	62	62	79	84	67.5	69.0	94	131
March 29	55	54	81	86	66.3	67.1	115	148
March 30	56	55	80	84	65.5	66.4	86	116
March 31	54	55	78	81	65.5	66.0	101	118
April 1	64	64	72	74	67.5	68.3	66	86
April 2	66	66	69	70	67.1	67.5	52	60
April 3	66	66	79	82	71.5	72.3	150	169
AVERAGES	58.8	58.3	76.1	79.5	66.2	67.1	86.4	110.4
Planting No. 2. April 16, 1965								
April 16	61	63	75	76	67.4	68.3	72	84
April 17	64	64	86	86	72.0	72.2	170	174
April 18	67	67	87	89	75.9	76.9	162	285
April 19	70	71	85	87	75.6	76.9	254	285
April 20	71	72	83	85	75.9	77.4	262	297
April 21	72	72	81	83	75.4	76.7	249	281
April 22	72	72	86	89	77.4	78.7	297	333
April 23	72	72	92	95	79.9	81.9	359	406
AVERAGES	68.7	69.1	84.4	86.6	74.9	76.1	241	268

¹Average of hourly temperatures during 24-hour day.

²Degree-hours represent number of degrees above 65° F. accumulated each hour during the 24-hour period.

on an hourly basis during the germination and emergence period for several small scale plantings. Thermocouples used as sensing elements were placed with the seed in the soil 2 inches deep with both planting methods. Soil temperature records were normally valid for periods up to 8 days after planting. After the seedlings began to emerge, soil around the thermocouples was disturbed. Erratic readings were obtained after this period. Typical soil temperatures, which were recorded during a clear day, are shown in Figure 16. Table 2 summarizes daily soil temperatures recorded during two germination and emergence periods.

Minimum daily soil temperatures at seed depth were approximately the same in both planting methods. Maximum temperatures at seed depth, however, ranged from 1.4° F. higher in the precision bed. The average of the daily maximum temperatures for the first planting, Table 2, was 3.4° F. higher in the shaped beds than in the conventional seedbeds. In the later planting with higher daily temperatures, the difference was 2.2° F. Additional heat energy absorbed by the shaped beds was retained and resulted in a temperature differential of 1.4° F. for periods up to 10 hours per day. Heat energy accumulated each day in the seed zones is expressed in degree-hours in Table 2. The degree-hour system of indicating differences in heat energy absorbed in the seed zones reflects differences in temperatures and the time in which higher temperatures occurred. Values are determined by accumulating total number of degrees each hour that the temperature was above 65° F. An overall average of 26.5 more degree-hours were accumulated per 24-hour day in the precision beds than in the conventional beds, Table 2.

Further evidence of crop response to the precision system of production has been indicated in the rate of plant growth, root development and rate of maturity and yields. Differences in plant growth rates are usually quite apparent in the first 30 to 45 days after planting, Figure 17. Plant measurements on two



Figure 17. Difference in rate and uniformity of cotton growth experienced in several plantings is evident. Cotton on the left was planted in shaped beds. That on the right was planted in conventional beds. The test was in the Blackland area near Thrall.

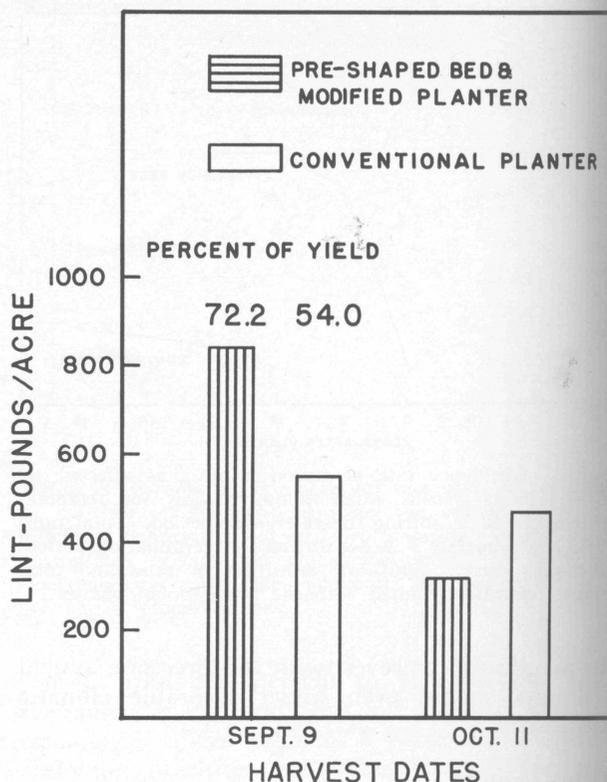


Figure 18. An increase in the maturity rate has been obtained with the precision planting system, as reflected by the percentage of the total yield harvested in the first mechanical picking. These data were taken from the planting made in experiment No. 2 in Table 1. Eight hundred and twenty-five pounds of lint cotton, representing 72 percent of the total yield, was open at the first harvest in the precision planted plots, as compared with only 550 pounds representing 54 percent of the total yield in the conventionally-grown cotton.

of the plantings have shown that the average plant heights on the precision seedbed were 25 to 35 percent greater than the plants which emerged in the conventional system. Final plant heights at harvest have been approximately equal. In some of the experiments, the increase in rate of plant development has been reflected in maturity rate of cotton, Figure 18.

In 1967, cotton plants from both planting methods were extracted by hand from adjacent rows in four replicated blocks. The soil was Norwood Silt Loam. Tap root length was measured from the point of soil contact on the stems to where the roots broke when pulled from the soil. Average length of the main roots on the plants from the plots on the precision beds was 9.12 inches, as compared with 7.82 inches for plants grown in the conventional production system. Besides difference in root length, 55 percent of the roots from the conventionally-produced cotton had some deformity. Only 17 percent of the plants from the precision beds had similar deformed tap roots. The malformed roots consisted of severely twisted roots, abrupt changes in direction of growth and plants which had no main tap roots.

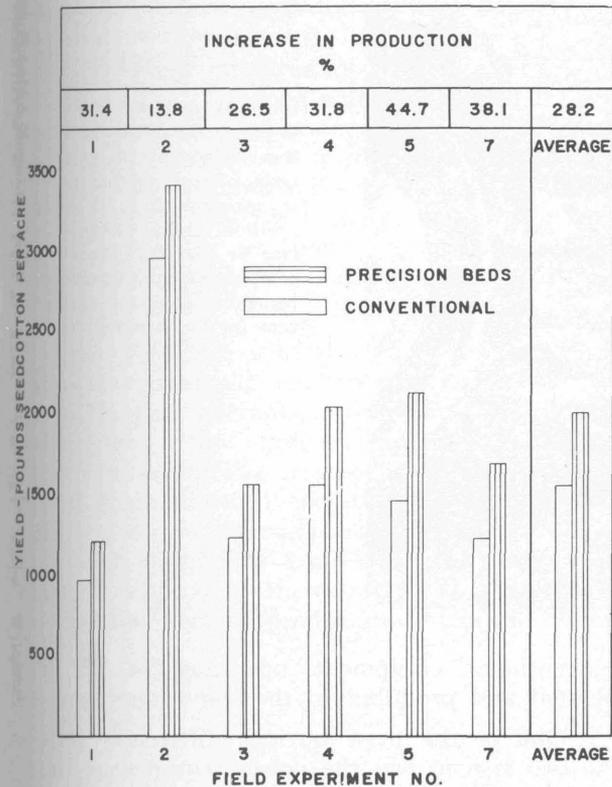


Figure 19. Cotton yields were obtained with the two planting systems for six experiments. Increase in yields obtained in the precision planted system over the conventional system ranged from 13.8 to 44.7 percent.

Yields were obtained from six of the eight field experiments, in which the two planting systems have been compared. These data are given in Table 1 and presented graphically in Figure 19. Yield increase of cotton planted in the precision beds with the precision-depth planter ranged from 13.8 percent to 44.7 percent with an overall increase of 28.2 percent. Yield increases were attributed primarily to stand uniformity established along and among the rows. A typical comparison of yields from individual rows between the two planting systems is shown in Figure 20. In other experiments, variation among consecutive rows in the conventional system have varied as much as 72 percent, as compared with 11 percent in the new planting system.

CULTIVATION AND OTHER CULTURAL PRACTICES

Precision shaped seedbeds, which were used to obtain greater precision in seed placement in the soil, can also be used effectively for control planes in several production operations. Horizontal surfaces on the crest of the beds, as well as in the furrows, have been used as the control plane for vertical movements. Slanting vertical surfaces on the sides have been used effectively as control planes for lateral movements. Both gauge wheels and sliding skids have been used effectively on the horizontal surfaces as control mechanisms for the vertical movements.

The basic machine consists of a multiple tool bar arrangement, from which the various implements and tools are suspended. The height of the tool bars can be adjusted in relation to the controlling mechanism to accommodate the crop and the tools. Sled-type runners, as controlling mechanisms, have maintained the selected vertical position of the tool bars in relation to the soil surface while operating. They also support the machine weight. Because of the weight, the horizontal surfaces of the furrows between the shaped beds have provided the most effective reference plane for movements in the vertical plane.

Required lateral movements of the machines were controlled with cone-shaped guide wheels, Figure 21. The convex surface of the wheels, operating against the sides of the shaped beds, senses the changes in the direction of rows. The wheels, which are fixed in a rigid position to the tool bars, cause the entire machine to shift laterally in the required direction.

Field evaluations with this approach for maintaining control over the critical lateral and vertical movements of the machine have shown that the tool carrier must be completely independent of any tractor movements, except for the required draft in the longitudinal plane. Machine components are interconnected to where the entire machine performs as an independent rigid unit. In these evaluations, the standard three-point-hitch system without the stabilizer linkage satisfactorily provided the required free movement for normal operations.

Four cultivations have been made during a single growing season with the machine shown in

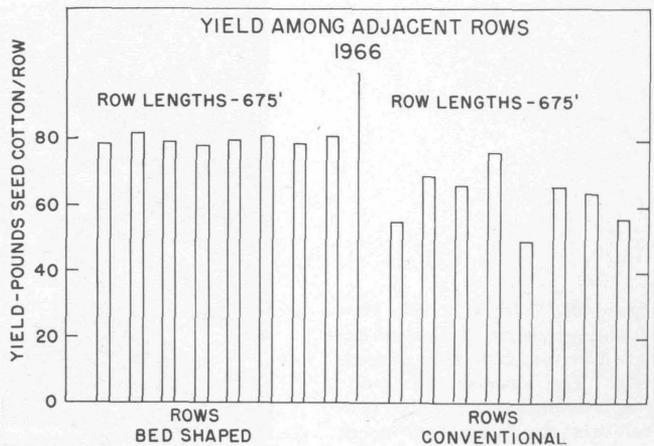


Figure 20. One of the major factors contributing to yield increases, which have been obtained in the precision planting system, has been the uniformity of production along the rows as well as among the rows. Yield increases along the rows in the precision planted cotton have been attributed to the uniformity of emergence and final stands. Yield variations among consecutive rows was 42 percent in conventionally-planted cotton, as compared with 4.5 percent in the shaped bed in this experiment.

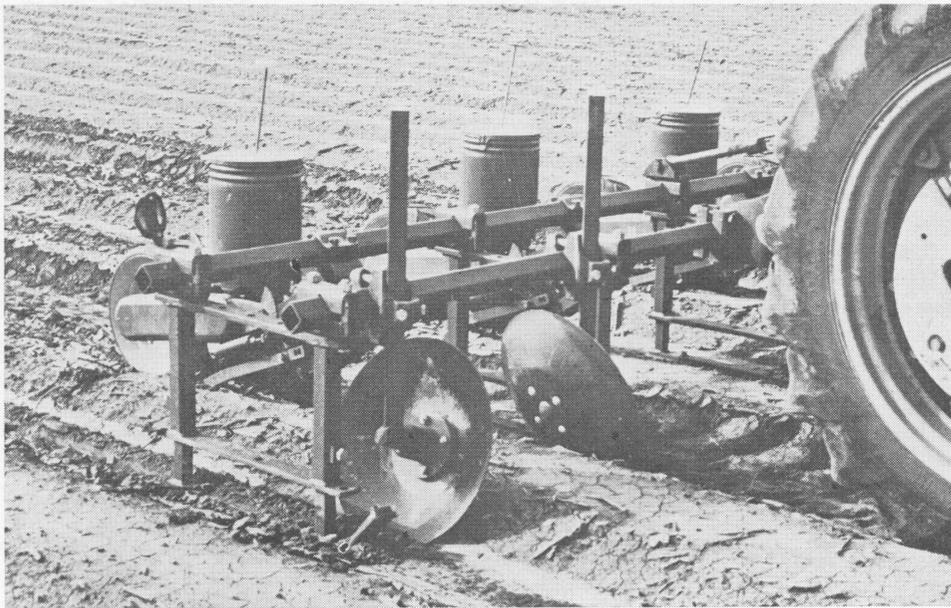


Figure 21. Cone-shaped guide wheels operating against the sides of the beds are used to control lateral movements of the four-row precision planter and to center the planter drill on the top surface of the pre-shaped beds. Height of the tool bars is maintained in a constant position relative to the bed surface by the skid runners. The complete machine operates independently from the tractor, except for the required draft.

Figure 22. Operating frequency was determined by weed infestations, which usually developed after rains and irrigations. The shape of the original row profile was maintained during the season with the cultivating tools so that the beds could be used as reference planes for subsequent cultivations.

Subjective observations in this research have indicated that this approach has potential for increasing efficiency in the production operations. These observations were made concurrently with

conventional equipment operating in the plots planted and produced in the conventional manner.

One of the most obvious differences between the two systems was the power requirements in the cultivating and planting operations. Approximately 230 tons of soil per acre being displaced during the conventional planting operation in removing the crest of the listed beds confirms this. Covering soil over the seed is also pressed in a separate operation from planting in the conventional production system.

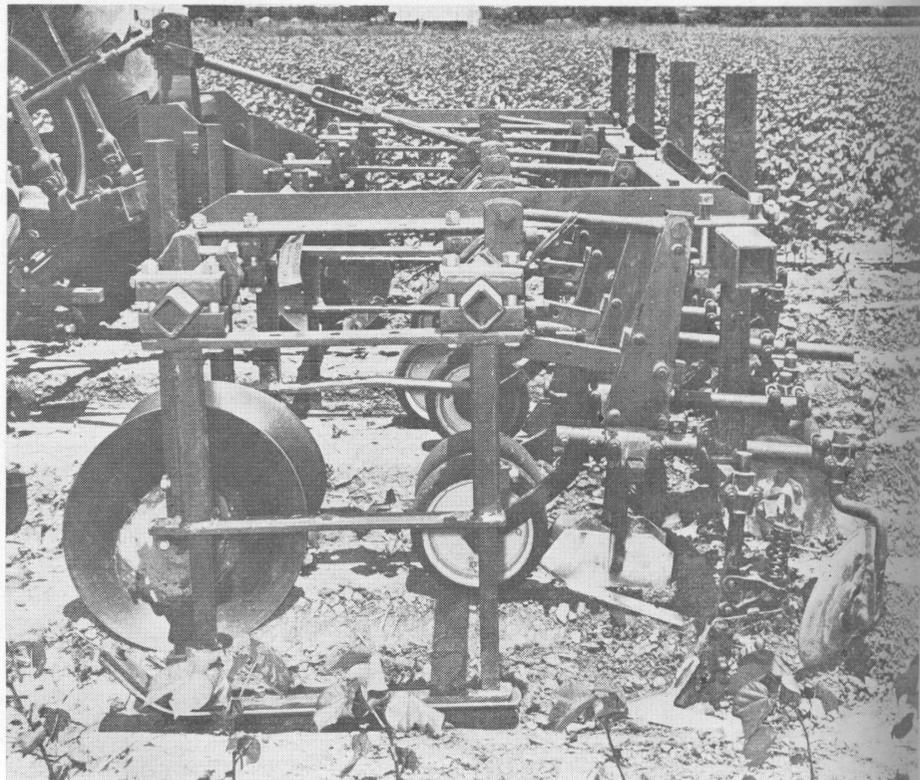


Figure 22. This is a side view of the precision cultivator designed for precision shaped seed-beds. The cone-shaped guide wheels maintained positive control over the lateral movement of the machine. Precision type sweeps were used to cultivate the top surface of the beds. Standard cultivating disks cultivated sides of the beds and kept the desired shape for subsequent operations. The furrows were cultivated with standard sweeps. The entire machine functioned as an independent unit.

One operation only is required in the precision system. Only the soil that contacts the precision furrow opener is displaced or disturbed. Lack of uniform profiles, combined with poor depth control of the implements, displaces approximately 200 tons of soil per acre for each conventional cultivating operation. This is compared with less than 100 tons per acre in the precision system, where uniform surfaces permit the implement to be operated at shallower depths without sacrificing the effectiveness of the cultivators.

Field experience with this equipment has also demonstrated that the cultivator sweeps could be adjusted to closer tolerances than in the conventional system, which relies upon the operator's skill. In addition to the increase in effectiveness, it was possible to obtain practical operating speeds of 4 to 6 miles per hour for the early season operations. This is compared with 2.5 to 3 miles per hour with conventional cultivators. Increased speeds have indicated that the precision production system can obtain

increases in capacities in acres per hour of 35 to 50 percent per machine.

Two other precision operations have been performed, utilizing the control surfaces of the precision beds. These include applying systemic insecticides to the plant stems and in the soil. A rotary brush applicator developed at A&M successfully applied 65 percent of the material to the stems of cotton plants in the precision system. A maximum of only 15 percent was successfully applied in the conventional production systems. Using precision beds for positive control, continuous bands of systemic insecticides have been placed 8 inches deep and 5 inches laterally from the base of the growing plants. Without a guidance system, the latter treatments were impractical. Significant plant damage resulted.

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