Chapter **10**

Controlling Weeds In Peanuts[1]

ELLIS W. HAUSER, P. W. SANTELMANN,
GALE A. BUCHANAN AND O. E. RUD[2]

Providing favorable conditions for a desirable plant species (the crop) while concurrently excluding undesirable plants (the weeds) represents the major essence of agricultural pursuits. Crop species and weeds respond similarly to the environmental factors involved in plant growth; i.e., water, air, nutrients and light. Those portions of these factors used by weeds are not available to the crop. Under some conditions, crop plants and weeds can grow together for at least a portion of the growing season without significant harm to the crop. However, some factor usually becomes limiting to plant growth. Then, the presence of weeds limits crop growth and reduces yield or quality. Successful crop production demands that maximum economic yields be harvested from the land. To realize this goal, weeds cannot be allowed to deprive crop plants of water, air, nutrients and light. Therefore, weed control usually plays a vital role in the production of any crop.

[1]This is a report on the current status of research involving use of certain chemicals that require registration under the Federal Environmental Pesticide Control Act of 1972. It does not contain recommendations for the use of such chemicals, nor does it imply that the uses discussed have been registered. All uses of these chemicals must be registered by the appropriate State and Federal agencies before they can be recommended.

[2]Respectively, Research Agronomist, Georgia-South Carolina Area, Agricultural Research Service, U. S. Department of Agriculture University of Georgia Coastal Plain Experiment Station, Tifton, Georgia 31794; Professor, Oklahoma State University, Stillwater, Oklahoma 74074; Associate Professor, Auburn University, Auburn, Alabama 36830; and Assistant Professor, Virginia Polytechnic Institute, Tidewater Research Station, Holland, Virginia 23391.

General Principles of Plant Competition

An understanding of some general principles involved in competition among plants provides an increased perspective of competition between weeds and peanuts. One principle involves the competitive effects that one plant exerts upon another. These effects depend upon the relative ability of the two plants to utilize growth factors from the environment. Similarities in foliar characteristics, root patterns and methods of reproduction all contribute to the competitive relationship of a weed-crop system. Both between and within the species, the more similar plants are, the more they will compete with each other. Between species *per se,* that species which can better utilize the growth factors of the environment will dominate if population levels are similar. Tolerance to various stresses such as drought, flooding or suboptimal soil pH levels may become important under some conditions.

A second principle of plant competition is that the first species occupying a given space has an advantage over species which invade later. This is why farmers should strive to plant on a clean seedbed. In tall-growing crops such as soybeans or cotton, which shade the ground, weeds which emerge late in the season are unable to effectively compete with the crop species. Knake and Slife (77) have shown that giant foxtail *(Setaria faberi* Herrm.) seeded 3 weeks after corn was planted produced 500 pounds of dry matter per acre whereas giant foxtail seeded 3 weeks after soybeans produced virtually nothing. Thus soybeans compete better with giant foxtail than does corn. Weeds emerging late in the growing season usually compete with crops less than those emerging early in the season (15, 19, 39, 40, 69). Less competition by late emerging weeds is directly influenced by the competitive ability of the crop species at the time the weeds emerge.

Another principle of weed competition is that some weed species are more competitive than others on any given crop. Staniforth (117) reported that giant foxtail reduced soybean yields more than did either green foxtail *(Setaria viridis* (L.) Beauv.) or yellow foxtail *(Setaria lutescens* (Weigel) Hubb.). Velvetleaf *(Abutilon theophrasti* Medic.) competed more effectively with soybeans than did either yellow or green foxtail.

Soybean yields, according to Wilson and Cole (135) were equally affected by tall morningglory *(Ipomoea purpurea* (L.) Roth), ivy leaf morningglory *(Ipomoea hederacea* (L.) Jacq.) or mixtures of both species when the total weed density was equal. As the density of morningglory increased, soybean yields decreased. Soybean yields and other plant characteristics were not seriously affected when morningglories were removed 6 to 8 weeks after soybeans were planted.

Brimhall *et al.* (15) reported that green foxtail was less competitive per plant with sugarbeets than was redroot pigweed *(Amaranthus retroflexus* L.). When the density of foxtail was less than one plant per beet plant, yields were not reduced. When pigweed or pigweed plus green foxtail were grown with beets, yields were significantly reduced at densities as low as one weed per eight beets. Zimdahl and Fertig (140) later reported that, generally, broadleaf weeds were more competitive than annual grasses in sugarbeets.

Weed Competition in Peanuts

Peanut plants are less adapted to mechanical cultivation than are most other agronomic crops. Although initial elongation of the radicle is rapid, peanut foliage grows slowly. In the USA, peanuts are usually planted from April to June but complete ground cover (in conventional row spacings) is not attained until 8 to 10 weeks after planting. The peanut canopy is usually thinner in depth than crop canopies such as soybeans or cotton. Consequently, weeds, usually broadleaf species, that germinate early and are not controlled by various weed control practices "escape" the peanut canopy and compete with the crop relatively late in the growing season. Although these are often referred to as "late-season" weeds, preliminary research, initiated in 1971 by Hauser and Buchanan, suggests that with at least two species, sicklepod and Florida beggarweed, germination is early in the growing season. Additional research will be required to further document these observations.

Because of the low-growing nature of peanuts, covering weeds with soil during cultivation is not practical. In fact, the peanuts may suffer more than the weeds. Numerous workers (3, 12, 13, 48, 49) reported yield reductions following cultivation in which soil was allowed to partially cover peanut plants.

The growth habits of the peanut plant make weed removal extremely difficult, once weeds have become established in the row. After both peanuts and annual grass weeds, such as crabgrass (see Table 1 for Latin names of common weeds in peanuts) and goosegrass achieve some measure of growth, mechanical removal with tractor-mounted cultivators is impossible. Hand weeding is difficult, costly, and unrealistic under modern-day conditions. Consequently, peanut growers very rapidly accepted chemical weed control practices.

Oram (90) reported that when peanuts were grown under irrigation (which promoted rapid and vigorous growth of weeds) on the sandy soils of Libya, unweeded plots yielded less than half as much as weeded plots. He pointed out that higher peanut yields depend on weed suppression late in the growing season, since careful hand weeding following herbicide treatments improved weed control and resulted in substantial yield increases.

Table 1. Nomenclature of common weeds in peanuts

WSSA Common name[a]	Latin name
barnyardgrass	*Echinochloa crus-galli* (L.) Beauv.
beggarweed, Florida	*Desmodium tortuosum* (Sw.) DC.
carpetweed	*Mollugo verticillata* L.
cocklebur, common	*Xanthium pensylvanicum* Wallr.
copperleaf	*Acalypha* spp.
crabgrass	*Digitaria* spp.
croton	*Croton* spp.
crowfootgrass	*Dactyloctenium aegyptium* (L.) Richter
foxtail	*Setaria* spp.
goosegrass	*Eleusine indica* (L.) Gaertn.
horsenettle	*Solanum carolinense* L.
jimsonweed	*Datura stramonium* L.
johnsongrass	*Sorghum halepense* (L.) Pers.
lambsquarters, common	*Chenopodium album* L.
morningglory, smallflower	*Jacquemontia tamnifolia* (L.) Griseb.
morningglory, tall	*Ipomoea purpurea* (L.) Roth
nightshade, silverleaf	*Solanum elaeagnifolium* Cav.
nutsedge, purple	*Cyperus rotundus* L.
nutsedge, yellow	*Cyperus esculentus* L.
panicum, fall	*Panicum dichotomiflorum* Michx.
panicum, Texas	*Panicum texanum* Buckl.

[a]Common names of weeds are those published by the Weed Science Society of America (WSSA) Subcommittee on Standardization of Common and Botanical Names of Weeds. Weed Science 19:435-476. 1971.

Table 1. Nomenclature of common weeds in peanuts — Continued

WSSA Common name[a]	Latin name
pigweed	*Amaranthus* spp.
purslane, common	*Portulaca oleracea* L.
pusley, Florida	*Richardia scabra* L.
ragweed	*Ambrosia* spp.
sandbur	*Cenchrus* spp.
sedges, annual	*Cyperus* spp.
sicklepod	*Cassia obtusifolia* L.
sida	*Sida* spp.
signalgrass, broadleaf	*Brachiaria platyphylla* (Griseb.) Nash
smartweed, Pennsylvania	*Polygonum pensylvanicum* L.
starbur, bristly	*Acanthospermum hispidum* DC.

[a]Common names of weeds are those published by the Weed Science Society of America (WSSA) Subcommittee on Standardization of Common and Botanical Names of Weeds. Weed Science 19:435-476. 1971.

Hauser and Parham (62) reported from an 8-year study that natural infestations of annual weeds reduced the average yield of harvestable peanuts about 20 percent. Yield reductions ranged from 1 to 50 percent, depending primarily upon weed density. The predominant weeds were large crabgrass and Florida pusley. The authors suggested that competitive pressures and resultant yield reductions might have been different had other weed species been present.

Influence of time and duration of weed competition on peanuts. In Oklahoma, Hill and Santelmann (69) studied peanut growth and yields as affected by weed growth of different durations and at various stages of crop growth. Peanut yields were not reduced when weeds were removed within 3 weeks after planting and the peanuts kept weed-free for the remainder of the season. Yields were reduced when weeds were allowed to compete for 4 to 8 weeks after peanuts were planted. When peanuts were kept weed-free for at least 6 weeks after planting, no yield reductions due to weed competition occurred from weeds which germinated after this critical period. As weed competition increased, yield of peanuts, yield of forage, and soil moisture decreased. It is a common practice among peanut growers to rogue thin stands of "escape" broadleaf weeds from peanuts. Where weed stands are thick, roguing is not practical. These "escape" weeds are usually large-seeded broadleaf weeds such as sicklepod, cocklebur, or Florida beggarweed. These species are not controlled effectively with currently available herbicides or by cultivation. These weeds are rogued usually after they have achieved substantial growth. Although no data on when these weeds exert their maximum competition is available, in all probability, they have little effect on the peanut crop if removed sometime prior to pegging and before the weeds become large. Preliminary data of Hauser and Buchanan indicate that sicklepod or Florida beggarweed can remain in peanuts for at least 4 weeks and perhaps longer without causing a reduction in yield. If allowed to persist all season, competition from these broadleaf weeds undoubtedly reduces the yield of peanuts both directly through competition for light, nutrients, and moisture as well as indirectly by interfering with disease control programs.

Competitive ability of particular weed species in peanuts. The competitive ability of specific weed species in peanut plantings has received little study. Rawson (98) reported that an infestation of morningglory may reduce yields of peanuts by about 7.5 percent. Noogoora bur *(Xanthium pungens* Wallr.), a plant similar to common cocklebur, when present at a density of one plant per 9 square feet reduced peanut yields approximately 16 percent. It is likely that common cocklebur would reduce the yield of peanuts to a similar degree. In Alabama, one or more sicklepod or Florida beggarweed plants per linear foot of row reduced yield of peanuts by approximately 50 percent. In later studies, only one sicklepod plant per 3.0 feet of row resulted in 30% loss of peanut yield. In these studies, higher weed populations also resulted in a higher incidence of leaf spot even though considerable effort was made to effect control (unpublished data of G. A. Buchanan).

Influence of weeds on harvesting peanuts. All aspects of peanut production are now mechanized and most cultural operations are handled with multiple row equipment. Although weeds seriously reduce the yield of peanuts through competition, major losses also occur by weeds interfering with efficient harvesting.

During digging, the peanut plant is lifted out of the ground and, with an "inverter" device, the peanuts and root system are exposed directly to the sun. A heavy stand of weeds, especially grasses, makes this operation almost impossible. A tight, fibrous root system of the weeds become entwined with the peanut plant, and when this occurs many peanuts are stripped from the vine during digging operations. Peanuts that become detached from the plant remain unharvested in, or on, the soil.

If broadleaf weeds and annual grasses are present in high populations, substantial quantities of soil are brought up with the peanuts. This soil and weed foliage slows drying. In summary, large amounts of weeds and soil mixed with the peanut plants make harvesting difficult, cause loss of peanut pods, and often remain as foreign matter in the harvested peanuts.

Major Weeds in Peanuts

Major weeds that plague the peanut grower are those commonly found in crop areas throughout the southern and southwestern United States (see Tables 2 and 3). Annual grasses such as crabgrass, crowfootgrass and signalgrass, are among the currently most troublesome grass species. Texas panicum is now a major problem throughout southwestern Georgia, southeastern Alabama and in some areas of Oklahoma and Texas (27, 28). Texas panicum is a vigorous, fast-growing weed. According to Chandler *et al.* (27, 28), maximum germination occurred at a depth of 0.5 to 1.5 inches. Seedling emergence declined with each increase in depth down to 3 inches although some plants emerged from 3 inches. Other grasses that are found in peanut fields, but which are of less general importance, include barnyardgrass, fall panicum, foxtails, johnsongrass and sandbur.

Table 2. Most Common Weed Species in Peanuts as Reported by Research Scientists and Extension Personnel[a]

State and Reporter	Order of Most Common 1	2	3	4	5	6	7	8	9	10
Alabama G. A. Buchanan and M. D. Bond	Crabgrass	Florida pusley	Florida beggar-weed	Sickle-pod	Common cockle-bur	Goose-grass	Morning-glories	Texas panicum	Nut-sedges	Bristly starbur
Florida W. L. Currey and E. B. Whitty	Crabgrass	Florida pusley	Florida beggar-weed	Sickle-pod	Nutsedges	Pigweeds	Morning-glories	Common cockle-bur	Sand-bur	Texas panicum
Georgia E. W. Hauser and J. F. McGill	Crabgrass	Florida pusley	Nutsedges	Sickle-pod	Florida beggar-weed	Common cockle-bur	Morning-glories	Texas panicum	Pig-weeds	Crotons
North Carolina A. D. Worsham and Harold Coble	Crabgrass	Common cockle-bur	Morning-glories (Mostly tall)	Lambs-quarter	Goose-grass	Redroot pig-weed	Common ragweed	Nutsedges (Mostly yellow)	Fall panicum	Sickle-pod
Oklahoma P. W. Santelmann and H. A. L. Greer	Crabgrass	Pigweeds	Johnson-grass	Texas panicum	Signal-grass	Prickly sida	Copper-leaf	Morning-glories	Horse-nettle	Nut-sedge
South Carolina B. J. Gossett	Crabgrass	Florida pusley	Nutsedges	Sickle-pod	Pigweeds	Common cockle-bur	Morning-glories	Lambs-quarter	Florida beggar-weed	Johnson-grass
Texas M. G. Merkle	Crabgrass	Pigweeds	Texas panicum	Purslanes	Carpet-weed	Nut-sedges	Signal-grass	Croton	Morning-glories	Silverleaf nightshade
Virginia O. E. Rud	Crabgrass	Goose-grass	Nut-sedges	Morning-glories	Pigweeds	Fall panicum	Lambs-quarters	Common cocklebur	Jimson-weed	

[a]If two or more species bearing the same common name were listed by one or more states, the plural form of the WSSA names is used (for example, morningglories in lieu of morningglory).

Table 3. Most Troublesome Weeds in Peanuts as Reported by Research and Extension Personnel[a]

State and Reporter	Order of Most Troublesome 1	2	3	4	5	6	7	8	9	10
Alabama G. A. Buchanan and M. D. Bond	Sicklepod	Florida beggarweed	Nut-sedges	Morning-glories	Bristly starbur	Texas panicum	Common cocklebur	Sandbur	Florida pusley	Crab-grass
Florida W. L. Currey and E. B. Whitty	Florida beggarweed	Sicklepod	Nut-sedges	Crabgrass	Pigweeds	Morning-glories	Common cocklebur	Texas panicum	Florida pusley	Sand-bur
Georgia E. W. Hauser and J. F. McGill	Florida beggarweed	Sicklepod	Common cocklebur	Morning-glories	Crotons	Texas panicum	Nut-sedges	Crabgrass	Sandbur	Bristly starbur
North Carolina A. D. Worsham and Harold Coble	Sicklepod	Common ragweed	Fall panicum	Common cocklebur	Tall morning-glory	Nutsedge yellow (mostly)	Prickly sida	Goose-grass	Common lambs-quarters	Horse-nettle
Oklahoma P. W. Santelmann and H. A. L. Greer	Horse-nettle	Copper-leaf	Johnson-grass	Nut-sedge	Silver-leaf nightshade	Morning-glories	Prickly sida	Texas panicum	Crotons	Pig-weeds
South Carolina B. J. Gosset	Nut-sedges	Johnson-grass	Sickle-pod	Common cocklebur	Morning-glories	Pigweeds	Florida beggar-weed	Lambs-quarters	Florida pusley	Crab-grass
Texas M. G. Merkle	Texas panicum	Nut-sedges	Broadleaf signal-grass	Morning-glories	Croton	Silver-leaf nightshade	Crabgrass	Pigweeds	Purslanes	Carpet-weed
Virginia O. E. Rud	Nut-sedges	Morning-glories	Crabgrass	Fall panicum	Common cocklebur	Goose-grass	Pigweeds	Lambs-quarters	Jimson weed	

[a]If two or more species bearing the same common name were listed by one or more states, the plural form of the WSSA names is used (for example, morningglories in lieu of morningglory).

Table 4. Most Common and Most Troublesome Weeds in Peanuts and the Number of States Indicating Inclusion on the Appropriate List.

Most common		Most troublesome	
Weed	Number of reporters reporting that the species were among the 10 most *common* weeds in peanuts	Weed	Number of reporters indicating that the species were among the 10 most troublesome in peanuts
Crabgrass	8	Morningglories	8
Morningglories	8	Nutsedge	8
Nutsedges	8	Crabgrass	6
Pigweeds	7	Pigweeds	5
Cocklebur	6	Texas panicum	5
Texas panicum	5	Sicklepod	5
Sicklepod	5	Cocklebur	6
Florida beggarweed	4	Florida beggarweed	4
Florida pusley	4	Lambsquarters	3
Goosegrass	3	Crotons	3
Lambsquarters	3	Sandburs	3
Johnsongrass	2	Florida pusley	3
Crotons	2	Bristly starbur	2
Broadleaf signalgrass	2	Fall panicum	2
Fall panicum	2	Goosegrass	2
Common ragweed	1	Johnsongrass	2
Sandbur	1	Silverleaf nightshade	2
Prickly sida	1	Prickly sida	2
Silverleaf nightshade	1	Horsenettle	2
Copperleaf	1	Common ragweed	1
Carpetweed	1	Jimsonweed	1
Jimsonweed	1	Copperleaf	1
Bristly starbur	1	Carpetweed	1
Horsenettle	1	Purslanes	1
Purslanes	1	Broadleaf signalgrass	1

Sicklepod, Florida beggarweed, cocklebur, morningglories, Florida pusley, and pigweeds are the major broadleaf weeds found in peanuts. Numerous other species including carpetweed, prickly sida, bristly starbur, purslane, Pennsylvania smartweed, ragweed, lambsquarters, horsenettle, silverleaf nightshade, copperleaf, croton, jimsonweed and annual sedges are also often found in peanuts.

Yellow nutsedge and purple nutsedge are among the most ubiquitous weeds in peanuts. They are extremely difficult or impossible to control mechanically. Many herbicides currently used in peanut fields, such as substituted anilines, have essentially no activity against the nutsedges. Extensive usage of these herbicides in some areas appears contributory to increases in sedge populations, particularly in the Southeastern States. Fortunately, herbicides of the thiocarbamate group offer some control of nutsedge in peanuts as well as in other crops normally grown in rotation with peanuts.

A summary of the most common and most troublesome weeds in peanuts as reported by research and extension personnel is presented in Tables 2, 3, and 4. Although considerable variation occurred in ranking the various weed species by different reporters, there was striking agreement as to the total weed list. Reporters from eight states responded to the "most common" and "most troublesome" survey. Crabgrasses and morningglories were listed by all reporters as being among the ten most common weeds in peanuts.

In Plates 2 to 16 are shown fifteen troublesome weeds in peanuts.

Interrelationships of Peanut Diseases and Weed Control

Increased knowledge of the interrelationships between weed control and certain diseases of the peanut plant tremendously influenced both the philosophy and practices of controlling weeds. Over 50 years ago, Silayan (116) reported that in the Philippines flat cultivation resulted in higher yields of peanuts than did ridge cultivation. The importance of this provincially published research apparently remained unrecognized for about 30 years. It was 1949 before Venezuelian investigators Ciccarone and Platone (32) first correlated ridge cultivation with infestations of *Sclerotium rolfsii* Sacc., the causative organism of peanut stem rot. Piling soil into the row created conditions favorable for growth of this fungus.

The research of L. W. Boyle (10, 11) first clarified the interrelationships between methods of weed control in peanuts and the incidence of both stem rot and *Rhizoctonia* spp. He pioneered the principles for controlling stem rot through appropriate land preparation and subsequent weed control procedures. Boyle (10) in 1952 reported that flat culture involving application of a herbicide helped control stem rot. Later, Boyle and Hammons (13) increased the yield of peanuts (up to 32 percent) with new methods of culture including (a) turning all litter at least 3 inches deep, (b) planting in flat beds followed by application of a herbicide preemergence and (c) cultivating only where necessary without moving soil to, or ridging it against, the row. They indicated that planting conventionally in a furrow then subsequently cultivating soil into the row was hazardous because (a) the lower nodes on the peanut plant were covered with soil thus smothering potential branches, flowers, fruits; and (b) the stage for severe disease outbreaks was set.

The intensive studies of Garren (48, 49) supported Boyle's research. Garren achieved what he labeled "non-dirting" weed control by (a) planting on slightly raised beds, (b) applying a herbicide preemergence in bands over the row and (c) cultivating the unsprayed middles without moving soil to the peanut row. Deeply covering the litter (which buries the weed seed on the soil surface) followed by "non-dirting" cultivation proved most beneficial. Garren considered "non-dirting" cultivation as especially important. Further observations from North Carolina (91) correlated severe outbreaks of *S. rolfsii* with covering peanut leaves and stems during cultivation.

To facilitate flat-culture weed control, Shepherd (115) devised methods for shaping flat "table-top" beds immediately after turning the soil. For controlling weeds in the bed before planting, he used staggered, overlapping sweeps running flat and shallow in order not to bring litter back to the soil surface.

Although certain "non-dirting" cultivation tools such as "beet-knives" kill very small weeds in the inter-row spaces, no cultural implement consistently kills weeds in the peanut row without depositing soil on or around the peanut plant. Although rotary hoes are popular in some localities for early weeding of peanuts, their use is generally discouraged because any implement which brings soil and dying weeds into contact with peanut plants provides a favorable medium for the development of stem rot.

The difficulties inherent in proper mechanical cultivation of peanuts contributed to an intensified search for acceptable herbicides. New and effective weed control practices, especially those which met the specifications of the plant pathologists, contributed to higher peanut yields directly through control of weeds and indirectly through disease prevention. Use of herbicides in peanut production was so well accepted that currently farmers emphasize intensive or multiple application of herbicides.

At the present stage of development of the art and science of weed control one might ask "should peanuts always be treated with herbicides?" Philosophically, the answer is "no" if weeds can be controlled satisfactorily with "non-dirting" cultivation. But the difficulties involved are numerous (83).

Preliminary unpublished research (Hauser *et al.*) strongly suggests that one timely layby cultivation may be essential on certain soil types. Therefore, a logical balance between herbicides and precision cultivation may consist of using as little of both as is necessary to keep weeds under control.

With the present emphasis on herbicides in peanuts, the value of minimum but timely "non-dirting" cultivation can easily be underestimated.

Herbicide Research and Development

Beginning about 1949, scientists conducted much research on controlling weeds in peanuts with herbicides. From Alabama, Scholl and Searcy (108) reported that (2,4-dichlorophenoxy) acetic acid (2,4-D) and (2,4,5-trichlorophenoxy) acetic acid (2,4,5-T) controlled annual weeds but injured peanuts. Among herbicides evaluated in North Carolina by Shaw *et al.* (113), 2-*sec*-butyl-4,6-dinitrophenol (dinoseb) most effectively controlled weeds and least injured the peanuts. They further found that four large-seeded peanut varieties responded similarly to 2,4-D, dinoseb and pentachlorophenol (PCP). However, in Australia, Rawson (96, 97) reduced the yield of the Virginia Bunch variety with 0.38 lb/A[3] of 2,4-D applied 6 weeks after emergence. The yield of the Red Spanish variety was unaffected. Searcy (109) injured peanuts with 2,4-D at 1 lb/A. In later work, he showed that several herbicides reduced neither the stand nor grade of peanuts (110). North Carolina workers (132) reported that 2,4-D, 2-(2,4-dichlorophenoxy) ethyl sodium sulfate (sesone), and a mixture of dinoseb + 2,4-D controlled weeds satisfactorily but dinoseb alone proved erratic. They suggested delaying application of 2,4-D until the peanut seedlings are cracking the ground (beginning to emerge). Upchurch (121) later reported that peanuts tolerated preemergence applications of dinoseb. In Florida (66), both 2,4-D and dinoseb controlled weeds but 2,4-D delayed maturity of peanuts at least 10 days. In Libya (90),

[3]In this chapter, all rates of herbicides refer to active ingredient, acid equivalent or phenol equivalent, whichever is applicable.

PCP effectively controlled weeds with excellent crop tolerance and in Queensland (96) 2,4-D appeared very promising.

In 1954, Witherspoon and Rogers (136) controlled weeds for 8 to 15 weeks with dinoseb applied as an early postemergence spray. The next year, Rea (99) found sesone safe if applied at layby but preemergence applications injured peanuts. Sesone at the rate of 4 lb/A reduced yields in Florida (67) and later Burt (20) reported that both sesone and isopropyl *m*-chlorocarbanilate (chlorpropham) were ineffective but dinoseb performed well. However, in 1956, Burt (21) found that preemergence application of dinoseb injured peanuts more and controlled weeds less effectively than sesone when 3 inches of rain fell immediately after treatment. Sesone controlled weeds better than the other herbicides evaluated as preemergence treatments in Georgia from 1953 to 1955 (120). These results were confirmed by Wheatley and Wells (133) in extensive farm demonstrations. Upchurch (121) reported that sesone did not control weeds in North Carolina as effectively as in Georgia and that dinoseb controlled weeds less satisfactorily in North Carolina than in Florida. In South Carolina, peanuts tolerated most of the 18 herbicides evaluated.

Of 24 herbicides applied as preemergence treatments after planting or applied at the emergent stage of peanuts, only preemergence treatments with 3-(3,4-dichlorophenyl)-1,1-dimethylurea (diuron) and 2-(2,4,5-trichlorophenoxy) propionic acid (silvex) greatly reduced the stand and vigor of peanuts in Virginia (29). In related research, Chappell and Duke (30) found that peanut yields were not influenced by rate of sesone, planting depth, or rolling versus non-rolling of the soil surface. In another study, Chappell (31) indicated that mixtures of herbicides for peanuts needed further investigations. He also compared granular and spray formulations of several herbicides. Later field experience showed that, with proper application equipment, granular formulations controlled weeds effectively.

Watson and Nation (130) found that although tolerance of peanuts to dinoseb applied as a postemergence spray varied, the herbicide could be effectively and safely used until the peanut plants were 3 inches in diameter. However, unpublished data (Hauser *et al.*) showed that while dinoseb at 4.5 lb/A did not affect peanut yields if applied "at cracking" under Georgia conditions, it did reduce both stands and yields if applied seven days later. Hauser and Parham (58) later reported that a low rate of dinoseb (1.5 lb/A) applied as an overtreatment 7 or 14 days after peanuts emerged always increased crop injury and suggested that peanuts be shielded if dinoseb is applied after the "cracking" stage. In contrast, Rud and Chappell (101) reported that dinoseb, at 3 to 9 lb/A applied at growth stages up to 10 leaves, did not significantly reduce peanut yields.

Several conclusions can be made from the foregoing review of research conducted mostly from 1950-1960. First, extreme variation in weed control occurred with the same herbicides evaluated at different locations and under different environmental conditions (8, 120). Both weed control and crop reaction to sesone and dinoseb, two of the herbicides evaluated most extensively in the 1950's, varied widely. Secondly, from these and later studies (8, 57, 64, 101, 125), dinoseb emerged as the most promising herbicide for use as a postemergence treatment for peanuts, but its activity varied as influenced by climatic conditions and the physiological condition of both peanuts and weeds. Thirdly, the peanut plant generally tolerated a number of herbicides applied as as preemergence treatments.

Selectivity of many of these early candidate herbicides was based on either (a) limited physiological or biochemical tolerance, (b) differential herbicide concentration in the crop-seed zone versus the weed-seed zone or (c) protective morphological characteristics of the peanut plant. With limited biological selectivity existing between peanuts and certain weed species, differential concentration of herbicides in the crop seed zone appeared functional with such compounds as tris[2-(2,4-dichlorophenoxy)ethyl] phosphite (2,4-DEP), dinoseb and sesone. Under normal rainfall conditions, concentrations of these herbicides usually did not exceed that tolerated by the emerging peanut plant. This phenomenon resulted in one type of selectivity.

The peanut tolerates certain preemergence treatments, such as 2,4-D, which severely injure many other legumes (75). Apparently, certain morphological characteristics of the peanut plant provide partial protection against many herbicides. Unlike small-seeded legumes, peanut plants usually emerge vigorously within 5 to 7 days after planting. In addition, the primary taproot grows downward to depths of about 6 to 12 inches below the seed by the time emergence occurs. We can assume that, under normal conditions, most herbicides applied as preemergence treatments do not leach readily into all of the zone of soil occupied by the rapidly growing taproot of the peanut plant.

Research from 1959-1969 emphasized mixtures of herbicides for peanuts in an effort to improve weed control while maintaining crop tolerance. Sesone or 2,4-DEP mixed with dinoseb and applied at the "cracking" stage produced excellent control of both crabgrass and Florida pusley in Georgia (64). Components of the mixtures, sprayed alone at twice the rate used in the combination, did not control weeds as well or as long. Results from Florida were similar (134) and further indicated that a mixture of 2,4-DEP + PCP controlled weeds well. Later, Hauser and Parham (58) reported that the best time to apply mixtures containing dinoseb was when the peanuts were cracking the ground or when the weeds were barely visible, whichever occurred first. This finding was confirmed by subsequent research in Oklahoma by Matthiesen and Santelmann (82).

A report from Upchurch and Selman (123) indicated that a mixture of dinoseb + *N*-1-naphthylphthalmic acid (naptalam) was the most successful commercial treatment in North Carolina developed prior to 1963. However, mixtures containing dinoseb were not as effective in North Carolina as in other peanut areas. In 1965, Upchurch and Worsham (126) reported that the herbicides in their studies did not affect the commercial grade of peanuts. Previous data from Georgia (58) suggested that neither commercial grade nor sensory charcteristics were changed by herbicides.

Herbicide mixtures were utilized widely by peanut farmers during the 1960's especially in the Southeastern States. For example, two of the most popular treatments in 1966 for peanuts in North Carolina were mixtures of either N,N-dimethyl-2,2-diphenylacetamide (diphenamid) or naptalam with dinoseb (138). Rud (102) reported from Virginia in 1968 that when preplanting treatments were followed by mixtures at "cracking", the mixtures contributed more to overall weed control than did the preplanting treatments. In Georgia (54), a mixture of herbicides applied at "cracking" increased the average yield of peanuts over a 5-year period. A 1968 report from North Carolina (125) indicated that dinoseb at 6 lb/A applied as delayed preemergence treatments controlled weeds better than dinoseb at lower rates in mixture with other herbicides. From the Southwestern area, Santelmann *et al.* (104, 105) reported that most herbicides evaluated on peanuts over a 7-year period were satisfactory with particularly good control of weeds from mixtures of dinoseb with either 3-amino-2,5-dichlorobenzoic acid (chloramben) or 2,4-DEP applied at "cracking". A mixture of naptalam or 2,4-DEP with dinoseb controlled broadleaf weeds better than other postemergence treatments. (23). In later studies (106) five herbicides failed to consistently reduce the yield of peanuts regardless of imposed variations in depth of planting or soil moisture. No herbicide evaluated in Oklahoma affected the market or organoleptic quality of peanuts.

The commonly used herbicide mixtures did not control Texas panicum. During the 1950's and 1960's this grass became a major pest for many peanut growers, especially in the Georgia-Florida-Alabama (GFA) and Southwestern peanut belts. The herbicide α,α,α,-trifluoro-2,6-dinitro-*N*,*N*-dipropyl-*p*-toluidine (trifluralin), incorporated into the soil before planting (92), proved especially effective on annual grasses, including Texas panicum. It produced satisfactory results in Texas and Oklahoma (8, 9, 105) on Spanish peanuts. In Brazil (78, 79) trifluralin controlled certain weeds without damaging peanuts. However, in the Southeastern States, unpublished data from several sources showed that trifluralin sometimes prevented normal fruiting of peanuts. Another substituted toluidine, *N*-butyl-*N*-ethyl-α,α,α,-trifluoro-2,6-dinitro-*p*-toluidine (benefin), was described by Guse *et al.* in 1966 (51). They reported that peanuts tolerated benefin better than trifluralin; and that, like trifluralin, it controlled many annual weeds, especially grasses, but that it would not control certain broadleaf weeds such as sicklepod and Florida beggarweed. Because of its safety on peanut and its effectiveness on annual grasses, peanut farmers have increasingly accepted benefin. Another herbicide with similar weed control properties, 4-(methylsulfonyl)-2,6-dinitro-*N*,*N*-dipropylaniline (nitralin), appeared especially effective in Texas (8) and, in addition, was evaluated in Oklahoma (105) and in Alabama by Buchanan *et al.* (16). The Alabama workers, and Lipscomb and Wilcox (81) in Florida also found that 2,3,5-trichloro-4-pyridinol (pyriclor) controlled many species of weeds. In Gambia (4), in preliminary experiments, 2,4-bis(isopropylamino)-6-(methylthio)-*s*-triazine(prometryne), diuron, and 3-(3,4-dichlorophenyl)-1-methoxy-1-methylurea (linuron) controlled annual grasses without injuring peanuts.

Perennial nutsedges, possibly the world's worst weeds (70), became a major problem for many peanut growers between 1955 and 1965. Several factors promoted increasing infestations of nutsedge in peanuts especially in the Southeastern area. The supply of labor, previously used for hoeing nutsedge out of peanuts and other row crops, dwindled. Also, as herbicides helped bring many annual weeds under control and the use of cultivation lessened, nutsedge encountered decreased competition within the ecosystem. Increased mechanization, in general, contributed to the spread of both purple and yellow nutsedges.

None of the herbicides used by peanut farmers during the 1950's controlled nutsedge. The thiocarbamates, later intensively evaluated for controlling nutsedge, were first evaluated for use in peanuts by Burt (22). He found that *S*-ethyl dipropylthiocarbamate (EPTC), *S*-propyl butylethylthiocarbamate (pebulate) and *S*-propyl dipropylthiocarbamate (vernolate) effectively controlled certain annual weeds. These herbicides performed more effectively when incorporated into the soil than when sprayed on the soil surface.

Hauser (52, 59) described the responses of nutsedge, sicklepod, and Texas panicum to EPTC, pebulate, and vernolate. The herbicides controlled these weeds most effectively when they were applied in subsurface layers between the peanut seed and the soil surface; however, layering increased injury to peanuts over that from incorporation. Later research showed that manipulation of herbicide placement (utilizing injectors or covered sweeps) and precision positioning of both the peanut seed and the herbicide substantially decreased injury sustained by peanuts from vernolate (44, 53, 56, 60, 61). In fact, Georgia data (63) averaged over 2 years and two soil types showed that peanuts yielded 14 percent more after subsurface applications than after incorporation of vernolate.

Devices for the subsurface application of the relatively volatile thiocarbamates under field conditions were described by Wooten and McWhorter (137) in 1961, by Holstun and Wooten (71) in 1964, in 1966 by Hauser *et al.* (56) and by McWhorter *et al.* (86), then in 1970 by Dowler and Hauser (44).

The optimum use of vernolate for peanuts evaluated by Upchurch *et al.* (124, 125) was power-driven rotary hoe incorporation of the herbicide 1-inch deep in split applications 0, 7 and 14 days after planting. A single postplanting treatment controlled annual weeds better than a single preplanting incorporation. A single preplanting incorporation was the standard technique used by farmers.

In areas where peanuts are irrigated, the performance of benefin, nitralin and vernolate incorporated into soil may be related to the irrigation method. Jordan *et al.* (74) found that sprinkler irrigation produced better results than furrow irrigation with some herbicides.

Recently, due to intensifying cocklebur populations, research workers in the United States evaluated postemergence applications of 4-(2,4-dichlorophenoxy) butyric acid (2,4-DB) on peanuts and soybeans. McWhorter and Hartwig (85) found low rates effective for controlling cocklebur in soybeans. Although Oram (90) injured peanuts with 2,4-DB at 2.5 lb/A, published (7) and unpublished data from several U. S. locations show that peanuts can tolerate low rates (0.2 to 0.4 lb/A) of this herbicide. Also, earlier reports from Queensland by Rawson (97, 98) indicated that low rates of 2,4-DB were relatively safe on peanuts. When applied 6 or 7 weeks after emergence, at rates of 0.25 and 0.5 lb/A, the mean yield reduction of peanuts was 0.45 percent for each ounce of 2,4-DB applied compared to 3.5 percent for each ounce of 2,4-D. Therefore, 2,4-DB was about eight times as safe as 2,4-D when applied at these rates and stages of growth. However, Selman and Upchurch (111) reported that low rates of 2,4-D appeared safe if applied within 20 days after planting peanuts.

Technical Description of Herbicides Registered for Use in Peanuts

Extensive research and development efforts by state, federal and industry scientists have led to the registration and labeling of several chemical treatments which are used to control weeds in peanuts. Registration in accordance with the Federal Environmental Pesticide Control Act of 1972, administered by the Environmental Protection Agency, usually has been followed by State recommendations.

As a result of this cooperative research and development, the following herbicides (see Table 5 for nomenclature) were registered for use on peanuts as of December 31, 1971 (127): (a) alachlor, (b) benefin, (c) chloramben, (d) dinoseb, (e) diphenamid, (f) naptalam, (g) nitralin, (h) sesone, (i) trifluralin, (j) vernolate, and (k) combinations involving mixtures of certain individual herbicides. Because of constant evaluation and development, some registrations may be cancelled and other treatments may be registered, thus any list soon becomes obsolete.

Technical Description of Herbicides

Alachlor. The pure compound is an odorless, cream-colored solid at room temperature, with solubility in water of 148 ppm. It is formulated either as an emulsifiable concentrate or as a granule.

Alachlor is applied primarily as a preemergence treatment at rates of 2 to 3 lb/A. Rain or irrigation within 5 to 7 days after application is necessary for best results. Under reduced moisture, soil incorporation is considered advantageous. Shallow cultivation, when necessary to remove escaped weeds, will not destroy the herbicidal activity. Alachlor is also effective as a "cracking stage" or early postemergence treatment in combination with dinoseb. The combination appears to be superior to either compound used alone for control of prickly sida, pigweed, Florida pusley, sicklepod, copperleaf, goosegrass, morningglory, and Florida beggarweed [Duncan *et al.* (46), Andrews *et al.* (2), Rud and Timmons (103)].

Alachlor is subject to microbial breakdown and at rates of 2 to 3 lb/A should not persist in the soil (in herbicidal concentrations) more than 10 to 12 weeks. However, it is somewhat mobile in the soil.

Table 5. Nomenclature of Herbicides Registered for Weed Control in Peanuts (as of December 20, 1971[a])

WSSA common name	Trade name as of 12/31/71	Formula
alachlor	Lasso	2-chloro-2′, 6′-diethyl-*N*-methoxymethyl-acetanilide
benefin	Balan	*N*-butyl-*N*-ethyl-α, α, α,-trifluoro-2,6-dinitro-*p*-toluidine
chloramben	Amiben	3-amino-2, 5-dichlorobenzoic acid
dinoseb	Various names	2-*sec*-butyl-4,6-dinitrophenol
diphenamid	Dymid and Enide	*N,N*-dimethyl-2,2-diphenylacetamide
naptalam	Alanap	*N*-1-naphthylphthalamic acid
nitralin	Planavin	4-(methylsulfonyl)-2,6-dinitro-*N,N*-dipropylaniline
sesone	Sesone	2-(2,4-dichlorophenoxy)ethyl sodium sulfate
trifluralin	Treflan	α, α, α,-trifluoro-2,6-dinitro-*N,N*-dipropyl-*p*-toluidine
vernolate	Vernam	*S*-propyl dipropylthiocarbamate

[a]Trade names are used solely to provide specific information. Mention of a trademark or proprietary product does not constitute a guarantee or warranty of the product by the United States Department of Agriculture or by the Alabama, Georgia, Oklahoma or Virginia Agricultural Experiment Stations, and does not imply its approval to the exclusion of other products that may also be suitable.

Chloramben. The pure compound is a white odorless powder with a water solubility of 700 ppm. For herbicidal use it is formulated as the ammonium salt.

Chloramben is applied at rates of 2 to 3 lb/A before weeds and crop emerge. For best effectiveness moisture should move the material into the zone of germinating weeds. Under conditions of deficient soil moisture, shallow cultivation may be necessary to destroy germinated weed seedlings. This cultivation will not interfere with the herbicidal action when rains do occur.

Chloramben inhibits root development of seedling weeds. It moves readily in sandy soils or following heavy rains. It is subject to microbial breakdown in soils, making the average persistence about 6 to 8 weeks from applications of 2 to 3 lb/A.

Benefin. The pure compound is a yellow-orange crystalline solid with a water solubility less than 1 ppm. It is formulated primarily as an emulsifiable concentrate.

Benefin has preemergence activity but because of its volatility it is incorporated into the soil at time of application or within the time specified on the product label. Under most conditions, the PTO driven rotary tiller, double disk, rolling cultivator or similar other equipment effectively mixes benefin with the soil to specified depths. Benefin is used at rates of 1.12 to 1.5 lb/A with the lower rate on sandy soils and higher rates on soils having high exchange capacities. Soil particles strongly adsorb benefin; therefore, it resists leaching. Microbial breakdown occurs gradually in soils. Rates of 1.12 to 1.5 lb/A usually control weeds for 4 to 5 months in temperate zones.

Naptalam. The technical compound is a purple crystalline powder with a water solubility of 200 ppm. It is formulated as a sodium salt which is highly soluble in water.

Naptalam is usually applied as a preemergence treatment. Moisture is necessary for activation. The most common rate is 4 lb/A, but the dosage range is 2 to 6 lb/A with the heavier rate for soils of higher base exchange capacities. Naptalam leaches rapidly in highly porous or silt loam soils of extremely fine texture. Heavy rains after application may cause leaching and result in crop injury. It is subject to microbial breakdown and, at normal rates, controls weeds from 3 to 8 weeks. It is relatively nonvolatile and photo-stable.

The most widespread use of naptalam in peanuts has been in combination with dinoseb. The mixture is applied when the peanut plants are beginning to crack through the soil. This stage is commonly referred to as the "at cracking" stage.

2,4-DEP. The technical product is a brown liquid formulated as an emulsifiable concentrate. The herbicide 2,4-DEP kills weeds by preemergence activity. Tank mixtures of liquid 2,4-DEP at 2.0 + dinoseb at 1.5 lb/A applied "at cracking" have been used widely by farmers in the GFA peanut belt. However, Federal registration for this compound was canceled in 1971.

Dinoseb. The technical chemical is a dark brown solid or dark orange liquid with low water solubility. For herbicidal use in peanuts, the material has been formulated as water soluble alkanolamine salts (of the ethanol and isopropanol series) and as a triethanolamine salt, both of which are water soluble.

Dinoseb controls weeds both as a preemergence and postemergence treatment. Rates vary from 0.75 to 12 lb/A, with the higher rates (6 to 12 lb/A) generally required for preemergence treatment to achieve consistent residual action in soil. The current use of dinoseb in peanuts is generally as a "cracking" or as an early postemergence spray for the control of seedling weeds (at rates of 0.75 to 6 lb/A).

Direct cell necrosis is the primary mode of action involved after postemergence treatment. Dinoseb leaches readily in soils; however, there is some evidence of partial adsorption in certain organic and clay soils. Microbial breakdown in soil prevents buildup and suggested rates persist in concentrations phytotoxic to weeds from about 2 to 6 weeks depending on weather conditions and the rate applied.

Diphenamid. The technical material is a white solid which is soluble in water at

260 ppm. It is formulated as a wettable powder or as a water dispersible concentrate.

Diphenamid is ordinarily sprayed on the surface of the soil but shallow soil incorporation may increase its effectiveness under dry conditions. Absorption is mainly through the roots. Sub-lethal concentrations in susceptible species severely inhibit normal root development. Diphenamid is tightly adsorbed to soil colloids. It leaches quite rapidly in sandy soils but more slowly in loams and clay soils. The usual rates for peanuts are 2 to 3 lb/A but rates up to 6 lb/A are registered. Under warm, moist conditions persistence at herbicidal levels is from 3 to 6 months, but under low rainfall, diphenamid may persist longer.

Nitralin. The technical material is a light orange solid that is relatively insoluble in water. It is formulated either as a wettable powder or a water dispersible concentrate.

Nitralin is used as a preemergence or preplanting treatment and, because of its volatility, it is incorporated in the soil either by mechanical means or by rainfall within a day or two after application. It is used in peanuts at about 0.5 lb/A. Absorption is by seed or roots of plants. Nitralin is relatively immobile in soil and leaches little. It is broken down by microbes in the soil.

Sesone. The technical material is a relatively nonvolatile, white crystalline solid. Sesone is formulated as a water soluble powder.

Sesone is used as a preemergence spray at rates of 2 to 2.7 lb/A. Sesone *per se* is not very active, but it is hydrolyzed by soil microorganisms to 2,4-D, and then kills seedlings as they germinate. Sesone leaches in sandy soils following heavy rains. It is subject to microbial breakdown and at normal rates persists in the soil for 4 to 6 weeks.

A tank mixture of sesone + dinoseb is often used "at cracking".

Trifluralin. Technical material is an orange crystalline solid with very low solubility in water. It is formulated as an emulsifiable concentrate.

Trifluralin controls weeds best when incorporated in the soil. Application is either before or after planting the crop, but it is not effective unless it is applied preemergence to the weeds. The rate used in peanuts is 0.5 lb/A. It affects weed seedling emergence and the associated physiological growth processes. Trifluralin is not easily leached through the soil. It is strongly adsorbed on clay colloids and organic matter (131). It is degraded by sunlight unless incorporated. Microbial action plays a significant role in the breakdown of the compound in soils. Trifluralin is registered only for Spanish peanuts grown in Oklahoma and Texas.

Vernolate. The technical material is a liquid with a solubility of about 109 ppm in water at 24 C.

Vernolate exerts preemergence effects on germinating weeds but is much less effective if sprayed on the soil surface than if incorporated or injected. Farmers commonly incorporate vernolate with disk harrows. Application rates are from 2 to 2.5 lb/A. Vernolate is adsorbed onto dry soil but may leach after hard rains. Microbial breakdown is significant in detoxication in soil, and vernolate is readily lost from the soil by volatilization when the soil surface is wet at the time of application. When applied at 2.0 to 2.5 lb/A, vernolate does not persist in soil long enough to interfere with rotational cropping.

Weeds Controlled by Herbicides Registered for Peanuts

On the product label of a registered herbicide, a list of weeds which the herbicide controls must appear. This list is approved by public regulatory agencies based on evidence submitted as to the efficacy of the herbicide. Labels often indicate that

Table 6. Summary of weeds controlled by designated herbicides based on information derived from the manufacturer's labels and from various other sources.

Weed Species Common Name	Herbicide									
	alachlor	chloramben	naptalam	nitralin	dinoseb[a]	benefin	trifluralin	vernolate	sesone	diphenamid
Annuals:										
Carpetweed	x[b]		x	x	x	x	x	x	x	x
Cocklebur			x		x					
Crabgrasses	x	x	x	x	x	x	x	x	x	x
Fall panicum	x	x		x		x	x			x
Florida beggarweed	x	x	x		x				x	x
Florida pusley	x	x	x	x	x	x	x	x	x	x
Foxtails	x	x	x	x	x	x	x	x	x	x
Goosegrass	x	x	x	x	x	x	x	x	x	x
Johnsongrass (from seed)	x	x	x	x		x	x	x		x
Lambsquarters	x	x	x	x	x	x	x	x	x	x
Morningglory, tall					x			x	x	
Pigweed, redroot	x	x	x	x	x	x	x	x	x	x
Purslane, common	x		x	x	x				x	
Ragweed, common	x	x	x		x				x	
Sicklepod					x			x		
Signalgrass	x			x		x	x			
Smartweed	x	x								
Texas panicum				x		x	x			
Perennials:										
Nutsedge, yellow	x							x		
Nutsedge, purple								x		

[a]Applies only to contact kill by dinoseb at rates of 1.5 to 6 lb/A.
[b]"x" indicates that the species listed is normally controlled or suppressed by rates of herbicide registered for use in peanuts.

under conditions of delayed germination and abnormal environmental conditions, control may be incomplete.

Table 6 contains a partial list of weeds controlled or suppressed by the herbicides registered for use on peanuts.

Toxicology of Herbicides Registered for Peanuts

With all herbicides, toxicology is determined at an early stage of development. One common indicator of toxicity is the LD_{50} value. This term represents the lethal dose in milligrams of a compound per kilogram of body weight required to kill 50 percent of the test animals (frequently rats or mice) with a single dose administered by mouth. Such a value may vary considerably between species, sexes, and ages so the LD_{50} information is only an indication of relative hazards, and other information is required for adequate evaluation of toxicity to nontarget organisms. Additional supporting information of extended chronic feeding studies on rats and dogs and other tests on skin, eye, and inhalation; also, toxicity to fish and marine life are used to categorize the potential hazards (89).

Table 7 lists the relative toxicity as measured by the LD_{50} of herbicides registered for use on peanuts (127, 128, 131). If a residue remains in or on the plant after treatment, registration will depend on evidence that will establish that the residue is generally safe, exempted from tolerance requirements, or is within limits of amounts declared safe. Presently, due to recent changes in the register requirement, many herbicides now have an extended tolerance status. The final established tolerances are pending the review or submission of additional supporting data.

Table 7. Relative toxicity of several herbicides and certain other compounds to mammals (usually rats and mice).

Common name or designation	LD_{50}[a] (mg/kg)	Test animal	Toxicity[b] rating
dinoseb	5-60	rats	1
diphenamid	970±140	rats	4
aspirin	1240	rats	4
sesone	1230-1400	rats	4
naptalam	1770	rats	4
alachlor	1800	rats	4
vernolate	1780	rats	4
nitralin	>2000	rats and mice	4
table salt	3320	rats	4
chloramben	3500	rats	4
trifluralin	10000	rats	4
benefin	>10000	rats	5

[a]From Virginia Weed Control Guide. Extension Division Control Series I. Virginia Polytechnic Institute. 1969; and Herbicide Handbook of the Weed Science Society of America. Second Edition. W. F. Humphrey Press, Inc., Geneva, N. Y.

[b]Numerical toxicity rating is based on a modification of the classification of pesticides in the Federal Insecticide, Fungicide, and Rodenticide Act and from Clinical Toxicology of Commercial Products by M. N. Gleason, R. E. Gosselin, H. D. Hodge. Williams and Wilkins Co., Baltimore, Md. 1957. Ratings range from 1 (extremely toxic) to 6 (non-toxic).

Effects of Environmental Conditions on Activity of Herbicides Used in Peanuts

Herbicide activity is directly influenced by environmental conditions. Thus, knowledge of how environment regulates herbicide performance is essential to successful use of these materials. Most herbicides for weed control in peanuts are applied to the soil so the soil environment is critical. Various soil properties such as moisture, temperature, fertility, and pH influence herbicide activity and persistence through their effects on herbicide movement, microbial breakdown, adsorption onto colloids, volatilization, plant uptake and other factors.

Soil moisture. Weed control with herbicides applied to soil varies widely with the amount of moisture available. Rain or irrigation is usually needed to activate most of these herbicides, and this interaction of rainfall with activity is one of the most important factors controlling the field performance of herbicides applied as preemergence treatments. In laboratory experiments, Cooke (33) found that chloramben required 0.5 inch of simulated rain for activation. High amounts of rain leached chloramben from the surface layers of the soil and thus lowered weed control. Burnside and Lipke (18) found that as the chloramben rate was increased, less water was required for optimum weed control. Researchers reported similar results for most other preemergence treatments.

Most research with moisture and rain has involved the influence of different soil moisture levels on the activity of herbicides. Knake *et al.* (76) reported that shallow incorporation of chloramben increased effectiveness significantly under high moisture conditions but decreased effectiveness under low moisture conditions. Hill *et al.* (68) reported that peanut root injury was significantly increased when they used chloramben under very dry conditions. According to Stickler (118), chloramben activity increased linearly with increasing moisture through the entire range of soil moistures from 25 to 37 percent while trifluralin activity decreased (Figure 17). Upchurch *et al.* (124), working with several herbicides incorporated in soil for weed control in peanuts found that in some instances they controlled weeds poorly with vernolate. They comment that the relatively poor performance of the standard treatment with vernolate was corelated with a low average minimum temperature and a low annual amount of rain during the 30 days after treatment. Hauser and Parham (58) found differences among treatments with vernolate most pronounced when dry weather followed the vernolate application, as under these conditions poorer weed control was obtained following incorporation. Hauser *et al.* (63) also reported that both temperature and rain influenced the activity of vernolate, but lack of adequate rain during the month after treatment seemed particularly important in decreasing the weed control by vernolate.

More research evaluating soil moisture levels has been conducted with trifluralin than with any other herbicide for peanuts. Since benefin is closely related to trifluralin, it is probably affected by soil moisture in the same manner as trifluralin. Hill *et al.* (68) found trifluralin injured peanut roots most when the soil was driest. Stickler *et al.* (118) found that weed control response to trifluralin decreased linearly with increasing moisture, which contrasts to the results obtained with chloramben.

Sweet *et al.* (119) found no consistent benefit from incorporation of trifluralin compared with surface application as long as soil moisture was adequate. However, Knake *et al.* (76) reported that under three different moisture conditions shallow incorporation of trifluralin was beneficial at all moisture levels used.

Moisture also influences persistence of trifluralin in the soil. Bardsley *et al.* (5) reported that vapor losses of trifluralin were greater from a soil at a maximum moisture

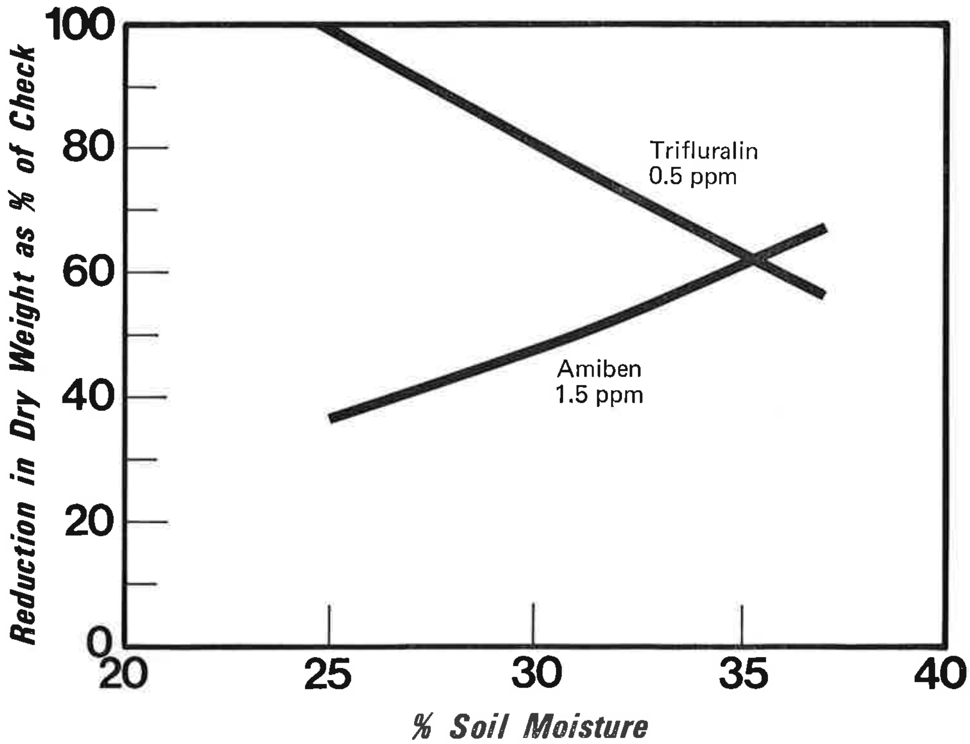

Figure 17. Effect of various soil moisture levels on herbicide effectiveness. Herbicide concentrations are expressed as parts of herbicide per million parts of oven-dry soil [from Stickler *et al.* (118)].

retention capacity than from a soil at field capacity when the trifluralin was applied at equal rates to the soil surface. This was attributed to the greater proportion of free liquid available for vapor loss under high moisture activity, and to competition of water with the herbicides for absorption sites. Placement of the trifluralin at 1.5 inches below the soil surface resulted in a very low vapor loss regardless of the moisture regime used. Probst *et al.* (94) reported that trifluralin was lost rapidly from a wet Brookston soil (200 percent field capacity) (Figure 18). Within 10 days 50 percent of the added trifluralin disappeared and after 24 days 84 percent disappeared. Loss of trifluralin from the soil was considerably slower at 50 and 100 percent of field moisture capacity levels. Loss from air dry soil was very slow.

The influence of rain and soil moisture on dinoseb appears quite variable, depending on whether dinoseb is used to produce an immediate burn, residual weed control, or both. Davis (36) reported that rain may leach dinoseb from the surface thereby decreasing the kill of emerging plants by vapor burn. A moderate rain 3 or 4 days after emergence increased vapor activity and the kill of weeds. Davis *et al.* (38) and Dowler *et al.* (45) found that the leaching of dinoseb was proportional to the amount of water applied, and that the amount of leaching varied with soil type. Hauser and Parham (58) reported that, in general, mixtures of dinoseb applied as ground-cracking treatments were most effective if sprayed on a dry soil surface with no subsequent rain for several days or more. Poorest results occurred when mixtures were applied on wet soils with no rain subsequently for several days to several weeks.

Temperature. Temperature, both of the air and soil, strongly influences the activity and persistence of herbicides. Hill *et al.* (68) reported that soil temperature

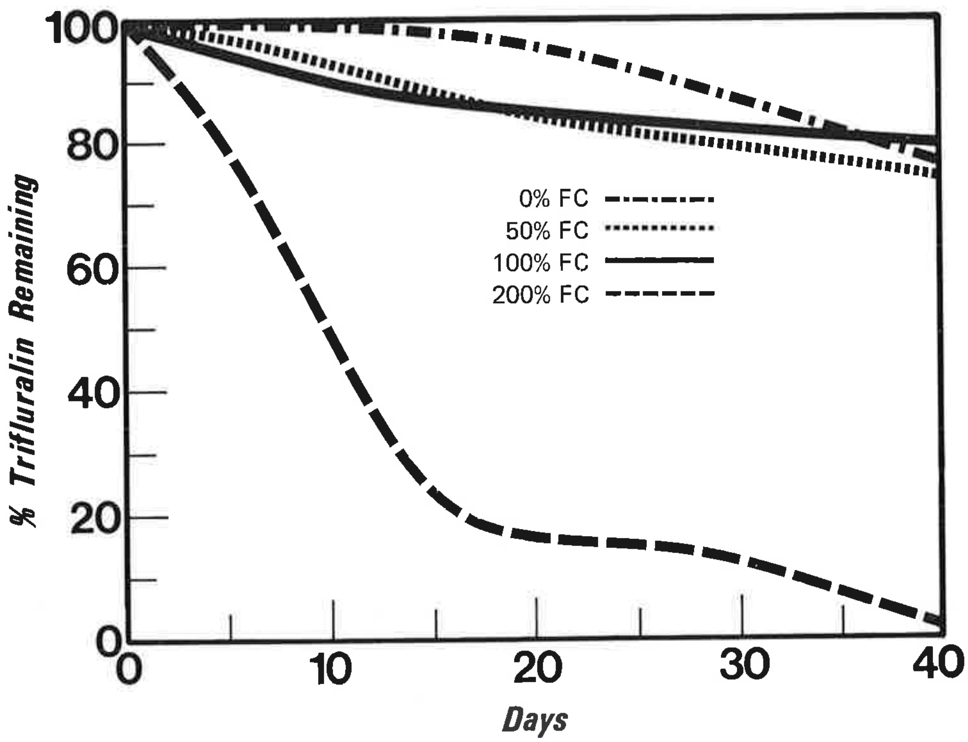

Figure 18. Trifluralin degradation in Brookston soil of differing field moisture capacity [from Probst *et al.* (94)].

variations significantly affected injury to roots of peanuts by chloramben. The amount of injury occurring at 90° F was significantly less than that which occurred at both 70° F and 100° F. Schliebe *et al.* (107) reported that temperature had little influence on dissipation of chloramben by volatilization.

Dowler and Hauser (43) reported that at a soil temperature of 75° F, trifluralin reduced plant growth significantly regardless of soil type, while at 90° F trifluralin affected growth very little. This agrees with the results of Hill *et al.* (68) who reported peanuts were injured less by trifluralin if the soil temperatures were in the 80 to 90° F range. Probst *et al.* (94) found that the disappearance of trifluralin was faster at 70° F than at 38° F. They concluded that trifluralin degradation is temperature dependent and proceeds more rapidly in a non-sterilized soil. This indicated that part of the breakdown of trifluralin in the soil is by microorganisms.

The influence of soil temperature on vernolate activity is similar to that with trifluralin. Less crop injury occurred at moderate soil temperatures (80 to 90° F) than at more extreme temperatures (43, 68). Gray and Weierich (50) reported that the rate of loss of vernolate from a moist soil increased with rising temperature.

The influence of temperature on the activity of dinoseb varies depending upon the temperature involved and upon whether the temperature variable is imposed before or after treatment. Davis (36) reported that a relatively small increase in temperature from 84 to 96° F substantially increased the percentage of plants killed by dinoseb. Meggitt *et al.* (87) reported that the activity of dinoseb increased as temperature after treatment increased from 60 to 96° F. Dinoseb was less phytotoxic under growing temperatures of 60 and 90° F prior to treatment than with temperatures of 70 and 80° F. In general, field results with dinoseb show that as temperatures increase, particularly above 85° F, there is greater possibility of injury to the peanuts, but with accompanying increases in weed control.

Soil fertility levels. We found few reports describing the influence of soil fertility levels on the activity of herbicides used in peanuts. Walker and Jones (129) reported a highly significant phytotoxic interaction between trifluralin and nitrogen at rates of 1 to 4 ppm of trifluralin and nitrogen rates of 100 to 400 ppm. Recoverable trifluralin increased with the higher nitrogen concentration. They also found an interaction between trifluralin and selected nitrate and chlorine salts and concluded that synergistic effects between trifluralin and salts were due to the interdependence of trifluralin and the anions present. In particular, high levels of sodium nitrate caused a significant phytotoxic interaction with recommended rates of trifluralin. Miller (88) reported no detrimental interaction between nitrogen or phosphorous fertilizers and trifluralin. In preliminary work, Doll and Meggitt (42) found that chloramben caused less plant injury as more nitrogen was added to the soil and suggested that the uptake mechanism of chloramben may be linked with plant metabolism in such a way that it becomes less lethal as the plant responds to nitrogen. Variations in available phosphorus and potassium did not cause significant effects.

Soil pH. Herbicides react differently under various soil acidity conditions. The pH of the soil may influence both phytotoxicity and persistence of herbicides. In general, the ionization of the herbicide in the soil will vary widely with different pH levels. For instance, Corbin reported that vernolate was more persistent at a pH of 4.3 than at pH 7.5 (34). The soil pH may affect vapor losses of herbicides in two ways. First, pH influences adsorption and desorption of the herbicide on soil particles. Secondly, within the pH range encountered in natural soils some herbicides vary from an ionized form to a non-ionized form. In the spring of 1952 when dinoseb vapors injured or killed many acres of emerging cotton, such injuries did not occur on limed soils. At a low pH dinoseb was in a volatile, non-ionized form. When the pH of the soil increased, dinoseb ionized to a less volatile form.

Thus, the ionic characteristics of some herbicide molecules vary with pH causing different degrees of adsorption in the soil. Selman and Upchurch reported that dinoseb decreases in toxicity as soil pH increases (112). Davis and Davis (37) found that the vapor injury to plants from dinoseb was prevented in soils of high lime content. Dowler *et al.* (45) reported similar results with some reduction in dinoseb activity occurring as soil pH approached neutrality but indicated some variation in that greatest effect was at pH 5 in one soil, pH 7 in another, and pH 6 in still another.

Some detailed work involving soil pH in detoxication of herbicides in soil was reported by Corbin and Upchurch from North Carolina (35). Vernolate caused striking differences between test plants growing in soil with pH 4.3 or 7.5. A pH level of 7.5 in the soil appeared optimum for microbial growth and for herbicide inactivation. Inactivation at lower pH levels (4.3 and 5.3) was much slower. However, chloramben detoxification was not affected by pH. Miller (88) reported that lime did not significantly influence the effect of trifluralin on plant growth.

Soil organic matter content. The major influence of soil organic matter on herbicide activity and persistence appears to be through its effect on the adsorption of the herbicide in the soil. Most herbicides are affected similarly by organic matter in the soil as illustrated by Upchurch and Mason (122) who also reported that the capability of organic matter to inactivate a herbicide increases on a percentage basis with an increase in herbicide concentration. For example, they reported that the amount of dinoseb required to reduce growth 50 percent increased rapidly as the soil organic matter also increased.

Bardsley *et al.* (6) indicated that addition of organic matter to soil influenced the persistence of trifluralin by increasing the retention of the herbicide and that the increased absorptive capacity of the organic material probably is instrumental in retaining trifluralin vapors. Since they believed that trifluralin dissipated as a vapor they felt that the addititon of organic matter colloids retains more of the vapor in the soil and thus increases toxicity. Eshel and Warren (47) reported that the organic matter content of the soil appeared to be the most consistent factor affecting herbicide persistence because of its high capacity to inactivate herbicides in the soil. They also found much greater activity of chloramben and trifluralin in fine soil with little organic matter as compared with a high organic matter soil. Linscott *et al.* (80) and Schliebe *et al.* (107) reported that the adsorption of radioactive chloramben was closely associated with level of organic matter in soil.

Soil type. The effects of all the preceding factors on the growth of plants and the activity of herbicides can be related to the influence of soil type on these factors. Such items as clay type and organic matter content have a direct bearing on the classification of the soil type; therefore, most farmers find that the type of soil on which they are growing the crop will have a direct influence on both the kind and amount of herbicide that should be used to control weeds. Eshel and Warren (47) and Rauser and Switzer (95) reported that the phytotoxicity of chloramben was much less in a high organic soil than in silt loam and fine sands. Linscott *et al.* (80) reported more adsorption of chloramben in soils containing an illite clay than in soils containing other types of clay. Schliebe *et al.* (107) also studied four clays and found that kaolinite adsorbed chloramben most readily; however, they did not include an illite clay.

Dowler and Hauser (43) reported more injury to soybeans from vernolate on a Tifton loamy sand than on a Greenville sandy clay loam. Depth of incorporation was more crucial in Tifton soil than in Greenville soil. Hauser *et al.* (63) reported that several factors influenced the activity of vernolate on weeds in peanuts; but that soil type was particularly important. Their data suggested that the methods of placement were less critical on Greenville sandy clay loam than on the Tifton loamy sand. Peanuts on the Greenville soil were injured less by incorporated vernolate than peanuts growing on the Tifton loamy sand. Trifluralin and chloramben caused considerably more injury in a fine sand than in a silt loam, and more in the silt loam than in a muck soil (47) (see Figure 19). Dowler and Hauser (43) also found more injury to soybeans with trifluralin and benefin on Tifton loamy soil than on Greenville sandy clay loam. Dowler *et al.* (45) reported that on light soils movement of dinoseb seems as much a function of soil type and pH as it was of the amount of rainfall applied. Activity of dinoseb tended to be greatest in the lower soil layers. Davis (36) reported that dinoseb was less toxic on a silt loam soil than on a sandy loam soil. Results such as these give rise to the general recommendation that herbicide rates be reduced as the soils become more sandy and lower in organic matter.

Photochemical Breakdown

Some herbicides applied to the soil surface may be broken down by sunlight. Sheets (114) reported that exposure of chloramben to sunlight or fluorescent sunlamps

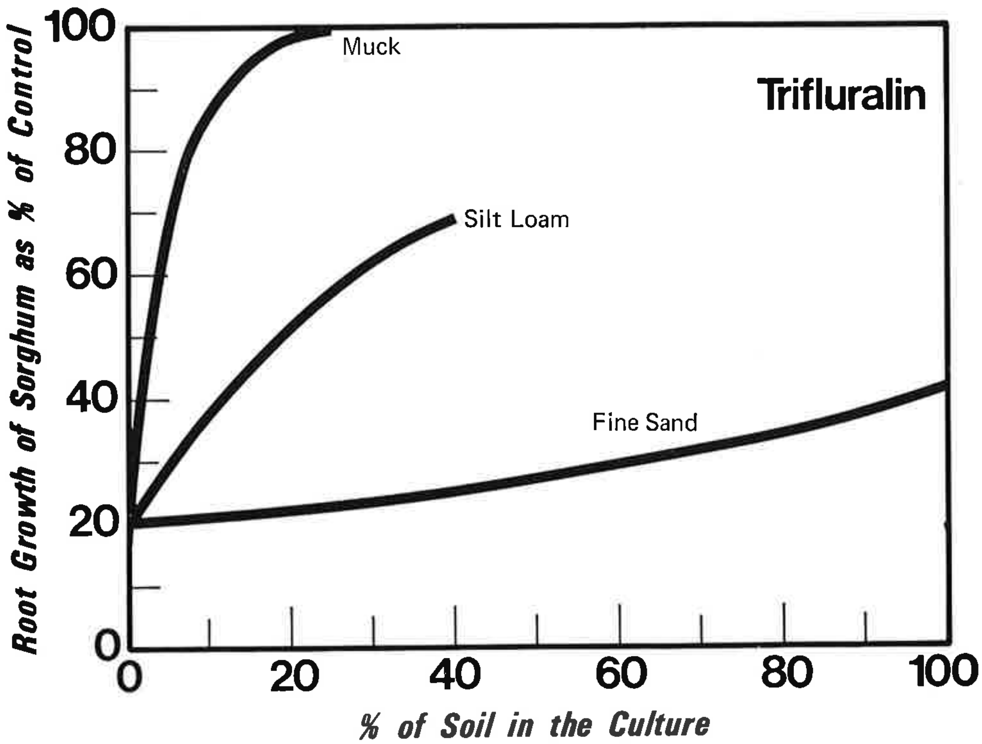

Figure 19. Effect of relative amount of soil in seedling culture on inactivating trifluralin. Concentration of herbicide solution was 2 ppm. [from Eshel and Warren (47)].

for periods of 4 to 6 hours caused a slight chemical change. Wright and Warren (139) reported that trifluralin exposed to sunlight or ultraviolet light changed progressively with time and intensity of exposure. When exposed on the soil surface for 2 hours the herbicidal activity was significantly lower than that of unexposed trifluralin.

Pesticide Interactions

A herbicide placed in or on the soil may react not only with the soil, but also with other pesticides. Most of the research on pesticide interactions in the soil concerned cotton, but a little was conducted with peanuts.

Much of the interaction research involved trifluralin. Ivy and Pfrimmer (72) reported no detrimental interaction of trifluralin with disulfoton or phorate insecticides. Helmer *et al.* (65) and Chambers *et al.* (26) reported similar results with aldicarb as well as with disulfoton or phorate. Neither chloramben or triflularin alone or in combinations with disulfoton or methomyl caused significant differences in mature height, date of maturity, or seed yield and quality of soybeans (73).

Pinckard and Standifer (93) reported that a combination of trifluralin and the fungicide PCNB retarded the growth of cotton seedlings.

Cargill and Santelmann (24) reported some detrimental interactions to seedling peanuts when trifluralin was used in combination with certain other pesticides in the greenhouse. They found no significant interactions between the herbicides chloramben or vernolate and other pesticides. In Georgia (unpublished data of E. W. Hauser) certain insecticides (disulfoton or phorate) applied on field grown peanuts sometimes interacted with vernolate or with an "at cracking" treatment (2,4-DEP + dinoseb) to produce more injury than when either pesticide was applied alone.

In addition to possible interactions with other pesticides, herbicides applied sequentially may interact with each other and adversely affect peanuts. For example, in Georgia research by Hauser *et al.*[3], incorporation of vernolate before planting followed by application of a mixture of 2,4-DEP + dinoseb at "cracking" substantially depressed the yield of peanuts. However, if the vernolate was injected, or certain other mixtures were applied at "cracking" after incorporated vernolate, yields were normal. It is also possible that certain sequential treatments may favorably affect peanuts.

Past and current studies notwithstanding, much more research is needed on possible interactions of the various pesticides used in producing peanuts.

Seed Quality

Research with peanuts and other crops, particularly cotton, indicated that the quality of the seed used in planting the crop may influence injury from a herbicide. Boyle and Hauser (14) suggested that poor emergence of herbicidally treated peanuts may be due in part to seed of poor vitality. Their greenhouse data showed that sesone did not depress emergence of peanut seed with over 80 percent germination, but seedlings from poor seed did not emerge satisfactorily.

Helmer, *et al.* (65) reported that although the emergence, growth and yield of peanuts was directly related to seed quality, no interactions existed between trifluralin and seed quality. In contrast, Cargill and Santelmann (25) found that the presence or absence of the seedcoat was sometimes related to the effect of trifluralin and chloramben on peanut seedlings. They also found that plants from small peanut seeds were more susceptible to herbicide injury than those from large seeds; and that injury to the germ end of peanut seeds resulted in greater herbicide injury to the seedling.

We believe that farmers can obtain better results by planting only seed of high quality. Vigorous seedlings resist unfavorable environmental factors (which may occur singly or in combination) much better than seedlings of poor vitality. For example, potential stress from herbicides alone may be innocuous but if combined with such other potentially detrimental influences as bad weather, seedling diseases and poor seedling growth, two or more of these factors may interact to drastically and adversely affect the peanuts. Therefore, high-vitality seed form an essential component of a well-executed weed control program.

Outlook for Weed Control in Peanuts

Weed populations are not static but are constantly changing — sometimes subtly but often rapidly. At the present time, and the trend will probably project well into the future, rapidly changing weed populations are challenging research scientists, extension workers and farmers. Uncontrolled weeds encroach, shifting the weed patterns from easily controlled species to those controlled only with difficulty or not controlled at all.

Before the era of mechanized farming, ecological shifts in weed populations usually were relatively slow. Recently, however, innovative mechanization, including widespread application of selective herbicides induced accelerated and often dramatic

[3]Hauser, Ellis W., Cecil, S. R. and Clyde C. Dowler. Systems of Weed Control for Peanuts. Manuscript was in preparation for the journal Weed Science when this chapter was written.

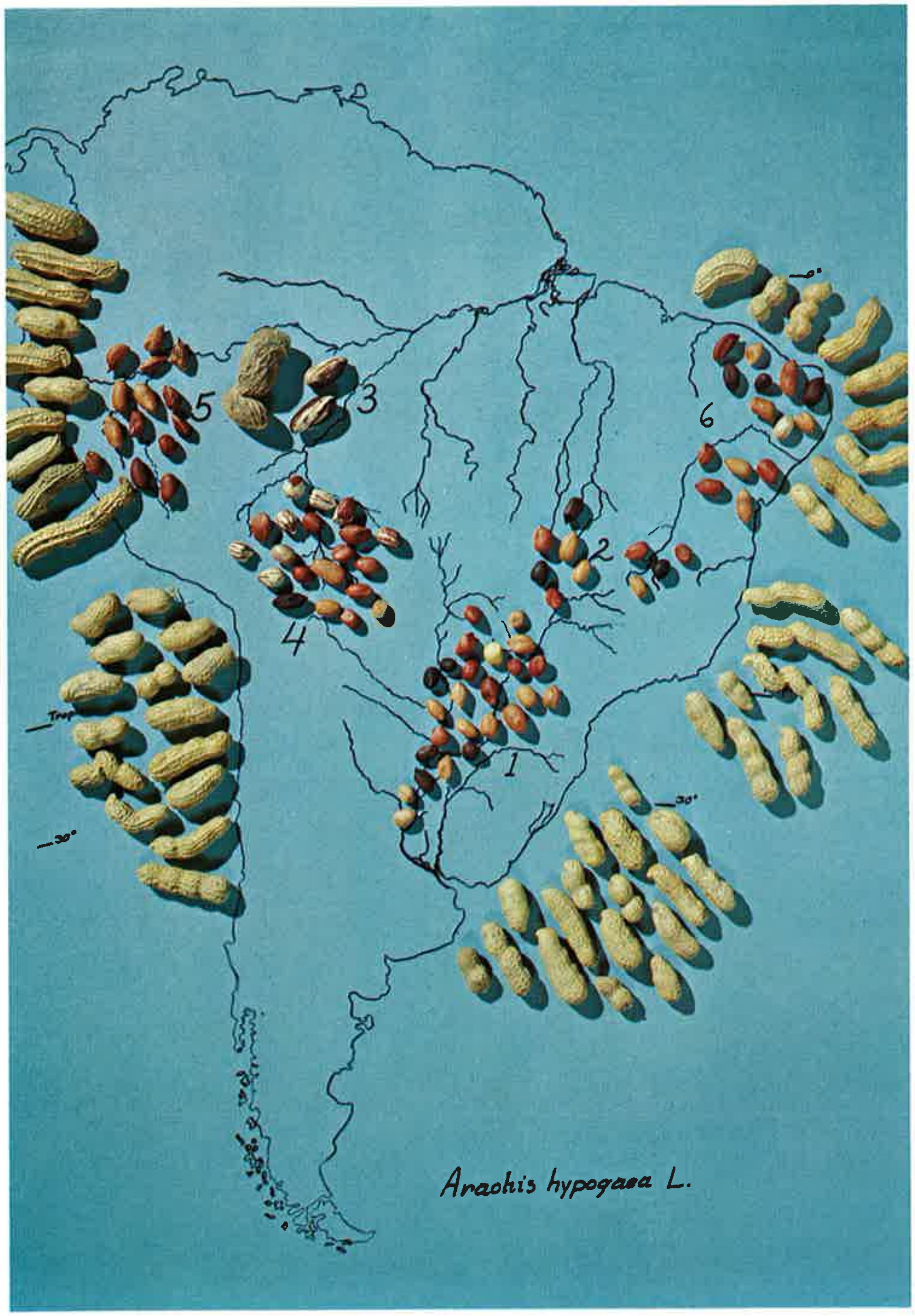

PLATE 1. A sample of fruit and seed types characteristic of the gene centers of *A. hypogaea* L. by geographic region.

A single seed of each varietal type representing a region lies on the map close to the exact locality from which it came. The fruits are clustered near their associated seed types. (1) Guaraní region (Paraguay-Paraná); (2) Goiás and Minas Gerais region (Tocantins, São Francisco); (3) Rondonia and northwest Mato Grosso (south Amazon); (4) Bolivian region (southwest Amazon); (5) Peruvian region (upper Amazon and west coast); (6) northeastern Brazil.

PLATE 2. Florida beggarweed

PLATE 3. Goosegrass

PLATE 4. Tall morningglory

PLATE 5. Smallflower morningglory

PLATE 6. Large crabgrass

PLATE 7. Redroot pigweed

PLATE 8. Yellow nutsedge

PLATE 9. Purple nutsedge

PLATE 10. Common cocklebur

PLATE 11. Florida purslane or pusley

PLATE 12. Texas panicum

PLATE 13. Sicklepod

PLATE 14. Sandbur

PLATE 15. Prickly sida

PLATE 16. Jimsonweed

ecological changes within cultivated fields. For example, during the 1940's, in the Georgia-Florida-Alabama (GFA) peanut belt, the predominating weeds in many fields were crabgrass and Florida pusley. Farmers controlled these weeds with cultivation and hoeing. As the supply of labor decreased and the demand for better and more precise weed control procedures increased, industrial and institutional research scientists developed herbicide practices which effectively controlled crabgrass and Florida pusley. Subsequently, in the 1950's, another weed, nutsedge (which previously was removed by hoeing) predominated in many peanut fields. About 1965, farmers began controlling nutsedge with a new selective herbicide. As this chapter is written, certain other weeds in GFA peanut fields overshadow nutsedge in importance. Recently such broadleaf weeds as cocklebur, sicklepod, and Florida beggarweed, persisting in the environment for many years, emerged as very serious problems (84) (Figure 20). These and other broadleaf weeds, although they may emerge early, often become troublesome after cultivation is no longer feasible. These uncontrolled broadleaf weeds interfere with harvesting operations and also damage combines. Planting of high-vitality seed in closely spaced rows (to encourage quick formation of a thick canopy of peanut leaves) will help suppress these troublesome weeds.

Similar ecological changes, involving these or other weeds, have occurred in other peanut producing areas (82). These changes will undoubtedly continue to challenge the ingenuity of research scientists, extension personnel, and peanut producers.

An urgent need in peanut production, especially for the control of weeds that cause trouble late in the season, is a herbicide for postemergence use (with very low mammalian toxicity and little or no persistence in soil) capable of selectively removing these weeds from peanuts. The growth habits of the peanut plant preclude applica-

Figure 20. Rapid ecological change during 16 weeks following application of a selective peanut herbicide. Untreated center bed contains Florida pusley and yellow nutsedge. Florida beggarweed predominates on the adjacent treated beds.

tion of herbicides as directed postemergence treatments. Current research shows that low rates of 2,4-DB effectively suppress cocklebur and certain other weeds with acceptable crop tolerance. Unfortunately, this herbicide does not consistently suppress such weeds as sicklepod and Florida beggarweed.

Another major problem of the modern peanut farmer is integration of the effective cultural and chemical weed control methods into the most logical procedure for controlling his specific weeds. The term "prescription approach" implies tailoring control measures to specific weeds and environmental conditions (84, 100). A closely related concept involves "systems of weed control". Such systems could involve as components: (a) herbicides only; (b) cultivation only; or (c) a number of logical combinations of both herbicides and cultivation. Although published reports are few, research studies and extension demonstrations evaluating systems of weed control are currently underway. Timeliness of either the herbicide application or of cultivation may be critical in a weed control system. Followup sprays of dinoseb controlled weeds better if applied one week rather than two weeks after herbicide mixtures "at cracking" (58). Rud (102) and Rogerson (100) evaluated herbicides incorporated before planting followed by different "at cracking" treatments. Weeds were controlled better by Derting (41) when he applied alachlor as a preemergence treatment followed by dinoseb "at cracking" than when the two herbicides were applied together as a preemergence treatment. Current Georgia studies involving systems of weed control suggest that, under some conditions, only one timely cultivation contributes substantially to controlling late-season weeds where herbicides were applied previously (Figure 21).

Figure 21. *Center:* Results from a system of weed control involving a herbicide injected at planting, a preemergence treatment with a herbicide and one timely cultivation. *Right and left:* Untreated checks with heavy stands of Texas panicum, prickly sida, sicklepod, morningglories and other weeds.

Another concept which undoubtedly will become more important in the future is herbicide-crop rotation. It may be particularly applicable to peanuts since directed postemergence treatments with herbicides are precluded. The herbicide-crop rotation concept (55) involves a total rotational approach emphasizing excellent control of weeds with the herbicides and cultural techniques best suited to each crop. Weeds difficult to control in one crop may be easily controlled in another. For example, Florida beggarweed, hard to control in peanuts, is relatively easy to control in corn or cotton. Over a period of years, controlling each weed at its most vulnerable spot in the rotation should reduce infestations considerably.

LITERATURE CITED

1. Albert, W. B. 1956. Tolerance of peanuts to various preemergence herbicides. Proc. So. Weed Conf. 9:36-39.
2. Andrews, Jr., O. N., C. W. Derting, C. T. Dickerson, R. G. Duncan, D. F. Jones and G. W. Selleck. 1970. Lasso®, a new herbicide for peanuts. Proc. So. Weed Sci. Soc., 23:89-94.
3. Anonymous. 1959. Deep plowing, proper cultivation check stem rot of peanuts. Crops and Soils 12:28.
4. Ashrif, M. I. 1966. Preemergence herbicide trial on groundnuts in the Gambia. Pans (C) 12:203-210.
5. Bardsley, C. E., K. E. Savage and V. O. Childers. 1967. Trifluralin behavior in soil. I. Toxicity and persistence as related to organic matter. Agron. J. 59:159-160.
6. Bardsley, C. E., K. E. Savage and J. C. Walker. 1968. Trifluralin behavior in soil. II. Volatilization as influenced by concentration, time, soil moisture content, and placement. Agron. J. 60:89-92.
7. Boswell, T. E. 1971. Postemergence weed control in peanuts. Proc. So. Weed Sci. Soc., 24:124-130.
8. Boswell, T. E., B. R. Spears and M. G. Merkle. 1968. Herbicides for peanut production in Texas. Proc. So. Weed Conf. 21:113-116.
9. Boswell, T. E., M. G. Merkle and B. R. Spears. 1969. The effect of concentration and incorporation depth upon performance of substituted aniline herbicides in peanuts. Proc. So. Weed Sci. Soc. 22:150.
10. Boyle, Lytton W. 1952. Factors to be integrated in the control of southern blight on peanuts (Abstr.). Phytopathol. 42:282.
11. Boyle, Lytton W. 1956. Fundamental concepts in the development of control measures for southern blight and root rot on peanuts. Plant Disease Reporter 40:661-665.
12. Boyle, Lytton W. 1967. A factorial study of certain schemes of peanut culture. Res. Bull. 18, Univ. of Georgia Agr. Exp. Sta.
13. Boyle, Lytton W. and R. O. Hammons. 1956. Cultural practices with respect to peanut yields and control of southern blight and root rot. Georgia Exp. Sta. Mimeo Series (New Series) 31.
14. Boyle, Lytton W. and Ellis W. Hauser. 1962. Response to sesone and development of root rots in peanuts. Weeds 10:106-111.
15. Brimhall, Phil B., Earl W. Chamberlain and H. P. Alley. 1965. Competition of annual weeds and sugar beets. Weeds 13:33-35.
16. Buchanan, Gale A., Ray Dickens, Earl R. Burns and Robert M. McCormick. 1969. Performance of several herbicides for weed control in peanuts. Proc. So. Weed Conf. 22:122-131.
17. Buchanan, Gale A. and Earl R. Burns. 1970. Influence of weed competition on cotton. Weed Sci. 18:149-154.
18. Burnside, O. C. and W. G. Lipke. 1962. The effect of applied water on preemergence applications of amiben. Weeds 10:100-103.

19. Burnside, O. C. and G. A. Wicks. 1967. The effect of weed removal treatments on sorghum growth. Weeds 15:204-207.

20. Burt, E. O. 1955. Preemergence weed control in peanuts. Proc. So. Weed Conf. 8:127-129.

21. Burt, E. O. 1956. Pre- and postemergence herbicides in peanuts. Proc. So. Weed Conf. 9:40-47.

22. Burt, E. O. 1959. Soil incorporation of thiolcarbamates for control of weeds. Proc. So. Weed Conf. 12:19-22.

23. Cargill, Roland L., H. A. Greer and P. W. Santelmann. 1970. Chemical weed control in Spanish peanuts. Proc. So. Weed Sci. Soc. 23:95-100.

24. Cargill, Roland L. and P. W. Santelmann. 1971. Response of peanuts to combinations of herbicides with other pesticides. Weed Sci. 19:24-27.

25. Cargill, Roland L. and P. W. Santelmann. 1971. Influence of peanut seed quality and variety on susceptibility to herbicides. Agron. J. 63:98-100.

26. Chambers, Albert Y., William G. Russell, Joseph R. Overton and Henry Andrews. 1969. Interactions of recommended preemergence herbicides, systemic insecticides, and soil fungicides on cotton: two years' results. Proc. So. Weed Sci. Soc. 22:83-87.

27. Chandler, James M. and P. W. Santelmann. 1969. Growth characteristics and herbicide susceptibility of Texas panicum. Weed Sci. 17:91-93.

28. Chandler, James M. and P. W. Santelmann. 1969. Ecology and control of *Panicum texanum*. Proc. So. Weed Sci. Soc. 22:341.

29. Chappell, W. E. 1956. Screening tests on peanuts, soybeans, and castor beans. Proc. So. Weed Conf. 9:57-60.

30. Chappell, W. E. and G. B. Duke. 1956. The effects of rollers and depth of planting on peanuts and weeds sprayed with 2,4 dichlorophenoxy-ethyl sulphate. Proc. So. Weed Conf. 9:54-56.

31. Chappell, W. E. 1957. Comparison of granular and spray application of herbicides on peanuts. Proc. So. Weed Conf. 10:87-94.

32. Ciccarone, A. and E. Platone. 1949. Notizie su *Sclerotium rolfsii* Sacc. in Venezuela. Riv. agr. top. e subtrop. 43:71-80.

33. Cooke, Anson R. 1966. Controlled studies on the interaction of rainfall and preemergence herbicide activity. Proc. So. Weed Conf. 19:535-538.

34. Corbin, F. T. 1967. Influence of pH on the detoxication of herbicides in the soil. Proc. So. Weed Conf. 20:394.

35. Corbin, F. T. and R. P. Upchurch. 1967. Influence of pH on detoxication of herbicides in soil. Weeds 15:370-377.

36. Davis, D. E. 1956. Some factors that affect the phytotoxicity of water-soluble DNBP. Weeds 3:227-234.

37. Davis, D. E. and F. L. Davis. 1954. Some effects of rainfall and lime on the phytotoxicity of water soluble dinitro. Proc. So. Weed Conf. 7:208-211.

38. Davis, F. L., F. L. Selman and D. E.. Davis. 1954. Some factors affecting the behavior of dinitro herbicides in soils. Proc. So. Weed Conf. 7:205-207.

39. Dawson, J. H. 1964. Competition between irrigated field beans and annual weeds. Weeds 12:206-208.

40. Dawson, J. H. 1965. Competition between irrigated sugar beets and annual weeds. Weeds 13:245-249.

41. Derting, Claude W. 1969. Performance of preemergence herbicide combinations on corn, soybeans, and peanuts. Proc. So. Weed Sci. Soc. 22:170-174.

42. Doll, Jerry D. and William F. Meggitt. 1969. Uptake and effectiveness of herbicides at different nutrient levels and combinations. WSSA Abstr., No. 212.

43. Dowler, Clyde and E. W. Hauser. 1969. Factors affecting the response of soybeans to trifluralin, vernolate, and benefin. Proc. So. Weed Sci. Soc. 22:360.

44. Dowler, Clyde C. and E. W. Hauser, 1970. An injector-planter for subsurface placement of herbicides. Weed Sci. 18:461-464.

45. Dowler, Clyde C., N. M. Baughman and Collins Veatch. 1958. The effect of soil type, soil pH, and simulated rainfall on the distribution of DNBP in the soil. Weeds 6:281-288.

46. Duncan, R. G., O. N. Andrews, F. D. Timmons and G. W. Selleck. 1971. Alachlor and alachlor combinations in peanuts. Proc. So. Weed Sci. Soc., 24:110-117.

47. Eshel, Y. and G. F. Warren. 1967. A simplified method for determining phytotoxicity, leaching, and adsorption of herbicides in soils. Weeds 15:115-118.

48. Garren, Kenneth H. 1959. The stem rot of peanuts and its control. Va. Agr. Exp. Sta. Tech. Bull. 144. 29 pp.

49. Garren, Kenneth H. 1961. Control of *Sclerotium rolfsii* through cultural practices. Symposium on Sclerotium rolfsii. Phytopathol. 51:120-124.

50. Gray, R. A. and A. J. Weierich. 1968. Behavior and persistence of thiocarbamate herbicides in soils under different environmental conditions. Proc. Brit. Weed Contr. Conf. 9:94-101.

51. Guse, L., W. Humphreys, J. Hooks, J. Gramlich and W. Arnold. 1966. Benefin, Balan™, a preemergence herbicide for peanuts. Proc. So. Weed Conf. 19:121-125.

52. Hauser, Ellis W. 1965. Preemergence activity of three thiocarbamate herbicides in relation to depth of placement in the soil. Weeds 13:255-257.

53. Hauser, Ellis W. 1966. A promising method for control of nutsedge in peanuts. Proc. Nat. Peanut Conf. 4:82-84.

54. Hauser, Ellis W. 1967. The influence of DMPA on peanut yields. Weeds 15:84-85.

55. Hauser, Ellis W. 1968. Yellow nutsedge — problems, research trends and outlook. Proc. No. Eastern Weed Contr. Conf. 22:37-48.

56. Hauser, Ellis W., J. L. Butler, J. L. Shepherd and S. A. Parham. 1966. Response of yellow nutsedge, Florida pusley and peanuts to thiocarbamate herbicides as affected by method of placement in soil. Weed Res. 6:338-345.

57. Hauser, Ellis and Clyde C. Dowler. 1971. Control of Florida beggarweed in peanuts. Proc. So. Weed Sci. Soc., 24:137.

58. Hauser, Ellis W. and S. A. Parham. 1964. Herbicide mixtures for weed control in peanuts (*Arachis hypogaea* L.), 1961-63. Weed Res. 4:338-350.

59. Hauser, Ellis W. and S. A. Parham. 1964. Preliminary report on methods for the control of yellow nutsedge (*Cyperus esculentus* L.) in peanuts. Proc. So. Weed Conf. 17:158-159.

60. Hauser, Ellis W. and S. A. Parham. 1965. Progress report: Subsurface application of thiolcarbamate herbicides for weed control in peanuts. Proc. So. Weed Conf. 18:115-116.

61. Hauser, Ellis W. and S. A. Parham. 1967. Progress report: Control of yellow nutsedge in peanuts with a soil-injected herbicide. Proc. So. Weed Conf. 20:33.

62. Hauser, Ellis W. and S. A. Parham. 1969. Effects of annual weeds and cultivation on yield of peanuts. Weed Res. 9:192-197.

63. Hauser, Ellis W., L. E. Samples and S. A. Parham. 1969. Incorporated versus subsurface vernolate for weed control in peanuts. Weed Res. 9:173-184.

64. Hauser, Ellis W., W. C. Shaw, H. F. Harrison and S. A. Parham. 1962. Herbicides and herbicide mixtures for weed control in peanuts. Weeds 10:139-144.

65. Helmer, J. D., F. A. Harris, C. D. Hobbs, J. A. Keaton, J. L. Pafford, J. H. Watson and W. J. Polzin. 1969. The effects of seed quality, systemic insecticides and trifluralin on cotton and Spanish peanuts. Proc. So. Weed Sci. Soc. 22:132-144.

66. Helms, C. C., Jr. and E. G. Rodgers. 1953. Herbicidal influences on Dixie runner peanuts and existing weed populations. Proc. So. Weed Sci. Soc. 6:143-149.

67. Helms, C. C. 1955. Weed control in peanuts. Proc. So. Weed Conf. 8:130-135.

68. Hill, L. V., Thomas Peeper and P. W. Santelmann. 1968. Influence of soil temperature and moisture on peanut injury from amiben, trifluralin and vernolate. Proc. So. Weed Conf. 21:324.

69. Hill, L. V. and P. W. Santelmann. 1969. Competitive effects of annual weeds on Spanish peanuts. Weed Sci. 17:1-2.

70. Holm, Leroy. 1969. Weed problems in developing countries. Weed Sci. 17:113-118.

71. Holstun, J. T., Jr., O. B. Wooten, R. E. Parker and E. E. Schweizer. 1963. Triband weed control — a new concept for weed control in cotton. U. S. Dep. of Agr., Agr. Res. Serv. 34-56. 14 pp.

72. Ivy, H. W. and T. F. Pfrimmer. 1969. Effect of combinations of preemergence herbicides and systemic insecticides on cotton stands and yields. Proc. So. Weed Sci. Soc. 22:94.

73. Johnson, B. J. 1969. Response of soybeans to combinations of herbicides and systemic insecticides. Proc. So. Weed Sci. Soc. 22:95.

74. Jordan, L. S., B. E. Day and W. A. Clerx. 1963. Effect of incorporation and method of irrigation on preemergence herbicides. Weeds 11:157-160.

75. Klingman, Glenn C. 1961. Weed control: as a Science. John Wiley and Sons, N. Y. 421 pp.

76. Knake, Ellery L., Arnold P. Appleby and William R. Furtick. 1967. Soil incorporation and site of uptake of preemergence herbicides. Weeds 15:228-232.

77. Knake, E. L. and F. W. Slife. 1965. Giant foxtail seeded at various times in corn and soybeans. Weeds 13:331-334.

78. Leiderman, L. and C. A. Lobatos dos Santos. 1967. Controle de gramineas na cultura do amendoim com misturas de trifluralin e diuron em tres regioes do Estado de Sao Paulo. O Biologico 33:227-232.

79. Leiderman, L., C. A. Lobato dos Santos and R. I. Silverira. 1965. Aplicacao do herbicida Treflan na cultura do amendoim em solos arenosos e massape. O Biologico 31:279-283.

80. Linscott, J. J., O. C. Burnside and T. L. Lavy. 1969. Phytotoxicity and movement of amiben derivatives in soil. Weed Sci. 17:170-174.

81. Lipscomb, R. W. and M. Wilcox. 1967. Yields and visual ratings from weed control experiments in 1966. Fla. Agr. Exp. Sta. Agron. Mimeo Report AG 67-4.

82. Matthiesen, Robert and P. W. Santelmann. 1971. Influence of postemergence herbicides on peanut development. Proc. So. Weed Sci. Soc. 24:131-136.

83. McGill, J. Frank and L. E. Samples. 1968. Growing peanuts in Georgia. Univ. of Georgia Ext. Serv. Bull. 640.

84. McGill, J. Frank, L. E. Samples and James F. Miller. 1969. Chemical weed control in peanuts. Georgia Ext. Serv. Peanut Release No. 57-69.

85. McWhorter, C. G. and E. E. Hartwig. 1966. Cocklebur control in soybeans with 2,4-DB. Weeds 14:187-190.

86. McWhorter, C. G., O. B. Wooten and R. S. Baker. 1966. Preemergence herbicide injection for weed control. Mississippi Agr. Exp. Sta. Bull. 723, 7 pp.

87. Meggitt, William F., R. J. Aldrich and W. C. Shaw. 1956. Factors affecting the herbicidal action of aqueous sprays of salts of 4,6-dinitro-ortho-secondary butyl phenol. Weeds 4:131-138.

88. Miller, J. F. 1968. Interaction of trifluralin with lime, nitrogen, phosphorus and a fungicide on soybeans. Weed Abstr. 17:2570.

89. National Research Council Subcommittee on Weeds. 1968. Volume 2 Weed Control. National Academy of Sciences, Washington, D. C. 471 pp.

90. Oram, P. A. 1961. Experiments on the control of weeds in groundnuts in Tripolitania. Weed Res. 1:211-228.

91. Perry, A. 1955. Peanut production guide for North Carolina farmers. N. C. Agr. Ext. Serv. Circ. 257. 23 pp.

92. Pieczarka, S. J., W. L. Wright and E. F. Alder. 1962. Trifluralin as a soil-incorporated preemergence herbicide for agronomic crops. Proc. So. Weed Conf. 15:92-96.

93. Pinckard, J. A. and L. C. Standifer. 1966. An apparent interaction between cotton herbicidal injury and seedling blight. Plant Disease Reporter 50:172-174.

94. Probst, G. W., Tomasz Golab, R. J. Herberg, F. J. Holzer, S. J. Parka, Cornelius Van Der Schans and J. B. Tepe. 1967. Fate of trifluralin in soils and plants. J. Agr. & Food Chemi. 15:592-599.

95. Rauser, W. E. and C. M. Switzer. 1962. Factors contributing to the loss of amiben phytotoxicity in soils. Weeds 10:62-64.

96. Rawson, J. E. 1962. Preemergence spraying to control weeds in peanuts. Queensland Agr. J. 88:3-5.

97. Rawson, J. E. 1963. Susceptibility of Virginia Bunch peanut to postemergence application of 2,4-D and related herbicides. Queensland J. of Agr. Sci. 20:463-467.

98. Rawson, J. E. 1964. Controlling weeds in peanuts. Queensland Agr. J. Advisory Leafl. No. 796. 90:656-661.

99. Rea, H. E. 1955. The control of weeds in corn and peanuts. Proc. So. Weed Conf. 8:143-147.

100. Rogerson, A. B. 1968. Peanut weed control on farm tests — 1968. Unnumbered North Carolina Ext. Serv. Mimeo. Leafl.

101. Rud, O. E. and W. E. Chappell. 1959. The performance of DNBP in weed control in peanuts. Proc. So. Weed Conf. 12:5-11.

102. Rud, O. E. 1968. The performance of preplant and early postemergence treatment combinations for weed control in peanuts. Proc. So. Weed Conf. 21:117-121.

103. Rud, O. E. and Frank Timmons. 1971. Field performance of alachlor on Virginia type peanuts. Proc. So. Weed Sci. Soc. 24:118 123.

104. Santelmann, P. W., W. C. Elder and R. S. Matlock. 1963. The effect of several herbicides on weed control, yields, and quality of Spanish peanuts. Proc. Peanut Improvement Work Group, p. 45-51.

105. Santelmann, P. W. and R. S. Matlock. 1964. The influence of pre- and postemergence herbicides on the yield and quality of Spanish peanuts. Proc. So. Weed Conf. 17:132-137.

106. Santelmann, P. W., R. S. Matlock and Lee Six. 1967. Phototoxicity of herbicides to Spanish peanuts (*Arachis hypogaea* L.) as influenced by planting depth and simulated rainfall. Crop Sci. 7:365-367.

107. Schliebe, K. A., O. C. Burnside and T. L. Lavy. 1965. Dissipation of amiben. Weeds 13:321-325.

108. Scholl, J. M. and V. S. Searcy. 1949. Effect of chemical preemergence weed control treatments on stands of weeds and stands and yields of peanuts. Proc. So. Weed Conf. 2:40-42.

109. Searcy, V. S. 1952. Effects of a preemergence chemical application on peanuts planted at various spacing. Proc. So. Weed Conf. 5:116-117.

110. Searcy, V. S. 1953. The influence of chemicals on weeds and on stands, yields, and percentage sound mature kernels of peanuts when applied as preemergence sprays. Proc. So. Weed Conf. 6:138-140.

111. Selman, F. L. and R. P. Upchurch. 1961. A progress report on weed control research for peanuts in North Carolina. Proc. So. Weed Conf. 14:120.

112. Selman, F. L. and R. P. Upchurch. 1963. The influence of pH on the activity of herbicides Proc. So. Weed Conf. 16:392.

113. Shaw, Warren C., E. T. York and W. C. Gregory. 1951. The effect of chemicals on weeds and the stand and yield of peanuts, when applied as preemergence sprays. Proc. So. Weed Conf. 4:112-120.

114. Sheets, T. J. 1963. Photochemical alteration and inactivation of amiben. Weeds 11:186-190.

115. Shepherd, James L. 1963. Mechanized peanut production — tillage through harvesting and curing. 1963. Georgia Agr. Exp. Sta. Mimeo Series (New Series) 163.

116. Silayan, H. S. 1917. Culture and fertilization as affecting the oil content of peanuts. Philippine Agr. and Forest. 6:84-97.

117. Staniforth, David W. 1965. Competitive effects of three foxtail species on soybeans. Weeds 13:191-193.

118. Stickler, R. L., E. L. Knake and T. D. Hinesly. 1969. Soil moisture and effectiveness of preemergence herbicides. Weeds 17:257-259.

119. Sweet, R. D., D. W. Davis, C. T. Dickerson, Jr. and G. H. Bayer. 1966. Effectiveness of trifluralin in vegetable crops. WSA Abstr., p. 17.

120. Thompson, Jack T., Ellis W. Hauser and S. V. Stacy. 1955. Three years results on the use of chemicals to control weeds in peanuts under Georgia conditions. Proc. So. Weed Conf. 8:118-122.

121. Upchurch, Robert P. 1955. Field experiments conducted in North Carolina during 1953 and 1954 relating to weed control in peanuts. Proc. So. Weed Conf. 8:110-117.

122. Upchurch, R. P. and D. D. Mason. 1962. The influence of soil organic matter on the phytotoxicity of herbicides. Weeds 10:9-14.

123. Upchurch, R. P. and F. L. Selman. 1963. Peanut weed control research in North Carolina (a progress report). Proc. So. Weed Conf. 16:88.

124. Upchurch, R. P. and F. L. Selman. 1968. Compatibility of chemical and mechanical weed control methods. Weed Sci. 16:121-130.

125. Upchurch, R. P., F. L. Selman and H. L. Webster. 1968. Incorporated vernolate and other weed control treatments for peanut production. Weed Sci. 16:317-323.

126. Upchurch, R. P. and A. D. Worsham. 1965. Weed control research and demonstrations for peanuts in North Carolina in 1964. Proc. So. Weed Conf. 18:117.

127. U. S. Environmental Protection Agency. Pesticide Regulation Division. Summary of Registered Agricultural Pesticide Chemical Uses. Vol. 1, 3rd edition (including subsequent supplements).

128. Virginia Polytechnic Institute. 1969. Virginia Weed Control Guide — 1969. Ext. Div. Contr. Series 1. January 1969.

129. Walker, J. C. and U. S. Jones. 1969. Synergistic effects of trifluralin and electrolyte concentration on the growth of seedling cotton. Proc. So. Weed Sci. Soc. 22:93.

130. Watson, A. J. and H. A. Nation. 1957. Response of peanuts and annual weeds to early postemergence applications of the alkanolamine salt of DNBP. Proc. So. Weed Conf. 10:95-100.

131. Weed Society of America Herbicide Handbook: 1967. Second ed. W. F. Humphrey Press Inc., Geneva, N. Y.

132. Westmoreland, W. G. and G. C. Klingman. 1953. Peanuts — preemergence weed control. Proc. So. Weed Conf. 6:150-155.

133. Wheatley, J. R. and W. W. Wells. 1955. 1954 trials with "Crag" Herbicide I (SES) on peanuts. Proc. So. Weed Conf. 8:123-126

134. Wilcox, M. and R. W. Lipscomb. 1964. Comparison of effectiveness of herbicides in peanuts. Proc. Soil and Crop Sci. Soc. of Florida 24:199-208.

135. Wilson, H. P. and R. H. Cole. 1966. Morningglory competition in soybeans. Weeds 14:49-51.

136. Witherspoon, A. G. and E. G. Rodgers. 1954. Comparative "Preemerge" preemergence and postemergence treatments for control of annual weeds in peanut fields. Proc. So. Weed Conf. 7:151-153.

137. Wooten, O. B. and C. G. McWhorter. 1961. A device for subsurface application of herbicides. Weeds 9:36-41.

138. Worsham, A. D. and Astor Perry. 1967. Test-demonstrations on weed control in peanuts in North Carolina in 1966. Proc. So. Weed Conf. 20:26-31.

139. Wright, W. L. and G. F. Warren. 1965. Photochemical decomposition of trifluralin. Weeds 13:329-331.

140. Zimdahl, Robert L. and Stanford N. Fertig. 1967. Influence of weed competition on sugar beets. Weeds 15:336-339.