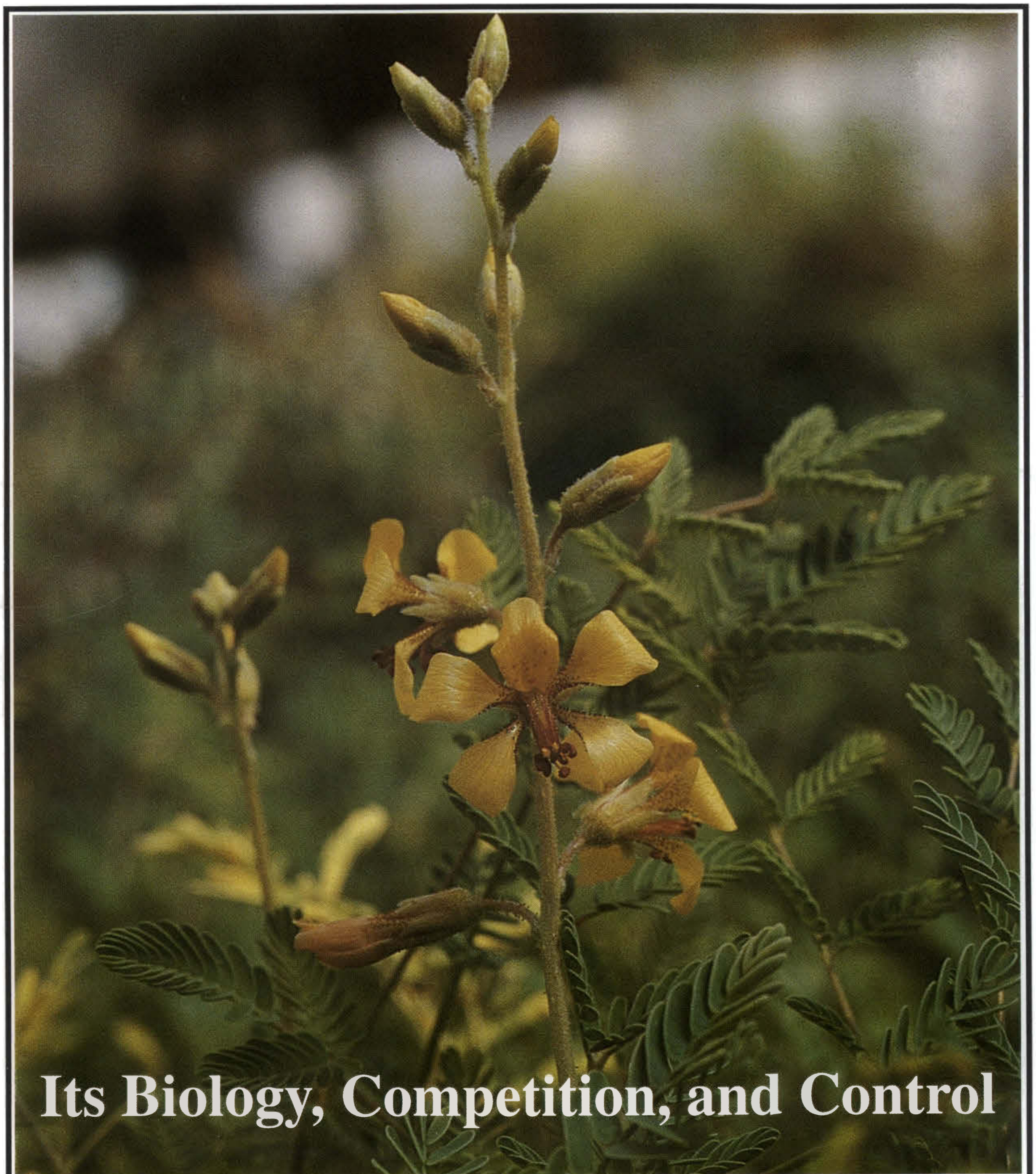
HOGPOTATO

(Hoffmanseggia glauca)



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Contents

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Hogpotato *(Hoffmanseggia glauca)*: Its Biology, Competition, and Control[1]

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INTRODUCTION

Hogpotato, a perennial warm-season legume, is native to Oklahoma (20, 38), Texas (16, 41), New Mexico (J. Schroeder, personal communication), Arizona (30), and California (1, 32). (See Table 1 for the scientific name of hogpotato and for those of other plants mentioned in this report.) Ball and Robbins (1) reported that hogpotato was occasionally found in the San Joaquin Valley and was common in the Mohave and Colorado deserts and in the Imperial Valley. Infestations have been reported in all climatic zones of Texas except in East Texas and along the Gulf Coast (16). Severe infestations were noted on several sandy soils on the Rolling Plains of Texas, and occasional infestations were detected on fine-textured soils in the Central Panhandle (41). Three species in the genus have been identified in Oklahoma (38); however, infestations of this particular species occur more commonly on rangeland in the southwestern part of the state. The primary cotton production area in Oklahoma also occurs in the southwest. Hogpotato is more commonly found on alkaline soils (1, 30). At this time, hogpotato is not a widespread problem for Oklahoma cotton producers; but occasionally, heavy infestations do occur in restricted areas. Infestations in cultivated fields normally appear as sharply defined, irregularly shaped, isolated areas . . . usually no larger than 2.5 acres in size.

Other common names for hogpotato include "pignut", "camote de raton", and "Indian rushpea" (1, 16, 32). At one time, hogpotato propagules were considered a delicacy by American Indians who roasted and ate them (30). Wiese (41) noted that at least two of the common names for the weed arose from hogs rooting the propagules from the ground and eating them.

Hogpotato grows semiprostrate and seldom exceeds 12 inches in height. The weed has bipinnately compound leaves and produces yellow or orange-red flowers on erect racemes (Figure 1). Blooms develop into typical legume pods (1.2 to 1.6 inches long) (Figure 2) which usually contain seven to eight seed; however, only three or four normally reach maturity. Poor seedset makes collection of viable seed difficult. Additionally, a bruchid (i.e., a seed beetle) [*Acanthoscelides compressicornis* (Schaeffer)] feeds on seed produced by two legume genera including hogpotato (25). This beetle had already damaged many of the seed we collected. However, plants produced from seed quickly become established as perennials in as few as 20 days after emergence (22).

Hogpotato is very competitive with cotton; and the weed is difficult to control. Hogpotato plants produce an extensive root system characterized by tuber-like vegetative propagules (Figure 3). The propagules are typically found in the upper 20 inches of the soil profile, but they may be located as deep as 39 inches below the soil surface (23). Previous research has shown that the propagules are produced from 6 to 39 inches below the soil surface, and all are capable of producing new plants (20, 21). Mature propagules are light brown to black in color and range in weight from one to six tubers/ounce with the more common size being in the four-to-six-tuber range (Figure 4). Two distinct ends of each propagule are discernible. Upon sprouting, a single or multiple shoot arises usually from the distal end (Figure 5). Although reproduction by seed is possible, most field infestations are probably propagated vegetatively. The anatomical structure of the propagule has not been described in detail; however, at least one report (41) refers to them as "tubers".

The effects of weed interference on cotton are well documented for several annual weeds (6, 7, 8, 9, 10, 33, 34); however, such data for perennial weeds are more limited (5, 17, 18, 26). Earlier research has shown that weeds which emerge before or simultaneously with the crop are more competitive than weeds which emerge later (6, 27). The weed-free requirement and competitiveness of cotton with mixed broadleaf and grass weed species have been investigated (6). Maximum yield was achieved when cotton was maintained weed-free for at least the first 8 weeks after emergence. Yield

[1] Research in this bulletin was conducted under Oklahoma Agricultural Experiment Station Project H-933 (Management/Interference of Weeds-Cultivated Agronomic Row Crops).

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Table 1. Common and scientific names of plants and common, trade, and chemical names of herbicides discussed in this bulletin.

PLANT IDENTIFICATION

Common name	Scientific name
Common cocklebur	*Xanthium strumarium* L.
Cotton	*Gossypium hirsutum* L.
False broomweed	*Ericameria austrotexana* M.C. Johnst.
Grain sorghum	*Sorghum bicolor* (L.) Moench
Hogpotato	*Hoffmanseggia glauca* (Ortega) Eifert
Soybean	*Glycine max* (L.) Merr.
Wheat	*Triticum aestivum* L.
Yellow nutsedge	*Cyperus esculentus* L.

HERBICIDE IDENTIFICATION

Common name	Trade name	Chemical name
2,4-D	Several	(2,4-dichlorophenoxy)acetic acid
2,4,5-T[a]	Several	(2,4,5-trichlorophenoxy)acetic acid
Alachlor	Lasso	2-chloro-*N*-(2,6-diethylphenyl)-*N*-(methoxymethyl)acetamide
Dicamba	Banvel	3,6-dichloro-2-methoxybenzoic acid
Fenac[a]	Fenatrol	2,3,6-trichlorobenzeneacetic acid
Fenuron[a]	Dybar	*N,N*-dimethyl-*N'*-phenylurea
Glyphosate	Roundup	*N*-(phosphonomethyl)glycine
Imazapyr	Arsenal	(±)-2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1*H*-imidazol-2-yl]-3-pyridinecarboxylic acid
MCPA	Several	(4-chloro-2-methylphenoxy)acetic acid
Metolachlor	Dual	2-chloro-*N*-(2-ethyl-6-methylphenyl)-*N*-(2-methoxy-1-methylethyl)acetamide
Monuron[a]	Telvar	*N'*-(4-chlorophenyl)-*N,N*-dimethylurea
Prometryn	Caparol	*N,N'*-bis(1-methylethyl)-6-(methylthio)-1,3,5-triazine-2,4-diamine
Tebuthiuron	Spike	*N*-[5-(1,1-dimethylethyl)-1,3,4-thiadiazol-2-yl]-*N,N'*-dimethylurea
Triclopyr	Grandstand or Remedy	[(3,5,6-trichloro-2-pyridinyl)oxy]acetic acid
Trifluralin	Treflan	2,6-dinitro-*N,N*-dipropyl-4-(trifluoromethyl)benzenamine

[a] Now an obsolete herbicide.

reductions of up to 99% have been documented from full-season weed interference (14). Full-season yellow nutsedge competition resulted in seed cotton yield reductions of 34% while interference for 6 to 8 weeks resulted in a 20% reduction (26). Limited research has been reported on the effects of hogpotato interference on the growth and development of cotton (13, 14, 21).

Hogpotato's presence and apparent spread in some fields has concerned some producers. Previous research (20, 23) has described seedling germination and development of hogpotato and has documented its detrimental effects on cotton yield and fiber quality. The hogpotato plant is relatively small and, as a result, would be expected to be relatively noncompetitive; however, it has caused severe cotton lint yield reductions (13, 14, 20, 21). In Oklahoma, hogpotato interference has reduced cotton lint yield by 40 to 99% (13). Cotton plants growing within hogpotato infestations do not develop at a normal rate (14). Unpublished data of ours suggests that hogpotato may be allelopathic.

Competition for water (2) and nutrients (12) is more frequently blamed for the reduced crop yield than is competition for light. Experiments with common cocklebur and soybean indicate that the weed's roots exploit a greater volume of soil than does the crop, thereby giving the weed a competitive advantage (15). In early crop-weed competition work, it was found that competition begins when the root systems of the weed and crop overlap in their exploration of the soil profile (31). In the cotton producing areas of Oklahoma, water is commonly a limiting factor for crop growth. Thus, the availability of soil water and its relative utilization by crop and weed are highly important.

Because hogpotato does not produce many viable seed in a given year, experiments were established to evaluate the potential of transplanted hogpotato propagules to sprout and spread vegetatively at various dates during the cotton growing season. Additionally, anatomical studies were conducted to describe the structure of the propagule with the intent that future research in this species might be aided in regard to herbicide translocation.

Research was also conducted to evaluate the weed-free requirement of cotton having hogpotato infestations. Limited research has been conducted on the control of hogpotato in cropping systems. The weed is very difficult to control with selective methods (40, 41). Earlier researchers evaluated the use of soil sterilants and extremely high rates of selective herbicides. (See Table 1 for the common, trade, and chemical names of herbicides mentioned in this report.) Wiese and Rea (42) evaluated fenac (now an obsolete herbicide) and several polychlorobenzoic acid materials for hogpotato control. They reported that these herbicides controlled hogpotato very well when applied at rates of 25 to 50 pounds/acre. In more recent research, Wiese (41) evaluated 2,4-D, 2,4,5-T (now an obsolete herbicide), MCPA, and fenac at rates ranging from 1.25 to 5.0 pounds/acre. Results 2 months after the second application indicated that all herbicide treatments (except MCPA) controlled hogpotato quite well when two applications were made at approximately 10-month intervals. However, 1 year after the final treatment, fenac (at 2.5 to 5.0 pounds/acre) was the only herbicide that controlled hogpotato adequately. At those rates, fenac is a nonselective soil sterilant.

Good to excellent hogpotato control was reported when monuron (now an obsolete herbicide) or fenuron (also an obsolete herbicide) were applied at rates ranging from 50 to 100 pounds/acre as well as when sodium chlorate and borax were applied at rates of 1,000 and 4,000 pounds/acre, respectively (40). However, hogpotato control was not acceptable 1 year after application except with sodium chlorate and borax.

The objective of this bulletin is to make generally available to Oklahoma cotton producers information on the biology, competition, and control of hogpotato. The biological effects of salinity, temperature, pH, resprouting, date of planting, and depth of planting are reported. Propagule anatomy was also investigated. The effects of hogpotato interference on cotton and of the crop on the weed are described under field conditions, and soil water use by both was measured with and without interference. Finally, several commercially available herbicides were investigated for control of hogpotato, and their residual activity on subsequent crops was studied.

MATERIALS AND METHODS

General Biology Experiments

Evaluations of salinity, temperature, and pH on hogpotato seed germination were made under controlled environmental conditions. Weed seed were collected in 1984 and 1985 from a natural infestation near Altus in southwestern Oklahoma. Dry, mature, seed pods were collected by hand during late July and early August of each year, threshed by hand, and then cleaned with a seed blower to remove debris and lightweight seed. Cleaned seed were then stored for a minimum of 30 days at 39 F before use. Preliminary experiments indicated that scarification was necessary to stimulate germination. [After a 9-day incubation period, cumulative percent germination of scarified seed in distilled water was 94%, regardless of temperature (data not shown). In contrast, only 2 to 6% of unscarified seed germinated over the same time period at the same temperatures.] Therefore, all seed in subsequent experiments were scarified for 12 minutes in concentrated sulfuric acid. Scarification was terminated by rinsing the seed with a saturated solution of sodium bicarbonate, followed by a 2-minute rinse in distilled water.

Plastic boxes measuring 2.4 by 2.4 by 1.6 inches (with lids) were used as germination containers. The substrate utilized in each box was a double layer of absorbent paper towel. The substrate was moistened with 0.17 ounces of the appropriate solution (described below), and seed were covered with an additional layer of absorbent paper. Germination experiments were arranged as randomized complete-block designs with four replications. Seed were considered germinated when the radicle appeared. Each experiment was repeated, and values reported herein were averaged over both experiments. Seed were incubated in controlled-environment chambers for a total of 9 days.

Salinity

The effect of increasing salt concentrations on seed germination was evaluated by incubating them in NaCl solutions. This factor was considered important because irrigation water where this weed occurs is generally high in salt content. Sulfates at 700 parts per million (ppm) are the predominant salts, while Na^+ at 575 ppm and Cl^- at 375 ppm are the predominant ions. (Water drained through tiles from irrigated fields in the area has contained as much as 50,000 ppm of total salts.) Concentrations of NaCl in these experiments were 3,000, 6,000, 9,000, and 12,000 ppm. These solutions had pH values of 5.5 ± 0.2. A distilled water (pH = 6.7) treatment served as the control. Osmotic potential of these solutions was determined using calibrated thermocouple psychrometers. An experimental unit consisted of 20 seed/box. These experiments were conducted in the dark at a constant 86 F. Radicle lengths were measured on five germinated seed, chosen at random, in each replication after 3 days. After the 9-day incubation period, ungerminated seed from the two higher NaCl concentrations were removed, rinsed in distilled water, and placed in new boxes moistened with 0.17 ounces of distilled water. Germination and radicle length were recorded 3 days later.

Temperature and pH

Hogpotato germination was measured after exposure to selected temperature and pH combinations. Constant temperatures of 60, 70, and 90 F were evaluated under dark conditions; and an alternating 70 F, 16-hours dark, 90 F, 8-hours light treatment was also included. Preliminary observations indicate that hogpotato does not require light for germination. Buffered pH solutions were prepared using the method described by Wilson (43). A solution of 20,000 ppm potassium hydrogen thalate in combination with either 4,000 ppm HCl or 4,000 ppm NaOH was used to prepare solutions at pH levels of 4.0, 5.0, and 6.0 (± 0.1 pH units). A 10,000 ppm borax solution in combination with 4,000 ppm HCl was used to prepare solutions having pH levels of 7.0 and 8.0 (± 0.1 pH units). All pH levels were evaluated at each temperature. The percentage data from all experiments were converted to arcsine and analyzed as a split-plot design with temperatures considered as main plots and pH levels as subplots. Unscarified seed were also incubated in distilled water to measure their germination at the different temperatures. An experimental unit consisted of 25 seed/box.

Resprouting Ability

Hogpotato plants were grown from scarified seed under greenhouse conditions (77 ± 9 F, 14-hours light, and 10-hours dark) to evaluate seedling development. Seed were planted in plastic cups containing 39 ounces of air-dry Port silt loam (Cumulic Haplutoll). Each cup was planted with two seed. Cups were subirrigated initially, and subsequent water was surface applied. Each cup was watered once weekly with 1.7 ounces of half-strength Hoagland's solution. The experiment was conducted as a randomized complete-block design with 10 replications. Treatments consisted of clipping topgrowth at the soil surface at 5-day intervals from 20 to 55 days after seedling emergence. All cups were harvested 100 days after emergence. Measurements taken included leaf number and dry weight at each clipping date, number of days until resprouting occurred, and percent resprouting. Plants were counted as resprouted when 0.2 inches of new shoot growth appeared. Root growth at harvest was measured by washing the soil from the roots, drying them for 48 hours in an 176 F oven, and weighing them.

Date of Planting

Hogpotato tubers were collected from the natural infestation near Altus. The tubers used in these experiments weighed approximately 0.2 ounce. Within 24 hours after collection, four propagules were planted/plot to a depth of 4 inches. The tubers were equally spaced from the center of each plot. The experiments were conducted on the Agronomy Research Station near Stillwater, OK on a Kirkland silt loam (Udertic Paleustoll).

In 1984, the plots were arranged in a completely randomized design with seven replications. The 1985 experiment was designed as a randomized complete-block with 10 replications. Individual plots were spaced 7 feet apart in 1984 and 10 feet apart in 1985. Planting dates in each year were May 22, June 8, June 21, July 5, and July 19. No herbicides were applied in 1984; however, in 1985, a preemergence application of 2 pounds ai/acre of alachlor was applied to minimize hand weeding.

Data collected included the average number of days for each propagule to sprout, the number of secondary plants produced, the distance they spread, and propagule sprouting percentage. A propagule was considered as sprouted when an emerging shoot appeared above the soil surface. The number of secondary plants produced and their spread was determined on August 20, 1984 and August 25, 1985. The number of secondary plants produced/plot was determined by counting. Vegetative spread was estimated by measuring the distance from the center of the plot to the two most distant secondary plants and taking their arithmetic average. On September 1, 1985 (or approximately 15 months after the initiation of the 1984 experiment), the experimental area appeared as a dense mat of hogpotato. Aboveground shoot counts were made using a 10-inch^2 quadrant to estimate weed density.

All data were subjected to analyses of variance. Data were initially pooled over both years. Analyses by individual years were conducted for those parameters having a statistically significant interaction term with years in the combined analysis.

In 1984, propagules weighing about 0.25 ounce were also planted in steel cylinders 39 inches in diameter and 20 inches deep. Plants remained in the cylinders for 110 days (87 days after emergence). At that time, the cylinders were lifted from the soil; and the intact above- and underground portion of the hogpotato plant was recovered.

Depth of Planting

Hogpotato propagules weighing about 0.1 ounce were planted at Stillwater on a Kirkland silt loam at depths of 8, 16, 24, and 32 inches. The experiment was conducted in the field during 1985 as a randomized complete-block design with four replications. A 3-inch in diameter soil probe was used to bore holes in the soil to the appropriate depth. One propagule/plot was placed in the bottom of the hole, and the hole was then refilled with soil.

Anatomical Study

To determine the anatomical structure of the hogpotato propagule, cross sections of chemically fixed tissue were examined. The tissues were fixed and processed using procedures described by Berlyn and Miksche (3). Ten micrometer sections were cut on a rotary microtome and fixed to glass microscope slides. To aid in tissue identification, all slides were stained using Johansen's Quadruple Stain (24). The primary goal was to identify vascular tissue, particularly xylem, and note its position in the tissue so that a determination could be made as to whether the propagule contained stem tissue, root tissue, or both. Once suitable slides were obtained, photomicrographs were taken of tissues magnified at 100 and 200X.

Length of Competition Time

Experiments were conducted near Altus on an area of Tillman and Hollister clay loams (Typic and Pachic Paleustolls, respectively) from 1984 through 1986. 'Paymaster 404' and 'Paymaster 145', stripper-harvested cotton varieties, were planted with a conventional planter in 40-inch rows. Paymaster 404 was planted on June 2, 1984; Paymaster 145 was planted on May 10, 1985 and May 29, 1986. The cotton-growing seasons were 118, 201, and 166 days during 1984, 1985, and 1986, respectively. In 1984, 40 pounds N/acre as ammonium nitrate were applied. No additions of N were applied in 1985 or 1986. Cotton was planted in an area with a natural infestation of 10 ± 2 hogpotato plants/foot^2. Plots were four rows by 33 feet in 1984 and four rows by 26 feet in 1985 and 1986.

Treatments in 1984 were full-season weed-free maintenance and full-season weed interference. The two treatments were arranged in a completely randomized design with four replications. The experiment was expanded in 1985 and 1986 to include weed interference for the first 7 weeks after crop emergence followed by weed-free maintenance for the remainder of the season and vice versa. These two additional treatments will be referred to as early-season and late-season weed interference, respectively. A randomized complete-block design with four replications was used.

Trifluralin was applied preplant incorporated (PPI) at 1 pound/acre for general weed control during all years. Weed escapes were removed by hand pulling within the crop row and by hoeing between the rows. Furrow irrigation was applied as judged necessary throughout the growing season. In 1984, six irrigations supplied a total of approximately 13 inches of water. The experiment received two irrigations in 1985 and 1986 (approximately 4 inches of water/year).

Cotton plant height was measured from the soil surface to the main stem terminal on six, randomly selected plants/plot, a procedure used successfully in the past (18, 33). Height measurements were made on four dates each year beginning with cotton flowering and at periodic intervals thereafter through boll maturity. Before weed senescence, hogpotato weights were obtained by harvesting all aboveground biomass from four randomly placed, 10-inch^2 quadrants/plot. Samples were oven dried at 104 F for 72 hours and weighed. The cotton from the two center rows of each plot was hand harvested on December 1, 19, and 11 in 1984, 1985, and 1986, respectively. Prior to cotton harvest each year, one mature boll/plant was sampled in each plot from the center portion of 15 randomly selected plants in the rows to be harvested (18, 33). Samples were later ginned; and the data were used to estimate three cotton lint yield components, i.e., boll size (ounces of seed cotton/boll), picked lint percent [(weight of lint/weight of seed cotton) * 100], and pulled lint percent [(weight of lint/weight of seed cotton plus bur) * 100]. Using the estimate of pulled lint percent, snapped cotton yield from each plot was converted to lint yield and expressed in pounds/acre. In 1984 and 1985, measurements of fiber length, uniformity index, micronaire, and strength were taken using the lint obtained from the ginned boll samples.

An additional experiment was conducted in 1986 on a Kirkland silt loam near Stillwater. Four-row by 16-feet plots were arranged in a randomized complete-block design with four replications. Treatments evaluated were cotton with full-season hogpotato interference, cotton alone, hogpotato alone, and bare soil. Paymaster 145 cotton was planted on June 11 in 36-inch rows with a conventional planter. Cotton was planted into an established weed infestation with a density of 12 ± 2 hogpotato plants/foot^2. Ammonium nitrate was used to supply 40 pounds N/acre. A single preemergence application of a tank mixture containing 1.5 pounds ai/acre of metolachlor and 1.5 pounds ai/acre of prometryn was made on June 11 for the control of annual weeds. One irrigation was applied with an overhead sprinkler system on July 29 to supplement rainfall (Figure 6).

The number of cotton bolls in which one or more fluffy locks of seed cotton were visible was recorded, and plots were hand harvested twice to evaluate the effect of hogpotato on cotton maturity. Data were collected from the middle 13 feet in the two center rows of each plot. The first harvest was made on October 17 at an estimated 50% boll opening, and a final harvest was made on December 5. One mature boll/plant was sampled from the center portion of 15 randomly selected plants in the two center rows of each plot for boll size and lint percent determinations. Aboveground hogpotato biomass was harvested on October 14 from the center 3 feet by 13 feet of each plot prior to weed senescence and oven dried at 104 F for 72 hours.

Soil Water Use

In an experiment conducted in 1986 near Stillwater, soil water content was measured each week beginning on June 30 (approximately 2 weeks after cotton emergence) and continued until September 24 when cotton began to senesce. Each four-row plot contained one centrally located neutron probe access tube (nominal 1.5 inch EMT thin-wall steel tubing). Soil water content was measured at depths between 6 and 60 inches at 6-inch increments using a neutron probe with an Am:Be source. Neutron readings made at the 6-inch depth were interpreted from a single calibration curve while readings made at 12 inches and deeper were interpreted from a separate curve. The neutron probe was assumed to provide an average reading of soil moisture content from a spheroid bounded 3 inches above and 3 inches below the specific point at which the neutron source was positioned. Therefore, total water content in cubic inches was calculated to a depth of 63 inches. Crop and weed data were also recorded at each date.

All soil water data were subjected to analyses of variance by depth and time; and comparisons among means were made using the protected LSD at the 0.10 level of probability, except for total soil water content where means were also compared at the 0.05 level. Graphs of volumetric water content over time and depth were examined, and weed and crop water uptake patterns were compared. Following examination of weekly plant growth data, rainfall, and irrigation, the growing season was divided into two periods. An early-season period (June 30 to July 28) was identified which included germination up to the beginning of flowering. A late-season period (August 18 to September 24) was also noted which spanned peak flowering through boll maturity. This later period was preceded by an irrigation followed by heavy rainfall (Figure 6). Data, now separated into early and late season, were subjected to analyses of variance. Total water content data were analyzed as a split-plot experiment with crop and weed, crop, weed, and bare soil as whole units and with dates as subunits.

Field Weed-Control Experiments

During 1987 and 1988, a weed-control experiment was conducted in the field on a Tillman and Hollister clay loam (pH = 7.2; organic matter = 2.0%) near Altus; and two experiments were conducted on a Kirkland silt loam (pH = 6.0; organic matter = 1.5%) near Stillwater. At Altus, the experiment was conducted on an area having a natural infestation of hogpotato with a density of approximately 10 ± 2 plants/foot^2. One experiment at Stillwater was conducted on an area which had been propagated with hogpotato in May 1984 and, by the time of its use in 1987, had a density of approximately 12 ± 2 plants/foot^2. The second site at Stillwater was on an area propagated with hogpotato in May 1985 and, by the time of its use, had a density of about 9 ± 1 plants/foot ^{2}.

Trifluralin was applied at 1 pound/acre as a PPI treatment at Altus for control of annual weeds. This treatment was not utilized at Stillwater. At each location, treatments were arranged in a randomized complete-block design with four replications. Plot sizes at Altus were 13.5 feet wide by 23 feet long and at Stillwater were 12 feet wide by 15 feet long. Herbicides used were dicamba, glyphosate, imazapyr, 2,4-D, tebuthiuron, and triclopyr. With the exception of the pelleted tebuthiuron and spot applications of glyphosate or glyphosate + 2,4-D, all treatments were applied with a tractor-mounted compressed-air sprayer at a constant speed of 4 miles/hour and a carrier volume of 10 gallons/acre. Tebuthiuron pellets were broadcast by hand. A single application time each year was used for each experiment. The spot applications were made with a pump-up back-pack sprayer, and the entire plant foliage was wetted.

Herbicide treatments at Altus and in one Stillwater experiment consisted of glyphosate applied in a 2% w/w $(NH_4)_2SO_4$ (feed grade ammonium sulfate) carrier applied at 1, 2, and 3 pounds ae/acre, imazapyr applied at 0.75, 1.0, and 1.5 pounds ai/acre, and dicamba applied at 0.50 pounds ai/acre (and at 0.25 pounds ai/acre at Stillwater). At application, hogpotato was 1 to 10 inches tall and 50% in bloom. Application dates were June 18 and July 23, 1987 at Altus and Stillwater, respectively. Triclopyr applied at 2 pounds ai/acre and tebuthiuron applied at 2 and 3 pounds ai/acre were evaluated in the second experiment at Stillwater. Application was on August 6, 1987. At application, the hogpotato was 10 to 12 inches tall and in late bloom with seed pods present.

Visual ratings for hogpotato control were recorded approximately 3 weeks after herbicide application and continued throughout the 1987 and 1988 growing seasons at about 3-week intervals. All treatments from all locations were evaluated about 11 months later for hogpotato regrowth.

All plots at each location were retreated with selected herbicides in June 1988. Application dates for these experiments were June 21 and 30 at Altus and Stillwater, respectively. Preliminary results at the end of 1987 showed that imazapyr at the rates used was controlling hogpotato and that glyphosate and dicamba were less effective. The least effective first-year treatments were replaced with more effective ones (or those expected to be). The two higher rates of glyphosate at Stillwater were retreated with glyphosate and glyphosate + 2,4-D spot treatments. The 1988 treatments also consisted of imazapyr at 0.75, 1.0, and 1.5 pounds ai/acre at Altus as well as in one experiment at Stillwater. The glyphosate spot application was 2% v/v of the commercial formulation or 2.5 fluid ounces/gallon. The glyphosate + 2,4-D spot application was 3% v/v of the commercial formulation containing 1.2 pounds/gallon glyphosate and 1.9 pounds/gallon 2,4-D. The growth stage of the hogpotato at Altus at the time of retreatment was 4 to 8 inches high, full bloom, and approximately 70% ground cover. At Stillwater, it was 3 to 12 inches high, late bloom, and approximately 80% ground cover.

The second Stillwater site was retreated with reduced rates of tebuthiuron at 1 and 2 pounds ai/acre on June 30, 1988. It is predominantly a soil-active herbicide, and preliminary results suggested improved control as the season progressed. With improving control and wanting to retain the option of planting sensitive crops, the herbicide rates were reduced. The triclopyr rate remained unchanged. Hogpotato growth stage at the time of retreatment was 3 to 12 inches high, late bloom, and approximately 80% ground cover.

Hogpotato biomass was harvested July 11, 1989 at Altus and July 12, 1989 at Stillwater. During each harvest, two 3-feet^2 quadrants were hand clipped at ground level from each plot, bagged, oven dried at 120 F for 10 days, and weighed.

Bioassay

Soil samples were collected on January 29, 1988 from selected plots in the two field studies described in the previous section at Stillwater. A total of 40 cores (0.75 inches in diameter and 6 inches deep) were randomly removed from each sampled plot, screened through a 5-mesh sieve, and air dried. Climatic conditions between herbicide application and soil sampling were not considered unusual. Temperature and moisture extremes were judged to be reasonably close to long-term averages.

Separate bioassays were performed for each field study. From a plot sample, 7 ounces of soil were removed and placed in a cup. Eight cotton, 10 grain sorghum, or 12 wheat seed were evenly spaced on the soil surface of each cup and then covered with an additional 3.5 ounces of soil to give a planting depth of 0.75 inches. For each study, cups were arranged in a randomized complete-block design with four replications. Within each replication, the cups having the same crop were arranged in a single row; and rows were randomized. Cups, each having four holes near the bottom, were placed into separate watering dishes and subirrigated with 3.3 ounces of distilled water. Cups were then placed under continuous light provided by fluorescent lamps, and a temperature of 88 ± 4 F was maintained. Following germination, plants were subirrigated at 2-day intervals with 1.7 ounces of distilled water. One week after planting, cotton, grain sorghum, and wheat were hand-thinned to 4, 4, and 6 plants/cup, respectively. All aboveground plant growth was harvested 21 days after planting, and fresh weights were taken.

Treatments and treatment dates differed between the two experiments; therefore, they were analyzed separately. All data were subjected to analyses of variance, and means were separated with a protected LSD test at the 0.10 level of probability.

RESULTS AND DISCUSSION

Salinity

Hogpotato seed germination after 3 and 9 days was significantly reduced at NaCl concentrations of 3,000 ppm and greater when compared to the distilled-water control (Table 2). Generally, each increase in NaCl concentration significantly reduced germination percentage. The only exception was 9,000 ppm after 3 days. By that time, 93% of the seed in the control had germinated. Radicle lengths measured after 3 days followed a similar pattern (data not shown). Radicle length was reduced approximately 30% by the 3,000-ppm concentration and reduced more than 60% with the 6,000- and 9,000-ppm concentrations when compared to those in distilled water. No seed germination occurred in the 12,000-ppm concentration during the first 3 days; however, 12% had germinated at that concentration by the 9th day. The increases in germination from 3 to 9 days indicated that the rate at which hogpotato seed germinated was reduced as well by NaCl concentrations.

Table 2. Effect of NaCl concentrations on acid-scarified hogpotato seed germination.[a] [Adapted from Hackett and Murray (22).]

NaCl concentration	Germination 3 days	Germination 9 days
ppm	%	%
0	93 a	95 a
3,000	71 b	89 b
6,000	16 c	76 c
9,000	3 cd	31 d
12,000	0 d	12 e

[a] Within a column, means followed by the same letter are not significantly different at the 0.05 probability level according to a protected LSD test.

Several authors have noted that increased osmotic potential from NaCl solutions decreased germination (4, 28, 35, 37). Uhvits (37) also showed that Na^+ and Cl^- ions can exert a toxic effect on germination. Mayeux (28) reported that false broomweed seed germination in 9,000 ppm NaCl (osmotic potential = -0.65 mPa) was about equal to germination in a -0.6 mPa polyethylene glycol (PEG) solution. Since PEG is nontoxic and the osmotic potentials of the two solutions were similar, it was concluded that the osmotic property of the NaCl solution reduced germination more than the physiological effect of the solute ions. PEG solutions were not evaluated in the present study; but after the 9-day incubation period, ungerminated hogpotato seed were removed from the 9,000- and 12,000-ppm NaCl solutions, rinsed, and placed in new germination boxes moistened with 0.17 ounces of distilled water to determine if the NaCl effects were osmotic or physiological. After 6 hours, the seed were checked; and 99% of them had begun to germinate (data not shown). After 3 days of reincubation, radicles averaged 1.1 inches in length. These data suggest that the effects of NaCl on hogpotato seed germination were osmotic because nearly all seed germinated after the NaCl was removed and because those seedlings appeared normal. The longer radicles observed after reincubation, compared to the control, may have occurred because the seed were partially imbibed (primed) enabling them to germinate faster.

Temperature and pH

Analysis of variance indicated that the main-plot error (temperature) was less than the subplot error (pH level). Therefore, the error terms were pooled; and one LSD value was used for each column in the following table (Table 3).

Table 3. Effect of temperature and pH on acid-scarified hogpotato seed germination after 9 days of incubation.[a] [Adapted from Hackett and Murray (22).]

pH level [b]	Temperature (F) 60	70	70/90 [c]	90
	%			
4.0	2 a	38 b	26 a	1 a
5.0	66 b	88 c	90 b	86 c
6.0	66 b	90 c	89 b	84 c
7.0	0 a	15 a	16 a	32 b
8.0	0 a	16 a	25 a	48 b

[a] Within a column, means followed by the same letter are not significantly different at the 0.05 probability level according to a protected LSD test.
[b] pH levels were prepared to ± 0.1 pH units.
[c] Alternating 70 F, 16 hours dark and 90 F, 8 hours light.

At pH levels of 4, 7, and 8, germination was less than at pH 5 and 6. Buchanan et al. (11) reported that the growth of 10 warm-season and 6 cool-season weed species varied widely when cultivated in soil with pH levels ranging from 4.7 to 6.3. Germination at pH values of 5 and 6 was 66% at 60 F, substantially less than other temperatures at those pH levels. Percent germination increased with temperature at pH levels 7 and 8; however, the radicles from those seedlings were discolored and necrotic at the tip. Moderate temperature (70 F) enhanced germination at pH 4 relative to higher and lower temperatures.

Over the levels studied, hogpotato's pH requirements were fairly narrow for high percent germination of seed. However, of the temperatures evaluated, scarified hogpotato seed exhibited high germination over a wide range.

Resprouting Ability

Hogpotato seedlings were able to regenerate topgrowth 20 days after emergence (Table 4). All plants that resprouted resumed normal growth. When older seedlings were clipped, the percent resprouting increased, ranging from 15% at 20 days to 98% at 55 days after emergence. Number of leaves also increased with plant age at clipping. Leaf dry weight (data not shown) followed the same trend. Regrowth normally occurred 12 to 16 days after clipping. Although statistical differences existed among days for regrowth to occur, no consistent trend with respect to seedling age was present. Root weights (data not shown) were fairly consistent over all clipping dates.

No apparent trend existed in the formation of propagules or multiple stems (data not shown). At harvest, some seedlings at the last four clipping dates had one to three fairly well-defined tuber-like propagules present; others showed some evidence of root swelling which may be an indication of initial propagule formation. From these results, it is apparent that hogpotato can function as a perennial early in its life cycle.

Table 4. Effect of 5-day clipping intervals, beginning 20 days after seedling emergence, on hogpotato regrowth.[a] [Adapted from Hackett and Murray (22).]

Clipping interval after emergence	Leaves on clipping date	Time until resprouting occurred	Resprouting
days	no.	days	%
20	3 a	15 bc	15 a
25	4 b	15 bc	48 b
30	5 c	12 a	43 b
35	6 d	16 c	78 cd
40	7 e	13 a	70 c
45	9 f	14 ab	75 cd
50	10 g	14 ab	80 d
55	12 h	13 a	98 e

[a] Within a column, means followed by the same letter are not significantly different at the 0.05 probability level according to a protected LSD test.

Date of Planting

Data presented (Table 5) for secondary plants and their spread are on a per plot basis (four propagules were planted/plot). Sprouting percentage and the number of days to emerge are based on individual propagules (28/planting date in 1984 and 40/planting date in 1985). A significant interaction term prevented the averaging of treatment effects for days until sprouting and for number of secondary plants produced. Therefore, analyses for each year are presented separately for those two traits.

In 1984, propagules emerged 21 to 31 days after planting. Sprouting time for each planting date, except for June 21, were within 3 days of each other. In 1985, emergence times for the May 22 and June 8 planting dates were 8 to 9 days longer, respectively, than in 1984. Cooler soil temperatures caused by increased precipitation during that time may have delayed emergence. Emergence times for the other three planting dates were similar to those of the previous year. In 1984, the early planting date produced an average of 129 secondary plants/plot within 69 days after sprouting. In 1985, the early date produced 160 secondary plants within 66 days. Numbers of secondary plants declined dramatically from the earliest to the latest planting dates. Propagules planted on July 5 produced four secondary plants in 1984 and seven in 1985. In 1984 and 1985, zero and one secondary plants were produced, respectively, on the last planting date. Averaged over both years, the spread of secondary plants from the center of the plot ranged from 58 inches on the earliest planting date progressively downward to only 2 inches on the last planting date. As would be expected, later planting dates led to fewer

Table 5. Effect of planting date on various growth parameters of hogpotato when grown in the field during 1984 and 1985. [Adapted from Hackett and Murray (20, 21).]

Planting date	Days until sprouting 1984	Days until sprouting 1985	Secondary plants 1984	Secondary plants 1985	Distance spread	Sprouting
	——days——		——no.——		in.	%
May 22	21 ± 1	29 ± 2	129 ± 9	160 ± 20	58 ± 4	93 ± 3
June 8	22 ± 1	31 ± 1	33 ± 5	68 ± 11	39 ± 4	94 ± 3
June 21	31 ± 2	29 ± 1	9 ± 4	50 ± 11	30 ± 5	80 ± 5
July 5	22 ± 1	26 ± 1	4 ± 1	7 ± 1	12 ± 4	91 ± 3
July 19	24 ± 2	23 ± 1	0	1 ± 1	2 ± <1	79 ± 5

secondary plants and decreased spread. Sprouting percentages ranged from 79 to 94% averaged over years. All were sufficient to ensure the establishment of the weed.

One hundred ten days after planting in the steel cylinders (87 days after emergence), the above- and underground portions of the hogpotato plant were recovered (Figures 7 and 8). An average of eight propagules/plant were produced. Hogpotato exhibits an initially low growth habit after sprouting, gradually becoming more erect. Vegetative growth varied from 8 to 12 inches in height on erect shoots.

Approximately 15 months after establishment, the area used for the 1984 date of planting study was a solid mat of hogpotato. It was impossible to distinguish among individual plots initiated the year before, and the hogpotato had spread several feet beyond the test boundaries. Aboveground shoot counts made at this time indicated that there were 12 ± 2 aboveground shoots/10 inch^2. Flowering was prolific, many pods were formed, but very few viable seed were present.

Depth of Planting

In 1985, 75% (three of four) of the propagules planted at 8 inches emerged approximately 37 days after planting (Table 6). This observation compared well with emergence times in the date of planting study where propagules emerged 21 to 31 days after planting at a 4-inch depth. All propagules planted at 16, 24, and 32 inches emerged 51, 57, and 65 days, respectively, after planting. Only the 37 days for the 8-inch depth was significantly earlier than the 65 days for the 32-inch depth.

Hogpotato has the potential to become a serious problem for cotton producers in Oklahoma. At present, herbicides typically used in cotton production do not adequately control the weed. Producers that utilize hoe labor to remove escaped weeds often skip hogpotato infestations because they require considerable time and effort for removal. Although seed production does not appear to be a major problem in the perpetuation of hogpotato, the vegetative propagule may cause severe problems. Many propagules are found at depths well below those commonly used in plowing. Most propagules are found at depths of 6 to 20 inches; however, in the 1985 date of planting experiment, evidence of propagule formation was observed 47 inches below the soil surface 21 months after the experiment was established. Ease of establishment and emergence 3 to 4 weeks after planting suggests that the propagule does not have a strict dormancy period before it will sprout. Propagules did emerge from as deep as 32 inches in this experiment. Effective, long-term control of hogpotato will be complicated by the necessity of long-distance translocation of toxic concentrations of herbicides throughout the plant.

Table 6. Effect of planting depth on time of emergence of hogpotato when grown in the field during 1985.[a] [Adapted from Hackett and Murray (20).]

Planting depth	Sprouting	Planting to emergence
in.	%	days
8	75 a	37 a
16	100 a	51 ab
24	100 a	57 ab
32	100 a	65 b

[a] Within a column, means followed by the same letter are not significantly different at the 0.05 probability level according to a protected LSD test.

Anatomical Study

Cross sections of the "upper" propagule revealed xylem elements present in bundles forming a ring that surrounded pith, suggesting stem tissue. Conversely, a section made from the "lower" portion of the propagule showed evidence of centrally located xylem elements and no pith tissue, suggesting root tissue. The propagule apparently contains both stem and root tissue and serves as a transitional structure between the two. Because a "tuber" is a short, fleshy, usually underground stem bearing minute scale leaves (each of which bears a bud in its axil), the propagule of hogpotato, in the strict sense, is not a tuber.

Length of Competition Time

Hogpotato present from cotton emergence reduced cotton plant height at all measurement dates in all 3 years (Table 7). Full-season weed interference reduced cotton plant height by 44, 36, and 14% for 1984, 1985, and 1986, respectively. When grown weed-free for the first 7 weeks following emergence in 1985, cotton height was comparable to cotton grown weed-free until 216 days after emergence when a 10% reduction was noted. No differences were observed in 1986 between the two treatments. When cotton was grown with hogpotato for the first 7 weeks after crop emergence, cotton height was reduced at all measurement dates in 1985 and at the first two of four dates in 1986. Early-season interference caused cotton height reductions at the end of the season of 7% in the 2 years. By harvest each year, cotton heights in the early-season interference treatment had recovered to heights equivalent to those in the late-season treatment.

Full-season hogpotato interference reduced cotton lint yield by 98% in 1984 (Table 8). Bolls were considerably smaller and poorly developed compared to bolls from weed-free plots. Hogpotato dry matter production in that year was 2501 pounds/acre. Full-season interference reduced cotton lint yield by 58 and 42% in 1985 and 1986, respectively, compared to weed-free cotton. The greater severity of yield loss in 1984 can be attributed to the extremely short growing season that year. Cotton with full-season weed interference appeared to mature at a slower rate than did cotton maintained weed-free. The growing seasons were much longer in 1985

Figure 1. Typical hogpotato plant showing leaflets and flowers. This particular plant is approximately 8 inches tall.

Figure 2. Typical hogpotato seed pod with seed. Pods are generally 1.2 to 1.6 inches long.

Figure 3. Hogpotato "tuber" showing its development "in line" with the root.

Figure 4. Typical variation in the size of hogpotato tubers.

Figure 5. Sprouting hogpotato tubers. Note sprouts at each end of one tuber. Tubers such as these have emerged from soil depths greater than 3 feet.

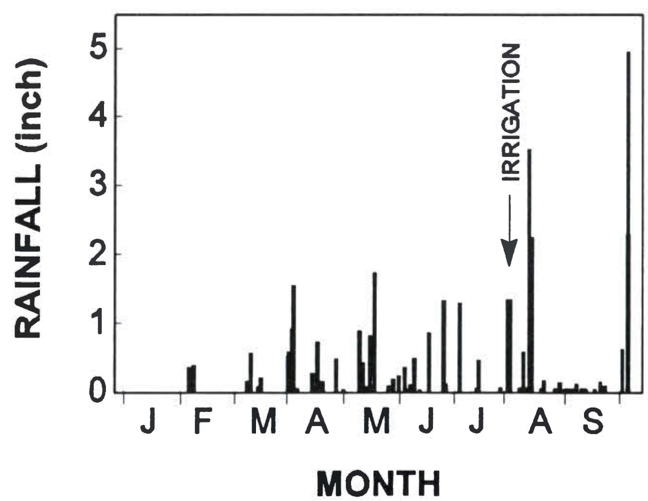

Figure 6. Distribution and amount of rainfall and irrigation applied at Stillwater in 1986. [Adapted from Castner et al. (14).]

Figure 7. The hogpotato plant second from the upper right-hand corner was the original "mother" plant. It arose from the tuber at its base. All of the "daughter" plants and tubers displayed developed from that single plant in one growing season.

Figure 8. Hogpotato root development in the soil.

and 1986, and cotton was able to develop eventually into larger and presumably more competitive plants. Hogpotato dry matter production in the full-season treatment was greater by 67% in 1985 and 18% in 1986 when compared to the previous year. Cotton maintained weed-free for the first 7 weeks after crop emergence had similar yields to cotton maintained weed-free for the entire season. However, when hogpotato was allowed to compete with cotton for the first 7 weeks following crop emergence, lint yield was reduced by approximately 40% in both years. When measurements of hogpotato dry weight in the early- and late-season interference treatments were made in 1986, no differences were detected in weed weight; the large differences in lint yield recorded between those treatments indicated that early-season interference was far more damaging to the crop than late-season interference.

Yield component data, obtained from the boll samples taken before harvest, indicated differences in boll size and lint percent in 1984 and 1985, but not in 1986 (data not shown). Boll size was reduced 39% in 1984 in plots having full-season hogpotato interference and by 18% in 1985. Partial-season hogpotato interference did not influence boll size in either year. Pulled lint percent in 1984 was reduced 6.3% by full-season hogpotato interference. Early-season weed interference decreased pulled lint percent by 1.9% in 1985 compared to weed-free cotton. No other treatments affected

Table 7. Impact of hogpotato interference on cotton plant height at Altus in 1984-1986.[a] [Adapted from Castner et al. (14).]

	1984				1985				1986			
	Days after cotton emergence				Days after cotton emergence				Days after cotton emergence			
Treatment	23	40	63	82	49	74	96	216	61	76	105	189
	in.											
Weed-free, full-season	6 a	14 a	24 a	30 a	10 a	20 a	22 a	24 a	19 a	24 a	32 ab	33 a
Weed-free 7 weeks,[b] then weedy	- -	- -	- -	- -	10 a	19 a	22 a	22 b	18 a	24 a	34 a	33 a
Weed inter. 7 weeks,[b] then weed-free	- -	- -	- -	- -	8 b	13 b	20 b	22 b	13 b	20 b	30 bc	31ab
Weed inter., full-season	4 b	7 b	11 b	17 b	8 b	11 c	13 c	15 c	14 b	18 c	29 c	28 b

[a] Within a column, means followed by the same letter are not significantly different at the 0.05 probability level according to a protected LSD test.
[b] After cotton emergence.

Table 8. Impact of hogpotato interference on weed dry weight and cotton lint yield at Altus in 1984-1986.[a] [Adapted from Castner et al. (14).]

Treatment	Hogpotato dry weight			Cotton lint yield		
	1984	1985	1986	1984	1985	1986
	lb/acre					
Weed-free, full-season	---	---	---	427 a	570 a	774 a
Weed-free 7 weeks,[b] then weedy	---	1486 b	970 b	---	543 a	676 a
Weed inter. 7 weeks,[b] then weed-free	---	---	1175 b	---	338 b	472 b
Weed inter., full-season	2501	4192 a	4957 a	9 b	240 b	454 b

[a] Within a column, means followed by the same letter are not significantly different at the 0.05 probability level according to a protected LSD test.
[b] After cotton emergence.

pulled lint percent that year. Picked lint percent exhibited similar trends as did pulled lint percent over all 3 years (data not shown). Both lint percents are important to producers because they have a direct effect on ginning costs (19).

During the short 1984 growing season, full-season interference decreased 2.5 and 50% span lengths, uniformity index, and micronaire (data not shown). Full-season weed interference reduced micronaire from 4.4 (in the desirable range) to 2.6 (below that range) which would result in severe price penalties to the producer (19). Fiber quality analyses revealed no differences among treatments in 1985, a more typical growing season. These results tend to reinforce earlier reports (8, 10, 33, 34) that cotton fiber traits are generally not affected by weed interference. Cotton was not graded in either year because it was hand harvested and because the weed was removed prior to harvest. Hogpotato growth with cotton at Stillwater was reduced by 54% compared to the weed growing alone (Table 9). At first harvest, full-season weed interference reduced cotton lint yield by 311 pounds/acre (or 58%) compared to weed-free cotton. Lint yield from the second harvest was similar between weed-free cotton and that with weed interference. Full-season weed interference resulted in a significant ($P > t = 0.09$) total cotton lint yield reduction of 31% compared to cotton yield from plots maintained weed-free throughout the growing season.

Cotton boll size (data not shown) and number (Table 9) were two lint yield components reduced by full-season weed interference. Results from the first harvest indicated that hogpotato interference reduced ($P > t = 0.08$) seed cotton/boll by 0.02 ounce. Total boll number was reduced in the first harvest from 35/yard^2 in weed-free cotton to 15 in cotton with interference. As with lint yield, no differences were detected at the 0.05 probability level in either trait at second harvest. Total boll number was reduced 27% by full-season hogpotato interference ($P > t = 0.07$). Pulled and picked lint percents were not affected by the weed (data not shown).

Cotton lint yield and yield component results in this experiment provide evidence that full-season hogpotato interference reduced lint yield by delaying crop maturity. The delay in maturity is evident from the reductions in cotton lint yield, boll size, and boll number at first harvest. However, at second harvest, no statistical differences between treatments were detected at the 0.05 probability level.

Hogpotato is highly competitive when allowed to emerge and grow simultaneously with cotton. As with other weeds, the greatest yield reductions occur when the weed is allowed to compete in the earlier portion of the growing season (6). Cotton plant height was reduced by full-season hogpotato interference; however, this reduction was small and would likely pose no problems in mechanical harvest. Hogpotato delayed cotton maturity which could result in almost total

Table 9. Impact of hogpotato interference on weed dry weight, cotton lint yield, and boll number at Stillwater in 1986.[a] [Adapted from Castner et al. (14).]

Treatment	Hogpotato dry weight	Cotton lint yield			Boll number		
		First harvest	Second harvest	Total harvest[b]	First harvest	Second harvest	Total harvest[b]
	lb/acre				open bolls/yard^2		
Weed-free, full-season	---	534 a	240 a	774 a	35 a	18 a	53 a
Weed inter., full-season	774 b	223 b	312 a	535 a	15 b	24 a	39 a
Weed alone	1700 a	---	---	---	---	---	---

[a] Within a column, means followed by the same letter are not significantly different at the 0.05 probability level according to a protected LSD test.
[b] Within these two columns, means are significantly different at the 0.10 probability level according to a protected LSD test.

yield loss in years with short growing seasons. Cotton fiber properties are also subject to decline under those extreme situations. Cotton is competitive with hogpotato and reduces weed biomass when allowed to compete for the entire growing season.

Soil Water Use

Differences in soil water content among treatments appeared to develop as early as 3 weeks after cotton emergence (Figure 9B). The one significant difference at 2 weeks (Figure 9A) could be attributed to a Type I error. During the early stage of cotton development (i.e., from about two to five true leaves), the hogpotato treatments had less soil water in the upper 6 inches of the soil than did treatments with cotton alone or bare soil (Figure 9B). The treatment difference between hogpotato with cotton and cotton alone or bare soil was significant ($P > t = 0.20$). This apparent greater water use by hogpotato very early in the season probably resulted from the weed having an established root system (20, 21) which could immediately begin to use water from the soil; whereas, cotton during this same period would be in the process of root establishment (29). Water use by treatments including cotton was apparent to depths of 30 inches by 5 and 6 weeks after cotton emergence (Figures 9D and 9E). By 6 weeks, treatments involving cotton were significantly different from hogpotato alone or bare soil at depths of 6, 12, and 18 inches (Figure 9E).

After irrigation and following a period of intensive rainfall (Figure 6), treatments with cotton generally continued to exhibit increased water use from the upper half of the soil profile when compared to hogpotato alone and bare soil (Figure 10). Soil water content to a depth of 30 inches was generally lower in the treatments with cotton than with hogpotato alone or bare soil (Figures 10A and 10B), and those differences were eventually observed to a depth of 36 inches (Figures 10C, 10D, and 10E). Treatments with hogpotato continued to use proportionately more water from lower in the soil profile (> 42 inches) than did cotton alone. By the final reading date, treatments with hogpotato contained less water at the 60-inch depth than did either bare soil or cotton alone.

Analyses of total water in the soil profile indicated that early-season water loss trends were beginning to be established as early as 4 weeks after cotton emergence (Figure 11). By that time, all treatments containing plants had less water than did bare soil. By week 6, cotton with hogpotato showed greater total water loss from the profile than did hogpotato or cotton alone.

Trends in water loss established by the end of early season cotton development continued throughout the late season and boll development (Figure 11). At all dates in the late-season period, plots with bare soil had more total water than plots with weed, crop, or both. Cotton with hogpotato appeared to have the greatest use of soil water throughout the late portion of the growing season, using more soil water than any other treatment on weeks 10, 11, 12, and 15. Weed-free cotton used more total water than did hogpotato alone on weeks 11 and 12.

Because the trends for total water use appeared relatively consistent throughout the late growing season, a statistical analysis was conducted to evaluate that relationship. The interaction of treatments by time (i.e., weeks) was significant, but was relatively small compared to the treatment effects [treatment $F_{(3,9)} = 92.9$ vs. treatment by time $F_{(8,48)} = 8.9$]. The interaction was therefore judged to be relatively unimportant from a practical standpoint, and treatment means in the late season were pooled over time (Table 10). Bare soil had the highest amount of soil water followed in order by hogpotato alone, cotton alone, and cotton with hogpotato late in the growing season. Cotton with hogpotato used more soil water than cotton or hogpotato alone, thus indicating the two plants' potential as competitors for water. In the early season, the only significant difference was between bare soil vs. the other treatments.

Cotton used a larger amount of soil water in the upper soil profile while hogpotato used more from deeper in the soil. Competition between the weed and crop for water does not appear sufficiently intense to account for the large yield reductions documented. Other factors, such as allelopathy, may well be involved.

Table 10. Impact of cropping treatments on total soil water content during two periods after cotton emergence at Stillwater in 1986.[a,b] [Adapted from Castner et al. (14).]

Treatment	Period after cotton emergence[c]	
	Early	Late
	in. of water	
Hogpotato/cotton	16.9 a	14.1 a
Cotton alone	17.4 a	14.8 b
Hogpotato alone	17.5 a	15.4 c
Bare soil	18.5 b	18.2 d

[a] Within a column, means followed by the same letter are not significantly different at the 0.05 probability level according to a protected LSD test.
[b] Soil water content was measured to a depth of 63 in.
[c] The early period extended from June 30 through July 28; the late period from August 18 through September 24.

Field Weed-Control Experiments

At Altus on July 8, 20 days after treatment (DAT), glyphosate at 3.0 and 2.0 pounds ae/acre in a 2% $(NH_4)_2SO_4$ carrier solution controlled 56 and 60% of hogpotato top growth, respectively (Table 11). Hogpotato control by glyphosate declined to 20% or less 319 DAT. Dicamba controlled 39% of the weed early in the growing season, but at no point controlled hogpotato acceptably. Hogpotato control with imazapyr in 1987 increased as the growing season progressed. It controlled 31 to 43% on 20 DAT, 50 to 59%

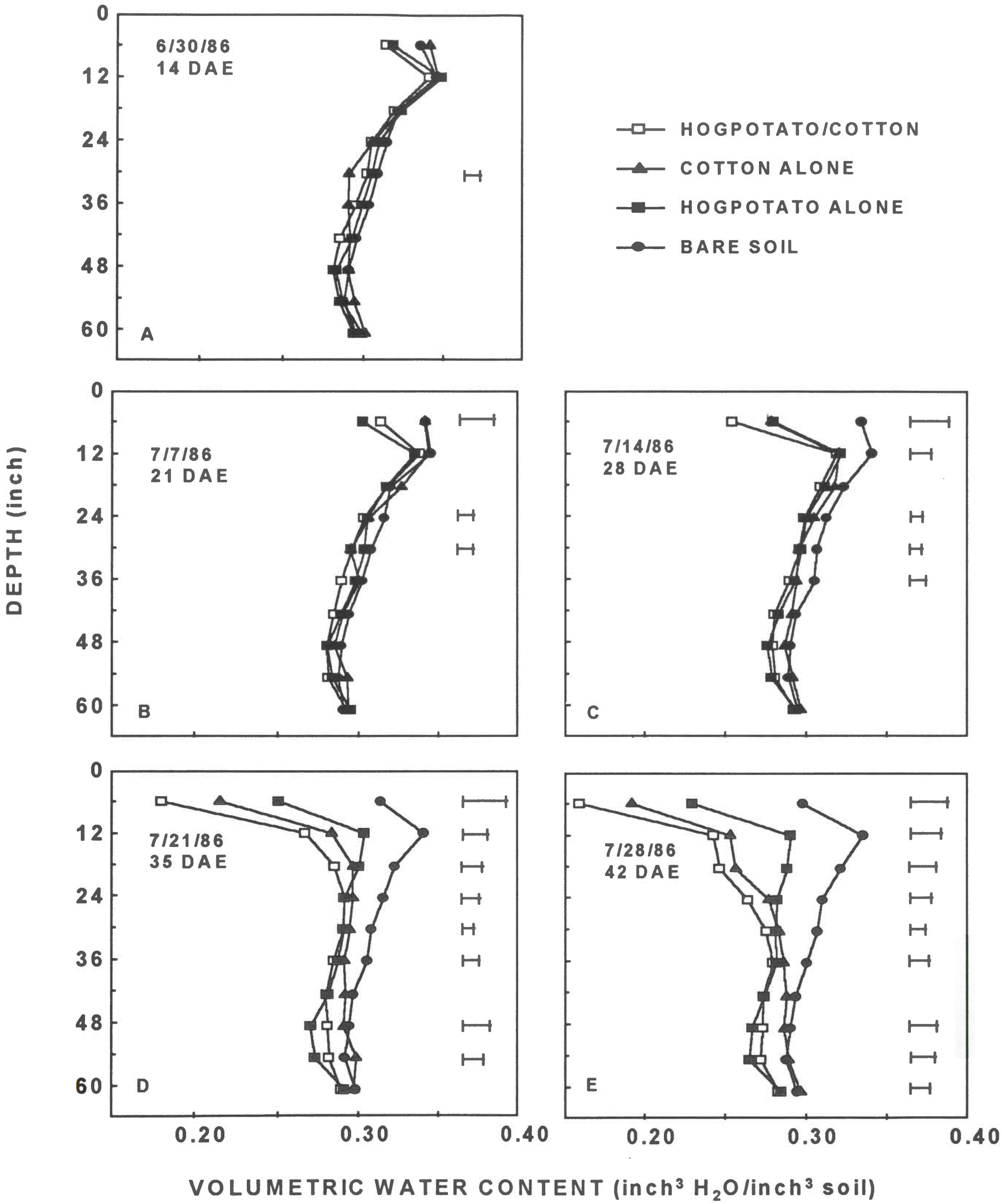

Figure 9. Early-season volumetric water content by soil depth on selected days after cotton emergence (DAE) at Stillwater in 1986. Protected LSDs (0.10 probability level) are represented by the horizontal lines. [Adapted from Castner et al. (14).]

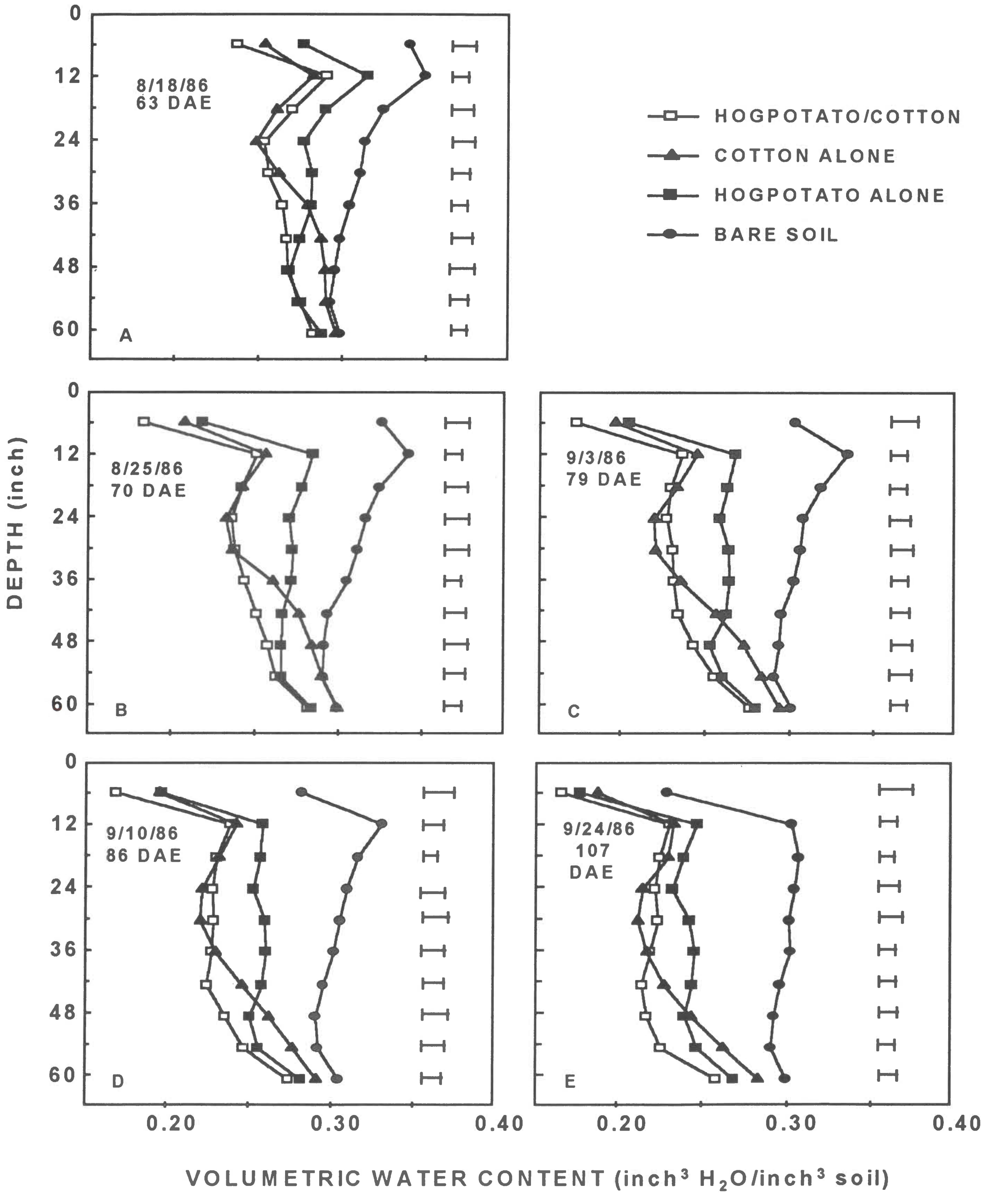

Figure 10. Late-season volumetric water content by soil depth on selected days after cotton emergence (DAE) at Stillwater in 1986. Protected LSDs (0.10 probability level) are represented by the horizontal lines. [Adapted from Castner et al. (14).]

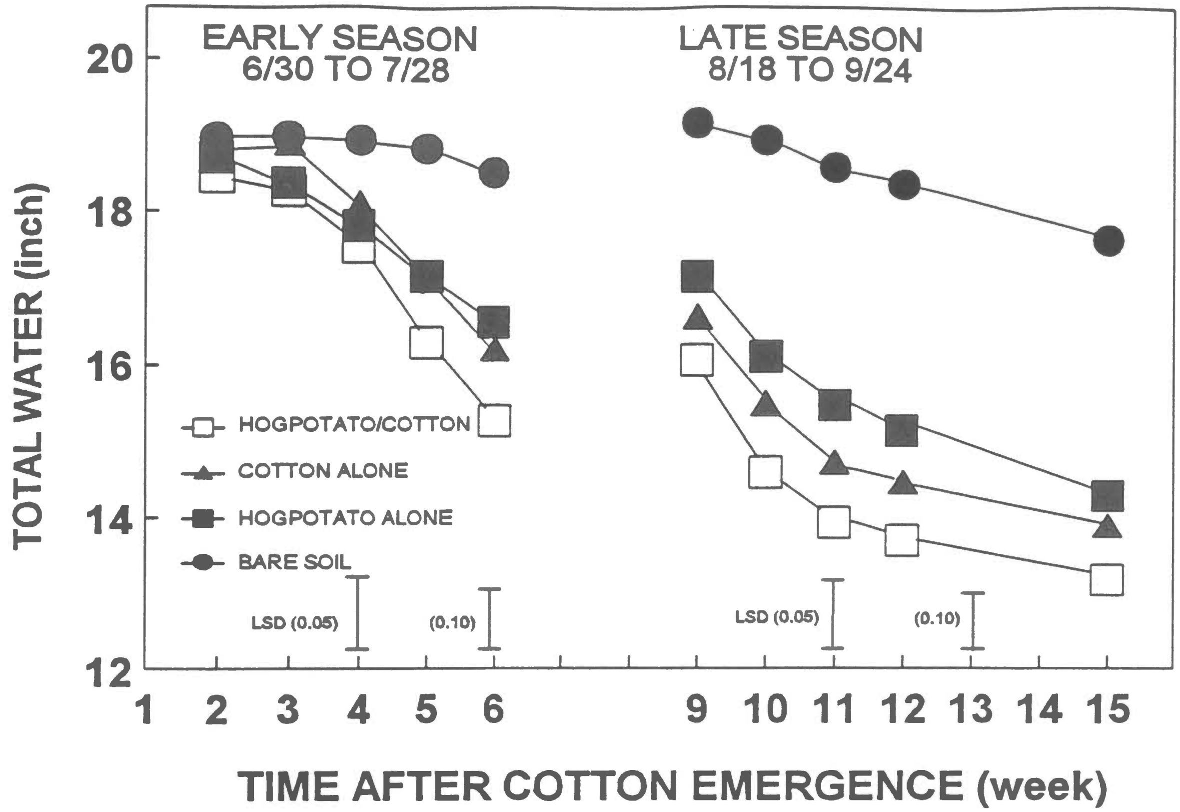

Figure 11. Total water content in the upper 63 inches of soil at Stillwater in 1986 during two periods after cotton emergence. Protected LSDs (0.05 and 0.10 probability levels) are represented by the vertical lines. [Adapted from Castner et al. (14).]

on 42 DAT, and 71 to 77% on 75 DAT. On June 8, 1988 (319 DAT), imazapyr at 1.0 and 1.5 pounds ai/acre controlled 81 and 92% of the hogpotato, respectively.

On July 14, 1988, 23 days after retreatment (DAR) of the Altus experiment, imazapyr at 0.75, 1.0, and 1.5 pounds ai/acre controlled 61, 82, and 90% of the hogpotato, respectively (Table 11). Throughout 1988 and 1989, imazapyr applied twice at 1.5 pounds ai/acre controlled 90 to 94% of the hogpotato. Glyphosate applied as a spot treatment in 1988 following dicamba in 1987 controlled 63% of the hogpotato top growth early, but control progressively declined thereafter. Imazapyr applied only in 1988 at 0.75, 1.0, and 1.5 pounds ai/acre to plots treated in 1987 with glyphosate controlled 66, 74, and 79% of the hogpotato, respectively, on July 11, 1989 (385 DAR). Hogpotato control on the same date with the same rates of imazapyr whether applied 1 or 2 years were not significantly different.

Weed biomass harvested July 11, 1989 at Altus was significantly reduced by all herbicide treatments when compared to the nontreated check (data not shown). Plots treated with imazapyr for 1 or 2 years tended to have the lowest hogpotato biomass.

At the first Stillwater site on August 18 (26 DAT), dicamba applied at 0.5 pounds ai/acre and glyphosate applied at 3 pounds ae/acre in a 2% $(NH_4)_2SO_4$ carrier solution controlled 79 and 72% of the hogpotato, respectively (Table 12). However, on September 4 (43 DAT), these treatments controlled 64% or less of the weed. Control from these treatments continued to decline as the season progressed.

Hogpotato control with imazapyr (as it did at Altus) gradually increased as the season progressed. It controlled 33 to 46% on 26 DAT, 53 to 59% on 43 DAT, and 93 to 94% on 81 DAT. On June 13, 1988 (325 DAT), imazapyr still controlled 84 to 89% of the hogpotato. On that date, all other treatments controlled 49% or less of the weed.

On July 18, 1988 (18 DAR), 75 to 86% control of hogpotato was obtained when plots were treated both years with imazapyr. On this date, hogpotato control with imazapyr applied for the first time was 31 to 58%. Approximately 1 year later on May 31, 1989, imazapyr controlled 98 to 100% of the hogpotato; only a slight reduction in control was observed on July 12, 1989 (377 DAR).

Glyphosate and glyphosate plus 2,4-D retreatment controlled 79 and 87% of the hogpotato, respectively, on July

Table 11. Hogpotato control from herbicide applications made in June 1987 and retreated with selected herbicides in June 1988 at Altus, OK.[a] [Adapted from Westerman et al. (39).]

		Visual estimate of control						Visual estimate of control				
Initial treatment[b]	Rate	7/8/87 (20 DAT)	7/30/87 (42 DAT)	9/1/87 (75 DAT)	6/8/88 (319 DAT)	Retreatment[b]	Rate	7/14/88 (23 DAR)	7/27/88 (36 DAR)	8/25/88 (65 DAR)	5/24/89 (337 DAR)	7/11/89 (385 DAR)
6/18/87	lb/acre	%				6/21/88	lb/acre	%				
Imazapyr	0.75	43 abc	59 a	77 a	58 b	Imazapyr	0.75	61 bc	77 bc	77 b	84 bc	70 bc
Imazapyr	1.0	34 bc	50 a	71 a	81 a	Imazapyr	1.0	82 a	84 ab	84 ab	91 a	86 ab
Imazapyr	1.5	31 c	51 a	72 a	92 a	Imazapyr	1.5	90 a	90 a	92 a	94 a	93 a
Dicamba	0.5	39 abc	21 b	23 b	3 d	Glyphosate (spot)	2% v/v	63 b	41 e	23 c	0 d	1 d
Glyphosate + $(NH_4)_2SO_4$	1.0 + 2% w/w	33 c	18 bc	13 bc	0 d	Imazapyr	0.75	50 c	66 cd	89 a	79 c	66 c
Glyphosate + $(NH_4)_2SO_4$	2.0 + 2% w/w	60 a	41 a	34 b	11 cd	Imazapyr	1.0	56 bc	65 d	87 a	88 ab	74 bc
Glyphosate + $(NH_4)_2SO_4$	3.0 + 2% w/w	56 ab	41 a	34 b	20 c	Imazapyr	1.5	58 bc	70 cd	90 a	91 a	79 abc
Nontreated	- -	0 d	0 c	0 c	0 d	Nontreated	- -	0 d	0 f	0 d	0 d	0 d

[a] Within a column, means followed by the same letter are not significantly different at the 0.05 probability level according to a protected LSD test.

[b] DAT and DAR are days after treatment in 1987 and days after retreatment in 1988, respectively.

18, 1988 (18 DAR). By the end of the season, only 58 to 65% hogpotato control was obtained. Hogpotato control on July 12, 1989 (377 DAR) was greater with glyphosate plus 2,4-D spot than with glyphosate spot treatment (66 and 85%, respectively).

All herbicide treatments significantly reduced hogpotato biomass harvested on July 12, 1989 (data not shown). Hogpotato biomass was 65 ounces/100 feet^2 or less when imazapyr was applied for 1 or 2 years. Hogpotato regrowth in 1989 was less where 2,4-D was included with glyphosate compared to glyphosate alone.

At the second Stillwater site, tebuthiuron applied at 2.0 or 3.0 pounds ai/acre controlled 34% or less of the hogpotato during the 1987 growing season; however, control with it

Table 12. Hogpotato control from herbicide applications made in July 1987 and retreated with selected herbicides in June 1988 at Stillwater, OK.[a] [Adapted from Westerman et al. (39).]

		Visual estimate of control						Visual estimate of control			
Initial treatment[b]	Rate	8/18/87 (26 DAT)	9/4/87 (43 DAT)	10/12/87 (81 DAT)	6/13/88 (325 DAT)	Retreatment[b]	Rate	7/18/88 (18 DAR)	8/26/88 (57 DAR)	5/31/89 (335 DAR)	7/12/89 (377 DAR)
7/23/87	lb/acre	%				6/30/88	lb/acre	%			
Imazapyr	0.75	36 cd	53 abc	94 a	84 a	Imazapyr	0.75	75 a	81 a	100 a	96 a
Imazapyr	1.0	33 cd	54 abc	93 a	84 a	Imazapyr	1.0	80 a	85 a	100 a	97 a
Imazapyr	1.5	46 c	59 ab	94 a	89 a	Imazapyr	1.5	86 a	89 a	100 a	99 a
Dicamba	0.25	50 bc	4 e	11 de	5 de	Imazapyr	1.0	33 c	58 b	99 a	95 a
Dicamba	0.5	79 a	33 cd	30 cd	28 bcd	Imazapyr	1.5	58 b	69 b	100 a	100 a
Glyphosate + $(NH_4)_2SO_4$	1.0 + 2% w/w	20 de	26 d	8 de	20 cde	Imazapyr	0.75	31 c	61 b	98 a	88 a
Glyphosate + $(NH_4)_2SO_4$	2.0 + 2% w/w	54 bc	41 bcd	39 bc	49 b	Glyphosate (spot)	2% v/v	79 a	58 b	75 b	66 b
Glyphosate + $(NH_4)_2SO_4$	3.0 + 2% w/w	72 ab	64 a	54 b	40 bc	Glyphosate + 2,4-D[c]	3% v/v	87 a	65 b	91 a	85 a
Nontreated	- -	0 e	0 e	0 e	0 e	Nontreated	- -	0 d	0 c	0 c	0 c

[a] Within a column, means followed by the same letter are not significantly different at the 0.05 probability level according to a protected LSD test.

[b] DAT and DAR are days after treatment in 1987 and days after retreatment in 1988, respectively.

[c] Treatment is the commercial prepackage formulation containing 1.2 lb ae/gal glyphosate and 1.9 lb ae/gal 2,4-D. This prepackage was spot applied as a 3% v/v solution.

Table 13. Hogpotato control from herbicide applications made in August 1987 and retreated with selected herbicides in June 1988 at Stillwater, OK.[a] [Adapted from Westerman et al. (39).]

		Visual estimate of control						Visual estimate of control			
Initial treatment[b]	Rate	8/24/87 (18 DAT)	10/12/87 (67 DAT)	10/26/87 (81 DAT)	6/13/88 (311 DAT)	Retreatment[b]	Rate	7/18/88 (18 DAR)	8/26/88 (57 DAR)	5/31/89 (335 DAR)	7/12/89 (377 DAR)
8/6/87	lb/acre	—— % ——				6/30/88	lb/acre	—— % ——			
Tebuthiuron	2.0	4 b	5 c	8 c	66 a	Tebuthiuron	1.0	85 a	80 a	93 a	89 b
Tebuthiuron	3.0	6 b	29 b	34 b	59 a	Tebuthiuron	2.0	71 a	71 ab	98 a	98 a
Triclopyr	2.0	91 a	86 a	87 a	51 a	Triclopyr	2.0	58 a	61 b	93 a	94 ab
Nontreated	- -	0 b	0 c	0 c	0 b	Nontreated	- -	0 b	0 c	0 b	0 c

[a] Within a column, means followed by the same letter are not significantly different at the 0.05 probability level according to a protected LSD test.
[b] DAT and DAR are days after treatment in 1987 and days after retreatment in 1988, respectively.

nearly a year later on June 13 (311 DAT) was 59 to 66% (Table 13). Triclopyr applied at 2.0 pounds ai/acre controlled 91% of the hogpotato early (18 DAT) and 87% of the hogpotato late in the season (81 DAT). By June 13, 1988 (311 DAT), control had declined to 51%.

After retreatment on June 30, 1988, tebuthiuron controlled 71 to 85% of the hogpotato on July 18 (18 DAR). On May 31, 1989 (335 DAR), hogpotato control of 93 to 98% was achieved. On July 12, 1989 (377 DAR), treatments with tebuthiuron and triclopyr provided control of 89% or greater.

All herbicide treatments significantly reduced hogpotato biomass harvested July 12, 1989 (377 DAR) (data not shown). The nontreated hogpotato biomass was 2,947 ounces/100 feet^2 while the herbicide treatments reduced biomass to 65 ounces/100 feet^2 or less.

Bioassay

Cotton plant fresh weight was significantly reduced by imazapyr applications of 1.0 and 1.5 pounds ai/acre (Table 14). Dicamba did not affect cotton fresh weight. Grain sorghum and wheat fresh weights were not reduced by either herbicide.

Grain sorghum fresh weight was significantly greater in soil previously treated with 0.25 pounds ai/acre dicamba than in untreated soil. A similar, though nonsignificant, trend was observed with the cotton and wheat. The resulting increase in plant fresh weight caused by the low rate of dicamba may be a result of growth promoting properties (cell elongation, prolific tissue growth) characteristic of the benzoic acid herbicide family. Schroeder et al. (36) have shown that sublethal rates of several herbicides in this family, specifically dicamba, can cause increased plant biomass production. Imazapyr at the 0.75 pounds ai/acre rate also increased grain sorghum fresh weight.

Tebuthiuron applied at 3.0 pounds ai/acre caused significant fresh weight reductions for all three crops; and at the 2.0 pound rate, cotton and wheat were reduced (Table 15). Triclopyr did not reduce the fresh weight of any indicator crop species.

Imazapyr, tebuthiuron, and triclopyr will control hogpotato. With the pelleted formulation of imazapyr, producers have at their disposal an easily available method of treating small hogpotato-infested areas of a field. At the rates studied, significant aboveground biomass reductions of important rotational crop species can occur following the application of imazapyr and tebuthiuron. However, the need and ability to control hogpotato in small dense stands may outweigh the injury temporarily resulting from use of those herbicides. Given the usual growth habits of the weed (relatively small, densely covered areas) and the very large potential crop yield losses in those infested areas, producers may choose to sacrifice these small areas for a time and use herbicides with limited selectivity to control the weed. This

Table 14. Effects of imazapyr and dicamba on cotton, grain sorghum, and wheat fresh weights when applied in July 1987 and sampled in January 1988 at Stillwater, OK.[a] [Adapted from Westerman et al. (39).]

		Fresh weight		
Treatment	Rate	Cotton	Grain sorghum	Wheat
7/23/87	lb/acre	— % of nontreated check —		
Imazapyr	0.75	98 a	125 ab	98 ab
Imazapyr	1.0	82 b	109 bc	91 b
Imazapyr	1.5	84 b	99 c	91 b
Dicamba	0.25	110 a	129 a	116 a
Dicamba	0.5	98 a	103 c	104 ab
Nontreated	- - -	100 a	100 c	100 ab

[a] Within a column, means followed by the same letter are not significantly different at the 0.10 probability level according to a protected LSD test.

Table 15. Effects of tebuthiuron and triclopyr on cotton, grain sorghum, and wheat fresh weights when applied in August 1987 and sampled in January 1988 at Stillwater, OK.[a] [Adapted from Westerman et al. (39).]

		Fresh weight		
Treatment	Rate	Cotton	Grain sorghum	Wheat
8/6/87	lb/acre	— % of nontreated check —		
Tebuthiuron	2.0	33 b	83 bc	31 b
Tebuthiuron	3.0	7 b	70 c	17 b
Triclopyr	2.0	94 a	116 a	107 a
Nontreated	- - -	100 a	100 ab	100 a

[a] Within a column, means followed by the same letter are not significantly different at the 0.10 probability level according to a protected LSD test.

decision may not be as drastic as it first appears when crop yield reductions of 99% are considered. Although crop production would likely be sacrificed on those treated areas for a minimum of 1 year, the weed can be controlled.

With the exception of spot applications of glyphosate resulting in only partial control, no registered herbicides are available for control of hogpotato in a cropping situation. The most effective treatments were either nonselective soil sterilants for use during fallow periods or for noncrop situations. Many of these herbicides have limited selectivity and wide usage is not anticipated.

SUMMARY

Hogpotato is a perennial legume capable of rapid propagation by vegetative organs (tuber-like in structure) and more slowly by seed. It is a very competitive and difficult-to-control weed. Seedlings quickly begin to function as perennials. Approximately 15% of 20-day-old hogpotato seedlings which had only three true leaves were able to resprout after their tops were removed at ground level. From 79 to 94% of the hogpotato propagules planted in the field every 2 weeks from late May through mid July emerged 21 to 31 days after planting. Propagules planted in late May produced 129 and 160 secondary plants in 1984 and 1985, respectively, and had spread an average of 58 inches when measurements were made in late August. Fifteen months after the establishment of the 1984 study, the experimental area contained 12 hogpotato plants/foot^2. Vegetative spread and secondary plant production generally decreased with later planting dates. In another experiment, small propagules (weighing approximately 0.10 ounce) emerged from as deep as 32 inches within 65 days after planting. Anatomical studies of the vegetative propagule indicate that it contains both stem and root tissue; therefore, the structure is actually a transitional organ and not strictly a "tuber" (an underground stem). Acid-scarified hogpotato seed germinated at 94% in distilled water compared to 2 to 6% for unscarified seed. Highest germination in buffered solutions occurred at pH 5 and 6 with reduced germination at lower and higher pH levels. Germination was higher at 70 to 90 F than at 60 F at pH 5.0 to 6.0. Sodium chloride concentrations of 3,000 ppm and greater reduced germination rate.

The effects of hogpotato competition on cotton and vice versa were measured under field conditions in four environments. Full-season competition from 10 hogpotato plants/foot^2 reduced cotton plant height by 14 to 44% and cotton lint yields by 42 to 98%. Conversely, weed dry weight was reduced 54% through full-season competition from cotton. Weed competition during the first 7 weeks of crop growth reduced lint yield by approximately 40%; whereas, hogpotato emerging and competing after 7 weeks of weed-free maintenance did not reduce lint yield. Hogpotato competition reduced boll size in 3 of 4 years, lint percent in 2 of 4, and boll number in the only year it was measured. Cotton fiber length, uniformity index, and micronaire were reduced by full-season interference in 1 of 2 years; however, fiber strength was not affected in either year. Significant use of soil water by hogpotato occurred at 42 inches and deeper in the soil while cotton used water primarily in the upper 30 to 36 inches.

Three field experiments were conducted in 1987 through 1989 to evaluate hogpotato control and rotational crop response resulting from applications of herbicides. At the end of the first season, triclopyr and imazapyr controlled hogpotato as much as 87 and 94%, respectively. Following a sequential application in 1988, triclopyr and imazapyr controlled 93 and 100% of hogpotato, respectively, through May of 1989. Hogpotato biomass, collected at the termination of the experiments, was reduced by all treatments at all locations except at Altus for dicamba applied in 1987 followed by a spot application of glyphosate in 1988. Soils from the Stillwater experiments were bioassayed for residual herbicide activity using three potential rotational crops. Imazapyr caused injury to cotton, but not to wheat or grain sorghum. Cotton and wheat were more sensitive to tebuthiuron than grain sorghum (which was also injured, but to a lesser degree).

LITERATURE CITED

1. Ball, W. S. and W. W. Robbins. 1935. Pignut (*Hoffmannseggia densiflora* Benth.). Calif. Dep. Agric. Monthly Bull. 24:260-261.
2. Banks, P. A., T. N. Tripp, J. W. Wells, and J. E. Hammel. 1986. Effects of tillage on sicklepod (*Cassia obtusifolia*) interference with soybeans (*Glycine max*) and soil water use. Weed Sci. 34:143-149.
3. Berlyn, G. P. and J. P. Miksche. 1976. Botanical Microtechnique and Cytochemistry. Ames, IA: Iowa State Univ. Press. 326 p.
4. Boyd, J. W. and D. S. Murray. 1982. Growth and development of silverleaf nightshade (*Solanum elaeagnifolium*). Weed Sci. 30:238-243.
5. Bridges, D. C. and J. M. Chandler. 1987. Influence of johnsongrass (*Sorghum halepense*) density and period of competition on cotton yield. Weed Sci. 35:63-67.
6. Buchanan, G. A. and E. R. Burns. 1970. Influence of weed competition on cotton. Weed Sci. 18:149-154.
7. Buchanan, G. A. and E. R. Burns. 1971. Weed competition in cotton. I. Sicklepod and tall morningglory. Weed Sci. 19:576-579.
8. Buchanan, G. A. and E. R. Burns. 1971. Weed competition in cotton. II. Cocklebur and redroot pigweed. Weed Sci. 19:580-582.
9. Buchanan, G. A., R. H. Crowley, and R. D. McLaughlin. 1977. Competition of prickly sida with cotton. Weed Sci. 25:106-110.
10. Buchanan, G. A., R. H. Crowley, J. E. Street, and J. A. McGuire. 1980. Competition of sicklepod (*Cassia obtusifolia*) and redroot pigweed (*Amaranthus retroflexus*) with cotton (*Gossypium hirsutum*). Weed Sci. 28:258-262.
11. Buchanan, G. A., C. S. Hoveland, and M. C. Harris. 1975. Response of weeds to soil pH. Weed Sci. 23:473-477.
12. Buchanan, G. A. and R. D. McLaughlin. 1975. Influence of nitrogen on weed competition in cotton. Weed Sci. 23:324-328.
13. Castner, E. P., N. M. Hackett, D. S. Murray, and L. M. Verhalen. 1987. Effects of hogpotato on the growth and development of cotton. Proc. South. Weed Sci. Soc. 40:299.
14. Castner, E. P., D. S. Murray, N. M. Hackett, L. M. Verhalen, D. L. Weeks, and J. F. Stone. 1989. Interference of hogpotato (*Hoffmanseggia glauca*) with cotton (*Gossypium hirsutum*). Weed Sci. 37:688-694.
15. Geddes, R. D., H. D. Scott, and L. R. Oliver. 1979. Growth and water use by common cocklebur (*Xanthium pensylvanicum*) and soybeans (*Glycine max*) under field conditions. Weed Sci. 27:206-212.
16. Gould, F. W. 1962. Texas plants--A checklist and ecological summary. Tex. Agric. Exp. Stn. Misc. Publ. MP-585. 112 p.
17. Green, J. D., D. S. Murray, and J. F. Stone. 1988. Soil water relations of silverleaf nightshade (*Solanum elaeagnifolium*) with cotton (*Gossypium hirsutum*). Weed Sci. 36:740-746.
18. Green, J. D., D. S. Murray, and L. M. Verhalen. 1987. Full-season interference of silverleaf nightshade (*Solanum elaeagnifolium*) with cotton (*Gossypium hirsutum*). Weed Sci. 35:813-818.
19. Greenhagen, B. E., L. M. Verhalen, R. K. Boman, D. W. Hooper, R. W. Thacker, O. H. Williams, and J. E. Baker. 1988. Cotton variety tests, Oklahoma--1987. Okla. Coop. Ext. Serv. Current Rep. CR-2094. 11 p.
20. Hackett, N. M. and D. S. Murray. 1985. Biological studies with hogpotato. Proc. North Central Weed Control Conf. 40:6.
21. Hackett, N. M. and D. S. Murray. 1985. Biology and development of hogpotato (*Hoffmanseggia densiflora*). Proc. South. Weed Sci. Soc. 38:360.
22. Hackett, N. M. and D. S. Murray. 1987. Germination and seedling development of hogpotato (*Hoffmanseggia densiflora*). Weed Sci. 35:360-363.
23. Hackett, N. M., D. S. Murray, and P. E. Richardson. 1986. Anatomy and physiology of hogpotato. Proc. South. Weed Sci. Soc. 39:372.
24. Johansen, D. A. 1940. Plant Microtechnique. New York, NY: McGraw-Hill Book Co., Inc. 523 p.
25. Johnson, C. D. 1977. Two new species of *Acanthoscelides* from North America and new host records from *Desmanthus* and *Hoffmanseggia* (Coleoptera: Bruchidae). Pan-Pacific Entomol. 53:60-73.
26. Keeley, P. E. and R. J. Thullen. 1975. Influence of yellow nutsedge competition on furrow-irrigated cotton. Weed Sci. 23:171-175.
27. Knake, E. L. and F. W. Slife. 1965. Giant foxtail seeded at various times in corn and soybeans. Weeds 13:331-334.
28. Mayeux, H. S., Jr. 1982. Germination of false broomweed (*Ericameria austrotexana*) seed. Weed Sci. 30:597-601.
29. McMichael, B. L. 1986. Growth of roots. In J. R. Mauney and J. M. Stewart, eds. Cotton Physiology. Memphis, TN: The Cotton Foundation. pp. 29-38.
30. Parker, K. F. 1958. Arizona ranch, farm, and garden weeds. Ariz. Agric. Ext. Serv. Circ. 265. pp. 152-153.
31. Pavlychenko, T. K. and J. B. Harrington. 1935. Root development of weeds and crops in competition under dry farming. Sci. Agric. 16:151-160.
32. Robbins, W. W., M. K. Bellue, and W. S. Ball. 1951. Weeds of California. Sacramento, CA: Calif. Dep. Agric. pp. 258, 260.
33. Rushing, D. W., D. S. Murray, and L. M. Verhalen. 1985. Weed interference with cotton (*Gossypium hirsutum*). I. Buffalobur (*Solanum rostratum*). Weed Sci. 33:810-814.
34. Rushing, D. W., D. S. Murray, and L. M. Verhalen. 1985. Weed interference with cotton (*Gossypium hirsutum*). II. Tumble pigweed (*Amaranthus albus*). Weed Sci. 33:815-818.
35. Ryan, J., S. Miyamoto, and J. L. Stroehlein. 1975. Salt and specific ion effects on germination of four grass. J. Range Manage. 28:61-64.
36. Schroeder, G. L., D. F. Cole, and A. G. Dexter. 1983. Sugarbeet (*Beta vulgaris* L.) response to simulated herbicide spray drift. Weed Sci. 31:831-836.
37. Uhvits, R. 1946. Effect of osmotic pressure on water absorption and germination of alfalfa seeds. Am. J. Bot. 33:278-285.
38. Waterfall, U. T. 1969. Keys to the Flora of Oklahoma. 4th ed. Stillwater, OK: Dep. Bot. and Res. Found., Oklahoma State Univ. p. 120.
39. Westerman, R. B., D. S. Murray, and E. P. Castner. 1993. Hogpotato (*Hoffmanseggia glauca*) control with herbicides and rotational crop response. Weed Technol. 7: 650-656.

40. Wiese, A. F. 1971. Monuron and other soil sterilants for controlling small patches of perennial weeds. Tex. Agric. Exp. Stn. Misc. Publ. MP-1002. 7 p.

41. Wiese, A. F. 1982. Control of hogpotato, a perennial weed in Texas. Tex. Agric. Exp. Stn. Prog. Rep. PR-3965. 4 p.

42. Wiese, A. F. and H. E. Rea. 1961. Control of field bindweed and other perennial weeds with benzoic and phenylacetic acids. Weeds 9:423-428.

43. Wilson, R. G., Jr. 1979. Germination and seedling development of Canada thistle (*Cirsium arvense*). Weed Sci. 27:146-151.

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