ESTABLISHMENT TECHNIQUES FOR COMMON COCKLEBUR (*Xanthium strumarium*)

By

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ESTABLISHMENT TECHNIQUES FOR COMMON

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(*Xanthium strumarium*)

Abstract: Three field experiments were conducted using common cocklebur as a "test species" to identify and measure weed growth differences due to method of propagation and to the age of the weed when planted. Two studies consisted of the establishment of individual common cocklebur using five propagation methods [direct seeded (DS), direct seeded then transplanted (DST), transplanted peat pellet (TP), transplanted peat pot using field soil (TPOT), and transplanted 1206 insert containing potting soil (TIN)] and three transplant timings [Time 1 (T1), i.e., at the cotyledon stage; Time 2 (T2) two "true" leaves; and Time 3 (T3) with four "true" leaves]. Propagation methods and transplant timings were contrasted to the DS propagation method because it was probably the "most natural" method of those compared. In 1996, for data collections, at 4 weeks after emergence (WAE) and 8 WAE, T1 weeds planted by TP were most similar to DS Several significant differences were noted at the 0.10 level treatments at senescence. In 1997, at 4 WAE, all propagation methods and transplant timings were equivalent to DS. At 8 WAE and senescence, results were comparable to the previous year. Because of its performance the previous year, the TP method at T1, T2, and T3 plus DS were used to establish common cocklebur in a soybean experiment in 1997 to determine whether weed response was different under the more stressed environment. At 4 WAE, no differences were detected between TP at T1 vs. DS. At 8 WAE, TP at T1 was again the most comparable treatment to DS. At senescence, no weed differences existed, but several crop

differences were detected.

Nomenclature: Common cocklebur, *Xanthium strumarium* L. #[1] XANST; soybean *Glycine max* (L.) Merr. 'Manokin'.

Additional index words: Weed establishment methods, peat tablet; direct seeded, competition, interference.

Abbreviations: WAE, weeks after emergence; T1, transplanting at the cotyledon stage; T2, transplanting at the two "true"-leaf stage; T3, transplanting at the four "true"-leaf stage; DS, direct seeded; DST, direct seeded then transplanted; TP, transplanted peat tablet; TPOT, transplanted peat pot; TIN, transplanted 1206 insert.

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[1]Letters following this symbol are a WSSA-approved computer code from *Composite List of Weeds*, Revised 1989. Available from WSSA, 810 East 10th Street, Lawrence, KS 66044-8897

INTRODUCTION

United States farmers, utilizing current weed-control strategies in 46 commonly grown crops, lose $4.6 billion annually due to production losses from weeds; but if herbicides were not available, that loss would likely be $19.6 billion (Bridges 1992). Research is conducted on methods of weed control and management to deter the rising costs of herbicides and improve weed control on weed ecology and biology to understand the effects of weed interference and competition of weeds on crops.

Many weed science studies focus on crop yield and economic loss. The crop losses can be attributed to weed density, time of weed emergence relative to crop emergence, and portion of the crop growing season when weeds are most injurious (Zimdahl 1980). Conducting such studies requires the selection of a weed species in a crop and manipulating each to meet experimental requirements (Kempenaar and Schnieders 1995). Often, the most difficult factor to manage is rapid, uniform establishment of the weed in the crop. Weed emergence varies, resulting in different aged plants with different competitiveness. Irregular competition can cause difficulty when analyzing data (Zimdahl 1980).

Establishing a weed population is almost an art form, unique to the individual researcher. An individual researcher may try several plant-establishment procedures and eventually use one which works best for him. The process encompasses many factors including soil type, season of the year, reproductive organ, seed size, time, labor requirements and availability, and convenience. Studies of annual weeds in crops have utilized a diverse methodology of weed establishment. Studying common cocklebur in cotton (*Gossypium hirsutum* L.), Snipes et al. (1987) utilized a field already heavily infested. Rushing et al. (1985) hand planted buffalobur (*Solanum rostratum* Dun.) seed in uniformly spaced hills 3 cm from cotton rows. In studying ivyleaf morningglory [*Ipomoea hederacea* (L.) Jacq.] with cotton, Rogers et al. (1996) scarified weed seed in sulfuric acid and hand planted seed 8 cm from cotton rows. Rowland and Murray (1997) established densities of Palmer amaranth (*Amaranthus palmeri* S. Wats.) in cotton using peat tablets, each containing a pigweed seedling.

Kempenaar and Schnieders (1995) compared the new "agar" method to the standard "paper" method for the uniform emergence of three annual weed species in a greenhouse and under field conditions. In wet soil, average emergence time was shorter when seed were planted using the agar method; seed were easier to establish and began development sooner. Seed germinated on blotting paper appeared to be damaged upon transfer probably due to physical contact with their root tips. In dry sand, agar-germinated seed exhibited the highest emergence. In general, the agar method was less laborious and allowed quicker planting with more uniform emergence.

Perennial weed establishment has varied as well. Silverleaf nightshade (*Solanum elaeagnifolium* Cav.) was established in experiments by starting seedlings in a greenhouse using seed in peat tablets; and when seedlings reached the four to six true-leaf stage, they were transplanted into the study site with cotton (Green et al. 1987). Johnsongrass [*Sorghum halepense* (L.) Pers.] rhizomes cut into two-node segments were germinated in plastic trays containing wet paper towels and then planted into clay-filled pots by Holshouser and Chandler (1996). Thullen and Keeley (1987) sowed yellow nutsedge

(*Cyperus esculentus* L.) tubers in rows. Brown et al. (1985) placed one-node common bermudagrass [*Cynodon dactylon* (L.) Pers.] clippings in 2.5 cm-diameter soil tubes maintained in a greenhouse. Prior to cotton emergence, common bermudagrass densities were established by plugs consisting of plant material from three tubes.

Little attention has been devoted to propagation method and transplant age on weed behavior. However, differences in growth due to methods of establishment have been noted in horticultural crops. Transplanted asparagus (*Asparagus officinalis* L.) maintained greater plant dry weight and number of shoots throughout the season than did direct-seeded plants (Fisher 1982). Field-seeded tomatoes (*Lycopersicon esculentum* L.) grown on a clay soil required approximately 200 more heat units than transplanted tomatoes to reach the same level of maturity (Liptay et al. 1982). Salter et al. (1986) reported that leeks (*Allium ampeloprasum* L. Porrum group) grown in modules gave lower transplant weight than "bare-root" plants from trays despite all other growth factors being controlled. The choice of a planting system in such crops depends on the economics of plant establishment, plant performance after establishment, and value of the subsequent yield (Leskovar and Cantliffe 1993). The selection of a planting system for a weed should be given serious consideration because such data will be utilized for economic purposes.

Determining weed growth differences if any, due to propagation method and/or transplant timing would be useful in initiating a uniform experiment or in replacing a weed in a study. Directly seeding a weed into a field, if possible, would be the most desirable propagation method to use because placement of the weed would be controlled and because artificial establishment could cause plant disturbance. Therefore, the objectives of these experiments were to identify and measure weed growth differences due to method of propagation and to the age of the weed when planted.

MATERIALS AND METHODS

Seed Collection. Common cocklebur was chosen as a "test species" since it has large leaves for counting and leaf-area determination and because it has large seed for easy harvest. Several hundred seed heads were initially collected from numerous plants in March, 1996 along Beaver Creek near Union City, OK. Those seed heads were stored at 4 C and 50% relative humidity in the Oklahoma State University (OSU) Plant and Soil Sciences "Seed Storage Room" until experimental establishment in May, 1996. Common cocklebur for study establishment in May, 1997 was taken from the previous year's study. Seed heads were sent to Mississippi[1] to be deburred and, when returned, were again stored in the Seed Storage Room until study establishment.

Study Environments. Field experiments were initiated May 27, 1996 and May 31, 1997 on a Kirkland silt loam (a fine, mixed, thermic Udertic Paleustolls) located on the OSU Agronomy Research Station near Stillwater, OK. Soil pH of the location was 6.8, and organic matter content was 1.0%, with organic carbon at 0.5%.

Common Cocklebur Study Parameters. These studies involved five propagation methods and three transplant timings. The propagation methods were direct seeded (DS), direct seeded then transplanted (DST), transplanted peat tablet[2] (TP), transplanted peat

[1]Azlin Seed Service, P. O. Box 914, Leland, MS 38756.

[2]American Plant Products & Services Inc., 9200 NW 10, Oklahoma City, OK 73127.

pot[2] using field soil (TPOT), and transplanted 1206 insert[2] containing potting soil (TIN). Transplant timings were Time 1 (T1), i.e., at cotyledon stage; Time 2 (T2) with two "true" leaves; and Time 3 (T3) with four "true" leaves.

In 1996, intact common cocklebur seed heads and in 1997, deburred heads, were placed in glass containers with a screen covering and secured under cold, running tap water for 24 h. The heads were then half-buried in a moist sand/soil mixture and germinated in a germinator at 30 C. At the time of radicle emergence, seed for DS and DST were planted and watered. Other germinating seed were taken from the germinator, planted in the appropriate growth media, and placed in well-drained pans in the greenhouse for further growth until the appropriate transplant maturity was realized. When the various propagation methods reached T1 (1 to 2 d after germination), T2 (2 to 4 d after T1), and T3 (1 wk after T2), they were also taken to the field, planted, and watered.

Common Cocklebur Study Outline. To prevent interference, all weeds were placed 3 m apart in a randomized complete-block experimental design with four replications in 1996 and five replications in 1997. Three plants were independently planted per replication to provide a common cocklebur for each collection at 4 WAE, 8 WAE, and senescence.

Ammonium nitrate fertilizer was applied each year at a rate of 45 kg N/ ha. A POST application of oryzalin [4-(dipropylamino)-3,5-dinitrobenzensulfonamide] at a rate of 4.49 kg ai/ha, and paraquat (1,1'-dimethyl-4,4'-bipyridinium ion) at a rate of 1.06 kg ai/ha was applied after all plant timings were established to control other common cocklebur weeds. At the time of application, common cocklebur plants were covered with plastic pots to prevent injury. Further weed control throughout each season was done by hoeing or mechanical cultivation. Supplemental water to minimize water stress was done by irrigating with a sprinkler system or by hand watering. Carbaryl (1-naphthyl N-methylcarbamate) was used for insect control when necessary and was applied with a hand sprayer.

Common Cocklebur Data Collection. Daily heat units were accumulated for the growth period of the weed. Daily heat units were calculated by subtracting the base temperature of 60 F (15.6 C) from the average daily temperatures in F (Supak 1984). The latter was calculated as the maximum temperature for the day plus the minimum temperature divided by 2. Heat units/day are summed from planting until a specified point in the season.

Data which required destruction of the plant were collected three times during the growing season, 4 weeks after emergence (WAE), 8 WAE, and at senescence (the end of September through October). Measurements of height from the soil surface to the highest point on the plant, width at the widest point, and number of leaves were taken. Weeds collected 4 WAE were carefully uprooted, washed, and separated into leaves, stems, and roots. Cylindrical volume for each weed was calculated; and after leaf area was determined by the LI-3000 Portable Area[3] meter, common cocklebur separates were bagged and placed in drier ovens for 1 week. Leaf, stem, and root dry weights were taken.

Height, width, number of leaves and nodes, and plant volumes were recorded on weeds collected 8 WAE. Common cocklebur was cut at ground level; separated into leaves and stems, bagged, placed in drier ovens for 1 wk, and weighed.

[3]LI-COR, 4421 Superior Street, Lincoln, NE 68504.

Weeds collected at senescence were cut at ground level, separated into stems and burs, bagged, air dried in a greenhouse at the OSU Agronomy Research Station near Stillwater OK for 3 to 4 wk, and the two fractions were weighed separately.

Common Cocklebur/Soybean Parameters. Results in 1996 indicated that TP was the propagation method most comparable to DS when the weed was grown without competition. However, knowing what would occur when the weed has competition from a crop, would be more useful to a researcher.

Common cocklebur was again selected as the test species with soybean as the crop. The study involved two propagation methods (DS and TP) and three transplant timings (T1, T2, and T3).

Common Cocklebur/Soybean Study Outline. On May 15, 1997 Manokin soybean was planted in 91-cm rows for 20 m. Every three rows, common cocklebur plants, which were started in the germinator on May 15, 1997, were established, by designated treatment, 3 m apart and 10 cm on the west side of the north-south crop rows. All combinations of propagation methods and transplant timings were placed in a randomized complete-block design with four replications and three plants were independently planted per replication to provide a common cocklebur for each collection at 4 WAE, 8 WAE, and senescence.

Ammonium nitrate fertilizer was applied at a rate of 45 kg N/ha. A POST treatment of acifluorfen {5-[2-chloro-4-(trifluoromethyl)phenoxy]-2-nitrobenzoic acid} was applied at a rate of 0.52 kg ai/ha. At time of application, common cocklebur was covered with plastic pots to prevent injury. A later treatment of sethoxydim {2-[1-(ethoxyimino)butyl]-5-[2-(ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one} was applied at a rate of 0.35

kg ai/ha with a hand sprayer. Further weed control throughout that growing season was done by hoeing or mechanical cultivation. Water stress was again minimized by irrigating with a sprinkler system and hand watering. Carbaryl was used for insect control when necessary and was applied with a hand sprayer.

Common Cocklebur/Soybean Data Collection. Data which required destruction of the plant were collected three times during the growing season at 4 WAE, 8 WAE, and at senescence (September through October). Measurements of height from the soil surface to the highest point, width on the plant at the widest point, and number of leaves were taken on weeds collected at 4 WAE. Weeds were cut at ground level and separated into leaves and stems. Cylindrical volume for each weed was calculated; and after leaf area was determined by the LI-3000 Portable Area meter, weed separates were bagged and placed in drier ovens for 1 wk. Leaf and stem dry weights were taken. Height and width were taken on a soybean plant 25-cm north and on one 25-cm south of each weed. Soybean plants were then cut at ground level, bagged, and placed in drier ovens for 1 wk. Total plant weights were then taken.

Weeds collected 8 WAE were cut at ground level, separated into leaves and stems, bagged, placed in drier ovens for 1 wk, and weighed. After common cocklebur height and width were recorded, soybean height, width, and total plant weight were taken for the intervals from 25 to 50 cm to the north and south of each weed. Soybean plants were cut at ground level, placed in drier ovens for 1 wk, and total plant dry weights were recorded by interval.

Common cocklebur collected at senescence was again cut at ground level, separated into stems and burs, bagged, air dried in a greenhouse on the OSU Agronomy Research Station near Stillwater, OK for 3 to 4 wk, and weighed. Soybean plants at distances of 25, 75, and 125 cm to the north and south of each weed were bagged separately, dried, and thrashed. Total seed weight (a measure of yield) and a 250 seed weight (a measure of seed size) were taken at each specified distance from the weed. Soybean without common cocklebur competition was also harvested.

Statistical Analyses. The DS propagation method is the usual way a weed is propagated; and therefore, it was chosen as the most logical reference point to use for comparisons. Utilizing it as our "control", all other propagation methods and transplant timings were contrasted to it. Soybean results were also contrasted on the same basis, determining the degree of weed influence, with competition/interference tested as either a linear or quadratic function. Analyses of variance were performed to test interactions between propagation methods and transplant timings using SAS[4] General Linear Models (GLM). Significance, unless otherwise specified, was determined at ($P \leq 0.05$).

RESULTS AND DISCUSSION

Observations of Common Cocklebur from Emergence to Establishment. After common cocklebur germination in 1996, emergence time, a visual estimation of growth, and general weed condition were noted (data not shown). Time differences in emergence occurred between common cocklebur DS in the field at radicle appearance and those kept in the greenhouse until their designated transplant time. Two days after germination,

[4]SAS Institute,Cary, NC 27512.

greenhouse-grown weeds had fully developed cotyledons while DS and DST common cocklebur were "cracking" through the soil surface. From the cotyledon stage until 2 wk after germination, differences were apparent between field established vs. greenhouse-grown common cocklebur, the latter appeared larger in height and had a more vigorous appearance. Upon establishment, all transplanted weeds experienced stress to some degree. This assessment was based on the weeds losing their apparent vigor and wilting for a few days. Direct seeded then transplanted common cocklebur, especially T2 and T3, was noticeably weaker, wilted, and (in some cases), shed one or two leaves upon establishment; however, they soon recovered.

In 1997, common cocklebur, collected from the previous year's harvest, displayed increased germination percentage. However, a reduction in the stiff prickles located on the bur (due to deburring) diminished the bur's ability to anchor the seed coat in the soil as the cotyledons emerged. Many common cocklebur seedlings died due to their inability to separate the growing point from the bur. However, a sufficient number of common cocklebur germinated to compensate for that loss, and less vigorous weeds did not have to be used in the establishment of this study.

Common Cocklebur Data Collected 4 WAE. Statistical analyses revealed no interactions between propagation methods and transplant timings. Therefore, the main effects of propagation methods (across all transplant timings) and transplant timings (across all propagation methods) could be examined independently at 4 WAE. Growth differences due to treatment were noticeable at 4 WAE for the study in both years. In 1996, heat units accumulated were 510, while in 1997, 596 heat units occurred. Among the transplant timings in 1996 (Table 1), T1 was no different than DS over all measurements, except for stem weights. However, T2 and T3 displayed numerous differences. The T2 weeds were shorter, narrower, had less volume, fewer leaves, and a lower leaf weight than did DS plants. The T3 weeds were inferior to DS weeds over all measurements. In 1997 the T3 weeds were shorter than DS; no other measurements displayed significant differences.

Propagation methods at 4 WAE in 1996 (Table 2) indicated DST common cocklebur was shorter, narrower, had less volume, fewer leaves, less leaf area, and a lower leaf weight than DS weeds. The TP weeds were comparable to DS for all measurements, except for a lower number of leaves. The TPOT and TIN methods for common cocklebur had inferior heights, widths, volumes, and leaf numbers than did DS. The TPOT common cocklebur also had a lower leaf weight. In 1997, all propagation methods at 4 WAE were statistically similar to DS common cocklebur, except DST weeds were shorter and TP weeds had more leaves (Table 3).

Common Cocklebur Data Collected 8 WAE. In both years, treatment differences in growth at 8 WAE remained noticeable among established weeds. Statistical analyses again showed no significant interactions between propagation methods and transplant timings; therefore, main effects of each were discussed separately. In 1996, a total of 1142 heat units were accumulated, and in 1997, 1223 total heat units were available.

In 1996 at 8 WAE, T1 was no different than DS (Table 4) with T2 and T3 exhibiting numerous differences. The T2 common cocklebur was narrower, had less volume, had fewer leaves, and lower leaf weight than DS. All measurements for T3 weeds were inferior to DS plants. In 1997, T1 weeds had less width and volume than DS weeds. The T2 common cocklebur was comparable to DS, except for a smaller weed volume. Again, all measurements for T3 common cocklebur were significantly less than DS plants.

Analyses of propagation methods at 8 WAE indicated that DST common cocklebur was inferior to DS weeds for all measurements (Table 5). The TP method was very similar to DS. The TPOT and TIN common cocklebur had fewer nodes and leaves and lower leaf weights than DS. The TIN method also had narrower plants. The 1997 results (Table 6) again showed all measurements of DST common cocklebur to be inferior to DS weeds. The TP common cocklebur was inferior to DS only for weed volume. The TPOT and TIN common cocklebur was narrower and had smaller volumes. Additionally, TIN common cocklebur was shorter.

Common Cocklebur Data Collected at Senescence. Growth differences noticeable throughout the early portion of each year's experiment were no longer apparent by the time of flowering. As before, statistical analyses indicated no significant interactions between propagation methods and transplant timings; therefore, main effects were independently considered in the presentation of results. In 1996, bur and stem weights of T1 and T2 weeds were not significantly different from DS weeds (Table 7). The T3 common cocklebur had a lower bur weight but retained similar stem weights to DS. All propagation methods had similar stem weights as the DS weeds (Table 7), but lower bur weights did occur for DST, TPOT, and TIN weeds. In 1997, no adverse (or beneficial) effects on mature common cocklebur plants were detected among transplant timings or propagation methods (Table 8).

Common Cocklebur/Soybean Data Collected 4 WAE. No significant differences at 4 WAE were noted between DS common cocklebur and TP weeds at T1, T2, or T3 except that T2 and T3 weeds were taller than DS (Table 9). No significant effects were found (Table 10) on soybean growth 25 cm to the north and 25 cm to the south of each common cocklebur.

Common Cocklebur/Soybean Data Collected 8 WAE. At 8 WAE, TP common cocklebur at T1 were no different than DS weeds (Table 11). At T2, common cocklebur were shorter, narrower, had less volume, and a lower leaf weight. All measurements of TP at T3 were inferior to DS common cocklebur.

At 8 WAE, the height of soybean plants 25- and 50-cm north and south of each common cocklebur were linearly affected by weed growth (Table 12). Soybean height tended to increase from 0 to 50 cm from the weed. Soybean north and immediately next to TP common cocklebur planted at T3 and DS were significantly shorter than soybean without weed competition. However, no differences in northern soybean height occurred among soybean with common cocklebur treatment. Soybean, 0, 25, and 50 cm south and directly next to DS and TP weeds, which were planted at T2, were significantly shorter than soybean without weed competition. Soybean with TP common cocklebur planted at T1 and T3 were taller than those planted at T2 and DS.

Width of soybean north, but not south, of the established common cocklebur were linearly affected by weed growth (Table 12). However, common cocklebur influence on growth toward northern soybean plants was not sufficient to cause a discrepancy with soybean not having weed competition. Soybean widths south of established common cocklebur plants were again comparable to soybean without competition, except soybean 25 cm south of DS common cocklebur plants were significantly less. However, soybean having a TP weed planted at T2 tended to be narrower than other soybean with common cocklebur competition.

Among northern soybean plants, all soybean having common cocklebur competition weighed similarly (Table 12). All southern soybean plant weight having weed competition were also similar, except for lighter soybean 25 cm south of common cocklebur planted at T1 and TP.

Common Cocklebur/Soybean Data Collected at Senescence. Bur and stem weights from TP common cocklebur were not significantly different than DS weeds at senescence (Table 11). Soybean at senescence north of common cocklebur plants showed a linear trend for seed weights which increased as distance interval was extended from the weed (Table 13). Total soybean seed weights 75-125 cm north of common cocklebur planted with TP at T2 were greater than soybean without weed competition. Additionally, soybean plants 25-75 cm and 75-125 cm had greater seed weights than soybean without competition/interference. All other seed weights from soybean with common cocklebur were statistically no different from those without weed competition/interference. With soybean seed weights south of common cocklebur plants, a linear trend was again present with seed weights increasing as distance interval increased. Soybean seed weights south of established common cocklebur plants were greater than seed weights without weed competition when weeds were planted by TP at T1, T2, and DS at 125 cm. All other seed weights were statistically equivalent. Soybean seed size estimates north of each common cocklebur plant had a linear trend decrease as the distance interval increased. Northern 250-seed weights were no different from those without competition, except for soybean harvested at 125 cm with a common cocklebur planted by DS. Southern 250-seed weights differed only from soybean without weed presence when common cocklebur were planted at T3 with the TP propagation method and were harvested at a distance of 25 cm.

The purpose of this study was not to determine the best method for establishing common cocklebur in the narrow sense, but to evaluate propagation methods and transplant timings on establishment for weeds in general. According to our data, those factors do have an effect on the growth of common cocklebur with and without competition/interference for at least 8 wk. The extent to which this is true for other weeds is unknown. Establishing a common cocklebur using TP at T1 was the closest equivalent to DS. By senescence, the weeds were essentially the same regardless of method of propagation or time of transplant. Depending on the method or time used, greater or lesser competition/interference can result for at least 8 wk of the season. Weed establishment in future studies should be considered with these results in mind.

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Table 1. Common cocklebur transplant timing data collected 4 WAE[a] in 1996 and 1997.

Measurement	Units	Transplant timing[b] Cotyledon (T1)	2 leaves (T2)	4 leaves (T3)	Direct seeded (DST)	SED[c]
			1996			
Height	cm	16.1	14.5*	11.7*	18.3	1.32
Width	cm	39.4	30.7*	21.9*	37.9	2.08
Volume	m^3	0.0208	0.0112*	0.0047*	0.0208	0.0025
Leaf no.		34.5	26.9*	9.2*	32.3	1.98
Leaf area	cm^2	1,202.62	1,038.53	250.95*	1,067.27	296.22
Leaf weight	g	6.55	3.89*	2.17*	6.28	1.06
Stem weight	g	3.25	1.25	0.44†	1.87	0.77
Root weight	g	1.02	0.90	0.42†	0.88	0.27
			1997			
Height	cm	21.3	20.7	18.9†	24.1	2.59
Width	cm	49.9	49.3	40.1	48.0	5.67
Volume	m^3	0.0603	0.0441	0.0278	0.0518	0.0170
Leaf no.		66.2	60.7	49.9	49.4	10.52
Leaf area	cm^2	1,607.94	1,487.98	902.48	1,389.69	404.09
Leaf weight	g	11.97	10.90	7.30	9.82	2.86
Stem weight	g	3.62	3.05	1.85	2.77	1.04
Root weight	g	2.31	1.97	1.25	1.71	0.43

[a] WAE, weeks after emergence.

[b] "*" Contrast significantly different ($P \leq 0.05$) than the direct-seeded treatment; "†" same contrast at $0.05 < P \leq 0.10$.

[c] Standard error of the difference for the pairwise contrasts of T1, T2, and T3 to the direct-seeded treatment.

Table 2. Common cocklebur propagation method data collected 4 WAE[a] in 1996.

		Propagation method[b]					
Measurement	Units	Direct seeded-transplanted (DST)	Peat tablet (TP)	Peat pot (TPOT)	1206 insert (TIN)	Direct seeded (DS)	SED[c]
Height	cm	11.4*	16.2	14.5*	14.3*	18.3	1.39
Width	cm	27.1*	34.5	29.8*	31.3*	37.9	2.18
Volume	m^3	0.0088*	0.0171	0.0113*	0.0119*	0.0208	0.0026
Leaf no.		19.4*	26.8*	23.3*	24.6*	32.3	2.09
Leaf area	cm^2	487.40†	990.07	686.21	1,159.31	1,067.27	312.25
Leaf weight	g	2.68*	5.41	3.58*	5.13	6.28	1.12
Stem weight	g	0.85	3.21	1.16	1.37	1.87	0.81
Root weight	g	0.52	0.71	0.69	1.20	0.88	0.28

[a] WAE, weeks after emergence.

[b] "*" Contrast significantly different ($P \leq 0.05$) than the direct-seeded treatment; "†" same contrast at $0.05 < P \leq 0.10$.

[c] Standard error of the difference for the pairwise contrasts of propagation methods to the direct-seeded treatment.

Table 3. Common cocklebur propagation methods data collected 4 WAE[a] in 1997.

		Propagation method[b]					
Measurement	Units	Direct seeded-transplanted (DST)	Peat tablet (TP)	Peat pot (TPOT)	1206 insert (TIN)	Direct seeded (DS)	SED[c]
Height	cm	14.9*	21.8	22.7	21.8	24.1	2.76
Width	cm	37.9	49.0	53.3	45.4	48.0	6.04
Volume	m^3	0.0204	0.0457	0.0579	0.0524	0.0518	0.0181
Leaf no.		48.5	72.2†	63.3	51.7	49.4	11.20
Leaf area	cm^2	791.16	1,507.46	1,560.05	1,472.53	1,389.69	430.08
Leaf weight	g	6.74	10.73	11.83	10.94	9.82	2.76
Stem weight	g	1.45	3.09	3.46	3.37	2.77	1.10
Root weight	g	1.09	2.02	2.24	2.02	1.71	0.46

[a] WAE, weeks after emergence.

[b] "*" Contrast significantly different ($P \leq 0.05$) than the direct-seeded treatment; "†" same contrast at $0.05 < P \leq 0.10$.

[c] Standard error of the difference for the pairwise contrasts of propagation methods to the direct-seeded treatment.

Table 4. Common cocklebur transplant timing data collected 8 WAE[a] in 1996 and 1997.

Measurement	Units	Transplant timing[b] Cotyledon (T1)	2 leaves (T2)	4 leaves (T3)	Direct seeded (DS)	SED[c]
				1996		
Height	cm	54.0	47.7	41.3*	51.3	4.41
Width	cm	140.9	120.1*	105.8*	141.6	9.32
Volume	m^3	0.904	0.612†	0.393*	0.862	0.134
Node no.		16.5	17.3	15.3*	18.6	1.37
Leaf no.		491.2	408.1*	265.6*	582.6	56.29
Leaf weight	g	201.03	177.19*	100.71*	235.41	24.18
Stem weight	g	146.71	88.38	48.12*	114.96	28.18
				1997		
Height	cm	61.8	63.7	51.7*	67.9	3.79
Width	cm	161.3†	163.1	134.3*	178.4	8.17
Volume	m^3	1.34*	1.39†	0.779*	1.78	0.183
Node no.		15.7	16.6	14.4*	17.0	1.43
Leaf no.		361.4	366.8	260.3*	395.3	35.81
Leaf weight	g	298.68	312.50	193.63*	372.79	41.02
Stem weight	g	276.06	274.60	163.32*	314.80	50.03

[a]WAE, weeks after emergence.

[b] "*" Contrast significantly different ($P \leq 0.05$) than the direct-seeded treatment; "†" same contrast at $0.05 < P \leq 0.10$.

[c] Standard error of the difference for the pairwise contrasts of T1, T2, and T3 to the direct-seeded treatment.

Table 5. Common cocklebur propagation method data collected 8 WAE[a] in 1996.

Measurement	Units	Propagation method[b]					
		Direct seeded-transplanted (DST)	Peat tablet (TP)	Peat pot (TPOT)	1206 insert (TIN)	Direct seeded (DS)	SED[c]
Height	cm	39.5*	53.3	52.5	45.3	51.3	4.64
Width	cm	100.5*	133.8	131.7	123.00†	141.6	9.83
Volume	m^3	0.408*	0.810	0.755	0.573	0.863	0.143
Node no.		15.9†	18.4	15.6*	15.5*	18.6	1.46
Leaf no.		286.9*	499.2	387.3*	379.9*	582.6	59.29
Leaf weight	g	111.89*	209.51	149.69*	167.50*	235.14	25.47
Stem weight	g	64.63†	120.30	98.64	94.03	114.96	29.68

[a] WAE, weeks after emergence.

[b] "*"Contrast significantly different ($P \leq 0.05$) than the direct-seeded treatment; "†" same contrast at $0.05 < P \leq 0.10$.

[c] Standard error of the difference for the pairwise contrasts of propagation methods to the direct-seeded treatment.

Table 6. Common cocklebur propagation method data collected 8 WAE[a] in 1997.

Measurement	Units	Propagation method[b]					
		Direct seeded-transplanted (DST)	Peat tablet (TP)	Peat pot (TPOT)	1206 insert (TIN)	Direct seeded (DS)	SED[c]
Height	cm	50.7*	64.7	60.7	60.1†	68.0	4.03
Width	cm	133.4*	162.4	156.6*	159.1†	178.4	8.70
Volume	m^3	0.804*	1.40†	1.25*	1.25*	1.78	0.195
Node no.		14.2*	16.8	16.0	15.3	17.0	1.53
Number of leaves		246.9*	362.9	359.1	349.2	395.3	38.12
Leaf weight	g	168.68*	310.96	298.49	294.95	372.79	43.67
Stem weight	g	114.90*	278.43	291.51	267.31	314.86	53.26

[a] WAE, weeks after emergence.

[b] "*" Contrast significantly different ($P \le 0.05$) than the direct-seeded treatment; "†" same contrast at $0.05 < P \le 0.10$.

[c] Standard error of the difference for the pairwise contrasts of propagation methods to the direct-seeded treatment.

Table 7. Common cocklebur data collected at senescence in 1996.

Measurement	Units	Transplant timing[a]				
		Cotyledon (T1)	2 leaves (T2)	4 leaves (T3)	Direct seeded (DS)	SED[b]
Bur weight	g	2,442.87	2,406.53	2,342.81†	3,379.66	541.65
Stem weight	g	2,130.76	1,717.05	1,452.09	2,014.92	349.47

Measurement	Units	Propagatio method[a]					
		Direct seeded-transplanted (DST)	Peat tablet (TP)	Peat pot (TPOT)	1206 insert (TIN)	Direct seeded (DS)	SED[b]
Bur weight	g	2,303.36†	2,958.82	2,150.39†	2,177.04†	3,379.66	570.50
Stem weight	g	1,644.60	1,834.38	1,607.97	1,974.57	2,014.92	368.08

[a] "*" Contrast significantly different ($P \leq 0.05$) than the direct-seeded treatment; "†" same contrast at $0.05 < P \leq 0.10$.

[b] Standard error of the difference for the pairwise contrasts of T1, T2, and T3 to direct-seeded and propagation methods to the direct-seeded treatment.

Table 8. Common cocklebur data collected at senescence in 1997.

Measurement	Units	Transplant timing					
		Cotyledon (T1)	2 leaves (T2)	4 leaves (T3)	Direct seeded (DS)	SED[a]	LSD (0.05)
Bur weight	g	3,001.94	2,583.76	2,323.99	2,248.07	361.13	NS[b]
Stem weight	g	1,572.97	1,606.17	1,264.97	1,429.16	155.67	NS

Measurements	Units	Propagation method						
		Direct seeded-transplanted (DST)	Peat tablet (TP)	Peat pot (TPOT)	1206 insert (TIN)	Direct seeded (DS)	SED[a]	LSD (0.05)
Bur weight	g	2,451.53	2,658.66	2,620.81	2,815.26	2,248.07	384.45	NS[b]
Stem weight	g	1,191 13	1,751.95	1,466.68	1,515.71	1,429.16	165.72	NS

[a] Standard error of the difference for the pairwise contrasts of T1, T2, and T3 to direct-seeded and propagation methods to direct-seeded treatment.

[b] NS, no significant differences from direct seeded.

Table 9. Common cocklebur data collected 4 WAE[a] from common cocklebur/soybean study in 1997.

		Propagation method and transplant timing[b]				
		Peat tablet			Direct	
Measurement	Units	Cotyldeon (T1)	2 leaves (T2)	4 leaves (T3)	Seeded (DS)	SED[c]
Height	cm	13.5	13.8†	14.0†	10.5	1.79
Width	cm	28.5	22.5	17.5	21.3	5.05
Volume	m^3	0.001	0.00545	0.00337	0.00506	0.00327
Leaf no.		23.8	24.3	15.8	20.8	4.13
Leaf area	cm^2	388.01	287.39	136.65	281.60	84.03
Leaf weight	g	2.32	1.71	0.87	1.57	0.49
Stem weight	g	0.32	0.28	0.19	0.23	0.07

[a]WAE, weeks after emergence.

[b] "*"Contrast significantly different ($P \leq 0.05$) than the direct-seeded treatment; "†" same contrast at $0.05 < P \leq 0.10$.

[c] Standard error of the difference for the pairwise contrasts of T1, T2, and T3 to the direct-seeded treatment.

Table 10. Soybean data collected 4 WAE[a] from common cocklebur/soybean study in 1997.

		Propagation method and transplant timing					
		Peat tablet			Direct		
Measurement	Units	Cotyldeon (T1)	2 leaves (T2)	4 leaves (T3)	Seeded (DS)	SED[b]	LSD (0.05)
North weight	g[d]	0.81	1.01	0.80	0.95	0.15	NS[c]
South weight	g[d]	1.54	1.00	0.90	1.69	0.93	NS

[a] WAE, weeks after emergence.

[b] Standard error of the difference for the pairwise contrasts of T1, T2, and T3 to the direct-seeded treatment.

[c] NS, no significant differences from direct-seeded.

[d] Samples taken at a distance of 25 cm.

Table 11. Common cocklebur data collected 8 WAE[a] from common cocklebur/soybean study in 1997.

Measurement	Units	Propagation method and transplant timing[b]					
		Peat tablet			Direct		
		Cotyledon (T1)	2 leaves (T2)	4 leaves (T3)	Seeded (DS)	SED[c]	LSD(0.05)
Height	cm	54.8	43.5*	42.3*	55.0	4.00	
Width	cm	115.5	84.5†	60.8*	111.0	12.22	
Volume	m^3	0.5950	0.2570*	0.1290*	0.500	0.1209	
Leaf weight	g	59.13	25.37†	16.28*	48.06	10.66	
Stem weight	g	44.65	16.42	9.78*	32.40	9.10	
Senescence							
Bur weight	g	231.11	218.75	306.44	315.85	59.00	NS[d]
Stem weight	g	279.56	227.15	244.84	336.44	61.57	NS

[a] WAE, weeks after emergence.

[b] "*" Contrast significantly different ($P \leq 0.05$) than the direct-seeded treatment; "†" same contrast at $0.05 < P \leq 0.10$.

[c] Standard error of the difference for the pairwise contrasts of T1, T2, and T3 to the direct-seeded treatment.

[d] NS, no significant differences from direct -seeded.

Table 12. Soybean data collected 8 WAE[a] from common cocklebur/soybean study in 1997.

Measurement	Units	Propagation method and transplant timing[b]					
		Peat tablet			Direct		
		Cotyledon (T1)	2 leaves (T2)	4 leaves (T3)	Seeded (DS)	Control[c]	SED[d]
North height[e]	cm						6.70
Distances:							
0 cm		58.3	52.0	54.5*	54.2*	—	
25 cm		61.0	56.5	59.0	58.9	—	
50 cm		67.3	60.3	60.3	63.2	67.5	
South height[e]	cm						5.08
0 cm		64.3	52.0*	59.5	51.8*	—	
25 cm		64.3	54.3*	64.0	61.5	—	
50 cm		68.8	55.5*	63.3	61.2	67.5	
North width[e]	cm						6.70
0 cm		45.0	39.0	47.3	42.2	—	
25 cm		51.5	39.8	47.0	44.6	—	
50 cm		49.8	44.8	48.8	46.6	47.1	
South width	cm						5.71
0 cm		45.8	37.8	54.8	45.6	—	
25 cm		43.0	40.8	48.8	36.3*	—	
50 cm		48.5	43.0	48.0	45.6	47.2	
North weight	g						17.08
25 cm		63.49	45.97	63.54	62.30	—	
50 cm		60.01	46.21	54.01	68.34	—	
South weight	g						14.83
25 cm		27.57	41.63	60.19	47.26	—	
50 cm		58.11	42.98	46.71	58.11	—	

[a] WAE, weeks after emergence.

[b] "*" Contrast significantly different ($P \leq 0.05$) than the direct-seeded treatment; "†" same contrast at $0.05 < P \leq 0.10$.

[c] Soybeans results without common cocklebur competiton.

[d] Standard error of the difference for the pairwise contrasts of T1, T2, and T3 to the direct-seeded treatment.

[e] Linear trend in present in data.

Table 13. Soybean data collected at senescence from common cocklebur/soybean study in 1997.

Measurement	Units	Propagation method and transplant timing[a]					
		Peat tablet			Direct		
		Cotyldeon (T1)	2 leaves (T2)	4 leaves (T3)	Seeded (DS)	Control[b]	SED[c]
North seed weight[d]	g						25.36
25 cm		103.97	80.02	79.23	82.27	---	
75 cm		144.20	134.97	130.42	159.93*	---	
125 cm		151.02	181.49*	171.09†	158.07*	111.24	
South seed weight[d]	g						27.16
25 cm		73.82	87.83	78.04	72.96	---	
75 cm		181.85*	102.06	150.72	144.12	---	
125 cm		164.46†	190.24*	161.30	172.19*	113.72	
North 250 seed[d]	g						1.40
25 cm		31.93	31.14	30.59	30.67	---	
75 cm		29.47	30.70	29.14	29.27	---	
125 (cm)		29.25	30.25	29.93	26.61*	30.71	
South 250 seeds	g						1.30
25 (cm)		28.62	30.27	27.31*	29.09	---	
50 (cm)		28.37	31.18	28.46	28.39	---	
125 cm		30.25	30.32	29.38	28.38	30.45	

[a] "*" Contrast significantly different ($P \leq 0.05$) than the direct-seeded treatment; "†" same contrast at $0.05 < P \leq 0.10$.

[b] Soybeans results without common cocklebur competiton.

[c] Standard error of the difference for the pairwise contrasts of T1, T2, and T3 to the direct-seeded treatment.

[d] Linear trend in present in data.

APPENDIX

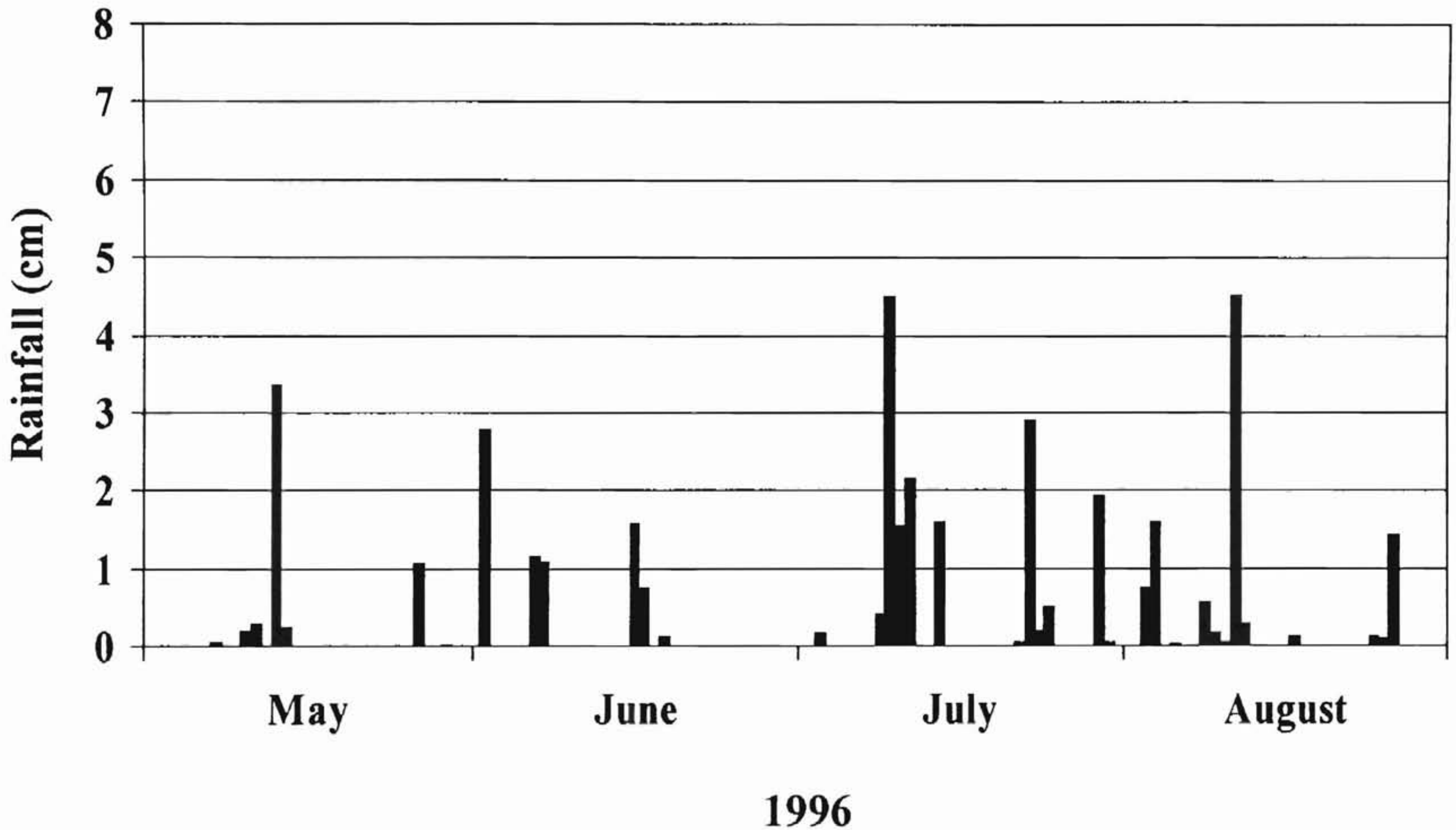

Figure 1. Rainfall data in 1996 from Agronomy Research Station near Stillwater, OK.

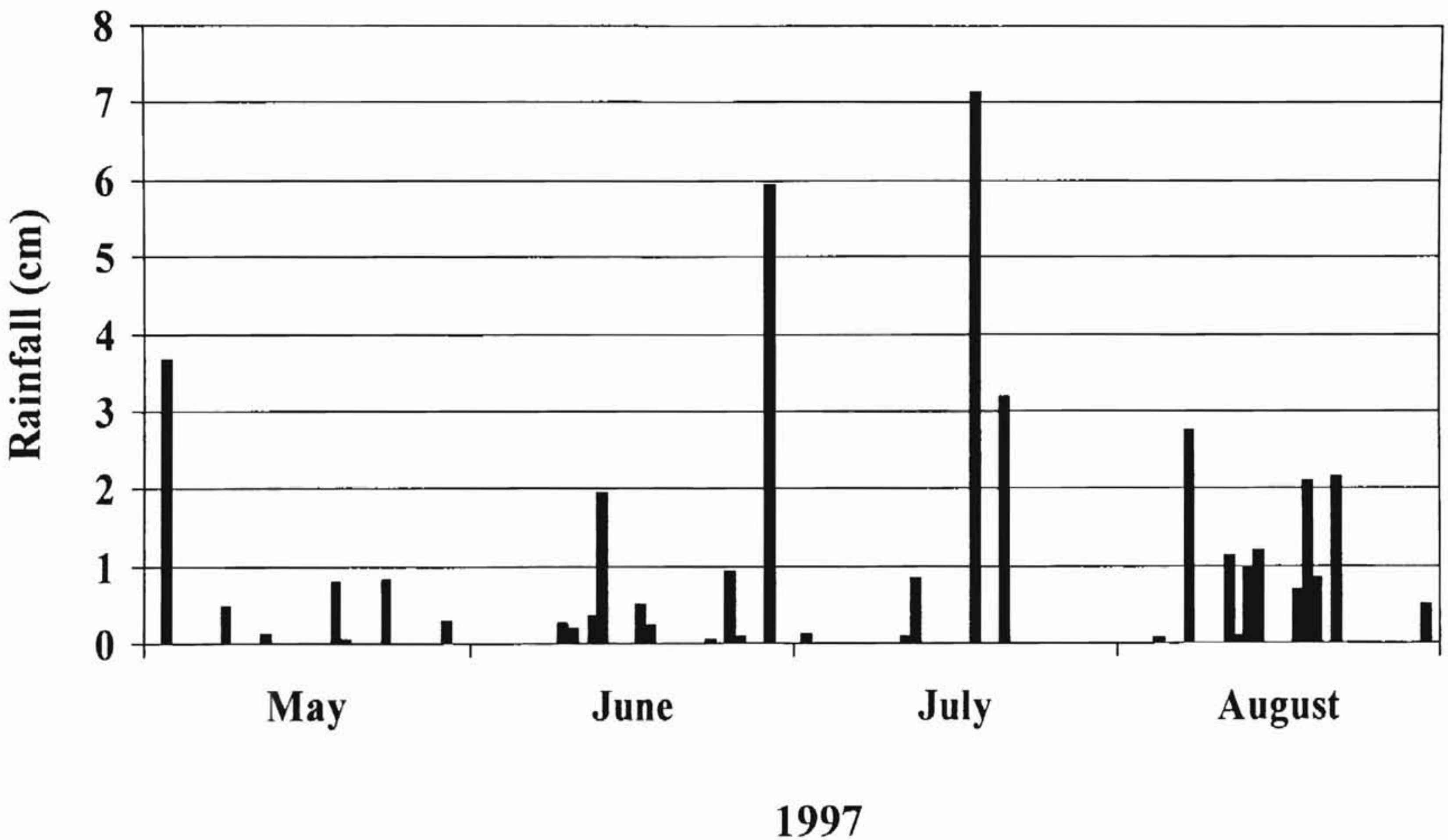

Figure 2. Rainfall data in 1997 from Agronomy Research Station near Stillwater, OK.

VITA

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