SOIL-MOISTURE EXTRACTION PROFILES OF COTTON (GOSSYPIUM HIRSUTUM) AND WEED SPECIES

By

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OF COTTON (GOSSYPIUM HIRSUTUM)

AND WEED SPECIES

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This thesis is a manuscript to be submitted for publication in Weed Science, the journal of the Weed Science Society of America. Articles in that journal are peer reviewed and must report original research repeated over time and/or space.

SOIL-MOISTURE EXTRACTION PROFILES OF COTTON (*GOSSYPIUM HIRSUTUM*) AND WEED SPECIES

Soil-Moisture Extraction Profiles of Cotton (*Gossypium hirsutum*) and Weed Species

Abstract. Research was conducted in 1989 and 1990 near Perkins, Oklahoma to determine and compare the soil moisture profiles of cotton, several weeds, and bare soil. Neutron probe access tubes were installed prior to plant establishment so that nondestructive volumetric water content determinations could be made at selected depths throughout the season. Plants were planted in a double circle pattern with both circles circumscribing the neutron probe access tube. The outer-circle plants served to prevent the inner-circle plants from exploring soil for moisture beyond the spatial detection limits of the neutron probe. Phenological and soil moisture data were taken on a weekly basis. When the plants began to senesce, they were clipped at ground level and oven dried to determine biomass yield. In 1989, upper soil profile moisture was frequently replenished by rain, and cotton, velvetleaf, devil's-claw, and tall morningglory had similar soil moisture profiles. Devil's-claw, however, was infested by bacterial blight which may have affected its soil moisture extraction. Late in the season, some differences developed in these species' soil moisture profiles. Common cocklebur and johnsongrass extracted moisture from greater depths than the other

species throughout the season. In 1990, the upper profiles of common cocklebur, devil's-claw, and silverleaf nightshade showed the greatest differences from bare soil early in the season. Later in the season, however, there was little difference in moisture content among the upper soil profiles of the plants. Johnsongrass and tall morningglory emerged much later than the other species in 1990 which probably affected their soil moisture extraction. Inner-circle biomass yield correlated with soil moisture depletion better than total biomass; however, the correlation was still poor and inconsistent. Nomenclature: Cotton, Gossypium hirsutum L. 'Paymaster 145' #[1] GOSHI; common cocklebur, Xanthium strumarium L. # XANST; johnsongrass, Sorghum halepense (L.) Pers. # SORHA; velvetleaf, Abutilon theophrasti Medik. # ABUTH; devil's-claw, Proboscidea louisianica (Mill.) Thellung # PROLO; tall morningglory, Ipomoea purpurea (L.) Roth # PHBPU; silverleaf nightshade, Solanum elaeagnifolium Cav. # SOLEL.

Additional index words. Phenology, water use, neutron probe, unicorn-plant, GOSHI, XANST, SORHA, ABUTH, PROLO, PHBPU, SOLEL.

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[1]Letters following this symbol are a WSSA approved computer code from 1983, Important Weeds of the World, Bayer AG, Leverkusen, Federal Republic of Germany, 711 pp.

INTRODUCTION

Weeds compete with cotton for light, nutrients, and water (4). Water is consistently the most limiting of those factors. Competition between two plants begins when their root systems overlap, suggesting the importance of competition for limited water and/or nutrients (13). Subsequent shoot growth proceeds in proportion to the root system. Radosevich and Holt (15) proposed three factors which govern water availability for plants, i.e., seasonal water supply, water-use efficiency of the plant, and development and structure of the plant's roots. Much research concerning crop-weed competition for water has been directed at their respective root system's development and structure.

In an experiment comparing the root development and distribution of soybean [*Glycine max* (L.) Merr.] vs. tall morningglory, the greatest concentration of roots for both species was in the upper 12 cm of soil (17). Late in the season, however, tall morningglory roots were found at greater depths and densities than were those of soybean. Although soybean roots grew faster than those of tall morningglory early in the season, the soybean roots expanded more slowly as the crop entered the reproductive stage. In contrast, the weed root system continued to expand at a relatively constant rate. Davis et al. (6) determined the extent of root growth for several weed species in single rows without interspecific competition. Common cocklebur (the only weed species in common between their study and this one) established its root system more rapidly than the other species studied; its roots reached a maximum depth of 2.9 m.

Other research has been directed toward determining soil-moisture extraction profiles. Common cocklebur has been the subject of many of those investigations. Davis et al. (7) determined that common cocklebur had a larger soil moisture extraction profile than grain sorghum [Sorghum bicolor (L.) Moench] and several other weed species. Geddes et al. (8) reported that common cocklebur roots explored a greater volume of soil than did soybean roots which may explain the weed's competitive advantage over soybean. In a study by Munger et al. (12), monocultured velvetleaf depleted a significant amount of soil moisture to a depth of 110 cm. Velvetleaf depleted significantly more soil moisture than monocultured soybeans in the upper 40 cm of the profile.

Several soil-moisture depletion studies have also been made in cotton (2, 9, 16). During a dry year, plots containing both cotton and silverleaf nightshade exhibited greater early season water loss in the lower soil profile than did plots containing only cotton (9). However, in a wet year, soil-water loss did not differ between the two treatments. In another experiment, hogpotato [Hoffmanseggia glauca (Ortega) Eifert] depleted soil moisture to a depth of

120 cm (2). In the same experiment, cotton depleted moisture primarily from the upper 90 cm of the profile. Riffle et al. (16) determined that plots containing devil's-claw, either alone or in combination with cotton, showed greater early-season water loss from the soil profile than did plots containing only cotton. By the time cotton reached the peak bloom to early boll stage, however, plots containing only cotton showed greater water loss.

In most soil-moisture depletion experiments, the crops are grown in rows as they are in a normal field situation. In this research cotton and selected weeds known to significantly reduce cotton yield (1, 3, 5, 10, 11, 18) were grown in monoculture in the same planting pattern and population density. The objective of this research was to determine and compare the soil moisture extraction profiles of each species throughout the growing season.

MATERIALS AND METHODS

Field experiments were located near Perkins in north central Oklahoma in 1989 and 1990 to determine the soil-moisture extraction profiles of cotton and selected weed species and bare soil (as a check) and to compare them to each other. The soils were a Teller (Udic Argiustoll) loam and sandy loam in 1989 and 1990, respectively. The 1990 experiment was conducted on a different site from the 1989 experiment to avoid possible residual effects. No fertilizer was applied in 1989; 45 kg ha^{-1} of nitrogen were added in 1990. Neither site was tilled from approximately 2 weeks before plant establishment until after harvest.

In both years, soil moisture was uniform across the experiment because of rainfall or of irrigation applied prior to the first readings. Irrigation was not necessary in 1989. In 1990, a side-roll sprinkler system was used to apply irrigation water to aid in plant establishment.

Several chemicals were used to assist in controlling extraneous weeds, diseases, and insects. Oryzalin [4-(dipropylamino)-3,5-dinitrobenzenesulfonamide] was applied preemergence at 1.1 kg ai ha^{-1} immediately after planting each year. Desired seed were protected from the herbicide during treatment by shielding them with 31 cm^2 covers (14). The experiment was also hand weeded at weekly intervals. In 1989, cupric hydroxide was applied at 2.2 kg ai ha^{-1} to control bacterial blight [caused by Xanthomonas campestris pv malvacearum (Smith) Dye] which infected devil's-claw. Carbaryl (1-naphthyl methylcarbamate) was applied once in 1989 at 2.2 kg ai ha^{-1} to control foliage feeding insects. In 1990, carbaryl was applied twice at 2.2 kg ai ha^{-1} and malathion (O,O-dimethyl phosphorodithioate of diethyl mercaptosuccinate) once at 0.7 kg ai ha^{-1}.

The experimental design was a randomized complete block with four replications except for the 1990 tall morningglory treatment which was only replicated three times. One replication of tall morningglory was omitted because the plants emerged considerably later than plants in other replications. The 1989 treatments were cotton, five plant species, and bare soil. In 1990, an additional weed, silverleaf nightshade, was included. All plants were grown in the field from seed except for johnsongrass and silverleaf nightshade. Johnsongrass was planted from 10- to 15-cm rhizome sections. Silverleaf nightshade was initiated in the greenhouse from seed in peat tablets[2] (10). All plants started in the field were planted June 19, 1989, and June 15, 1990. Silverleaf nightshade was planted in the greenhouse May 7, 1990, and transplanted to the field on May 22. Its foliage was removed near the soil surface on June 25, and regrowth from the perennial root system followed. A species was defined as "emerged" when at least half of its plants had displayed shoots above the soil surface.

All species were grown in a concentric circle pattern around a neutron probe access tube in the center of the plot (Figure 1). An inner circle of four symmetrically arranged plants had a radius of 25 cm. An outer circle of eight symmetrically arranged plants had a radius of 50 cm. The outer circle was grown to prevent the inner circle of plants from exploring an unlimited volume of soil for water. The two circles of plants comprised a plot. If the area that

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[2]Forestry Suppliers, Inc., P.O. Box 8397, Jackson, MS 39284-8397.

the inner-circle plants occupied is assumed to be a circle with a 37.5 cm radius, the population density was approximately 91,000 plants ha^{-1}.

As each species began to senesce, its plants were clipped at ground level and oven dried at 40 C for 2 weeks to determine aboveground dry matter yield. In 1989, common cocklebur, velvetleaf, and devil's-claw were harvested September 20. Cotton, johnsongrass, and tall morningglory were harvested October 12. In 1990, all species were harvested September 25. Inner-circle plants were harvested separately from outer-circle plants for all species except tall morningglory. Biomass was determined using the inner-circle yield and assuming that those plants occupied a circle with a 37.5 cm radius. Separation of tall morningglory plants into inner- vs. outer-circle was impractical; thus, tall morningglory biomass was calculated using total plot yield and an assumption that the plants occupied a circle with a 62.5 cm radius.

A neutron probe[3] was used to make nondestructive soil-moisture determinations. Neutron probe access tubes (nominal 3.8 cm thin-wall steel tubing[4]), similar to those used in other Oklahoma studies (2, 9, 16), were inserted into the center of the plots prior to the establishment of

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[3]Model 3330. Troxler Electronics Laboratories, Inc., Research Triangle Park, NC 27709.

[4]Harrison Electric, 914 S. Main, Stillwater, OK 74074.

plants. In 1989, the tubes were installed by creating a hole with a tractor-mounted hydraulic soil coring and sampling machine[5] fitted with a 4.1 cm auger[5] and by then pressing the tubes into the hole with the machine. In 1990, the tubes were installed in a similar manner except the hole was created by removing a soil core with a pick-up truck mounted hydraulic soil coring and sampling machine[6] fitted with a 4.1 cm soil tube and bit[6]. The tubes were 210 cm and 195 cm long in 1989 and 1990, respectively; 15 cm were allowed to extrude above the soil surface in both years.

Soil-moisture determinations were initiated on July 20, 1989, and July 26, 1990. The determinations were made on a weekly basis in both years until weed senescence. Phenological development data were also taken at each reading date. Soil moisture determinations were made starting at 15 cm below the soil surface and then at 15 cm increments to a depth of 150 cm.

The neutron count rate reading at the 15-cm depth was converted to cm^3 water/cm^3 soil with a shallow calibration curve for the 15-cm depth developed separately from the calibration curve used for all other depths. Total water for each 15-cm section of the profile was calculated by multiplying its volumetric water content by 15. The water

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[5]Giddings model GSR-T-S. Giddings Machine Co., P.O. Drawer 2024, Fort Collins, CO 80522.

[6]Giddings model GSRP-S. Giddings Machine Co., P.O. Drawer 2024, Fort Collins, CO 80522.

content of the 0-to-15-cm section was assumed to be the same as the water content at the 15-cm depth. The water content of the 15-to-30-cm section was assumed to be the average of the water contents at the 15- and 30-cm depths. The water contents of the remaining profile sections were determined in a similar manner. The total water of a particular profile zone was calculated as the sum of the total water in that zone's constituent 15-cm sections.

Soil-moisture depletion was determined by subtracting the total water of the total profile under a particular species from the total water of the total profile under bare soil on August 31, 1989 and September 13, 1990.

Degree-day accumulation was calculated for each plant species by subtracting a base of 15.5 C from each day's median temperature. Degree days began accumulating at the time of emergence for each species.

At the end of each season, a review of the preliminary soil moisture data analysis, rainfall distribution (Figure 2), and phenological data suggested that specific dates of soil-moisture determinations were more relevant than dates closely following a rainfall. Other scientists (2, 9, 16) have also viewed their data in retrospect to best describe soil-moisture extraction profiles. In 1989, the reading dates chosen for detailed discussion are July 20, August 2, August 31, and September 20. In 1990, the dates are July 26, August 9, August 30, and September 13.

Volumetric water content was subjected to analyses of variance by soil depth and date and then by species and date. Total water was subjected to analyses of variance by profile zone and date. Comparisons of means were made using the protected LSD test (0.05 probability level). Biomass yield and soil-moisture depletion were correlated, r, by species and year because major differences were expected due to the water-use efficiency of each species and differing weather patterns.

RESULTS AND DISCUSSION

Volumetric water content vs. soil depth. Frequent, heavy rainfall in 1989 (Figure 2) caused substantial upper-profile moisture recharge. The plant species utilized this moisture to various degrees which resulted in several differences in upper-profile moisture among species, particularly late in the season. In 1990, rainfall was less plentiful, and the resulting upper soil-moisture profiles were fairly uniform. Also in 1989, devil's-claw was infested with bacterial blight which resulted in its soil-moisture profile being more similar to bare soil during the early part of the season when compared to 1990.

At the beginning of each season, there were some significant differences in soil-moisture content between depths in the profiles of most of the species (Tables 1 and 2). However, the pattern of moisture content was similar for most profiles. The moisture content at 15-cm was significantly drier than at 30-cm in all cases. Many of the soil profiles were significantly drier in the 105-through-120-cm range than in the 45-through-60-cm range. In addition, most of the profiles were significantly wetter at the 150-cm depth than in the 105-through-120-cm range. As the season progressed and the plant species extracted soil moisture from the upper profile, the soil-moisture content at shallow depths was significantly drier than at deeper depths.

Only the soil profile under common cocklebur was significantly drier than that under bare soil at any depth on July 20, 1989 (Table 1). This difference occurred at the 30-cm depth. By August 2, 1989, the soil profiles under all species except velvetleaf were significantly drier than that under bare soil at 15-cm. At 30- and 45-cm the profiles under common cocklebur and johnsongrass were significantly drier than all others except the johnsongrass profile was not significantly different from that of devil's-claw at 45-cm.

On August 31, 1989, the soil profiles under all species were significantly drier than that under bare soil in the upper 45 cm. The johnsongrass profile was significantly drier than that of devil's-claw at 15-cm and 45-cm, and drier than that of tall morningglory at 45-cm. At 60-cm the johnsongrass profile was significantly drier than all others except that of common cocklebur. Only the profiles under cotton and velvetleaf were not significantly drier than that under bare soil at 60-cm. At 75- and 90-cm, the common cocklebur and johnsongrass profiles were significantly drier than all others. Also at 75-cm, only the soil profile under velvetleaf was not significantly drier than that under bare soil. At 105- and 120-cm, the common cocklebur soil profile was significantly drier than all others except that of johnsongrass, and in the 90-through-120-cm range of the soil profile, only the common cocklebur and johnsongrass profiles were significantly drier than that of bare soil. At 135-cm the common cocklebur soil profile was significantly drier than all others except those of cotton and tall morningglory, and was the only soil profile significantly drier than that of bare soil.

On September 20, 1989, which followed a heavy rainfall (Figure 2), the soil profile under devil's-claw was not significantly different from bare soil in the upper 60 cm. The soil profiles under all other species were significantly drier than that under bare soil in the same region. This indicates that devil's-claw was extracting less soil moisture from the upper 60 cm of the profile than the other plants late in the season. At 15-cm the common cocklebur, johnsongrass, and tall morningglory soil profiles were significantly drier than the devil's-claw soil profile. At 30- and 45-cm, the soil profiles under all species were significantly drier than that under devil's-claw. In addition, the velvetleaf profile was significantly drier than the common cocklebur and tall morningglory profiles at 30- and 45-cm. The cotton soil profile was also significantly drier than the profiles under common cocklebur and tall morningglory, but only at 45-cm. At 60-cm, only the cotton, common cocklebur, and johnsongrass soil profiles were significantly drier than that of devil's-claw. At 75-cm, only the velvetleaf profile was not significantly drier from the bare soil profile. Also at 75-cm, the johnsongrass soil profile was significantly drier than all others except common cocklebur. At 90- and 105-cm the common cocklebur and johnsongrass soil profiles were significantly drier than all others and were the only profiles which were significantly drier than the bare soil profile. At 120-cm only the common cocklebur and johnsongrass profiles were significantly different from the bare soil profile, but the johnsongrass soil profile was not significantly different from the cotton or devil's-claw profiles. At 135-cm only the common cocklebur soil profile was significantly different from the bare soil profile, though it was not significantly different from the tall morningglory profile.

In 1990, the soil moisture content of the 105-to-150-cm range of the profile was quite variable. Thus, differences in moisture content between the soil profiles of the species were difficult to determine (Table 2). There were significant differences declared throughout the season at 150-cm, but these can probably be mostly attributed to Type I errors.

On July 26, 1990 there were no significant differences among soil profiles excluding those at 150-cm. By August 9, 1990, the common cocklebur, devil's-claw, and silverleaf nightshade soil profiles were significantly drier than the bare soil profile in the upper 60 cm. At 75-cm only the devil's-claw and silverleaf nightshade soil profiles were significantly drier than that of bare soil.

On August 30, 1990, the soil profiles under all species were significantly drier than that under bare soil and were not significantly different from one another in the upper 75 cm. At 90-cm the cotton, common cocklebur, devil's-claw, and silverleaf nightshade soil profiles were significantly drier than that of bare soil. In addition, the devil's-claw and silverleaf nightshade profiles were significantly drier than all others except common cocklebur at 90-cm.

The soil profiles under all species were significantly drier than bare soil in the upper 90 cm on September 31, 1990, yet there were no significant differences among the soil profiles under the species in the upper 60 cm. At 75-cm the johnsongrass and silverleaf nightshade soil profiles were significantly drier than the tall morningglory profile, and at 90-cm the silverleaf nightshade soil profile was significantly drier than the velvetleaf profile.

Total water content of soil profile. Soil-moisture recharge from rain was generally confined to the upper 45 cm of the soil profile, thus the total water data was divided into upper- and lower-profile (Table 3). The upper-profile zones under common cocklebur and johnsongrass were significantly drier than all others on August 2, 1989, and the upper-profile zones under all plants except under velvetleaf were significantly drier than that under bare soil. There were no significant differences in the lower-profile zone total water at this time. Only the total-profile zones under common cocklebur and johnsongrass were significantly different from that under bare soil.

On August 31, 1989, the upper-profile zones under all species were significantly different from that under bare soil. The johnsongrass upper-profile zone was also significantly drier than that of devil's-claw. In the lower-profile zone, common cocklebur and johnsongrass were significantly drier than all others. Also, the lower-profile zones under cotton and tall morningglory were significantly drier than that under bare soil. In the total-profile zone, the soil profiles under all species were significantly drier than that under bare soil, and the common cocklebur and johnsongrass total-profile zones were significantly drier than those under all other plants.

On September 20, 1989, the upper-profile zones under all species except devil's-claw were significantly drier than that under bare soil. In addition, the johnsongrass upper-profile zone was significantly drier than that under tall morningglory. In the lower- and total-profile zones all plant species were significantly drier than bare soil, and common cocklebur and johnsongrass were significantly drier than all other plants. Also, the total-profile zones under cotton and tall morningglory were significantly drier than that under devil's-claw.

On August 9, 1990, cotton, common cocklebur, devil's-claw, and silverleaf nightshade were significantly drier than bare soil in the upper-profile zone, but were not significantly different from one another. In the total-profile zone only devil's-claw and silverleaf nightshade were significantly drier than bare soil.

By August 30, 1990, the upper-profile zones under all species were significantly drier than that under bare soil, and there were no significant differences among species. This was also true of the total profile zone except that the silverleaf nightshade total-profile was significantly drier than that of johnsongrass. In the lower-profile zone, all species were significantly drier than bare soil except johnsongrass and velvetleaf. Also, the lower-profile zones under devil's-claw and silverleaf nightshade were significantly drier than those under johnsongrass and velvetleaf.

Similar to August 30, the upper-profile zones under all species were significantly drier than that under bare soil, and no significant differences occurred among species on September 13, 1990. All species were significantly drier than bare soil in the lower- and total-profile zones, as well. Also, in the lower- and total-profile zones, silverleaf nightshade was significantly drier than velvetleaf.

Emergence, degree-day accumulation, and phenological development. All species emerged within one week of each other except for johnsongrass and tall morningglory in 1990 (Table 4). The difference in soil-moisture profiles of johnsongrass between 1989 and 1990 reflected its late emergence in 1990.

Degree-day accumulation was similar for all species by the end of 1989. By the end of 1990, however, johnsongrass and tall morningglory had considerably lower degree-day accumulation than the other species.

On July 20, 1989, devil's-claw was the only species that had begun flowering. By August 2, 1989, cotton had reached the early square growth stage, common cocklebur was still in the vegetative growth stage, and johnsongrass was in the early boot growth stage. Velvetleaf and tall morningglory had reached anthesis while devil's-claw was in the early fruit development growth stage. On August 31, 1989, all of the plant species were in the fruit development growth stage. The time corresponded to the early boll growth stage of cotton. By September 20, 1989, all of the plant species were in the fruit maturing growth stage.

As in 1989, devil's-claw was the only species which had begun to flower by the first reading date on July 26, 1990. On August 9, 1990, cotton was in the early square growth stage, common cocklebur and johnsongrass were in the vegetative growth stage, and velvetleaf and devil's-claw were in the early fruit development growth stage. Tall morningglory and silverleaf nightshade had reached anthesis. On August 30, 1990, cotton was in the early boll growth stage, common cocklebur and tall morningglory were in the full bloom growth stage, and the other species were in the fruit development growth stage. By September 13, 1990, all of the species were in the fruit maturing growth stage.

Correlation of biomass yield with total soil-moisture depletion. Soil moisture depletion correlations with inner-circle biomass yield were superior to either outer-circle or total plot yield (data not shown). Still, correlations with inner-circle biomass yield were generally poor and inconsistent (Table 5). However, there were too few data to get good estimates.

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Table 1. Volumetric water content by soil depth under bare soil and six plant species on four selected dates, 1989[a].

Date	Depth	Bare soil	Species[b]					
			GOSHI	XANST	SORHA	ABUTH	PROLO	PHBPU
	(cm)	------------------------(cm³ water/cm³ soil)----------------------						
7/20	15	0.21 a	0.19 a	0.17 a	0.19 a	0.19 a	0.20 a	0.19 a
	30	0 24 a	0.24 a	0 22 b	0.24 a	0.24 a	0.25 a	0.25 a
	45	0.26 a	0.26 a	0.25 a	0.25 a	0 26 a	0.26 a	0.26 a
	60	0 26 a	0.27 a	0 27 a	0.26 a	0.27 a	0.26 a	0 26 a
	75	0.25 a	0.24 a	0 25 a	0.24 a	0.26 a	0.25 a	0 25 a
	90	0.23 a	0.22 a	0.22 a	0.22 a	0.23 a	0 23 a	0.23 a
	105	0.20 a	0.20 a	0 21 a	0.20 a	0.21 a	0 20 a	0.21 a
	120	0 20 a	0.20 a	0.20 a	0 20 a	0 20 a	0 20 a	0 20 a
	135	0 21 a	0.21 a	0.22 a	0.22 a	0 23 a	0 23 a	0 21 a
	150	0 24 a	0.26 a	0.24 a	0 26 a	0.26 a	0.26 a	0 22 a
LSD	(0.05)	0 02	0 02	0.03	0 01	0 03	0 03	0.03
8/2	15	0.20 a	0 15 b	0 12 b	0.13 b	0 16 ab	0.15 b	0 15 b
	30	0 24 a	0.22 a	0 16 b	0 18 b	0 22 a	0 22 a	0 22 a
	45	0 25 a	0 25 a	0.21 c	0 22 bc	0 25 a	0 24 ab	0 25 a
	60	0 26 a	0 26 a	0.24 a	0.24 a	0 26 a	0 25 a	0 26 a
	75	0 25 a	0.24 a	0.23 a	0 23 a	0 25 a	0 24 a	0 25 a
	90	0 22 a	0 22 a	0.21 a	0 22 a	0.23 a	0 22 a	0.22 a
	105	0 20 a	0 20 a	0.20 a	0 20 a	0 21 a	0.20 a	0 21 a
	120	0 19 a	0 20 a	0 20 a	0.19 a	0.20 a	0 19 a	0 20 a
	135	0 21 a	0 21 a	0 22 a	0 22 a	0 23 a	0 23 a	0 20 a
	150	0 24 a	0 25 a	0.24 a	0.26 a	0 25 a	0.26 a	0.22 a
LSD	(0 05)	0.02	0 02	0 03	0 02	0 03	0 03	0 03
8/31	15	0.21 a	0.11 bc	0 11 bc	0.10 c	0.11 bc	0 13 b	0 11 bc
	30	0 23 a	0.15 b	0.14 b	0 13 b	0 14 b	0 16 b	0 16 b
	45	0 26 a	0 19 bc	0.18 bc	0 16 c	0.18 bc	0 20 b	0.20 b
	60	0.26 a	0.23 ab	0.20 bc	0.18 c	0 23 ab	0.22 b	0 22 b
	75	0.25 a	0 22 b	0 19 c	0 18 c	0 23 ab	0 22 b	0 22 b
	90	0 22 a	0.21 a	0.17 b	0.17 b	0.22 a	0.21 a	0.21 a
	105	0.20 a	0.20 a	0.15 c	0.17 bc	0 19 ab	0.19 ab	0 20 a
	120	0 19 ab	0 19 ab	0 15 c	0.17 bc	0.19 ab	0 20 a	0 19 ab
	135	0.21 a	0.20 ab	0.18 b	0.21 a	0.22 a	0 22 a	0 20 ab
	150	0 23 a	0.25 a	0.22 a	0 26 a	0.25 a	0.25 a	0 22 a
LSD	(0 05)	0 02	0.03	0 03	0.01	0.03	0 03	0 03
9/20	15	0 23 a	0.19 bc	0.18 c	0 16 c	0.19 bc	0.22 ab	0.18 c
	30	0.26 a	0.21 bc	0.22 b	0.20 bc	0.19 c	0 25 a	0.22 b
	45	0.27 a	0 19 c	0 22 b	0 20 bc	0.18 c	0.25 a	0 22 b
	60	0.27 a	0.20 cd	0 21 bcd	0.18 d	0.22 bc	0.24 ab	0.21 bcd
	75	0.25 a	0.20 cd	0.19 de	0.17 e	0.23 ab	0 22 bc	0.21 bcd
	90	0.22 a	0 20 a	0 16 b	0.16 b	0 21 a	0 20 a	0.20 a
	105	0.20 a	0 19 a	0 14 b	0.15 b	0.20 a	0.18 a	0 19 a
	120	0 19 a	0 18 ab	0.14 c	0 16 bc	0 19 a	0 18 ab	0 19 a
	135	0 21 ab	0.20 ab	0.17 c	0 20 ab	0 22 a	0.22 a	0 19 bc
	150	0.23 a	0.25 a	0.21 a	0 25 a	0.25 a	0.25 a	0.22 a
LSD	(0.05)	0.02	0 02	0.03	0 02	0.03	0 03	NS

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

[b]The computer code GOSHI indicates cotton; XANST, common cocklebur, SORHA, johnsongrass; ABUTH, velvetleaf, PROLO, devil's-claw, and PHBPU, tall morningglory

Table 2. Volumetric water content by soil depth under bare soil and seven plant species on four selected dates, 1990[a].

Date	Depth	Bare soil	Species[b] GOSHI	XANST	SORHA	ABUTH	PROLO	PHBPU	SOLEL
	(cm)	----------(cm^3 water/cm^3 soil)----------							
7/26	15	0.21 a	0.21 a	0 19 a	0.22 a	0.21 a	0.21 a	0 22 a	0 19 a
	30	0 25 a	0.25 a	0.24 a	0.25 a	0.24 a	0 23 a	0.25 a	0 23 a
	45	0.25 a	0.24 a	0.24 a	0.26 a	0.24 a	0.24 a	0.26 a	0 23 a
	60	0.25 a	0.24 a	0.25 a	0.25 a	0 24 a	0.24 a	0.26 a	0 23 a
	75	0.25 a	0.25 a	0 26 a	0.25 a	0 24 a	0.25 a	0.26 a	0 23 a
	90	0.24 a	0.24 a	0.26 a	0.25 a	0.24 a	0.25 a	0.26 a	0 23 a
	105	0 22 a	0.22 a	0.26 a	0.24 a	0.25 a	0.24 a	0.24 a	0 23 a
	120	0.22 a	0.21 a	0.25 a	0.25 a	0.25 a	0.24 a	0.22 a	0.22 a
	135	0 23 a	0.19 a	0 24 a	0.26 a	0 25 a	0 24 a	0 21 a	0 22 a
	150	0.26 ab	0.19 c	0.25 ab	0.28 a	0 26 ab	0 26 ab	0 23 bc	0 23 bc
LSD	(0.05)	0 02	0.04	0.02	0 01	0 02	0.02	NS	NS
8/9	15	0.20 a	0.19 ab	0 14 c	0.19 ab	0.17 abc	0 15 bc	0 19 ab	0 14 c
	30	0 25 a	0.23 a	0.17 bc	0.23 a	0 21 ab	0 16 c	0 23 a	0 15 c
	45	0 25 a	0 21 ab	0 18 b	0 24 a	0.21 ab	0 17 b	0 24 a	0 18 b
	60	0.25 a	0.23 ab	0 20 bc	0.25 a	0 23 ab	0 19 c	0.25 a	0 20 bc
	75	0.25 ab	0.24 ab	0 23 bc	0.25 ab	0 24 ab	0 21 c	0 26 a	0 21 c
	90	0.24 a	0.24 a	0.25 a	0.24 a	0 24 a	0 23 a	0.26 a	0 22 a
	105	0.23 a	0.22 a	0 25 a	0 24 a	0.24 a	0 23 a	0.24 a	0 22 a
	120	0.22 a	0 21 a	0 25 a	0.25 a	0.25 a	0 23 a	0 22 a	0 22 a
	135	0.23 a	0.19 a	0.24 a	0 26 a	0 25 a	0 24 a	0 21 a	0 21 a
	150	0 26 a	0 19 b	0.25 a	0.27 a	0.26 a	0.25 a	0.23 ab	0 23 ab
LSD	(0.05)	0 03	0.03	0.03	0 02	0 03	0 02	NS	0 03
8/30	15	0 19 a	0 10 b	0 09 b	0 10 b	0 09 b	0 11 b	0 10 b	0 09 b
	30	0 24 a	0 11 b	0 11 b	0 11 b	0.10 b	0 12 b	0 11 b	0 10 b
	45	0 24 a	0 11 b	0 12 b	0 13 b	0 12 b	0 13 b	0 13 b	0 12 b
	60	0.25 a	0.14 b	0.13 b	0 16 b	0.15 b	0 14 b	0 15 b	0 13 b
	75	0.25 a	0.17 b	0 15 b	0 18 b	0 18 b	0 15 b	0 19 b	0 15 b
	90	0 24 a	0.20 bc	0.17 cd	0.21 ab	0 21 ab	0.16 d	0 22 ab	0 16 d
	105	0 22 a	0.20 a	0.20 a	0.22 a	0.23 a	0.17 a	0 22 a	0 18 a
	120	0.21 a	0.20 a	0 21 a	0 24 a	0 24 a	0 19 a	0 21 a	0.18 a
	135	0 23 a	0.18 a	0 22 a	0.25 a	0.24 a	0.22 a	0.21 a	0 19 a
	150	0 26 ab	0.19 d	0.23 abcd	0 27 a	0.26 ab	0 25 abc	0.22 bcd	0 21 cd
LSD	(0 05)	0 02	0 04	0.02	0 02	0.03	0 03	0 05	0 03
9/13	15	0.19 a	0.09 b	0.09 b	0 08 b	0 09 b	0 10 b	0.09 b	0 08 b
	30	0.23 a	0.10 b	0.10 b	0.10 b	0.09 b	0 12 b	0.11 b	0 10 b
	45	0.23 a	0.11 b	0.11 b	0.11 b	0.11 b	0.12 b	0 13 b	0 11 b
	60	0.24 a	0.12 b	0.12 b	0.12 b	0.13 b	0.13 b	0 14 b	0 12 b
	75	0 24 a	0.14 bc	0 14 bc	0.13 c	0.15 bc	0.14 bc	0.17 b	0 13 c
	90	0 23 a	0.17 bc	0 15 bc	0 15 bc	0.19 ab	0 15 bc	0.18 bc	0 14 c
	105	0.22 a	0.18 a	0 17 a	0 18 a	0.21 a	0 16 a	0 19 a	0 16 a
	120	0.21 a	0.19 a	0 17 a	0 21 a	0.23 a	0.17 a	0.19 a	0 16 a
	135	0.23 a	0.17 a	0 18 a	0 23 a	0 24 a	0 19 a	0.19 a	0 16 a
	150	0.26 a	0.18 b	0.21 ab	0.26 a	0.26 a	0 21 ab	0.21 ab	0 19 b
LSD	(0.05)	0.02	0.05	0.02	0.02	0.03	0 04	0.05	0 04

[a]Within a row, means followed by the same letter are not significantly different at the 0 05 probability level according to a protected LSD test.

[b]The computer code GOSHI indicates cotton; XANST, common cocklebur; SORHA, johnsongrass, ABUTH, velvetleaf; PROLO, devil's-claw, PHBPU, tall morningglory, and SOLEL, silverleaf nightshade

Table 3. Total water content of the upper 45 cm, lower 105 cm, and total soil profiles under bare soil and each plant species on four selected dates, 1989 and 1990[a].

			Total water content							
				Species[b]						
Year	Date	Profile zone[c]	Bare soil	GOSHI	XANST	SORHA	ABUTH	PROLO	PHBPU	SOLEL
			(cm)							
1989	7/20	Upper	10.3 a	10 0 a	9.1 a	9 6 a	9 9 a	10 2 a	9 8 a	--
		Lower	24 0 a	24 1 a	24 4 a	24 1 a	24 8 a	24 4 a	24 0 a	--
		Total	34 3 a	34 1 a	33 5 a	33 7 a	34.7 a	34.6 a	33 8 a	--
	8/2	Upper	10 0 a	8 7 b	6 6 c	7 2 c	8 9 ab	8 5 b	8 6 b	--
		Lower	23 6 a	23 7 a	22 8 a	23 2 a	24 5 a	23 9 a	23 5 a	--
		Total	33 6 a	32 4 a	29 4 c	30 4 bc	33 4 a	32 4 a	32 1 ab	--
	8/31	Upper	10 1 a	6 2 bc	5 8 bc	5 3 c	5 8 bc	6 8 b	6 3 bc	--
		Lower	23 6 a	22 1 b	18 5 c	19.3 c	22 6 ab	22 3 ab	21 7 b	--
		Total	33 7 a	28 3 b	24.3 c	24 6 c	28 4 b	29 1 b	28 0 b	--
	9/20	Upper	11 1 a	8 9 bc	8 9 bc	8 1 c	8 6 bc	10 6 a	9 0 b	--
		Lower	23.9 a	20 9 b	18 3 c	18 7 c	22 3 b	22 2 b	21 0 b	--
		Total	35 0 a	29 8 c	27 2 d	26 8 d	30 9 bc	32 8 b	30 0 c	--
1990	7/26	Upper	10 5 a	10 0 a	9 8 a	10 7 a	10 1 a	9 9 a	10 6 a	9 4 a
		Lower	25.2 a	23 6 a	26 6 a	26 5 a	25 8 a	25 7 a	25 5 a	23 9 a
		Total	35 7 a	33 6 a	36 4 a	37 2 a	35 9 a	35 6 a	36 1 a	33 3 a
	8/9	Upper	10 2 a	8 1 bc	7 1 c	9 5 ab	8 6 abc	7.0 c	9 5 ab	6 9 c
		Lower	25 2 a	23 0 a	24 4 a	26 1 a	25.2 a	23 1 a	25 0 a	22 2 a
		Total	35 4 a	31 1 abc	31 5 abc	35 6 a	33 8 ab	30 1 bc	34 5 a	29 1 c
	8/30	Upper	9.7 a	4 6 b	4 5 b	4 8 b	4.5 b	5 2 b	4 9 b	4 5 b
		Lower	24 7 a	18 7 bcd	18 7 bcd	22 0 ab	21 4 abc	18 2 cd	20 6 bcd	17 3 d
		Total	34 4 a	23 3 bc	23 2 bc	26 8 b	25 9 bc	23 4 bc	25 5 bc	21 8 c
	9/13	Upper	9.4 a	4 2 b	4 3 b	4 2 b	4 1 b	4 9 b	4 6 b	4 2 b
		Lower	24 3 a	16 7 bcd	16 4 cd	18.3 bcd	20.0 b	16 7 bcd	18 4 bcd	15 4 d
		Total	33 7 a	20 9 bc	20.7 bc	22.5 bc	24 1 b	21.6 bc	23 0 bc	19 6 c

[a]Within a row, means followed by the same letter are not significantly different at the 0 05 probability level according to a protected LSD test

[b]The computer code GOSHI indicates cotton, XANST, common cocklebur, SORHA, johnsongrass, ABUTH, velvetleaf; PROLO, devil's-claw, PHBPU, tall morningglory, and SOLEL, silverleaf nightshade

[c]"Upper" refers to the soil profile from 0 to 45 cm, "lower" from 45 to 150 cm, and "total" from 0 to 150 cm

Table 4. Emergence date and degree-day accumulation for each plant species on five selected dates, 1989 and 1990[a].

	1989						1990					
Species[b]	Emerged	7/20	8/2	8/31	9/20	Harvest[c]	Emerged	7/26	8/9	8/30	9/13	Harvest[d]
		(degree days)						(degree days)				
GOSHI	7/1	208	339	611	755	809	6/25	376	514	784	963	1042
XANST	6/24	276	407	679	818	818	6/30	313	451	721	900	979
SORHA	6/28	236	367	639	783	837	7/19	79	217	487	666	745
ABUTH	6/24	276	407	679	818	818	6/25	376	514	784	963	1042
PROLO	6/26	256	387	659	798	798	6/30	313	451	721	900	979
PHBPU	6/25	267	398	670	814	868	7/13	123	261	531	710	789
SOLEL	--	--	--	--	--	--	6/30	313	451	721	900	979

[a]A base temperature of 15.5 C was used to calculate degree-day accumulation for each species from emergence through harvest

[b]The computer code GOSHI indicates cotton, XANST, common cocklebur, SORHA, johnsongrass, ABUTH, velvetleaf, PROLO, devil's-claw, PHBPU, tall morningglory, and SOLEL, silverleaf nightshade

[c]XANST, ABUTH, and PROLO were harvested September 20 GOSHI, SORHA, and PHBPU were harvested October 12

[d]All species were harvested September 25

Table 5. Correlation of biomass yield with total soil-moisture depletion for each plant species, 1989 and 1990.

	1989			1990		
Species[a]	Biomass	Moisture depletion	Correlation coefficient	Biomass	Moisture depletion	Correlation coefficient
	(kg/ha)	(cm)		(kg/ha)	(cm)	
GOSHI	10 100	5.4	0.36	8 200	12.8	0.12
XANST	26 300	9.4	-0.35	16 500	13.0	-0.42
SORHA	15 700	9.1	0.92	9 000	11.2	0.03
ABUTH	3 900	5.3	0.65	3 800	9.6	0.02
PROLO	3 600	4.6	0.25	12 700	12.1	-0.32
PHBPU	14 800	5.7	0.19	7 800	10.7	-0.93
SOLEL	--	--	--	6 600	14.1	-0.68

[a]The computer code GOSHI indicates cotton; XANST, common cocklebur; SORHA, johnsongrass; ABUTH, velvetleaf; PROLO, devil's-claw; PHBPU, tall morningglory; and SOLEL, silverleaf nightshade.

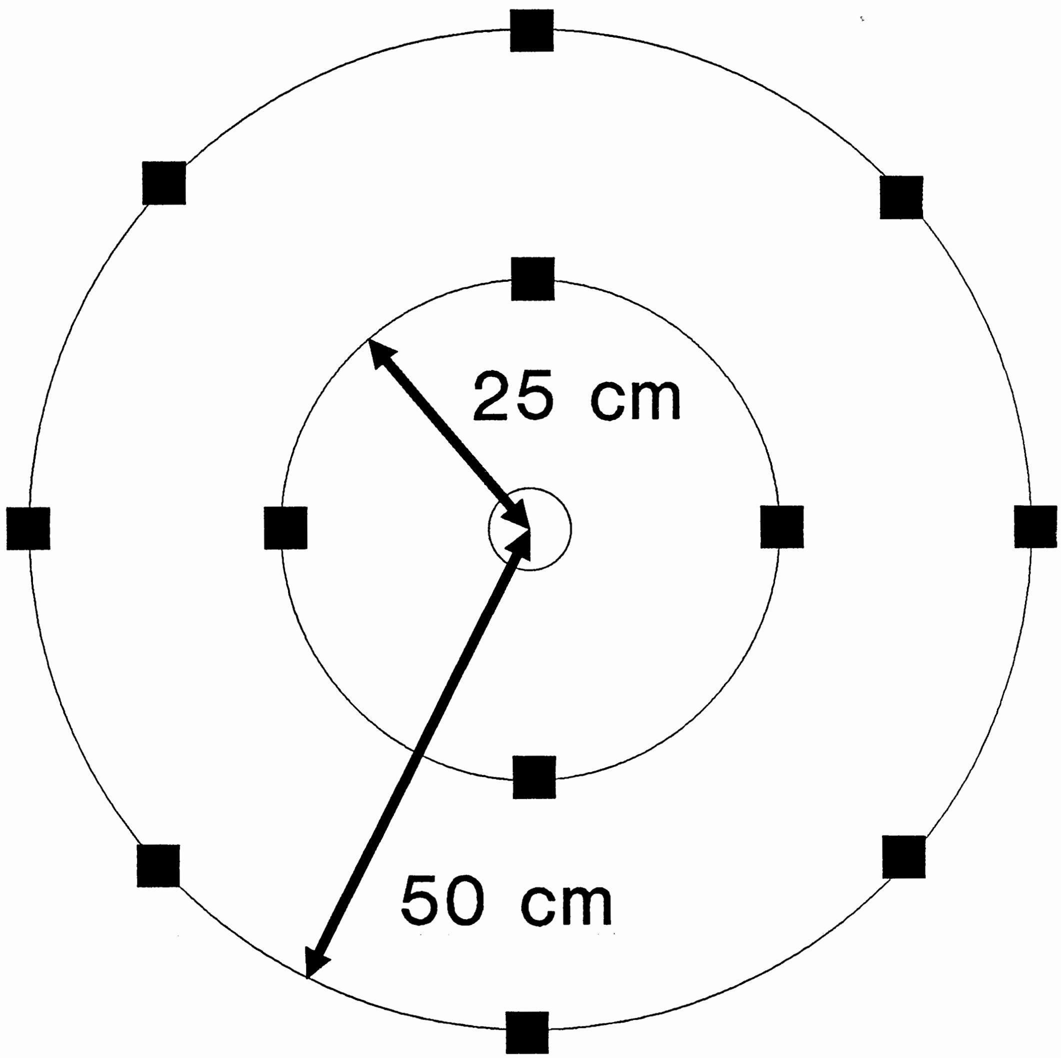

Figure 1. Planting pattern for an experimental unit consisting of a neutron probe access tube in the center of the plot and two concentric circles of plants. Plant positions are indicated by the darkened squares.

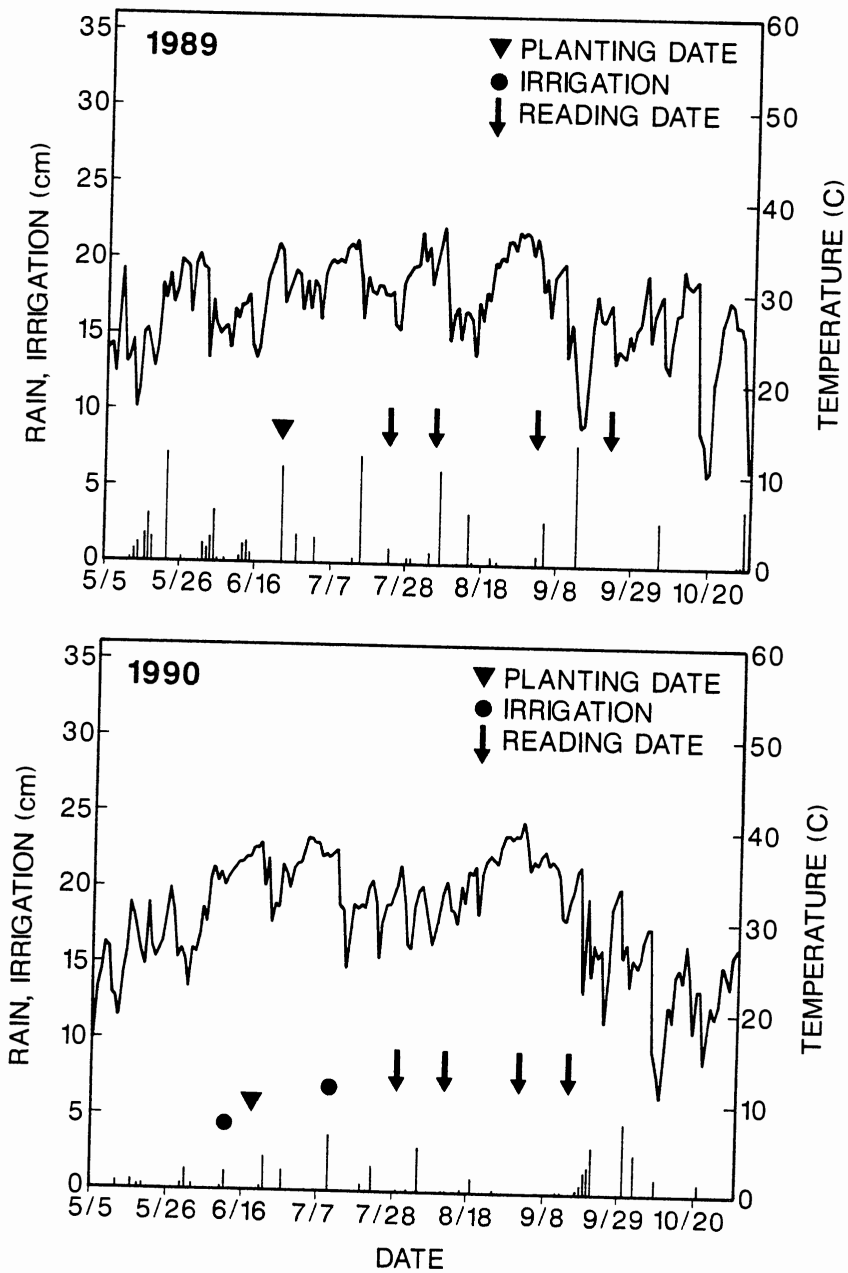

Figure 2. Rainfall and irrigation distribution and amounts and maximum daily temperature at Perkins, Oklahoma, in May through October, 1989 and 1990.

VITA

Brent Douglas Jacobson

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Master of Science

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