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Charles E. Snipes

William L. Barrentine

Ralph S. Baker

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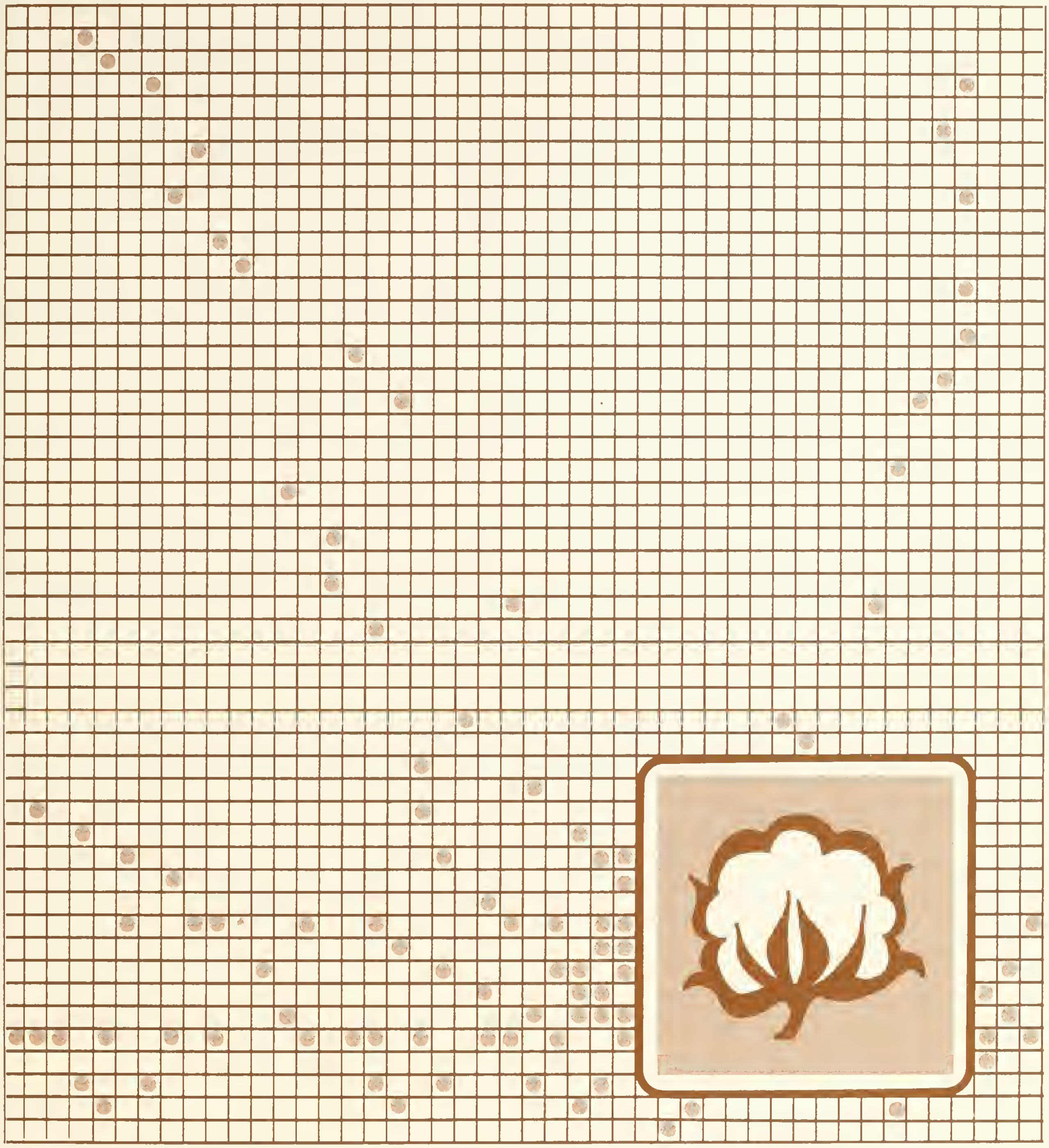

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MAFES
MISSISSIPPI AGRICULTURAL & FORESTRY EXPERIMENT STATION Verner G. Hurt, Director Mississippi State, MS 39762
Donald W. Zacharias, President Mississippi State University R. Rodney Foil, Vice President

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Charles E. Snipes
Assistant Plant Physiologist
Delta Branch Experiment Station

William L. Barrentine
Plant Physiologist
Delta Branch Experiment Station

Ralph S. Baker
Plant Physiologist
Delta Branch Experiment Station

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Introduction

Following the introduction of 2,4-D in 1945, dalapon was introduced in 1953, and diuron was introduced in 1954 (1). Other herbicides introduced prior to 1965 include DSMA, paraquat, linuron, trifluralin, and fluometuron. Some of these herbicides became extensively used in cotton to reduce the strong dependence on hand labor (5).

Selectivity (if present) of these compounds was an inherent property of the compound or was achieved by placement or precise delivery of the compound to the target. For example, diuron provided excellent preemergence weed control in cotton, but also could be used postemergence with the addition of a surfactant (8). Without selectivity to cotton, precise placement was necessary to prevent excessive crop injury. Equipment with parallel action mounting so that nozzles were positioned at a constant height and angle was designed to aid in herbicide placement (6).

Soil incorporation was another revolutionary procedure that evolved during the early 1960's. Because trifluralin and other dinitroanilines were volatile and photodegradable, considerable loss occurred with surface preemergence sprays. Thus, these were applied preplant and incorporated into the soil. The new application method resulted in consistently higher levels of weed control with less dependence upon rainfall than the conventional preemergence treatments. A burst of activity followed with the development of all kinds of equipment for soil incorporation. The conventional disk harrow was readily available, but new equipment ranged from many types of ground-driven incorporators to power tillers.

The first significant increase in the use of aerial application for herbicides in cotton came about with the broadcast preplant use of dinitroanilines. Wide disk harrows or field cultivators followed closely behind the herbicide application to prevent losses from volatilization. In this manner, large acreages were treated rather quickly. Aerial application using spray volumes of 3 to 5 gallons per acre are now standard, but ultra-low volumes (ULV) of 1 quart per acre or less are possible (9).

Innovative ideas have evolved over the years in order to make use of products that are non-selective. The recirculating sprayer was first developed in 1964 for spraying crops where weeds were taller than the crop (10). Chandler et al. (3) used activated charcoal to protect cotton from high rates of diuron.

The introduction of glyphosate in 1974 stimulated a great deal of interest in obtaining selectivity with this compound due solely to placement. The shielded sprayer was developed by Jordan in 1978 (7). The most widely used system was the ropewick applicator developed by Dale (4).

Weed scientists as a group have long recognized the need for improved application methodology because of experience with problems associated with calibration, getting the herbicide on target, and other factors which result in poor performance. The objective is optimum efficacy coupled with minimum cost per unit of production.

Producers' needs are the prime objective of research. Thus, their opinions are sought by weed scientists involved in application technology. Until more selective herbicides are discovered, current application technology must be used more efficiently. The objective of this report is to define major areas of herbicide application technology and identify present problems and future needs.

Materials and Methods

During the fall of 1987, a survey was mailed to approximately 70 farmers, consultants, extension workers, and research personnel. Of the 23 respondents (33% of total) 20 were farmers (19 Delta, 1 non-Delta), one was a state researcher, one was a consultant, and one was not identifiable. Ten of the 20 farmers reported acreages exceeding 20,000 acres. Assuming an average farm size of 500 acres for the remaining 10, the survey covers some 25,000 acres of cotton at some 17 locations, mainly within the Delta (Figure 1).

Equipment descriptions as described by Barrentine (2) were mailed along with each survey so that identification of certain pieces of equipment could be standardized. The survey was divided into three major categories or parts. The first asked the question *"What percent of the cotton acreage on your farm (or in your state) receives . . .?"* The various categories given were as follows:

A. Preplant foliar (PPF) or "burn down" herbicides _____%

B. Preplant incorporated (PPI) herbicides _____%
- Band _____%
- Broadcast _____%

C. Preemergence (PRE) surface herbicides _____%
- Band _____%
- Broadcast _____%

D. Postemergence (POT) over-the-top _____%
- Band _____%
- Broadcast _____%
- Spot _____%

E. Post-directed sprays (PDS) _____%
- Band _____%
- Broadcast _____%

F. Layby (LBY) _____%
- Band _____%
- Broadcast _____%

The second part asked the question *Of the PPI applications on your farm (or in your state), what percent is applied with:* where the categories were given as follows:

A. Ground-driven equipment ______%
   1. Tractor mounted sprayer attachment______%
   2. Hi boy, spray coupe, etc. ______%
   3. Planter attachment ______%
   4. Other ______%

B. Fixed wing aircraft ______%

These same responses were asked for after replacing "PPI" in the above with "PRE" or "POT," yielding three segments to this section of the survey.

The final section asked the question *Incorporation of dinitroanilines and other such herbicides is done with . . . ?* The choices given are covered in Figures 5 through 10. For clarity, descriptions of various types of incorporation equipment were included in each survey. These descriptions are provided in Table 1. Although 23 responses were returned, not all categories had a response. The number of responses ranged from 20 to 23 for Part I, 16 to 23 Part II, and 6 to 21 for Part III.

Results and Discussion

Only 3% of the cotton acreage reported received some sort of PPF treatment (Figure 2), indicating very little stale seedbed planting— probably due to raised beds required for adequate stand establishment and positive yield response from subsoiling.

Ninety-eight percent of the acreage received a PPI herbicide, of which 33% was applied in a band and the remain-

Table 1. Equipment description of devices used for soil incorporating herbicides, (Adapted from Barrentine, 1988).

Tandem disk harrows (four-gang). Types are: (1) Finishing disk, spherical blades, spaced <8 inches apart, <20 inches in diameter; (2) Combination disk, spherical, or conical blades, spaced 8 to 9 inches apart, 20 to 24 inches in diameter; (3) Cutting disk, spherical or conical blades, spaced >9 inches apart, >24 inches in diameter. Blades may be notched or not.

Field cultivators are equipped with spring steel shanks which have an integral forged point or mounting holes for replaceable sweeps. Sweeps may be 2 inch chisel points or 5 to 12-inch shovel sweeps. The shanks are generally spaced 6 to 9 inches and stagger-mounted on two or more rows. The "C" shanks can be rigid or spring (loaded) mounted.

Flexible shank cultivators (Danish S-Tine cultivators). The S-Tine or shanks may be coiled-S or S shaped. The spring steel shanks are usually lighter in weight than the field cultivators and are stagger-mounted on 2 or more rows. Sweeps may be small ¾-inch chisel or 2½-inch "goosefoot" sweeps.

Power-driven (PTO) tillers are tractor-mounted, PTO-driven and of three types; (a) *vertical-action* in which the tines (blades) ("L," "C," or straight shaped of various lengths) rotate about a transverse axis to the direction of tractor travel, (b) *horizontal-action* tillers in which tapered spikes rotate and 'stir' the soil in complete circles or oscillate, (c) *combination-action* tillers in which tapered spikes engage the soil with both vertical and horizontal action.

Spike/spring (tine) tooth harrows are drag harrows of two types, the spike tooth and the coil-tine harrow (often called spring tooth cultivator, tine-tooth harrow).

Ground-driven devices are of several designs and include the rolling cultivator (Lilliston), open-steel-mesh-wheel (Gandy-Ro-Wheel), rotary hoes, etc. The rolling cultivator consists of gangs of ground-driven tine wheels with curved, twisted blades radiating from the center as spokes on a wheel. The open steel mesh wheel is constructed of about 2-inch open steel mesh rolled and welded into a wheel. Rotary hoes are similar in design to the rolling cultivator except the tines are curved, rounded, tapering to a point (spiker tines). These have long been used to break the soil crust to aid in crop emergence and destroy small emerging seedling weeds. Other tine shapes are also used.

Combination tools (seedbed conditioners) are two or more tillage devices used in combination on the same implement. Various combinations of a ground driven rotary spiral cutter reel, spike tooth harrow, drag board or plank, field cultivator, disk gangs, coil-tined harrow, flexible shank cultivator (Danish or S-Tine harrow), rolling cultivator gangs, rotary hoe gangs, or power-tillers can be implemented.

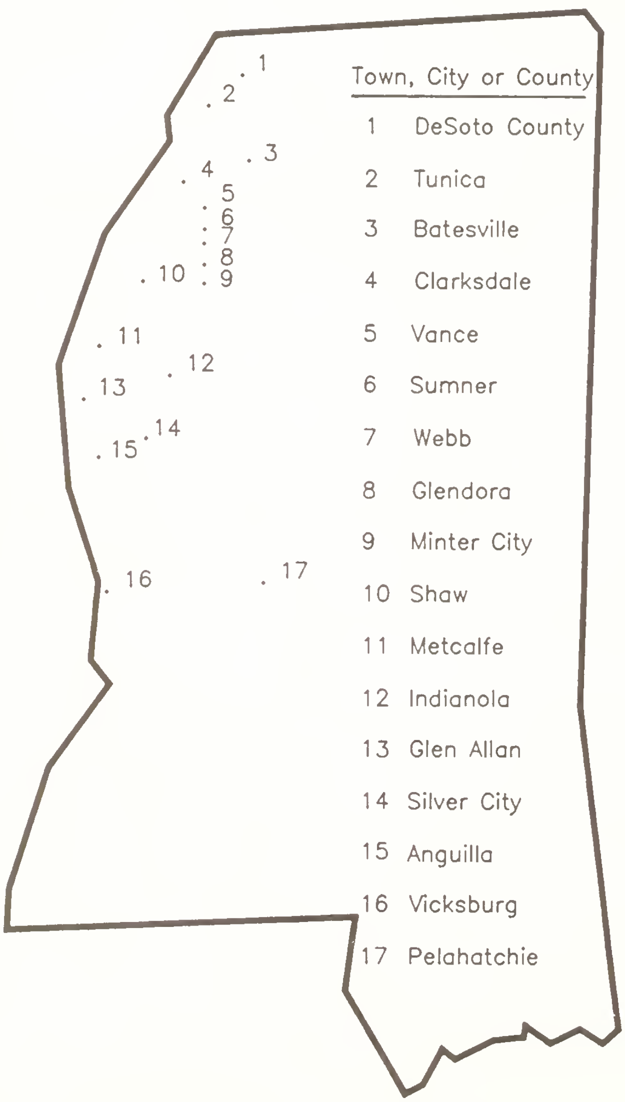

Figure 1. Distribution of responses to "Herbicide Application Techniques for Mississippi Cotton" survey, Fall 1987.

ing portion was broadcast. Less than 3% of this was applied by air (Figure 3), which indicated that interest in aerial application of these compounds was not as prevalent as during the 1960's and early 1970's (2).

Preemergence surface applications were applied to 100% of the cotton acreage, with 99% applied in a band (Figure 2). Aerial preemergence applications were less than 1% (Figure 3). The minor use of broadcast preemergence application is probably due to economics.

Less than one-third of the cotton acreage in the Mississippi Delta received a post-emergence-over-the-top (POT) treatment (Figure 2). This method constituted the highest percentage of aerial application, with 10% being applied with fixed wing aircraft (Figure 3). Of the 31% of POT-treated acreage, 64% was spot treated, 18% was band treated, and 18% was broadcast treated (Figure 2). The lack of selective broadleaf compounds for POT use in cotton was reflected by these numbers. Also, the large percentage of spot treatments reflect the widespread economical use of sethoxydim or fluazifop. These two compounds probably also make up a portion of the 36% of band and/or broadcast treatments.

Due largely to the lack of selective broadleaf POT compounds, 81% of the cotton acreage received a PDS treatment, of which 99% was applied in a band (Figure 2). These numbers were indicative of the widespread use of band applications for PRE treatments. Applying an herbicide in a band, in most cases, dictates that a second weed control measure will be necessary to alleviate weed problems in the untreated portion of the row. Also, available herbicides are less than 100% effective, and this makes a PDS application necessary.

Seventy-nine percent of the cotton acreage reported, received a LBY treatment of which 80% was broadcast (Figure 2). Apparently, late-emerging weeds were prevalent in sufficient quantities to warrant an extended weed control program. PDS and LBY treatments were both approximately 80%, which suggests that these two systems were used in combination.

Figure 4 provides an illustration of how PPI, PRE, and POT applications were applied by ground. PPI applications were made 89% of the time with a tractor-mounted sprayer. This allowed the use of an incorporating device along with the sprayer to eliminate one trip across the field. Due to the prevalence of band applications, 60% of the PRE treatments were applied with a planter-attachment, which enables the producer to plant and spray at the same time. Tractor-mounted sprayers were used 39% of the time, while high clearance equipment was used 1% of the time.

POT applications were applied 57% of the time with tractor-mounted sprayers, 35% of the time with spot sprayers, and 4% each for high clearance equipment and ropewick applicators. Introduction of sethoxydim and fluazifop has apparently reduced the application of glyphosate by ropewick applicators. These compounds are very selective and eliminate the need for slow precise application necessary for a non-selective herbicide such as glyphosate.

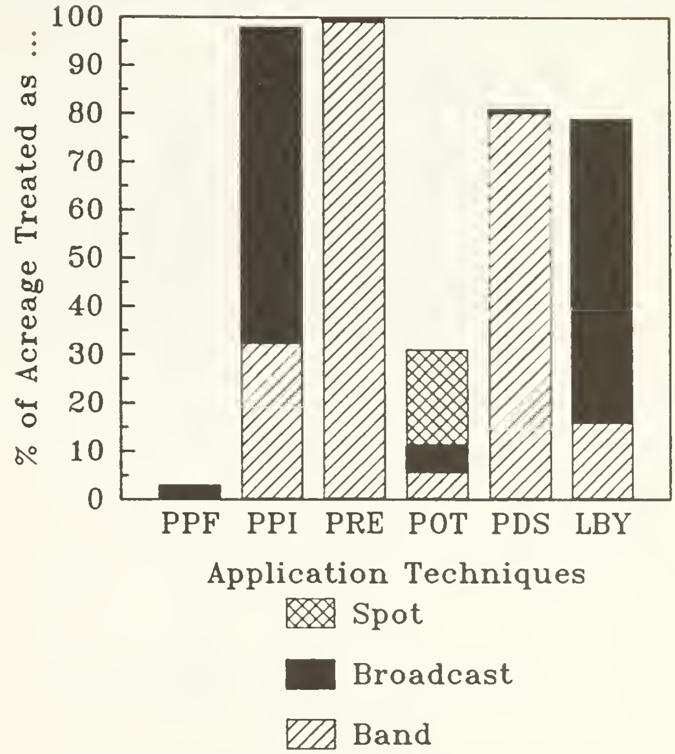

Figure 2. Percent of cotton acreage treated as preplant foliar (PPF), preplant incorporation (PPI), preemergence (PRE), postemergence over-the-top (TOP), post-directed spray (PDS) and layby (LBY) treatments in Mississippi, 1987.

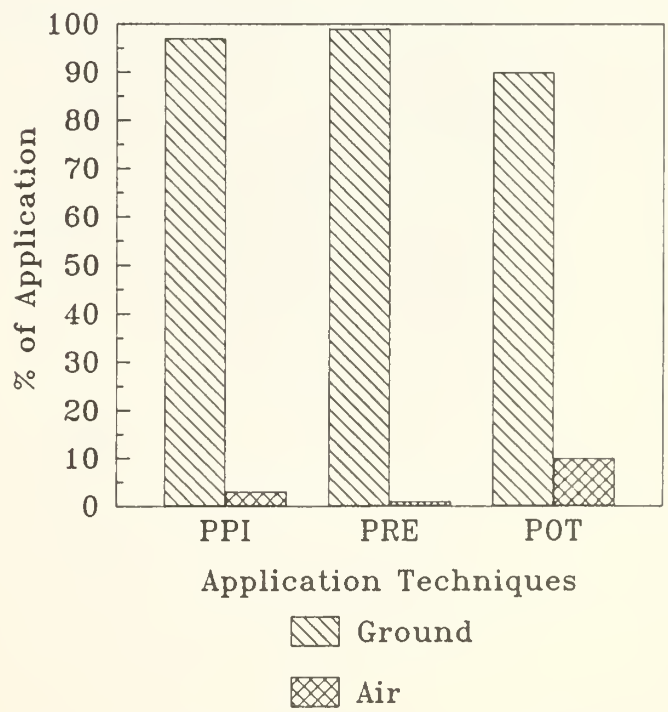

Figure 3. Distribution of ground versus air application of herbicides applied in cotton as PPI, PRE or POT treatments in Mississippi, 1987.

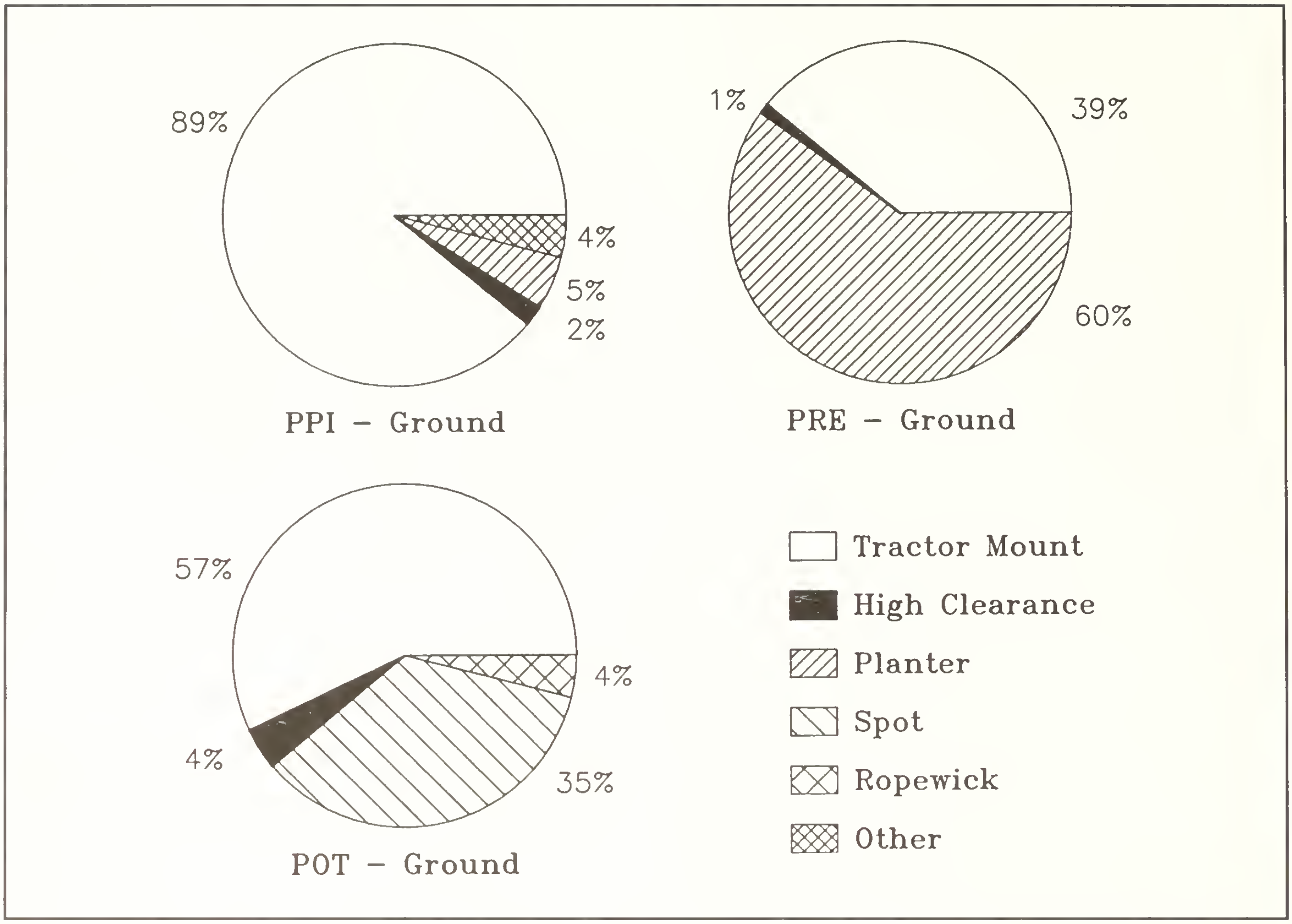

Figure 4. Distribution of how herbicides are applied in cotton by ground equipment in Mississippi, 1987.

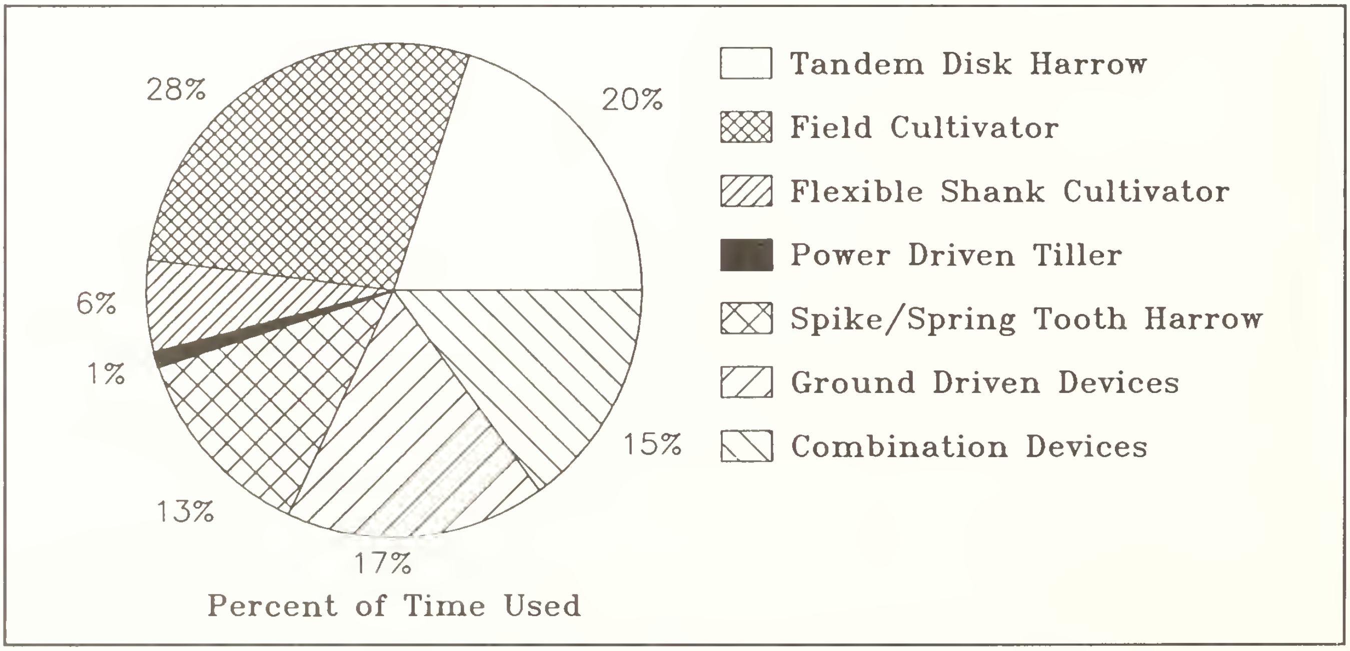

Figure 5. Producer preference of devices used to incorporate cotton herbicides in Mississippi, 1987.

Nearly half of all soil incorporation was done with either a tandem disk or field cultivator, with each type having a 20% and 28% use rate, respectively (Figure 5). Within the tandem disk category, 50% was done with a finishing disk while 28% used a cutting disk and 22% used a combination disk (Figure 6). Incorporation with a spring-mounted field cultivator accounted for 98% of the total (Figure 7). Of these, 83% were equipped with shovel sweeps, while 10% and 5% were equipped with forged points and chisel points, respectively. The remaining 52% of the incorporating devices were divided among flexible shank cultivators (6%), power-driven tillers (1%), spike/spring tooth harrows (13%), ground-driven devices (17%), or combination devices (15%).

Flexible shank cultivators accounted for 6% of the various types of incorporating devices. Seventy-five percent of these were a coiled S-tine type implement (Figure 8) equipped with either goosefoot sweeps (50% of total) or chisel sweeps (25% of total).

Spike or spring tooth harrows were used 13% of the time, with 75% of these being a spike tooth harrow (Figure 9). Ground-driven devices ranked third in use for incorporation. Of this, a rolling cultivator was used 68% of the time (Figure 10).

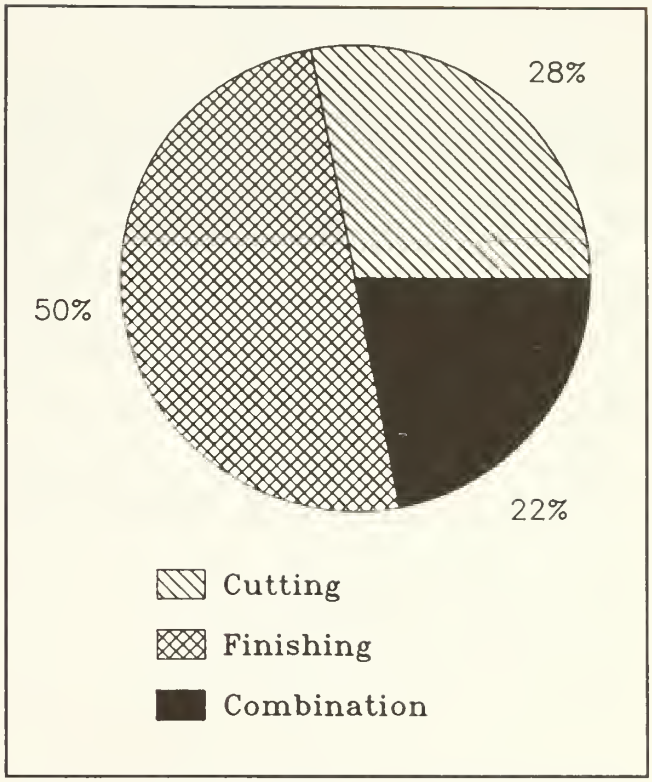

Figure 6. Producer preference of specific types of tandem disks for incorporation of dinitroaniline-type herbicides in Mississippi cotton, 1987.

Conclusions

Historically, herbicide application techniques have been tailored to provide the most effective use of available compounds. Classic examples of this include: incorporation of dinitroaniline type herbicides, post-directed sprays of compounds such as diuron or fluometuron which were originally developed for preemergence use, and ropewick applications. Based on the results presented, this is still the case today. For example, the introduction of sethoxydim and fluazifop has aroused interest in spot applications because of costs and scattered, light infestations of problem grasses such as johnsongrass [*Sorghum halepense* (L.) Pers.].

The most obvious gap in herbicide application technology is the low prevalence of POT sprays. This is directly related to the lack of selective and effective postemergence broadleaf compounds and also explains the heavy dependence upon post-directed sprays. Also, the apparent need for cultivation because of widespread use of preemergence sprays applied as a band reinforces the need for postemergence sprays.

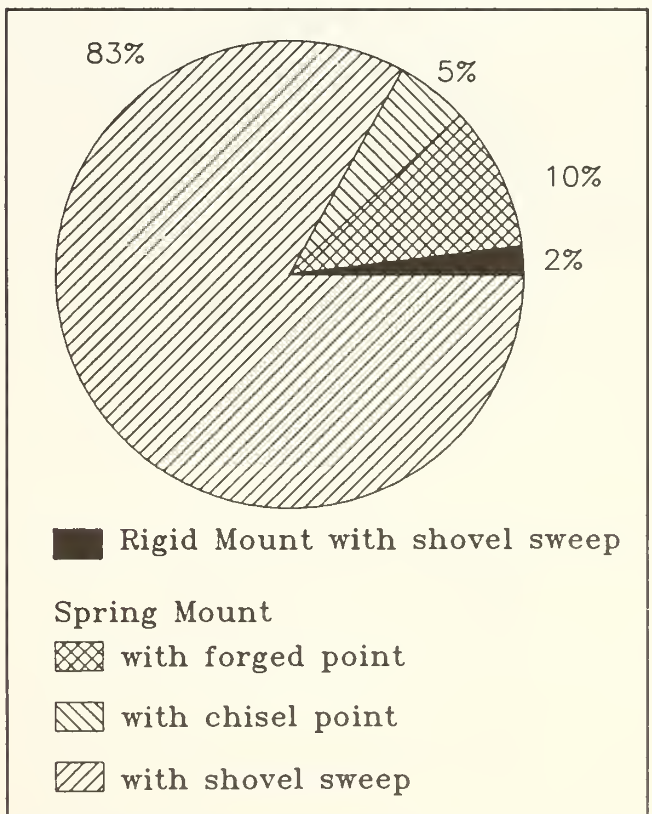

Figure 7. Producer preference of specific types of field cultivators used for incorporation of dinitroaniline-type herbicides in Mississippi cotton, 1987.

Acknowledgments

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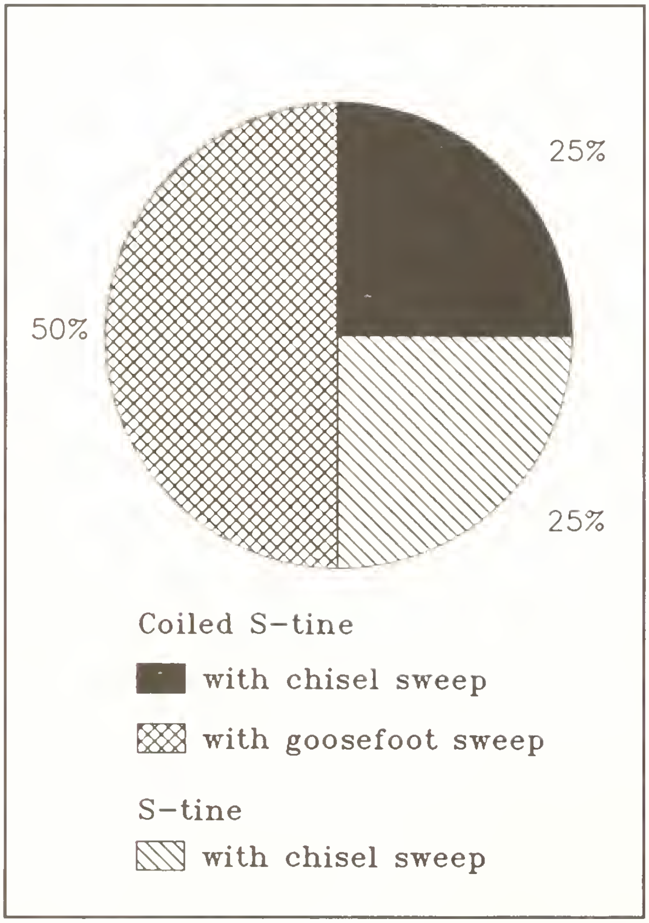

Figure 8. Producer preference of specific types of flexible shank cultivators used for incorporation of dinitroaniline-type herbicides in Mississippi cotton, 1987.

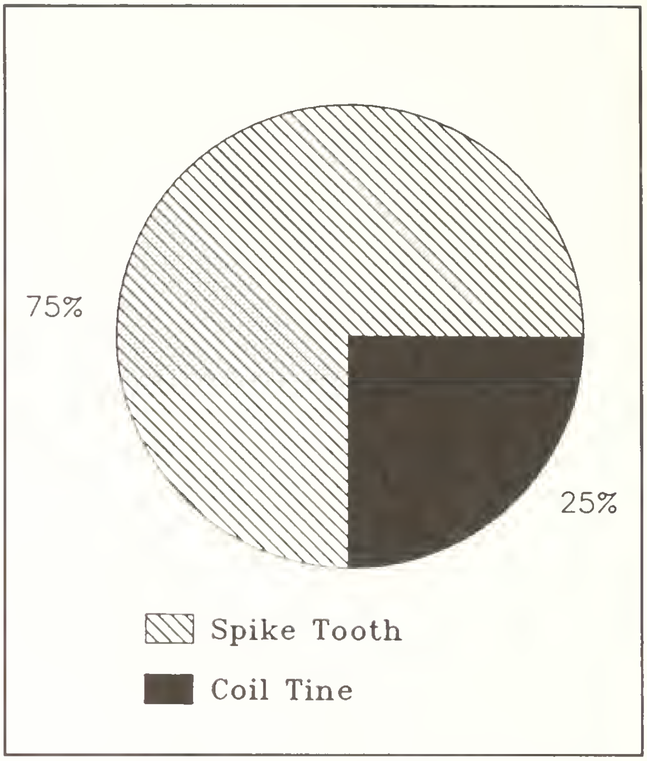

Figure 9. Producer preference of specific types of spike/spring tooth harrows used for incorporation of dinitroaniline-type herbicides in Mississippi cotton, 1987.

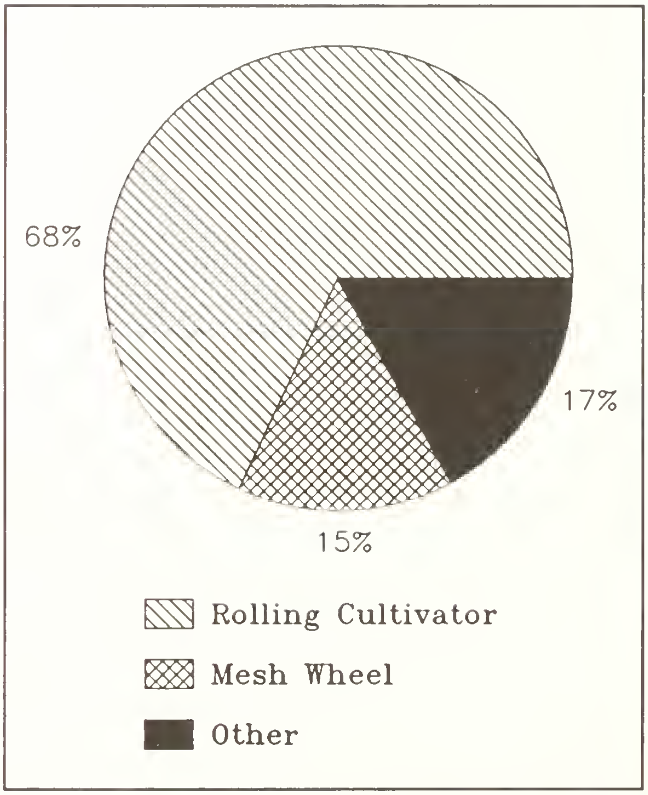

Figure 10. Producer preference of specific types of ground-driven devices used for incorporation of dinitroaniline-type herbicides in Mississippi cotton, 1987.