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Precision Cultural Practices for Commercial Vegetable Production

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Use of specific brand names is for identification only and does not imply endorsement by the Louisiana State University Agricultural Center.

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Precision Cultural Practices for Commercial Vegetable Production

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Introduction

Commercial vegetable production is an important part of the farm economy of Louisiana. In 1990, gross farm income from commercial vegetable production was $39.1 million from 22,000 acres. With additional income of $19.5 million in value added postharvest, the total net income to the state amounted to $58,600,000. Our state is blessed with soils and climate that are conducive to the production of many vegetable crops. Louisiana farmers have many advantages relative to Western vegetable growers such as our adequate water supplies for irrigation and our proximity to major markets in the East and Midwest.

As commercial vegetable farming becomes more competitive, the use of the most efficient cultural practices becomes necessary. In addition to many smaller, long-time vegetable growers in Louisiana, larger and more mechanized vegetable operations have been started in recent years. In some cases, farmers are switching from agronomic crops into commercial vegetable production. Cultural practices in the areas of planting, fertilization, and cultivation that work for agronomic crops are not precise enough for high-value vegetable crops. The adoption of precision cultural practices can help all Louisiana vegetable farmers become more competitive. The recommended practices discussed in this bulletin constitute a precision cultural system and include: bed shaping, precision seeding, use of cone guide wheels for precision cultivation and fertilizer placement (preplant and sidedress), and rotary tiller cultivation. This precision cultural system is equally applicable to small and large vegetable operations.

The objectives of this bulletin are to present a summary of research on precision cultural practices by the Louisiana Agricultural Experiment Station, to explain and discuss the advantages of these cultural practices, and to recommend practices that should help commercial vegetable growers.

Economic studies of some of the cultural practices discussed are underway but are not included in this bulletin. The recommendations contained here are not based on economic studies.

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This bulletin presents an overall summary of many projects conducted by the Louisiana Agricultural Experiment Station over a 4-year period. Space constraints preclude outlining each experiment in detail. If more details are needed, the reader is urged to contact one of the authors to obtain additional publications on the item(s) of specific interest.

Bed Forming and Shaping

Most vegetable crops in Louisiana and other parts of the Deep South are grown on raised beds. The beds provide surface drainage for excess water, keep fruit out of water in the case of cantaloupe and cucumber, and also aid in soil warming. If the beds are properly formed and shaped, they can be used as the basis for a mechanical guidance system to be used during subsequent operations.

Initial bed forming is usually done with either a disk bedder or a middlebuster. A disk bedder is recommended, particularly in heavier soils, because sticky soil will slide or scour off a disk more effectively. Also a disk bedder will not catch and jerk as badly in tough soil as will a middlebuster. In some soil conditions such as hard clay subsoil or when roots and stumps are present in the field, straighter beds can be made with the use of a disk bedder.

Beds can be formed to many different widths, depending on the needs of the individual crop and the grower. In all cases, the bed widths mentioned in this bulletin refer to the center to center distance. Producers in larger operations and farmers growing agronomic crops as well as vegetables will normally use beds of 38-40 inches. On the smaller farms of Southeast Louisiana, beds 44-48 inches wide are popular. In sugarcane areas, vegetables can be planted on 60-70 inch sugarcane beds. Most of the research on cultural practices at the Louisiana Agricultural Experiment Station in recent years has been conducted on 40-inch beds and, for some crops, on double-wide beds (80 inches). Forty-inch beds typically will have a bed top 20 inches wide, with 80-inch beds having a 60-inch bed top. Laying out 80-inch beds with a disk bedder is shown in Figure 1.

Figure 1. Laying out beds with disk bedder set up for 80-inch beds.

To maintain precisely shaped beds throughout the growing season, a tractor must be able to pass through the field without damaging the beds. Since a 40-inch bed with a 20-inch top will have a furrow bottom about 14 inches wide, 13.6-inch tractor tires are usually the largest that can be effectively used without damage to the beds. Popular front-wheel-assist vegetable tractors generally have front and rear tires sized 13.6-38 or 13.6-46. These tires work well; the use of wider tires will require adjusting the bed profile to provide a wider furrow. This will require that the shoes on the bed shaper be designed with a wider profile. Small, single-row vegetable tractors generally have considerably narrower tires and may allow the use of a narrower furrow.

After the beds are formed with a disk bedder or middlebuster, they should be shaped—preferably with a sled-type bed shaper[4] as shown in Figure 2. Some farmers prefer to use rollers to shape the beds. Although rollers do firm and somewhat smooth the bed top, cylindrical rollers will not firm or shape the sides of the bed; thus, using the bed for mechanical guidance is precluded. A spool-type bed shaper will firm the top and sides of the bed but is generally not as effective as a sled-type bed shaper.

Figure 2. Pan-type bed shaper running alone (without attached planter). An 80-inch bed is being shaped. A center shoe can be added to shape 40-inch beds.

Proper design and adjustment of a bed shaper is critical to obtaining the desired firm, level bed. First, the sides of the bed shaper must taper in at the rear to pack the sides of the bed. Second, the bed shaper should be tilted back slightly so that the bed top is firmed as well as leveled. Allowing soil to initially spill over onto the top of the bed shaper is desirable to add weight to the shaper pan. Proper operation of a sled-type bed shaper requires a tractor with good draft and position control on the three-point hitch. When operated properly, the bed shaper will carry a wave of soil in front and leave behind a firm, well-shaped trapezoidal bed.

The bed shaping operation is sensitive to soil moisture. Excessive moisture in the soil will cause soil buildup on the shaper; excessively dry soil will slough off, and the bed will collapse after shaping.

[4]Plans for constructing a sled-type bed shaper are available through the Louisiana Cooperative Extension Service.

Precision Seeding

Vegetables can be transplanted or direct seeded. Many vegetables grown in Louisiana can be successfully direct seeded at lower cost than transplanting, although a grower should carefully examine the net returns from both systems before making a decision. If direct seeding is to be used, a precision vegetable seeder is needed to obtain acceptable results when planting most small-seeded vegetable crops. Large-seeded crops such as beans, peas, and sweet corn can be effectively planted with a standard cotton, corn, or soybean planter; however, a standard agronomic planter cannot be used on shaped beds (it is too heavy and will crush the beds).

There are currently two main types of precision seeders readily available: belt and vacuum. Belt seeders use a rubber or plastic belt with punched holes slightly larger than the size of the seed to meter the seed. The seeds in a belt seeder are dropped by gravity as the holes in the belt pass over an opening. Vacuum seeders use vertical steel plates with holes somewhat smaller than the seed. A vacuum is drawn on one side of the plate, as the other side passes through the seed hopper and picks up a seed at each hole. When the vacuum is broken, the seed drops. A spurt of pressurized air may also be used to positively release the seeds. Vacuum seeders are more complicated than belt seeders but can be more versatile.

The vacuum seeder utilized in this work was made by Gaspardo and the belt seeder by Stanhay. A belt-type seeder can effectively meter seeds that are nearly spherical, such as cabbage. Flat or irregular seeds like cucumber and cantaloupe are more difficult to meter with a belt type seeder. A belt-type seeder will require a different belt with a slightly different hole size for each crop and sometimes for different varieties of the same crop. A vacuum seeder is more efficient in metering irregular seed and will generally be able to handle a moderately wide range of seed sizes with a single plate. Figure 3 shows a vacuum-type seeder and Figure 4 shows a belt-type seeder, each planting six rows on an 80-inch bed.

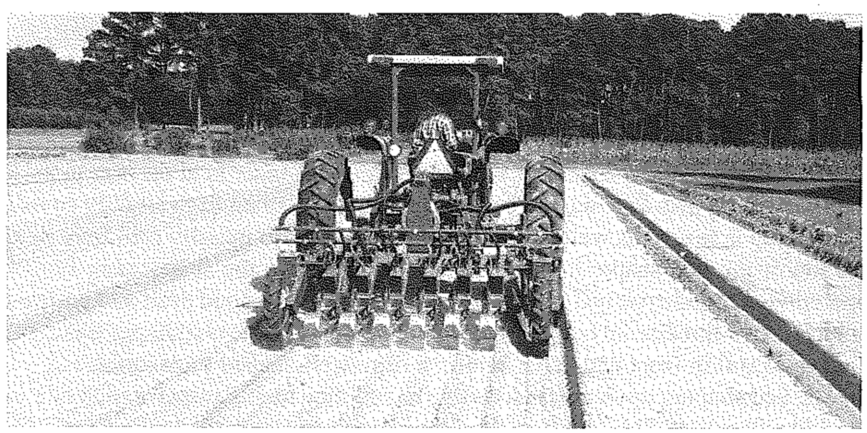


Figure 3. Precision seeding of 6 rows on 80-inch bed using a Gaspardo vacuum-type planter guided by cone guide wheels.

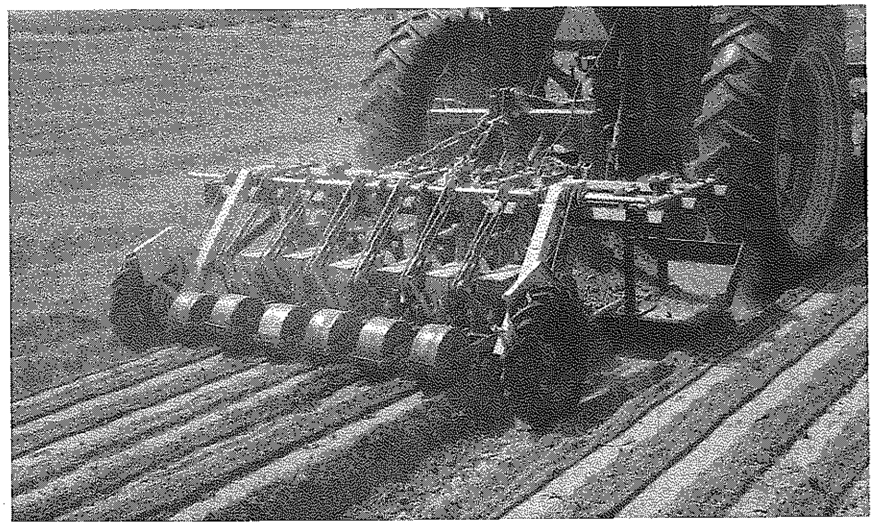


Figure 4. Precision seeding of 6 rows on 80-inch bed using a Stanhay belt-type planter mounted directly on a bed shaper.

Table 1 presents the results of a laboratory test comparing the seed metering ability of a vacuum planter and a belt-type planter using five different types of seed. Although test data on a Carraro seeder are shown, Carraro does not presently offer a vegetable seeder in the United States. The coefficients of variation are rather high in all cases, indicating a great deal of variability of spacing from seed to seed in all cases. Only with cucumber was there a major difference in seed metering uniformity. Data presented in table 2 illustrate the plant uniformity achieved in the field with the two types of seeder. In most cases, the differences in stand were not statistically significant. Tables 3-7 show the yield results obtained from using both types of seeder on several different crops. Both of the seeders did an acceptable job of planting most small-seeded vegetables.

Adjustment of both types of seeder is critical to getting a good, uniform stand. Depth of planting must be properly set. The appropriate number and size of holes in the plate or belt is necessary to properly singulate the seeds at the correct spacing. The correct drive ratios (belt or chain) must be used to give the desired nominal seed spacing.

Vacuum seeders have one or more adjustable pins to knock extra seeds off of the holes as the plates rotate. This knock-off system must be adjusted to eliminate doubles without causing skips. Vacuum level and air pressure can also be varied. These vacuum seeder adjustments normally have to be fine-tuned in the field to deliver optimum uniformity.

Both types of seeder can be used to plant multiple narrow rows on top of a bed. Twin drills 8 to 12 inches apart are common on 40- to 48-inch beds. Many combinations are possible on wider beds. Both types of seeder can be used to plant a wide drill with a single planter unit. With the belt seeder, this is accomplished by punching two or three rows of holes in the belt and then using an opener with two or three ribs on the bottom. A similar system is possible on some vacuum

Table 1. Results of laboratory study of seeders. The coefficient of variation (CV) is a measure of uniformity of seed spacing. The lower the CV, the more uniform the spacing. A CV of 0% would be completely uniform.

Seeder	Nominal spacing*** inches	Actual spacing inches	Coef. of variation %
CARROT SEED			
Stanhay belt	1.9	0.6	103 *
Carraro vacuum	1.9	1.3	94
Gaspardo vacuum	1.9	1.1	100
ONION SEED			
Stanhay belt	3.1	1.9	77 *
Carraro vacuum	3.1	1.9	82
Gaspardo vacuum	3.0	3.5	64
SPINACH SEED			
Stanhay belt	1.6	1.4	47a **
Carraro vacuum	1.9	1.7	37b
Gaspardo vacuum	3.0	3.1	51a
CABBAGE SEED			
Stanhay belt	3.5	3.7	38c **
Carraro vacuum	2.4	2.4	49b
Gaspardo vacuum	3.5	4.5	59a
CUCUMBER SEED			
Stanhay belt	12.0	4.4	104a **
Carraro vacuum	6.0	5.1	51b
Gaspardo vacuum	6.0	5.5	52b

* Differences in coefficient of variation are not significant at the 5% level for this crop.

** Differences in coefficient of variation are significant at the 5% level for this crop as determined by Duncan's Multiple Range Test. Entries followed by the same letter are not significantly different.

*** Nominal seed spacing assumes one seed per hole in seed belt or seed plate.

Coefficient of variation (CV) is a measurement of uniformity. It is defined as the standard deviation of the data divided by the mean of the data (and expressed as a percentage). The lower the CV, the more uniform the data. A CV of 0% implies absolutely uniform data.

Table 2. Field test results, comparison of plant spacing in field trials.

Seeder	Nominal seed spacing, inches	Actual plant spacing, inches	coef. of variation of plant spacing, %
CABBAGE — Spring, 1989			
Stanhay belt	2.8	4.1	65 *
Carraro vacuum	2.4	4.5	70
CABBAGE — Fall, 1989			
Stanhay belt	7.5	13.2	50 *
Gaspardo vacuum	7.6	14.5	59
Stanhay belt	11.3	16.6	45 **
Gaspardo vacuum	11.2	26.7	60
CABBAGE — Spring, 1990			
Stanhay belt	7.5	7.8	27 *
Gaspardo vacuum	7.6	9.0	29
Stanhay belt	11.3	11.3	22 *
Gaspardo vacuum	11.2	12.3	23

continued

Table 2. *continued*

Seeder	Nominal seed spacing, inches	Actual plant spacing, inches	coef. of variation of plant spacing, %
BROCCOLI — Spring, 1989			
Stanhay belt	2.8	4.4	76 *
Carraro vacuum	2.4	4.2	69
BROCCOLI — Fall, 1989			
Stanhay belt	3.5	4.8	63 *
Gaspardo vacuum	3.5	4.4	62
BROCCOLI — Spring, 1990			
Stanhay belt	3.5	5.6	54 *
Gaspardo vacuum	3.5	4.5	42
CANTALOUPE — Spring, 1990			
Stanhay belt	12.5	—	— ***
Gaspardo vacuum	15.1	16.5	32
CANTALOUPE — Summer, 1990			
Stanhay belt	12.5	15.1	66 *
Gaspardo vacuum	12.0	17.5	55

* Differences in coefficients of variation are not significant at the 5% level for this pair of CV's.
** Differences in coefficients of variation are significant at the 5% level for this pair of CV's as determined by Duncan's Multiple Range Test.
*** No statistical comparison is valid for spring, 1990, cantaloupe.

Table 3. Data from cabbage and broccoli seeding test, spring, 1989. Cabbage yields are expressed in 50-lb sacks/a and broccoli yields in 22-lb boxes/a.

	Mean head weight, lb		Yield	
Seeder	First harvest	Total	First harvest	Total
Cabbage				
Stanhay	2.18	2.04	416	984
Carraro	2.33	2.22	488	1048
Broccoli				
Stanhay	0.25	0.19	296	527
Carraro	0.27	0.21	245	473

There are no significant differences among means in this table at the 5% level as determined by Duncan's Multiple Range Test.

Table 4. Carrot yield comparisons as influenced by planter type and seed spacing, fall, 1989. Yields are expressed in tons/a.**

Seeder	Seed spacing, inches	Marketable yield (ton/a)	Culls ton/a
Stanhay belt, 2-line shoe	1.3	4.58*	6.03*
	1.9	7.14	6.38
	2.5	5.53	6.62
Stanhay belt, 3-line shoe	1.3	4.83	7.68
	1.9	5.78	8.94
	2.5	5.01	8.58
Gaspardo vacuum, scatter shoe	1.3	4.42	7.36
	1.9	2.89	7.88
	2.5	6.16	7.63

*No significant difference among yields or culls at the 5% level as determined by Duncan's Multiple Range Test.
**Yields with both seeders were greatly reduced and culls increased by a hard freeze at Christmas, 1989, that burned back the foliage.

Table 5. Data from broccoli seeding test, fall, 1989. Both seeders were set to plant 6 rows, 10 inches apart, per 80-inch bed. Yields are expressed in 22-lb boxes/a.

Seeder	Yield**, boxes/a	Head weight, lb	Rotten heads, lb/a
Stanhay belt	231*	0.100*	48*
Gaspardo vacuum	132	0.093	35

*No significant difference among entries in this column at the 5% level as determined by Duncan's Multiple Range Test.

**Total yields were reduced by a hard freeze at Christmas, 1989, that terminated harvest prematurely.

Table 6. Data from broccoli seeding test, spring, 1990. Both seeders were set to plant 6 rows, 10 inches apart, per 80-inch bed. Preplant and sidedress fertilizer rates were varied as noted. Yields are expressed in 22-lb boxes/a.

Seeder	Fertilizer rate	Yield, boxes/a
Stanhay belt	low**	614 b
Gaspardo vacuum	low	566 b
Stanhay belt	high***	954 a
Gaspardo vacuum	high	794 ab

*Means followed by the same letter are not significantly different at the 5% level as determined by Duncan's Multiple Range Test.

**48N-144P-144K lb/a (600 lb/a 8-24-24) preplant; 34 lb/a N (100 lb/a ammonium nitrate) - sidedressed twice

***96N-288P-288K lb/a (1200 lb/a 8-24-24) preplant; 68 lb/a (200 lb/a ammonium nitrate) - sidedressed twice

Table 7. Data from cabbage seeding test, spring, 1990. This test was replanted late because early plantings were washed out. As a result, the temperatures at the end of the season were too high for optimum cabbage growth. Small head size was also attributed to the cultivar grown. Yields are expressed in 50-lb sacks/a.

Seeder	Seed spacing in	Yield, First harvest	Yield, Total	Head size, lb
Stanhay belt	7.5	464 c*	876 b	0.94 a
Gaspardo vacuum	7.6	472 c	948 b	0.94 a
Stanhay belt	11.3	892 a	1208 a	1.21 a
Gaspardo vacuum	11.2	688 b	972 b	1.17 a

*Means followed by the same letter are not significantly different at the 5% level as determined by Duncan's Multiple Range Test.

seeders, but others use a scatter shoe to disperse the seed from one metering point across a small band. The wide drills are normally 2 to 4 inches across. This system works very well with mustard, spinach, onion, and carrot by allowing more plants per foot of row and, thus, higher potential yields.

With vacuum seeders, a vacuum cleaner attachment is available to expedite emptying the seed hoppers. The vacuum cleaner hose empties the seed into a cyclone that captures the seed for easy collection and storage.

Both vacuum and belt-type seeders can do a good job planting vegetable seeds. Both offer a number of useful options, and both must be operated properly. A vacuum seeder may have some advantage in planting irregularly shaped or nonuniformly sized seed. A vacuum seeder is a more complex mechanism, but no data on reliability are available. Soil type should have little effect on selecting a seeder.

Cone Guide Wheels

A seeder or transplanter can be run independently but is most effective mounted directly on the back of the bed shaper. This locks the plant row(s) exactly in place on the precisely shaped bed, so that the rows can easily be located for subsequent operations. Cone guide wheels can be used on the planter to lock plant rows in place on the bed, if the planter is not mounted directly on the bed shaper.

Cone guide wheels are cone-shaped steel wheels that operate on the sides of the beds. The side of the cone guide wheel rolls on the side of the bed, thus guiding the implement. Figure 5 shows a set of cone guide wheels on a cultivator.

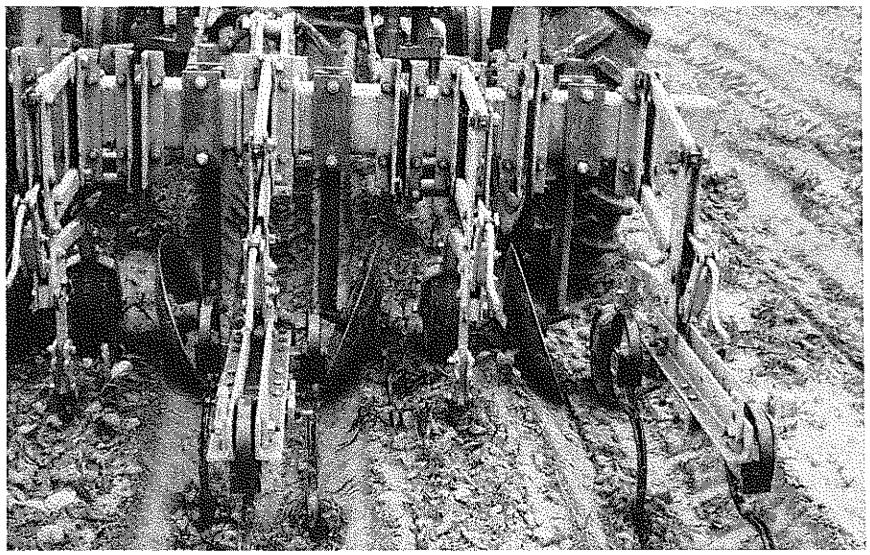


Figure 5. Cone guide wheels mounted on a cultivator set up for 40-inch beds.

Implement guidance after bed shaping is provided by cone guide wheels mounted on each implement. The sway blocks or sway links on the tractor should be released so that the implement can float laterally and follow the bed contour independent of the tractor. The cone guide wheels follow the sides of the shaped bed and control operations such as cultivation, sidedressing, directed spraying, knifing carrots, etc. This method is very accurate and relieves the tractor driver of the need for precise steering. Figure 6 shows the use of cone guide wheels on a fertilizer applicator used for sidedressing.

Most implements are too heavy to be carried entirely on the guide wheels. Excessive bed compaction and damage to the guide wheels can result. Most of the

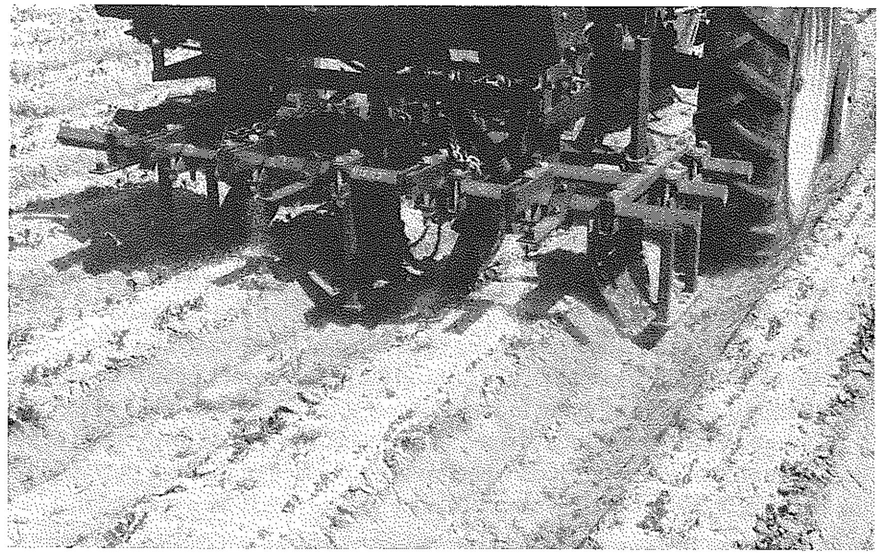


Figure 6. Sidedressing fertilizer using cone guide wheels to guide the fertilizer applicator.

implement weight should be carried on the 3-point hitch, with only enough weight on the guide wheels for them to firmly contact the sides of the beds.

An added benefit of using the cone guide wheels is that they assist with weed control. Although the wheels are smooth, they tend to remove small weeds from the sides of the beds—an area that is difficult to cultivate effectively.

Precision Cultivation

Precision cultivation is an important part of a cultural system for commercial vegetable production. Due to the costs of registering pesticides for minor crops, fewer herbicides are labelled for use on vegetable crops than major agronomic crops. Those that are available are often not as effective as the very specific herbicides available for major crops such as cotton, corn, soybeans, and rice. There is also greater consumer concern when pesticides are used on fresh produce. As a result of all these factors, commercial vegetable growers find it important to cultivate as effectively and completely as possible to obtain the maximum in mechanical weed control.

With cultivators, efficiency of weed control translates to precision in adjustment and operation. The most critical factor in precision cultivation is to cultivate as closely to the plant row as possible without injuring the crop plants. The use of cone guide wheels allows very close cultivation, while eliminating the need for precise steering by the tractor driver. Cultivation within 3 inches of the plant row is easy with cone guide wheels, and cultivation within 2 to 2½ inches of the plant row has been accomplished with limited plant damage. A farmer using cone guide wheels can easily cultivate between twin drills spaced only 10 inches apart, using a 4-inch sweep or tiller.

The correct choice of cultivator type is also important in obtaining good weed control and operating efficiency. Sweep cultivators of the type used for major agronomic crops can be very effective, but since depth control is very important, individual gangs with floating parallel linkage and a gauge wheel for each sweep are recommended. Cultivators of this type are shown in operation in mustard and cabbage in Figures 7 and 8, respectively. Depth adjustment is critical and may have to be changed to compensate for soil type, soil moisture, extent of soil crusting,

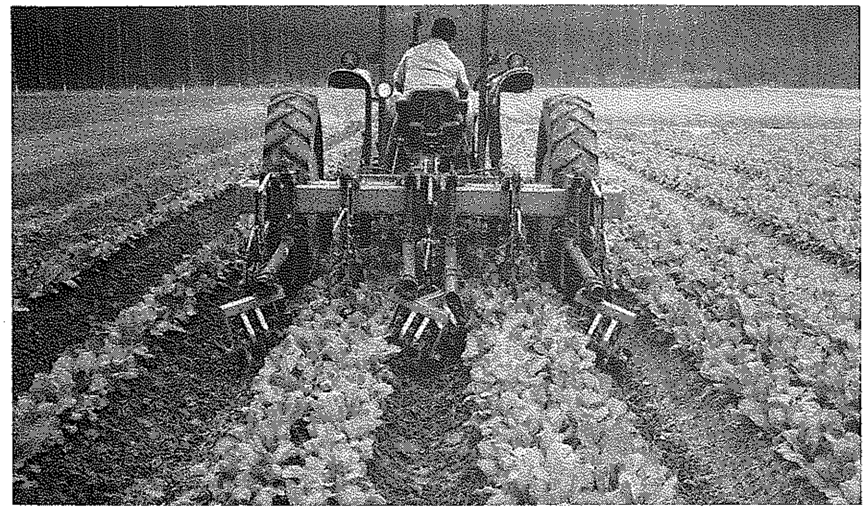


Figure 7. Sweep cultivation of two rows spaced 10 inches apart on 40-inch beds. Cone guide wheels are used for guidance, and rolling cultivator gangs are used to clean the sides of the beds.

Figure 8. Sweep cultivation of 6 rows spaced 10 inches apart on an 80-inch bed. Cone guide wheels are used for guidance and rolling cultivator gangs are used to clean the sides of the bed.

etc. With a sweep cultivator, burying crop plants with soil thrown from the sweeps is often a problem, especially when plants are very small and soils are crusted—a typical situation on many soils during the first cultivation after vegetable crops have been irrigated for germination. Fenders or shields on the cultivator may be helpful, but usually the sweep cultivators must be operated very slowly (½ to 1 mph) during the first cultivation.

An alternative type of cultivator can be used to reduce the problem of flakes of soil crust damaging small plants and the resultant need for very slow operation. Rotary tiller cultivators (cultivators composed of narrow individual gangs of rotary blades) are quite effective in this respect. The rotary tillers pulverize the flakes of soil crust and also have shields to contain the loose soil. This combination prevents burying of small crop plants, even when a tiller-cultivator is operated at twice the ground speed of a sweep cultivator. Two types of rotary tiller cultivators are shown in Figures 9 and 10.

Figure 9. Rotary tiller cultivation of 6 rows spaced 10 inches apart on an 80-inch beds. Cone guide wheels are used for guidance.

Figure 10. Rotary tiller cultivation of 4 rows spaced 15 inches apart on an 80-inch wide bed. Cone guide wheels are used for guidance.

Tables 8 to 15 show the results of extensive field tests comparing two brands of tiller-cultivator with a sweep cultivator in a variety of crops. With most crops, there were no significant differences in yield or quality with sweep or tiller cultivators, but being able to operate at twice the ground speed was a distinct advantage that may allow a farmer to get a crucial cultivation completed on schedule. Furthermore, a tiller-cultivator can be operated in wetter soil conditions than can a sweep cultivator. As shown in table 12, there was an advantage to using a tiller in the case of onions. Since the tiller-cultivator does not pile soil over the bulbs, larger bulbs were formed.

Table 8. Comparisons of cultivator types and row configurations for fresh market cucumbers, 1988. All plant count data are expressed in number of plants per 1.0 ft². Yield data are in 55-lb. boxes/a — total of 13 harvests.

	Plant counts								
Treatment	Sedges	Eclipta	Purslane	Pigweed	Grasses	Corn spurry	Total weeds	Cucumber	Yield
1 row, sweep	5.8ab*	2.3**	1.2b	0.2**	0.4**	1.5ab	11.4b	2.0b	339**
1 row, tiller A	2.5b	0.2	0.0b	0.1	0.0	0.2b	3.0c	2.2ab	387
2 row, sweep	10.6a	1.7	2.6a	0.2	0.2	2.8a	18.1a	3.1a	377
2 row, tiller A	8.2a	1.5	0.5b	0.2	0.2	0.7b	11.3b	3.0a	349

*Entries in each column followed by same letter are not significantly different at the 5% level as determined by Duncan's Multiple Range Test.

**No significant differences among entries in this column.

Weed species:		
	Sedges	Cyperus sp.
	Eclipta	Eclipta alba
	Purslane (common)	Portulaca oleracea
	Pigweed (spiny)	Amaranthus spinosus L.
	Goosegrass	Eleusine indica
	Crabgrass	Digitaria sp.

Table 9. Comparison of cultivator types for cabbage, 1988. All counts are plants per 1.5 ft². Yield data are in 50-lb sacks/a — total of 2 harvests.

	Plant counts				
Treatment	Sedges	Grasses	Broadleaves	Cabbage	Yield
Sweep cultivation	19.9	1.7	40.2	4.2	611
Tiller/cultivator A	18.9	2.6	41.3	3.5	678

Differences between treatments are not statistically significant at the 5% level as determined by Duncan's Multiple Range Test.

Table 10. Comparison of cultivator types for mustard; 1988 test #1. All counts are plants per 1.0 ft². Yield data are expressed in tons/a and dozen bunches/a — one harvest.

	Plant counts				Yield	
Treatment	Grasses	Broadleaves	Sedges	Mustard	Tons/a	Doz. bun./a
Sweep cultivation	17.6a*	32.6a	0.0a	43.0a	19.5**	2161**
Tiller/cultivator B	4.6a	24.6b	0.0a	35.2a	16.9	1874

*Entries in each column followed by same letter are not significantly different at the 5% level as determined by Duncan's Multiple Range Test.

**No significant differences among entries in this column.

Table 11. Comparison of cultivator types and row configurations for mustard; 1988 test #2. All counts are plants per 1.0 ft². Yield data are expressed in tons/a and dozen bunches/a — one harvest.

Treatment	Plant counts				Yield	
	Grasses	Broadleaves	Sedges	Total weeds	Tons/a	Doz. bun./a
4 rows/bed, sweep	2.5**	2.8**	0.0**	5.3**	15.1 b*	1675 b
4 rows/bed, tiller A	0.3	0.7	0.2	1.2	13.7 b	1525 b
6 rows/bed, sweep	0.5	3.5	0.2	4.2	18.0 a	2003 a
6 rows/bed, tiller B	1.2	2.0	0.0	3.2	19.8 a	2194 a

*Entries in each column followed by same letter are not significantly different at the 5% level as determined by Duncan's Multiple Range Test.

**No significant differences among entries in this column.

Table 12. Comparison of cultivator types for onions, 1988. All counts are plants per 1.0 ft². Yield data are in 50-lb sacks/a — one harvest.

Treatment	Plant counts				Yield			
	Grasses	Broad-leaves	Sedges	Onion	Large bulbs	Medium bulbs	Small bulbs	Total
Sweep cultivation	28.8**	43.0**	0.0**	5.8**	11.0 b*	45.1**	29.6 a	85.7
Tiller/cultivator A	5.8	18.0	0.0	4.3	30.8 a	45.7	15.3 b	91.8

*Entries in each column followed by same letter are not significantly different at the 5% level as determined by Duncan's Multiple Range Test.

**No significant differences among entries in this column.

Table 13. Comparisons of cultivator types and row configurations for cabbage, 1989. All counts are plants per 6.25 ft². Yield data are expressed in 50-lb sacks/a. Headweight is in lb — total of 3 harvests.

Treatment	Plant counts			Yield		Headweight	
	Grasses	Broad-leaves	Sedges	1st Harvest	Total	1st Harvest	Total
4 rows/bed, sweep	2.00*	4.75*	6.75*	249 ab*	919 **	2.27**	2.07a*
4 rows/bed, tiller A	2.25	2.50	2.00	347 a	903	2.22	2.03a
6 rows/bed, sweep	1.50	1.50	2.00	250 ab	875	2.09	1.73b
6 rows/bed, tiller B	1.00	2.75	1.25	200 b	1021	2.19	1.95ab

*Entries in each column followed by same letter are not significantly different at the 5% level as determined by Duncan's Multiple Range Test.

**No significant differences among entries in this column.

Table 14. Comparisons of cultivator types for broccoli, 1989. All counts are plants per 6.25 ft². Yield data are expressed in 22-lb boxes/a — total of 3 harvests.

Treatment	Plant counts			Yield		Headweight	
	Grasses	Broad-leaves	Sedges	1st Harvest	Total	1st Harvest	Total
sweep cultivator	0.75	6.00	2.75	311	462	0.26	0.21
tiller/cultivator B	1.25	8.63	1.50	310	475	0.23	0.20

No significant differences among means in this table at the 5% level as determined by Duncan's Multiple Range Test.

Table 15. Comparison of cultivator types and row configurations for mustard, 1989. Yield data are expressed in tons/a and dozen bunches/a — one harvest.

Treatment	Tons/a	Doz. bun./a
4 rows/bed, sweep cultivator	18.8	2083
4 rows/bed, tiller/cultivator A	17.3	1922
6 rows/bed, sweep cultivator	18.9	2094
6 rows/bed, tiller/cultivator B	18.5	2056

No significant differences among means in this table at the 5% level as determined by Duncan's Multiple Range Test.

Removing weeds from the sides of beds is difficult with either sweep or tiller cultivators. As noted above, the cone guide wheels are helpful in this respect but will not remove large weeds. Rolling cultivators angled correctly will not only clean the sides of the beds but can also move some soil back up to rebuild the beds. Rolling cultivators can be mounted on either sweep or rotary tiller cultivators. There is one disadvantage to the use of rolling cultivators with rotary tiller-cultivators: the rolling cultivators tend to throw flakes of soil on the crop row and thus may somewhat negate the speed advantage of the tiller-cultivator.

Carrots require an additional type of cultivation. To encourage the carrot roots to develop long and straight without forks or crooks, a vertical knife is run 8 to 12 inches deep adjacent to each row to fracture the soil. Figure 11 shows knives being run in a carrot field. This operation should be performed when the carrot tops are 4 to 6 inches tall. If the carrots are grown in a twin drill or multiple row configuration, the knives can be run between each pair of rows. Knives can be mounted on an existing machine such as a cultivator or fertilizer applicator to accomplish this operation. Cone guide wheels should be used to locate the knives accurately between the crop rows to prevent damage to the crop.

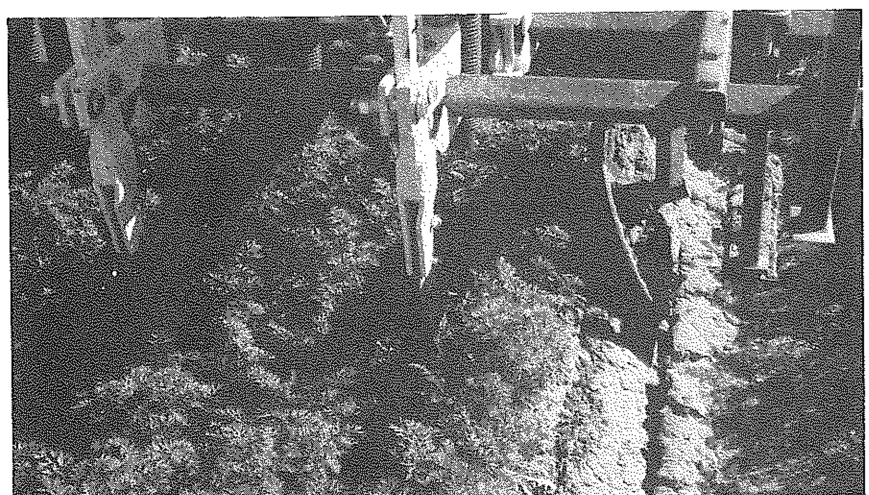


Figure 11. Vertical knives are used to loosen the soil between carrot rows to encourage the formation of straight roots. Cone guide wheels align the knives between the rows.

Row Configuration Studies

Many different row configurations are possible. All of the research on this project to date has involved either 40-inch beds or 80-inch beds with varying numbers of rows. The 40-inch rows will generally have either one or two rows per bed. If twin drills are used, a spacing of 8 to 12 inches is possible, with 10 inches being recommended. The 10-inch spacing is easy to cultivate and leaves an adequate shoulder at the sides of the bed for most crops. With some long-season crops, however, erosion of the beds may cause the rows to be on the sides of the beds by the end of the season. With 80-inch wide beds, many row spacings are possible, and several have been tested with different crops including single rows, twin drills 12 inches apart, twin drills 40 inches apart, two pairs of 10-inch twin drills spaced 40 inches apart, four rows 10 inches apart, four rows 15 inches apart, and six rows 10 inches apart.

Nine replicated experiments using five different vegetable crops were conducted at Bastrop, Louisiana in 1987 and Hammond, Louisiana in 1988 and 1989. Eight of the tests allow a direct comparison of single rows on a standard bed, two rows on a standard bed, and six rows on a wide bed. Soil types, crops, cultivars, and other cultural practices applicable to each location are presented in table 16. Table 17 gives the seeding rates for the five crops. Data on field results of these nine experiments are summarized in table 18.

Table 16. Soil type and cultural practices used for plant density and row spacing experiments in two Louisiana locations.

Crop	Cultivar	Planting date	Location[z]	No. of harvests
Broccoli	Baccus	25 Aug. 1987	Bastrop	4
Cabbage	Solid Blue 770	25 Aug. 1987	Bastrop	4
	Asgrow 5117	29 Aug. 1988	Hammond	2
	Asgrow 5116	1 Mar. 1989	Hammond	3
Cauliflower	Olympus	25 Aug. 1987	Bastrop	3
Mustard	Fla. Broadleaf	21 Sep. 1988	Hammond	1
	Fla. Broadleaf	1 Nov. 1988	Hammond	1
	Fla. Broadleaf	27 Jan. 1989	Hammond	1
Spinach	Shamrock	7 Dec. 1988	Hammond	1

[z]Soil type at Bastrop was Sterlington silt loam; soil type at Hammond was Cahaba fine sandy loam.

Table 17. Seeding rates for broccoli, cabbage, cauliflower, mustard, and spinach in various row configurations.

			Seeds planted/a		
Row Configuration	Broccoli	Cabbage[1]	Cauliflower[1]	Mustard	Spinach
1 row/40-inch bed	46,100	46,100	39,200	98,100	98,100
2 rows/40-in. bed	92,200	92,200	78,400	393,400	588,700
4 rows/80-in. bed	——[2]	92,200	——[2]	393,400	588,700
6 rows/80-in. bed	138,400	138,400	117,600	588,800	883,200

[1]Population thinned to 12-inch spacing at later date.
[2]Not planted in this configuration.

Table 18. Effects of row configurations on marketable yields of broccoli, cabbage, cauliflower, mustard, and spinach. Yields of broccoli are expressed in 22-lb boxes/a, cabbage in 50-lb sacks/a, cauliflower in 22-lb cartons/a, mustard and spinach in tons/a. Headweights are in pounds.

Row	Broccoli		Cauliflower		Cabbage		Mustard	Spinach
Configuration	Yield	Head wt.	Yield	Head wt.	Yield	Head wt.	Yield	Yield
1 row/40-in. bed	401 b[1]	0.38 a	592 a	1.26 a	765 b	2.83 a	10.8 c	2.4 c
2 rows/40-in. bed	544 a	0.30 b	577 a	0.78 b	715 b	1.87 b	15.1 b	5.3 b
4 rows/80-in. bed	——[2]	——	——	——	780 b	2.08 b	15.4 b	4.5 b
6 rows/80-in. bed	540 a	0.31 b	389 b	0.96 b	926 a	1.91 b	18.2 a	6.6 a
CV[3]	52.3	30.7	18.3	13.2	23.1	15.0	14.8	14.8

[1]Mean separation by Duncan's Multiple Range Test, 5% level.
[2]Not planted in this configuration.
[3]Coefficient of variation.

Yield from broccoli grown in two- and six-row plots was 36% higher than yield from broccoli grown in single-row plots. Marketable heads for fresh market broccoli (packed three or four heads per bundle, 18 bundles per 22-pound box) should weigh 0.29 to 0.44 lb. Head size was adequate for broccoli grown in all row configurations but was largest for broccoli in single-row plots. Large head size is an advantage for processing broccoli but not for fresh-market broccoli.

As shown in table 18, cauliflower yield decreased with higher plant density. Yield of cauliflower was reduced by 35% for six-row plots compared with single- or two-row plots. A problem with the bedding method on wide beds in this 1987 test resulted in delayed germination in the center of the wide beds, which reduced yield and average head weight for the six-row plots. The bedding problem was resolved by the use of 80-inch bedders in subsequent tests. Differences in yield between cauliflower grown in single- or two-row plots were minimal, though head weight was highest for cauliflower grown in single rows.

As shown in table 18, yield increases of 17%, 23%, and 16% were recorded with cabbage planted in the six-row configuration compared with cabbage planted in single-, two-, and four-row configurations, respectively. Yields were not different between cabbage grown in the single-, two-, or four-row plots, though average head weight was much higher for cabbage planted in single rows. Head size, based on fresh market requirements of 18 to 24 heads in a 50-pound sack, was adequate for cabbage grown in all row configurations. Seeding rates for the two-row and four-row configurations were identical, but distance between rows was greater in the four-row (15-inch) than in the two-row (10-inch) configuration, which may account for the larger head weights in cabbage planted in four rows per bed.

As shown in table 18, mustard grown in six rows on 80-inch beds yielded 40% more than mustard planted in a single row on 40-inch beds. Seeding rates for the six-row plots were six times greater than seeding rates for the single-row plots. One plant line per row was used in the one-row configuration, while two-plant lines per row were used in the other configurations. A 20% increase in yield was recorded for mustard in the six-row configuration compared with mustard in the two- or four-row configurations.

As shown in table 18, spinach grown in six rows on 80-inch beds produced 64%, 20%, and 33% more yield than spinach on single-, two-, or four-row plots, respectively. Seeding rate for the six-row configuration of spinach was nine times the rate used to plant the single-row plots. Yield from spinach planted in single-row per bed was 55% less than the yield from two-row plots and 46% less than the yield from four-row plots. Differences between yields produced on two- and four-row plots were not significant.

These tests indicate that vegetable farmers could increase yields by planting multiple rows per bed. Highest production was obtained when cabbage, mustard, and spinach were grown on the six-row configuration, and when broccoli was grown on two- or six-row configurations. Cauliflower produced the highest yields when planted in single or two rows per bed, but mechanical complications at planting may have affected the results of the experiment. In all crops, the two-row configuration offered a yield advantage over the one-row configuration. Head weight was highest for broccoli, cabbage, and cauliflower grown on single row per bed but was adequate to meet size standards of the fresh market on multiple-row configurations. Manual harvest is more difficult with the six-row configuration with some crops.

The two-row or twin drill configuration would possibly be easier for a row-crop farmer to use with existing equipment. Also the twin drill configuration can be irrigated through the furrow, whereas the wide bed configurations would require some other type of irrigation such as overhead sprinklers or drip.

Seed Spacing Studies

Several seed spacing studies were conducted as a part of this research. Carrot seed were spaced 1.25, 1.90, and 2.50 inches apart in two and three lines per row to evaluate the effect of plant spacing on yield. A vacuum seeder with a scatter shoe was also included in the evaluations during the second year of the test. The results are shown in tables 4 and 19. In the first test, carrots planted in three lines per row produced more marketable and cull roots than carrots planted in two lines per row. The ratio of cull to marketable roots, generally, was lower for carrots grown in three lines per row than for carrots grown in two lines per row. Yields decreased as seed spacing increased for carrots planted in two lines per row. Production of market-

Table 19. Yield data, 1988 carrot seed spacing study. Yields and culls are expressed in tons/a.

Treatment	Marketable yield	Culls
2-line, 1.25 in. spacing	12.0 bcd**	4.0*
2-line, 1.90 in. spacing	11.4 cd	3.9
2-line, 2.50 in. spacing	10.4 d	3.0
3-line, 1.25 in. spacing	13.9 abc	4.2
3-line, 1.90 in. spacing	15.2 a	4.0
3-line, 2.50 in. spacing	14.6 ab	3.5

*Entries in this column are not significantly different at the 5% level as determined by Duncan's Multiple Range Test.

**Entries in this column followed by the same letter are not significantly different.

able roots, however, increased as seed spacing increased for carrots planted in three lines per row. Highest yields were obtained with plant spacings of 1.9 inches in three lines. The lowest percentage of culls (24%) was recorded for carrots planted 2.5 inches apart in three lines. Differences in yield of marketable or cull carrots planted in three lines per row were not significant at any seed spacing. Planting carrots 1.9 or 2.5 inches apart in three lines per row would be recommended to produce the highest marketable yield and lowest percentage culls. In the second test, a freeze severely damaged the tops of the carrots, thus reducing yields. There were no significant differences in that test.

Tests on direct seeding cabbage to a stand without thinning were conducted for 2 years. The results are shown in table 20. In the 1989 test, the percentage of plants counted to seed planted indicated that approximately 75% of the planted seed germinated and survived in all treatments except those in the 8-inch spacing, which had only a 62% survival. Plant population was highest and head size was lowest for cabbage planted with two seeds every 12 inches. There were no significant differences in yield among any treatments, although highest yields were recorded for cabbage spaced 4 inches and thinned or seeded to 12 inches. Cabbage seeded at 8 inches or 12 inches (single seed) had significantly greater head weight than cabbage planted at 4 inches and thinned or 12 inches (two seeds). To meet fresh market standards of 18 to 24 heads in a 50-pound sack, cabbage heads should weigh between 2.0 and 2.8 pounds. Only cabbage seeded 8 inches or 12 inches (single seed) had marketable head size.

In the second year, the highest yield was obtained by direct seeding with the seeds spaced 10 to 12 inches apart and not thinned. Head size of cabbage planted

Table 20. Cabbage seed to stand data. All yields are expressed in 50-lb sacks/a. Head sizes are in lbs.

Seed spacing	Plants per ac.[1]	Survival %[2]	Yield	Heads as % of plants	Heads cut/ac.	Head size
Spring, 1989						
3-4 in., thinned to 12 in.	26,136[3]	73	722*	78	20,347	1.77 b**
6-8 in., not thinned	27,447	62	632	55	15,137	2.09 a
10-12 in., not thinned	22,219	77	719	73	16,200	2.22 a
10-12 in., two seeds, not thinned	43,131	75	675	47	20,074	1.68 b
Spring, 1990						
3-4 in., thinned to 12 in.	26,136[3]	88	972 b	110[4]	28,750	1.72 ab
6-8 in., not thinned	44,432	100	876 b	69	30,710	1.39 b
10-12 in., not thinned	31,364	109	1208 a	92	28,750	2.12 a
10-12 in, two seeds, not thinned	52,273	91	908 b	64	33,324	1.37 b

*Means in this group are not significantly different at the 5% level as determined by Duncan's Multiple Range Test.

**Means in this group followed by the same letter are not significantly different.

[1]Based on plant count in the field.

[2]Based on the ratio of plant counts in the field to seed counts in laboratory tests of the planters. A percentage over 100 indicates that 2 seeds were dropped at some locations in the field.

[3]Based on the estimated thinned spacing, rather than actual plant counts after thinning.

[4]A percentage over 100 means that the actual thinning spacing was less than the nominal spacing.

at all seeding rates was too small for fresh-market requirements. Head size was reduced by the hot weather that occurred during the last stage of growth.

Yields and head weights of cabbage direct seeded to 10 to 12 inches were equivalent or better than the production of cabbage planted 3 to 4 inches apart and later thinned to 12 inches (the current grower practice). Direct seeding to a 10- 12-inch spacing is the seeding pattern associated with the lowest cost. This work indicates that farmers can direct seed cabbage to a stand when favorable environmental and field conditions exist, rather than overseeding and thinning as is commonly done.

Other seed and row spacing studies were conducted with both pickling and fresh market types of cucumbers. The results of spacing studies with mechanically harvested pickling cucumbers are presented in table 21. The seed spacing was 3.75 inches. Four rows spaced 10 inches apart and centered on an 80-inch bed gave the best net returns.

Table 21. Field data from pickling cucumber planting configuration test, DeRidder. Second crop, 1988. Three bed heights (4, 6, and 8 inches) were used. Yields are expressed in bu/a.

Planting config.	Bed in.	Stand, plants/A	Yield, bu/A #1	#2	#3	#4	#5	oversize	#6	total	% in # 1-3	Value, $/A
XX XX	4	52,925	0.8	14.9	42.3	24.3	42.6	39.5	16.5	141.4	41	191.43
	6	63,216	1.1	12.6	34.6	31.7	39.8	36.9	24.3	144.2	33	176.96
	8	59,786	1.5	13.2	52.9	24.0	49.5	43.9	20.1	161.1	42	221.86
XXOOXX	4	59,949	1.5	10.5	45.9	21.6	42.3	47.7	25.8	147.4	39	198.84
	6	69,097	1.1	10.6	43.4	31.7	38.0	17.5	21.4	146.3	38	191.57
	8	61,093	1.8	14.7	54.9	25.6	33.1	50.3	17.5	147.6	48	225.84
OXXXXO	4	55,049	1.6	14.4	60.4	31.3	38.9	35.6	35.3	181.9	42	261.20
	6	64,523	1.5	12.4	49.0	29.6	43.6	25.8	31.8	167.8	37	222.49
	8	58,806	2.6	14.2	61.4	25.0	41.6	47.8	25.0	169.8	46	253.14
XXXXXX	4	92,456	1.1	13.4	43.9	24.7	30.9	30.5	36.2	150.2	39	209.69
	6	100,134	2.0	8.3	38.0	30.0	47.2	34.5	39.5	165.1	29	193.17
	8	90,006	1.6	11.6	45.7	32.2	50.9	28.4	47.5	189.5	31	231.02

Key to planting configuration code:

XX XX	Twin drills 10 inches apart on 40-inch beds
XXOOXX	Two twin drills 10 inches apart and separated by 30 inches on 80-inch beds
OXXXXO	Four drills 10 inches apart on 80-inch beds
XXXXXX	Six drills 10 inches apart on 80-inch beds

Key to cucumber grades and prices:

Grade	Size, quality	Price, $/bu.
#1	<1-1/16"	2.625
#2	1-1/16 to 1½"	2.625
#3	1½ to 2"	2.625
#4	2 to 2-1/8"	0.500
#5	2-1/8 to 2¼	0.250
oversize	>2¼"	0.000
#6	crooked cucumbers and nubbins	1.000

The results of a 1988 study using fresh-market cucumbers planted in single rows on 80-inch beds or in twin drills 12 inches apart on 80-inch beds is listed in table 8. No significant yield differences were recorded in that test. There were no significant differences in yield in 1989 and 1990. Yields were very low in 1989 due to an early frost (table 22). Yields were higher for cucumbers planted 12 inches apart regardless of row configuration. Cucumbers planted in the two-row configuration had higher early yields, but season totals were not significantly different from cucumbers grown in single row per beds.

Table 22. Results of 1989 and 1990 plant and row spacing studies with fresh-market cucumbers. Configurations tested were 1-row on 80-inch beds or twin drills 12 inches apart on 80-inch beds. Yields are expressed in 55-lb boxes/a.

	Yield				%
Planting configuration	Fancy	Number 1	Number 2	Total	Fancy
1989 test*					
1 row, 6-inch seed spacing	12**	18**	***	30	39
1 row, 12-inch seed spacing	16	17		33	49
1 row, 18-inch seed spacing	16	8		24	67
2 rows, 6-inch seed spacing	36	22		58	62
2 rows, 12-inch seed spacing	28	15		43	65
2 rows, 18-inch seed spacing	29	22		51	57
1990 test					
1 row, 6-inch seed spacing	33**	96**	64**	193	17
1 row, 12-inch seed spacing	40	101	62	203	20
1 row, 18-inch seed spacing	48	66	55	169	28
2 rows, 6-inch seed spacing	38	112	98	248	15
2 rows, 12-inch seed spacing	65	130	73	268	24
2 rows, 18-inch seed spacing	53	115	82	250	21

*1989 yields are low due to an early frost that terminated harvest.

**No significant differences among means in this group at the 5% level as determined by Duncan's Multiple Range Test.

***No data on Number 2 cucumbers were collected in 1989.

Fertilizer Rate Studies

Planting multiple rows per bed will increase yield with many crops, but the yield increases are generally not proportional to the increased number of rows. Fertilizer rates must be increased for the multiple row configurations to support the higher plant density, but a proportional increase would probably be excessive. Tests were conducted in spring and fall 1990 to determine an optimum fertilizer rate for several planting configurations of broccoli. The results of these tests are shown in table 23. Rates of 80N-240P-240K to 96N-288P-288K pounds per acre (1,000 to 1,200 pounds per acre of 8-24-24) plus 102 to 136 pounds per acre of N (300 to 400 pounds per acre of 34-0-0) as sidedressings were optimum for the production of broccoli in two- or six-row configurations in this research. Knifing in the additional nitrogen significantly increased the yields over dropping the fertilizer, but this situation was not repeated in the fall experiment.

Table 23. Results of 1990 fertilizer rate tests on broccoli. Preplant fertilizer was 8-24-24; ammonium nitrate (34-0-0) was used for the sidedress applications. Preplant fertilizer was knifed in; sidedress fertilizer was dropped on the surface and cultivated in unless noted otherwise. Yields are expressed in 22-lb boxes/a.

	Fertilizer rate lb/a			Avg.
	preplant	sidedress		head wt.
Configuration	N-P-K	N	Yield	lb
Spring test				
1 row on 40-inch bed	32- 96- 96	23	436 de*	0.42 ab
1 row on 40-inch bed	48-144-144	34	618 bcde	0.46 a
2 rows on 40-inch bed	48-144-144	34	690 abcde	0.40 ab
2 rows on 40-inch bed	64-192-192	46 knifed	890 ab	0.42 ab
2 rows on 40-inch bed	64-192-192	46	364 e	0.38 b
2 rows on 40-inch bed	80-240-240	57	782 abc	0.41 ab
2 rows on 40-inch bed	96-288-288	68	510 cde	0.41 ab
6 rows on 80-inch bed	48- 96- 96	34	618 bcde	0.41 ab
6 rows on 80-inch bed	72-216-216	51	764 abcd	0.43 ab
6 rows on 80-inch bed	96-288-288	68	946 a	0.44 ab
6 rows on 80-inch bed	120-360-360	85	854 ab	0.46 a
Fall test				
1 row on 40-inch bed	32- 96- 96	23	672 bc	0.48 a
1 row on 40-inch bed	48-144-144	34	710 bc	0.44 a
2 rows on 40-inch bed	48-144-144	34	836 ab	0.37 a
2 rows on 40-inch bed	64-192-192	46 knifed	872 ab	0.37 a
2 rows on 40-inch bed	64-192-192	46	800 ab	0.46 a
2 rows on 40-inch bed	80-240-240	57 knifed	510 c	0.41 a
2 rows on 40-inch bed	80-240-240	57	872 ab	0.39 a
2 rows on 40-inch bed	96-288-288	68	872 ab	0.45 a
6 rows on 80-inch bed	48-144-144	34	690 bc	0.37 a
6 rows on 80-inch bed	72-216-216	51	782 ab	0.39 a
6 rows on 80-inch bed	96-288-288	68	872 ab	0.41 a
6 rows on 80-inch bed	120-360-360	85	818 ab	0.39 a

*Entries in each block followed by the same letter are not significantly different at the 5% level as determined by Duncan's Multiple Range Test.

Other Vegetable Equipment Evaluated

In addition to the primary implements and operations discussed previously, several other implements have been evaluated as a part of this program in precision cultural practices for commercial vegetable production. Although not essential to the precision vegetable cultural system, these implements have many uses in a commercial vegetable operation.

A. Tiller/shaper

A bed shaper was attached to the back of a heavy-duty rotary tiller to allow tillage of the bed top and bed shaping in one operation, as shown in Figure 12. The depth of tilling is easily controlled by changing the height of the shaper relative to the tiller. Depths of 2 to 4 inches have been used most frequently. A shallow depth of 2 inches allows secondary tillage of the bed top without destroying the beds. This operation has proven useful for light tillage prior to replanting and for tillage over buried drip irrigation lines.

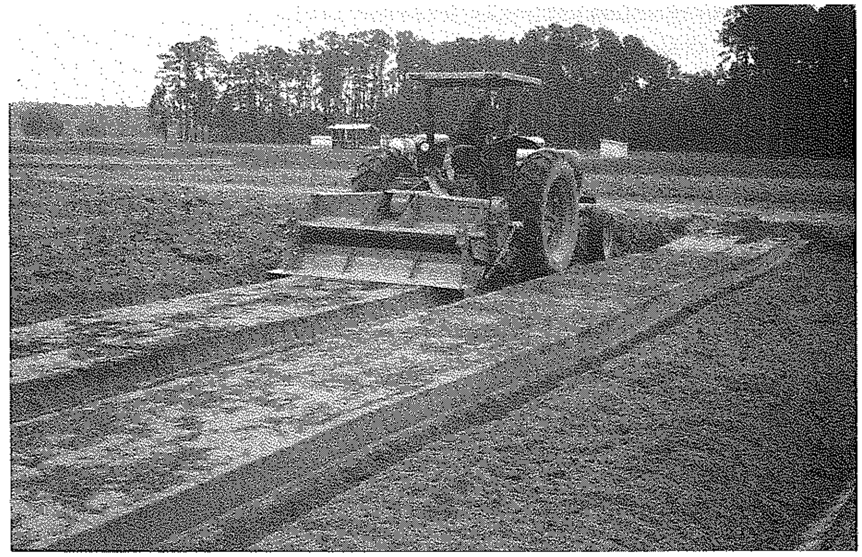


Figure 12. Combination rotary tiller and bed shaper forming 80-inch beds.

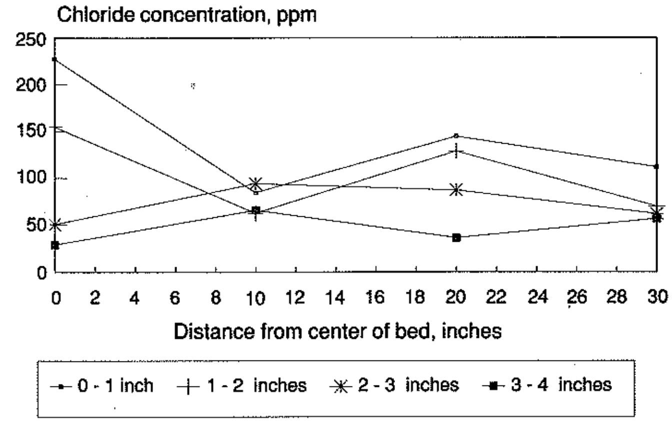
The tiller/shaper can also be used for preplant herbicide incorporation. Table 24 and Figures 13 to 19 show the results of a comparison of different methods of incorporating the herbicide trifluralin prior to planting. Incorporation with the tiller/shaper was not as uniform as with a high speed, straight tine tiller.

Table 24. Results of preplant herbicide incorporation study. Weed counts tabulated by species and distance from center for each treatment. Counts are weeds per 4 in² and represent the means of 4 replications.

	Distance from center	Mean weed counts							
Weed type	in	T1	T2	T3	T4	T5	T6	T7	LSD
Sedges	0	2.25	6.25	6.50	6.25	4.25	2.00	1.00	3.18
Sedges	10	6.75	3.25	3.25	6.75	3.75	5.25	2.50	3.36
Sedges	20	3.00	3.00	5.25	5.50	5.75	5.75	3.50	3.55
Sedges	30	2.75	3.00	4.75	5.75	4.50	3.25	2.75	2.62
Broadleaf	0	0.25	0.25	0.25	0.50	0.75	1.25	1.25	1.09
Broadleaf	10	0.00	1.25	0.50	0.75	0.25	0.50	0.75	1.16
Broadleaf	20	0.25	0.50	0.50	0.25	0.75	1.00	0.25	1.16
Broadleaf	30	1.25	1.25	1.25	0.00	0.00	1.50	0.75	1.43
Grasses	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grasses	10	0.25	0.00	0.00	0.25	0.25	0.00	0.00	0.48
Grasses	20	0.00	0.25	0.25	0.00	0.00	0.25	0.00	0.48
Grasses	30	0.00	1.00	0.75	0.00	0.25	0.25	0.25	1.32

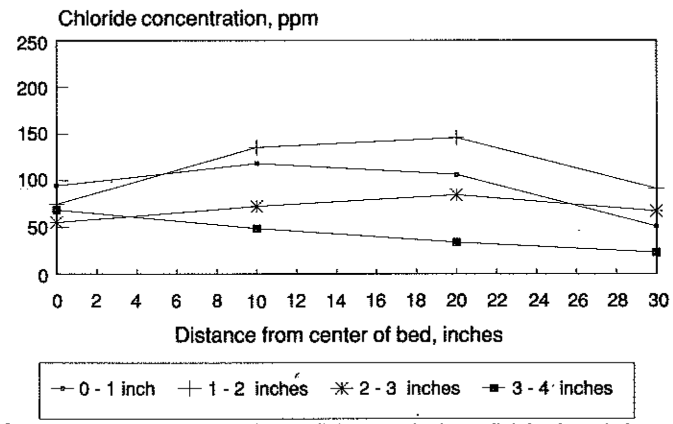
Key to treatment numbers:
T1 Spray flat, disk to a depth of 2-3 inches, disk bed, shape
T2 Spray flat, disk and cross disk to 2-3 inches, disk bed, shape
T3 Spray flat, till to 2 in. with "Flash Tiller," disk bed, shape
T4 Disk bed, spray, till bed top to 2 inches with "Flash Tiller," shape
T5 Disk bed, spray, till bed top to 4-6 inches with "Flash Tiller," shape
T6 Disk bed, spray, till bed top to 2 inches, shape with combination tiller/shaper
T7 Disk bed, spray, till bed top to 4 inches, shape with combination tiller/shaper

Figure 13. Incorporation uniformity, treatment number 1.



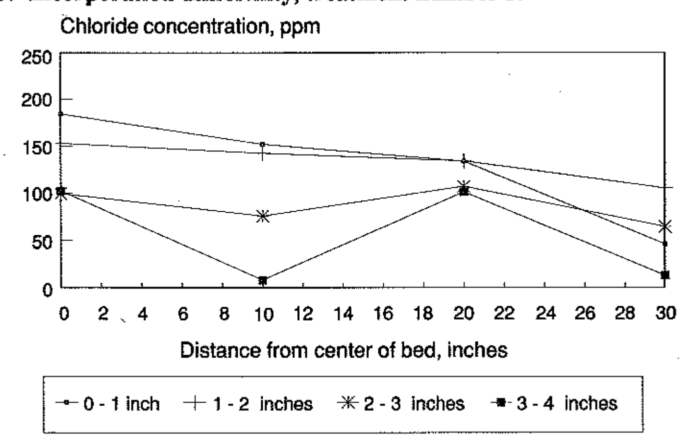
Spray flat, disk harrow to 2-3 inches, disk bed, and shape

Figure 14. Incorporation uniformity, treatment number 2.



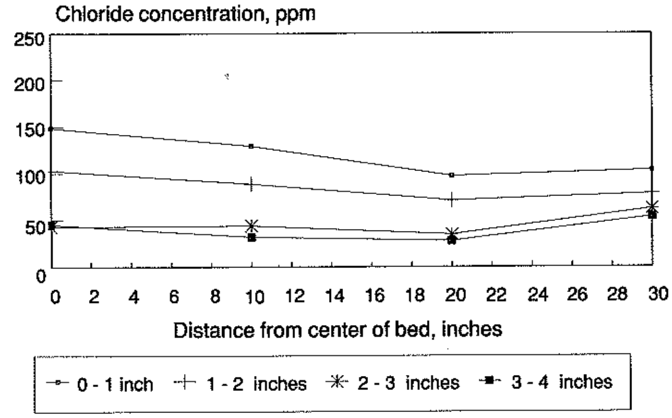
Spray flat, disk harrow and cross disk to 2-3 inches, disk bed, and shape

Figure 15. Incorporation uniformity, treatment number 3.



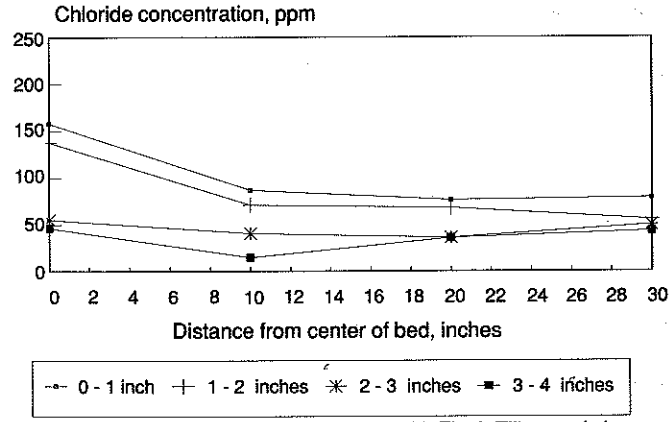
Spray flat, till to 2 inches with Flash Tiller, disk bed and shape

Figure 16. Incorporation uniformity, treatment number 4.



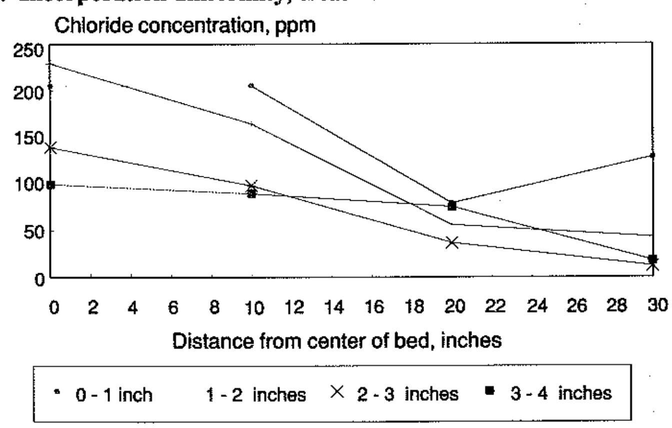
Disk bed, spray, till bed top to 2 inches with Flash tiller, and shape

Figure 17. Incorporation uniformity, treatment number 5.



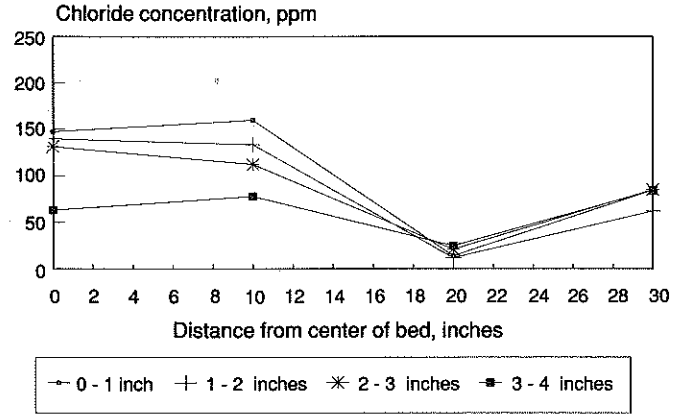
Disk bed, spray, till bed top to 4-6 inches with Flash Tiller, and shape

Figure 18. Incorporation uniformity, treatment number 6.



Disk bed, spray, till bed top to 2 inches with combination tiller/shaper

Figure 19. Incorporation uniformity, treatment number 7.



Disk bed, spray, till bed top to 4 inches with combination tiller/shaper

B. High Speed, Straight Tine Tiller

The "Flash Tiller," made by Befco, is a medium-duty rotary tiller with straight tines that are twisted slightly but do not have the L-shape of most tiller tines. This tiller is designed strictly for secondary tillage and chemical incorporation rather than heavy primary tillage. The tiller turns at a fairly high speed of 155 to 300 rpm and is designed to be used at a higher ground speed than a standard rotary tiller. The 300 rpm speed was found to be optimum for most work.

This tiller was found to be effective for incorporating light amounts of surface residue and for working up a bed surface for replanting. It also proved to be an excellent tool for herbicide incorporation, either on a bed top (Figure 20), or on flat ground prior to bedding. As shown in table 24 and Figures 13 to 19, the most uniform incorporation was obtained with this tiller running 2 inches deep.

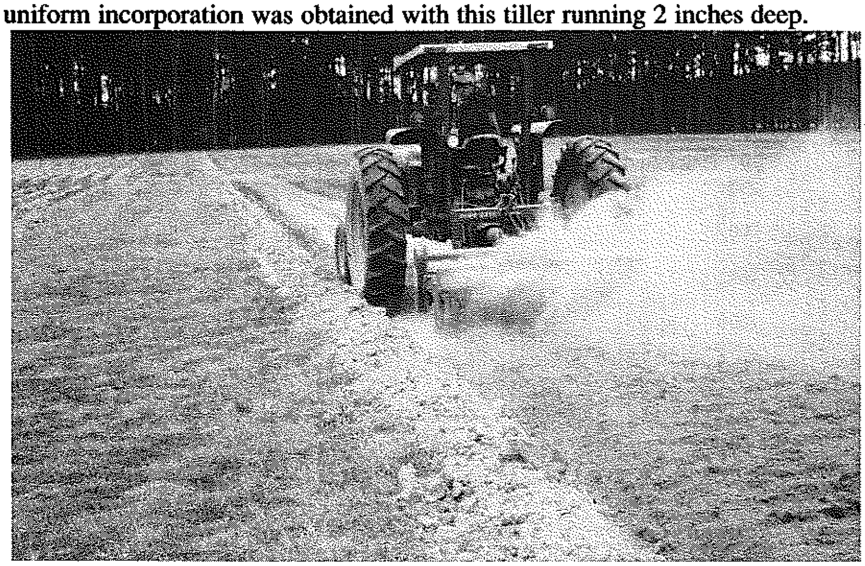


Figure 20. High-speed straight tine "Flash" tiller incorporating herbicide on beds.

C. Flail mower

A flail mower or shredder is a useful implement for shredding plant residue after harvest. With most vegetable crops, disposal of crop residue immediately after harvest is needed to discourage insect or disease buildup. A flail mower is generally more effective at shredding plant residue than is a rotary mower. A light-duty flail mower was evaluated and found to be effective at shredding a wide range of crops including broccoli, watermelon, pepper, sweet potatoes, and strawberries. The mower is shown in Figure 21. The same mower can then be used for mowing weeds and grass on the farm. It will do a very effective job of all general mowing except high-quality turfgrass.

Figure 21. Flail shredder used to shred plant debris after harvest. The machine is shredding broccoli stalks in this photo.

D. Undercutter

Root crops such as onion and carrot need to be undercut prior to harvest. There are specialized carrot harvesters available that are used in major production areas, but farmers with limited acreage may not want to invest that much money on one crop. Mechanical harvesters for sweet (short-day) onions are less readily available. Some semi-prototype machines are in use in other parts of the country, but most southern onions are hand harvested. When hand-harvesting onions or carrots, some type of undercutting blade run under the crop to cut the roots and fracture the soil prior to lifting the carrots or onions is helpful.

A simple and effective undercutter consists of a flat blade sharpened on the leading edge and angled down 5 to 10°. This can be mounted on a surplus toolbar frame with cone guide wheels to control depth and lateral location. A simple machine of this type, as shown in Figure 22, has proven to be effective for both carrots and onions. An even more effective, but more expensive, design for onions uses a ground-driven rotating square rod running under the onions.

Figure 22. A horizontal knife running under carrots to loosen the roots for harvest. The same machine is used for harvesting onions.

E. Pendulum spreader

Precise application of fertilizer is critical to commercial vegetable production. Granular fertilizer is the most common form applied on vegetable farms in Louisiana, although some liquid fertilizer is used. Sidedress as well as preplant applications are necessary for the production of most vegetable crops, unless higher priced controlled-release granular fertilizer is used. Preplant applications of fertilizer can be broadcast on the field or knifed in near the row locations. Sidedress applications can be made by fertigation (soluble fertilizer applied in irrigation water), but band applications of granular fertilizer are most common.

A relatively recent innovation in fertilizer application is the pendulum-type spreader. Pendulum spreaders have a horizontal tube or spout that is oscillated from side to side. Fertilizer is metered into the base of the tube and thrown out the rear where a deflector spreads it. Distribution can be fairly uniform, and the side-to-side skewing common to spinner spreaders is virtually eliminated. This type of spreader is very effective for broadcast applications, as shown in Figure 23. If broadcast applications were the extent of its uses, the pendulum spreader would not be particularly valuable for a vegetable farmer.

The feature that makes these spreaders especially versatile is the availability of optional accessories to allow precise banding. Banding can be accomplished two ways. Two fairly wide bands can be obtained by using a short spout with no deflector on the end. This method allows bands 2 to 3 feet wide to be spaced 8 to 20 feet apart (wider with some models). This type of band is very appropriate for fruit crops (grapes, blueberries, blackberries, etc) that are frequently grown in conjunction with vegetable operations.

Figure 23. Pendulum-action spreader operating in broadcast mode. The spout at the rear oscillates from side to side in a horizontal plane.

The second method of banding with a pendulum spreader involves mounting a divider box on the rear over a shortened spout to drop the material down 2 or 4 tubes. The tubes can drop the fertilizer on the surface, as in Figure 24, or the material can be knifed into the soil, as in Figure 25. This versatility makes a spreader of this type ideal for commercial vegetable farmers, since one fertilizer applicator can be used to broadcast, apply wide bands, or knife in precise bands of fertilizer for sidedressing.

Figure 24. Pendulum-action spreader with banding attachment used to sidedress vegetable crops.

Figure 25. Pendulum-action spreader with banding and knifing attachments, used to knife in preplant fertilizer.

Summary

Growing commercial vegetable crops requires a very high level of management. Precision cultural practices can make a significant contribution to the economic success of small and large commercial operations. These cultural practices include precise bed shaping, precisely locating rows on the beds, planting the rows with a precision vegetable seeder or transplanter, and using cone guide wheels for precise location of subsequent operations such as cultivation and sidedressing. The precision cultural system was assessed to be an excellent method for production of the vegetable crops that were tested.

Growing vegetable crops in multiple rows per bed offers potential yield increases, but it would be difficult and impractical with conventional equipment. Cultivation of multiple narrow rows is difficult and unwieldy with conventional equipment, but with the system tested in these experiments, subsequent cultivations were performed efficiently and effectively. Cultivation within 3 inches of the plant row was accomplished easily in all the crops grown with the use of the cone guide wheels on the precisely shaped and planted beds.

Planting in multiple rows per bed did not affect the incidence or amount of diseases or insects. Good spray equipment with appropriate spray nozzles, proper pressure, and accurate calibration is essential in any commercial vegetable operation. Most commercial units can be utilized for spraying multiple rows per bed with no changes in sprayer configuration.

With the exception of the bed shaper, the equipment was assembled from commercially available components, which were easily acquired from equipment dealers and assembled in a research shop. No special or unusual tools or machines were used to build the equipment. Plans for the bed shaper are available from the Louisiana Cooperative Extension Service, and construction of the implement can be accomplished in a local shop. ■

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