Rooting Depth, Growth and Yield of Sorghum as Affected by Soil Water Availability in an Ultisol and an Oxisol[1, 2]

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ABSTRACT

Grain and stover yields of RS 671 grain sorghum were measured at Barranquitas in an Oxisol and at Corozal in an Ultisol. Measurements were made of weather factors, soil moisture content and tension, plant growth, water deficits and rooting depths. At each site a plot was irrigated as often as necessary to maintain a soil water tension of less than 1 bar. Nonirrigated plots at Corozal were watered whenever necessary to prevent plants from wilting permanently.

During a prolonged drought and at grain filling, sorghum extracted water in the Oxisol to a depth of 120 cm. Plants became water stressed after the soil water tension at a depth of 90 cm reached 15 bars. In the Ultisol, sorghum plants were unable to effectively extract available soil moisture at depths below 45 cm. Both plant growth and grain yield were greater in the Oxisol than in the Ultisol. The relative soil compaction of the Ultisol was greater than that of the Oxisol.

INTRODUCTION

Previous results obtained by the authors[4] indicated that corn plants became water stressed after water tensions in the vicinity of 15 bars developed at a 90-cm depth in an Oxisol at Barranquitas. Furthermore, in an Ultisol at Corozal, corn plants were unable to effectively extract soil moisture at depths below 30 cm. Plant growth and yield in the Oxisol were greater than in the Ultisol. The soil was more compact in the latter than in the former.

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[4] Wahab, A., Talleyrand, H., and Lugo-López, M. A., Rooting depth, growth and yields of corn as affected by soil water availability in typical Ultisols and Oxisols, J. Agr. Univ. P.R. 60(3): 329–35, 1976.

This is a report on a similar study with sorghum, an important food crop with great production potential in the tropics. Basic information on water availability and rooting depths in soils of the hot humid tropics is urgently needed in order to choose varieties that can fully exploit available soil moisture and to schedule irrigations for maximum effectiveness.

MATERIALS AND METHODS

RS 671, a well-adapted grain sorghum for the tropics, with 80% germination at the end of 7 days was used. Test plots were selected at Barranquitas (Oxisol) and at Corozal (Ultisol). Soil conditions, plot size, experimental design, fertilization, other soil management practices, and treatments were identical as for the corn experiment previously mentioned.

Both sites were planted on January 12, 1973, in 51-cm rows to obtain even stands of six sorghum plants per meter of row. Immediately after planting, test areas were sprayed with preemergence herbicide (Simazine),[5] and treated with rat poison (Warfarin). Due to poor sorghum emergence at both sites, seeds were replanted on January 29. Emergence was good at both sites, but seedlings lacked vigor and plants appeared stunted. As time progressed plants damped-off considerably despite weekly applications of Dithane. Plots at both sites were replowed on March 15, and furrows were treated with a mixture of Terraclor (PCNB), Dithane, and Sevin. Immediately thereafter, seeds freshly treated with Captan-75 were planted and nematicide was applied at the rate of 1 kg/plot. Germination was excellent at both sites and seedlings grew rapidly. Test areas were irrigated as often as necessary to ensue adequate moisture for germination and early plant growth. Weekly applications of fungicide (Dithane) and insecticide (Sevin) were made at both sites following germination to protect against leaf-eating insects and damping-off organisms. Weeds were eliminated by hand as often as necessary.

One sorghum plot at each site was irrigated as often as necessary to maintain a soil moisture tension of 0.2 bar or less until crop growth ceased to permit estimation of yield limitation due to moisture. Gypsum soil moisture blocks were installed at 15-cm intervals down to 120 cm, and resistance recorded was converted to moisture tension in bars.

At both sites plant heights were determined on 30 test plants per plot

[5] Trade names in this publication are used for the sole purpose of providing specific information. Mention of a trade name does not constitute a guarantee or warranty of the equipment by the authors or the Agricultural Experiment Station of the University of Puerto Rico or an endorsement over other equipment not mentioned.

68 days after planting. Height was measured from the base of the plant to the tip of the panicle. Plant diameter was measured at the fifth node from the proximal end. As the crop approached physiological maturity, trenches were dug between rows to observe maximum depth and pattern of rooting in the soil profile.

Sorghum was harvested at both sites on July 3 (100 days after planting), and grain and stover yields were determined. Grain yields were expressed as kilograms per hectare at 15% moisture. Stover yields were also expressed as kilograms per hectare but on a 100% dry matter basis.

Records of temperature, relative humidity, rainfall, and evaporation from a class A pan were kept.

As the soil moisture of the nonirrigated plots diminished and plants began to wilt, the third uppermost leaf was sampled for leaf water deficit (LWD) determinations.[6] Plants were 78 and 56 days old at Barranquitas and Corozal, respectively, when the measurements were started.

RESULTS AND DISCUSSION

ROOTING DEPTH

Some physical and chemical properties of the test soils at Barranquitas and Corozal were given in a previous publication.[4] The Oxisol at Barranquitas had a greater capacity to hold water than the Ultisol at Corozal. The high soil resistance to penetration of the Ultisol could mechanically impede root penetration, reduce total air capacity and air transmission rate of the soil, and thus result in lower total root surface area and absorbing capacity than roots of plants growing in the Oxisol[7].

Data on plant heights 68 days after planting are given in the following tabulation:

Soil	*Irrigated, cm*	*Nonirrigated, cm*
Oxisol	141	138
Ultisol	110	106

At grain-filling stage 68 days after seeds were planted, plants growing in an Oxisol were 28% taller than those growing in the Ultisol.

Data on effective rooting depths of sorghum growing in the two soils are presented in figures 1 and 2. In the Oxisol, soil moisture was depleted significantly in the soil profile during a drought period. As in the case of corn, sorghum plants extracted moisture from a depth of 90 cm. As

[6] Catsky, T., Leaf disc method for determining water saturation deficit, UNESCO, Arid Zone Res. 25: 353–60. UNESCO, Paris, 1965.

[7] Vomocil, T. A., and Flocker, W. T., Soil compaction—its effects on storage and movement of soil, air and water, Trans. Amer. Soc. Agr. Eng. 4: 242–6, 1961.

moisture tension at this depth increased to 13 bars, plants began to use the available moisture between the 90- and 120-cm depth of soil layer since at no time were plants severely wilted.

Figure 2 shows that plants wilted in the Ultisol when soil moisture tension at 30 cm was only 9 bars. On May 23, just 6 dry days following field capacity conditions throughout the soil profile, plants were severely wilted. It is apparent that sorghum plants were unable to extract soil moisture beyond a depth of 45 cm in this soil. Indeed, as can be seen in the following tabulation, roots of sorghum plants in the Ultisol were not

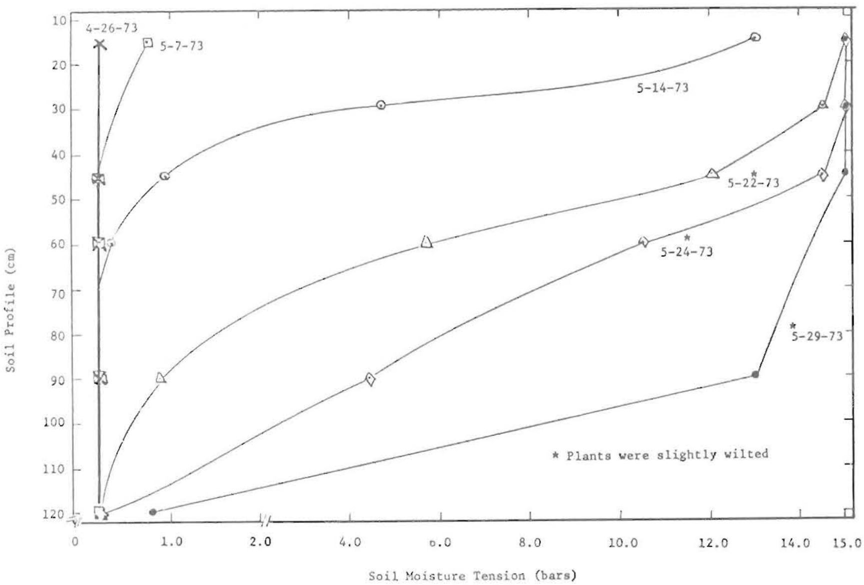

FIG. 1.—Water depletion in an Oxisol (Barranquitas) supporting sorghum growth during a drought period.

observed at depths greater than 40 to 45 cm, whereas in the Oxisol roots of both irrigated and nonirrigated plants were observed at depths of 90 to 100 cm:

Soil	*Maximum root depth, cm*	*Depth of 75% of total roots, cm*
Oxisol	90–100	30
Ultisol	40–45	15

Observations of root distribution patterns showed that about 75% of total roots were confined to the upper 15 cm of soil in the Ultisol as contrasted to 75% in the upper 30 cm in the Oxisol.

As previously pointed out in the case of corn, it appeared that vertical soil water movement was limiting in the Ultisol test plots but not the Oxisol. One plausible explanation for this difference is the higher bulk density, greater compaction, and lower porosity of the Ultisol compared to that of the Oxisol.

Table 1 shows water saturation deficits of sorghum growing in the Oxisol and the Ultisol. As in the case of corn, plants exhibited water deficits in both irrigated and nonirrigated plots; and plants growing in the Oxisol were always under less water stress than those growing in the Ultisol. Water tension values indicate that at both sites plants were able

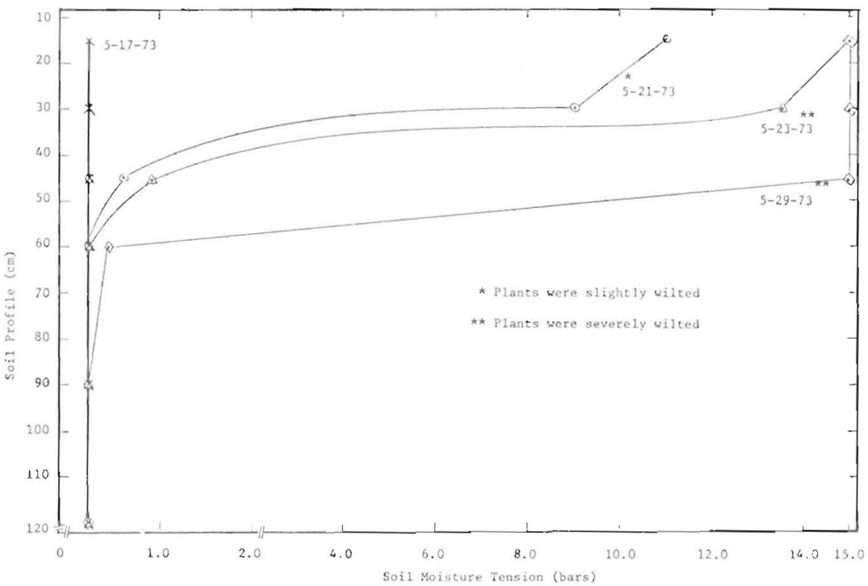

FIG. 2.—Water depletion in an Ultisol (Corozal) supporting sorghum growth during a drought period.

to utilize all of the available moisture at the 45-cm depth. It is inferred that sorghum plants are able to utilize available soil moisture in an Ultisol better than corn.

CROP YIELD

As shown in table 2, grain yields of the nonirrigated Oxisol plots exceeded those of the irrigated plot by 46%. Yields were 2,617 and 3,836 kg/ha for the irrigated and nonirrigated plots, respectively. On the other hand, the dry matter yields of the irrigated plot were 26% higher than yields of the nonirrigated plots. Also, whereas the ratio of grain weight to stover weight was 1.00 for the nonirrigated plot, this ratio was 0.56 for the irrigated plot. Meterological data showed that 242 mm of rain fell in Barranquitas from sowing to harvest, and evaporation accounted for 513 mm. To partially offset this rainfall deficit, the irrigated plot received 178 mm of water. The 3,836 kg/ha versus 2,617 kg/ha for the irrigated plot was due in part to a poor stand of diseased plants in the irrigated plot.

Grain yields in the Ultisol were essentially the same (about 2,600 kg/ha) for irrigated and nonirrigated plots. They were much lower than those obtained for the nonirrigated plot in the Oxisol. Stover dry weights were also almost the same for both irrigated and nonirrigated plots, and the ratios of grain to stover weight were 0.65 and 0.62, respectively. An examination of the meterological data shows that during the period from sowing to harvest, there were 565 and 469 mm of rainfall and evaporation, respectively, on the Ultisol. Also during this period 381 mm of water were

TABLE 1.—*Mean leaf water deficits (LWD) of sorghum plants growing with and without irrigation in an Oxisol (Barranquitas) and in an Ultisol (Corozal)*

Sampling date	Time of day	LWD	
		Irrigated	Nonirrigated
		%	%
	Oxisol (Barranquitas)		
5-17-73	11:00 AM	5.84	4.85
5-22-73	2:00 PM	2.92	3.71
5-24-73	2:30 PM	6.10	10.19
5-29-73	10:00 AM	6.32	9.24
5-30-73	12:00 N	3.43	8.52
Mean		4.92	7.30
	Ultisol (Corozal)		
5-11-73	1:30 PM	6.58	7.91
5-21-73	1:00 PM	4.04	9.18
5-23-73	1:00 PM	8.82	17.41
5-24-73	11:45 AM	5.56	13.05
5-29-73	12:00 N	6.64	19.60
5-30-73	10:00 AM	6.05	8.73
Mean		6.28	12.65

TABLE 2.—*Grain and stover yields of sorghum growing in an Oxisol and in an Ultisol, both with and without irrigation*

Soil	Moisture status	Grain yield (15% water)	Stover yields (100% dry matter)
		Kg/ha	*Kg/ha*
Oxisol	Irrigated	2617	4831
	Nonirrigated	3836	3827
Ultisol	Irrigated	2662	3927
	Nonirrigated	2535	4062

applied to the irrigated plot and 178 mm were applied to the nonirrigated plots to keep plants from wilting permanently.

From the previously reported corn results and from the sorghum yield data herein discussed, it would appear that in the Ultisol crop growth and yields are limited by factors other than fertility and moisture. Indeed, when the data on relative soil compaction is considered, one can infer that because of the high soil compaction of the Ultisol (25 to 28 bars), oxygen diffusion rates were reduced and roots were unable to elongate and proliferate as well as they would in the less compact Oxisol.

RESUMEN

Se sembró un tipo de sorgo para la producción de grano, RS 671, a principios de enero de 1973 en Barranquitas (Oxisol) y en Corozal (Ultisol). Las parcelas se encalaron, se abonaron y se trataron con plaguicidas antes de la siembra. En ambos sitios, hubo que resembrar a mediados de marzo por la pobre germinación de las semillas. Durante el ciclo de desarrollo de la cosecha se tomaron datos meterológicos, de la humedad del suelo y la tensión a la que ésta era retenida, del crecimiento y déficit hídrico de la planta y de la profundidad de penetración de las raíces. Al cosechar, se tomaron datos de rendimiento en grano y rastrojo. En cada sitio, se regó una parcela cuantas veces fue necesario para mantener la tensión con la que el suelo retenía el agua a menos de 1 bar.

Los resultados indican que, durante una sequía prolongada y al tiempo en que el grano se está llenando, el sorgo sembrado en el Oxisol extrajo agua a 120 cm. de profundidad; las plantas sufrieron por falta de agua después que la tensión con la que el suelo la retenía a 90 cm. de profundidad, llegó a 15 bares. En el Ultisol, las plantas de sorgo no pudieron extraer eficazmente la humedad disponible a profundidades mayores de 45 cm. El crecimiento de las plantas en el Oxisol fue mayor que en el Ultisol. La compactación relativa fue mayor en el Ultisol que en el Oxisol. Es evidente que el sorgo pudo ultilizar mejor que el maíz el agua disponible en el suelo cuando ambos se sembraron en un Ultisol.