Sugar Beet Irrigation Experiments in Wyoming[1]

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Experimental material reported in this paper was developed during three years of irrigation experiments by the University of Wyoming Agricultural Experiment Station in cooperation with the Great Western Sugar Company and Holly Sugar Corporation at a number of locations throughout Wyoming:[3]

Big Horn Basin:	1951 Powell, Cowley, Worland
	1952 Powell, Worland (new location)
	1953 Powell (new location)
Southeastern Wyoming:	1951 Wheatland, Torrington
	1952 Wheatland, Torrington
	1953 Torrington (new location)

This paper discusses only the principal objective of determining how dry the soil might be permitted to become before a significant reduction occurred in yield or sugar. Supplementary observations and analysis, of much value in interpreting results and in improving methodology, are not reported.

Procedure

Experimental design consisted of a single applied variable of the availability of soil moisture in the field immediately before irrigation. Fertility was minimized as a factor by selecting fields with a history of generally high yields and operated by growers of known ability, and by applying fertilizers each year according to the best available recommendations. The soil moisture availability was expressed in atmospheres tension as being the least affected by differences in soil texture, fertility, compaction and climate of the currently used methods of expressing soil moisture. While not directly usable by the grower, establishment of critical levels of moisture tension for irrigation appears to offer basic recommendations most stable over a wide range of soil types and climatological regimes.

Bouyoucos block electrical soil moisture units were used to determine soil moisture tensions throughout this study. As used in outfield work, all resistance readings were corrected for temperature and converted to atmospheres tension by means of a family of tension-resistance laboratory curves. Adjustments were made for calibration drift in the field.

Each experiment consisted of 16 plots comprising 4 replications of 4 irrigation treatments. Plots, 8-12 rows wide, were considered to be 100 feet long, although at some locations it was necessary to irrigate 300 feet

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of row to fit with irrigation practices over the balance of the field. The plots at Torrington in 1953 were situated on the experimental substation. All other experimental sites were located on fields of commercial growers after the planting and emergence of the sugar beets. Nominal irrigation treatments were to apply irrigation water in some excess to assure root zone saturation, when the soil-moisture tension reached 1 atmosphere (W-4), 2 atmospheres (W-3), 4 atmospheres (W-2), and 8 atmospheres (W-l). Yield determinations were made from 100 feet of the two central rows of each plot, hand topped, and washed at the nearest sugar factory.

Results

1951

New soil moisture units installed at all locations were found to be faulty and were replaced at midseason. The consequent root zone disturbance was found to render much of the moisture-tension data unreliable. While of invaluable assistance in refining subsequent field work and in indicating yield trends, results are not considered sufficiently precise to warrant reporting in this paper.

1952

Two columns of Bouyoucos blocks were installed in each plot at the upper and lower 1/4 length of one of the harvest rows (50 feet between columns) at depths of 6 inches, 18 inches, 30 inches, and 42 inches. Irrigations were based on the mean of four replicates. These means were calculated for the 6 inch units at the start of the season, on the average of the 6 inch and 18 inch units when the latter showed a tension rise above field capacity (presumed to indicate progressive root development), and on a mean of the 18 inch and 30 inch units when the latter showed a tension increase.

Tensions on which irrigations were scheduled, were therefore a mean of 8 block readings when a single horizon was used, and a mean of 16 block readings when two horizons were averaged. At the end of the season blocks were excavated, and all readings prior to irrigations were adjusted for the indicated calibration drift.

The assumption that root penetration would be indicated by tension rises and that therefore mean tensions would indicate the lower *2/3* of the root zone was found to be untrue. This fact, plus indications that yields may be more closely correlated with the tension at 6 inches than at 18 inches (or the mean of the 6 inch and 18 inch tensions), directed the reporting of all tensions as a mean for single horizons. Departures from intended treatment tensions which may be observed in Table 1 are the combined result of the change in the method of calculating means and the postseason calibration corrections. Mean integrated tensions were calculated for all plots by a method similar to that described by Taylor (1)[4]. The data are not reported since no advantage was found for expressing mean tensions in this manner, and in comparing Wheatland and Torrington data, this appeared to mask causative data. Seasonal mean peak tensions *in* atmospheres are presented in Table 1.

[4] Numbers in parentheses refer to literature cited.

Table 1,—Mean Atmosphere Peak Tension, 1952.

		Treatment			
		W-l (8 atm)	W-2 (4 atm)	W-3 (2 atm)	W-4 (1 atm)
Powell	Mean 6" depth	8.0	6.0	4.3	2.9
	Mean 18" depth	6.7	5.5	2.0	1.3
	Number of peak tensions	2	3	4	6
Worland	Mean 6" depth	10.2	4.1	3.0	2.2
	Mean 18" depth	3.3	0.6	0.3	0.4
	Number of peak tensions	2	4	5	6
Wheatland	Mean 6" depth	5.0	4.7	3.6	2.4
	Mean 18" depth	3.0	4.2	1.6	1.0
	Number of peak tensions	1	2	3	4
Torrington	Mean 6" depth	6.1	5.7	4.6	3.2
	Mean 18" depth	4.6	4.5	.6	1.4
	Number of peak tensions	2	3	4	5

With the exception of a slight tension rise at 30 inches at Powell for the dry treatment, all other 30 inch and 42 inch readings remained at or near field capacity of about 0.3 atmosphere. Whenever the final reading for the season approached design levels for irrigation it was included in the seasonal mean. The existence of treatment differences, and tension rises at 18 inches for the dry treatments, is emphasized in Table 1. The relatively low 18 inch tensions at Worland reflect poor root development caused by a very heavy infestation of root rot. The small number of tension peaks for the Wheatland location were the result of a high water table through most of the growing season.

No significant differences between treatments were found for stand count, although the Worland data approached significance in the direction of increasing count with increasing moisture. Similarly, no significant differences were found for percentage of sugar. Table 2 presents the results for yield.

Table 2.—Yield Data and Number of Irrigations, 1952.

Treatment	Powell		Worland		Wheatland		Torrington	
	Yield	No. Irr.	Yield	No. Irr.	Yield	No. Irr.	Yield	No. Irr.
8 atm (W-1)	12.0	2	5.9	1	14.1	0	11.8	1
4 atm (W-2)	14.7	3	9.3	4	14.2	1	14.4	2
2 atm (W-3)	16.3	4	11.6	5	15.2	2	16.0	4
1 atm (W-4)	17.3	6	12.3	6	15.0	4	16.3	4
No. growers irr.		6		4		3		5
F-value (3.86 at 5%) (6.99 at 1%)	8.62[1]		39.0[1]		0.94ns		27.1[1]	
LSD, 5% level	2.5		1.5		1.7		1.2	

[1] r = 0.606 significant at the 1 percent level.

In general, yields increased with increasing moisture, but differences were not significant for treatments with a mean value of about four atmospheres or less. Examination of detailed tension data showed that, whenever the mean of four replicate tensions rose to eight atmospheres at six inches depth anytime during the season, a statistically significant yield reduction resulted. There were a number of late season tensions above eight atmospheres at six inches not evident in Table 1.

It has been suggested by plant pathologists that anaerobic conditions promoted by higher moisture levels could retard damage by rhizoctonia, and that this influence may be reflected in the improved stand count and higher yields at the Worland location. Analysis of variance on data combined for locations in 1952, and on data combined for locations and the years 1951 and 1952, showed no significant difference in yield between the one-atmosphere and the two-atmosphere treatments.

Consistent deviations from replicate means for some plots suggested the use of regression analysis of yield on moisture tension. Table 3 presents a tabulation of correlation coefficients for the regression lines.

Table 3.—Correlation Coefficients of Yield on Mean of Peak Tensions.

Location	6" depth	18" depth
"Powell	—0.832[2]	-0.427[1]
Worland	—0.855[2]	—0.716[2]
Wheatland	—0.504[1]	—0.642[2]
Torrington	—0.719[2]	—0.427ns

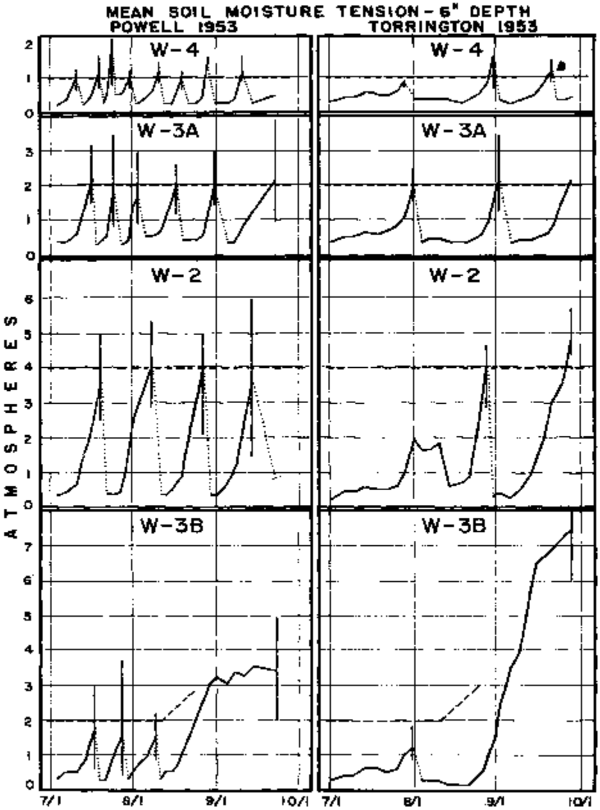
[1] r = 0.482 significant at the 5% level
[2] r 0.606 significant at the 1% level

The apparently better correlation for the 6 inch depths, already referred to, is obvious. The magnitude of the coefficients is supporting evidence that individual tension deviations for some plots were not a random variation. Examination of diagrams showed a broad scatter of points below about 4 atmospheres mean tension, indicating that the major part of the correlation was due to the drier plots.

1953

Irrigations during 1953 were scheduled on the basis of indicated mean tensions at the six-inch depth throughout the season. The three wet treatments were nominally the same—1 atmosphere (W-4) , 2 atmosphere (W-3a) , and 4 atmospheres (W-2) —but being based on the six-inch depth only, were in effect wetter treatments than previously used. Although it was apparent that yield reductions resulted from tensions of the order of eight atmospheres during the midportion of the growing season, additional information was wanted on the effect of high tensions after the peak water-use period had passed. To this end, treatment W-3b was initiated and irrigated at 2 atmospheres as W-3a until August 10 (peak use period in 1952 was the last week in July) , at which time no further irrigations were made.

New locations were selected at both Powell and Torrington, with the same plot design and Bouyoucos block installations plus the addition of two extra units per plot at 6 inches in the row adjacent to the original 6 inch units. Tensions were calculated for 4 readings per plot and 16 readings per treatment. All plots received a uniform irrigation after units were installed.



LEGEND: ——— TENSION FOR IRRIGATION
.... IRRIGATION
(VERTICAL LINES SHOW RANGE IN REPLICATES)

Figure 1—(left half of page)
Figure 2—(right half of page)

Figures 1 and 2 present the tension-time curves for the two locations. Plots were irrigated quite close to design mean tensions. The vertical line segments on the curves emphasize the considerable differences between replicates. The curves for the W-3b treatments are of particular interest. Following the August 10 irrigation-termination date, the tension at Powell rose to mean $3^1/_2$ atmospheres by September 1 and remained approximately the same until harvest. The continued low tensions at 18 inches indicated a constant tension at 6 inches was not accounted for in increased subsoil moisture use, but the result of very low moisture use by the plants over this period. A similar effect was observed in consumptive use investigations on the 1952 data. On the other hand, Torrington shows a nearly linear tension rise until harvest.

It is believed that the continued cool and rainy weather that occurred during July retarded development of the plants so that the peak use period occurred after August 10, and the period of low moisture extraction did not occur before harvest. Treatments W-3b were directly comparable only to treatments W-3a and were analyzed as a paired comparison. Due to the low number of degrees of freedom, t-values were not significant. For Powell, treatment W-3b yielded 14.62 tons per acre against 13.45 tons per acre for treatment W-3a (2 atmospheres throughout the season), three out of the four replicates showing higher yields in favor of terminating irrigations on August 10. At Torrington, permitting the W-3b plots to dry to a mean value of 7.5 atmospheres by harvest reduced the yield from 19.72 to 17.72 and was consistent for all replicates. This reduction is considered to be real and, in view of field reports that tops died back to the ground two times, is surprisingly small.

Table 4 presents yield results for the 1 atmosphere, 2 atmosphere, and 4 atmosphere treatments maintained throughout the season.

Table 4.—Yield Data and Number of Irrigations, 1953.

	Powell		Torrington		Locations
	Yield	No. Irr.	Yield	No. Irr.	Combined Yield
4 atm (W-2)	14.5	5	19.4	2	16.9
2 atm (W-3a)	13.4	6	19.7	3	16.6
1 atm (W-4)	14.1	9	19.5	4	16.8
No. growers irr.		7		5	
F-value	1.69ns		0.09ns		0.09ns
LSD, 5% level	1.3		1.9		1.6

Neither a significant difference nor a consistent trend between yield and moisture tension was found over the range to 4 atmospheres.

The correlation coefficient for regression analysis was +0.551 for Powell (the 5 percent level for significance was 0.553), and —0.048 for Torrington. Far from showing a significant yield depression with increasing tensions, Powell nearly has a significant increase in yield with increasing tensions to 4 atmospheres.

Combined Data—1952 and 1953

A final analysis was made to determine whether tensions to four atmospheres significantly reduced yields. Because of different overall yield levels at the various locations, a regression analysis of combined field data would show a broad scatter even if the regressions for the individual locations had been perfect.

To make data comparable between locations, yields were expressed as a percentage of the mean yield for the replicate in which they were located. Since tension levels differed considerably between locations, and somewhat between replicates, they were recalculated as atmospheres tension above the lowest tension found within the replicate in which the plot was located. The transforms appear logical and were tested for all individual locations for 1952 and 1953. In every case negative correlation coefficients were increased, and the few positive coefficients were either numerically reduced, or converted to small negative values. If any bias exists it is toward increasing correlation. Data were discarded for 62 plots with a seasonal mean tension greater than 4 atmospheres, or with any peak tensions during the season in excess of 5.0 atmospheres. Using transformed data for the remaining 30 plots, a correlation coefficient of---0.204, and a regression slope of 1.06 percent yield per atmosphere tension were determined. The correlation coefficient was nonsignificant compared with the 5 percent level of 0.355, indicating that any yield effect due to moisture within the 4-atmosphere range was at best erratic. Had the correlation been perfect, the regression slope indicates that the maximum yield reduction due to tensions of four atmospheres, for an average yield of 15.94 tons per acre, would have been 1.2 tons per acre.

Discussion

Additional information is needed to establish more definitely the particular horizon at which yield most closely correlated with soil-moisture tension. There is evidence on hand that this may be influenced by phosphate nutrition and by the height of the water table.

Certainly there is an immediate need to develop inexpensive instrumentation techniques, or visual relations, that will permit the grower to estimate the magnitude of soil moisture tension in his field, and the need for irrigation. It is apparent that accurate recommendations in terms of day intervals must account for soil differences, water table contributions, stage of growth, and climatological factors.

It is suggested that the absence of significant differences in many previour irrigation experiments based on percentage of moisture in the soil, or even the percentage of available moisture in the soil, may well have been the result of all treatments falling within the four-atmosphere range. It is within this range that the greatest changes in percentage of soil moisture occurs.

Conclusions

1. Variability of data makes it questionable that treatment differences of less than 1.0 to 1.5 tons per acre could have been detected. Allowing this tolerance, the preponderance of information indicated that, under the conditions of this investigation, no yield reduction resulted for soil moisture tensions up to four atmospheres soil moisture tension at the six-inch depth.

2. There is definite and consistent yield reduction for soil moisture tensions of eight atmospheres at the six-inch depth.

3. Information to date would indicate that yield may be more frequently correlated with soil moisture tensions at the 6 inch depth than at the 18 inch depth or at a mean of the 6 inch and 18 inch depths.

4. A saving of two or three irrigations may be achieved by permitting the soil to dry to four atmospheres tension at the six-inch depth compared with irrigating at one atmosphere tension. At most of the locations investigated, irrigation practices of the commercial grower compared with the one atmosphere treatment.