Some Effects of Furrow Spacing and Depth on Soil Moisture in Central Australia

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During the course of trials near Alice Springs, N.T. on the establishment of perennial grasses by seeding, treatments using widely spaced furrows indicated that these increased soil moisture storage by deep penetration in the profile but had no apparent establishment advantages (Winkworth, unpublished data). It was clear that during rain small plowed furrows were retaining surface water flow which otherwise would continue downslope. The hypothesis that a series of favoured soil moisture sites imposed on an otherwise uniform habitat could lead to higher plant productivity in an arid environment, promoted further investigation.

Alice Springs has an average annual rainfall of about ten inches with a high proportion of small falls of rain e.g. 35 percent of the total rain occurs in falls of less than one inch. Evaporation potential is high and results in rapid soil drying.

The purpose of the experiment reported here was to examine the ability of various furrow situations to accumulate run-off water; to see if accumulation would occur during the lighter falls of rain; and if they could reduce the rapid drying of the uppermost soil especially in the zone where seed is usually sown.

The experiment was carried out in a hard spinifex *(Triodia basedowii)* sand-plain pasture land (Perry, 1960), 62 miles north-west of Alice Springs. Such areas are among the least favourable for water harvesting since slopes are gentle and the soil is very permeable. At the site the slope is 0.2 percent. The soil belongs to the Connors family of Jackson (1962) and is an acid, red, coarse clayey sand to a depth of five feet. The field capacity is about six percent moisture. At 15 atm tension the soil contains about 3.5 percent moisture.

Methods

The spinifex vegetation was cleared in two ways, by burning and by burning followed by disc cultivation. The direction of cultivation was with the slope. Furrows were then formed across the slope, some with a road grader, others with a single-share mouldboard plow. The shape of the furrows was determined by a single passage of the implement through the dry sand at the required depth. Plowed furrows were three to four inches deep and grader furrows were six and twelve inches deep. In a second set of grader furrows a V-shaped cut was made at the bottom by hand-spade in an attempt to have a narrow steep-sided trench along them. The trench soon slumped. Figure 1 illustrates typical furrows three months after forming.

For each furrow depth three spacings were used. These were two yards, five yards, and ten yards. Each treatment consisted of a group of four furrows. The uppermost of each group was not sampled, its purpose being to establish the spacing treatment for those downslope from it. The groups were disposed at random and the whole block split for the two clearing treatments.

The observations made during the experiment were as follows:

Climatic records: Rainfall was recorded by a pluviometer and temperature and relative humidity by a thermohygrograph in a standard Stevenson screen.

Water Accumulation: The depth to the wetting front in the soil profile was measured two to

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Table 1. Climatic records at the experimental site

		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Rainfall (inches)	1960	2.39	0.75	0	0	2.32	0.16	0	0	0	0.98	0.10	0.89	7.59
	1961	0.78	0.12	0	0.61	0	0	0	0	0	0.08	0.41	0.02	2.03
	1962	3.57												
Average daily	1960	99.8	97.1	93.6	84.7	67.3	67.6	74.0	73.3	85.4	89.2	91.8	94.2	
maximum temper-	1961	98.5	98.4	99.2	90.7	73.2	71.8	68.2	73.1	85.9	92.0	94.5	101.0	
ature (°F)	1962	96.2												
Average daily	1960	72.5	73.0	60.8	59.5	47.8	43.1	39.3	39.3	51.1	60.1	61.7	69.3	
minimum temper-	1961	74.3	71.8	65.2	65.7	45.3	40.8	37.0	42.0	54.8	51.4	66.8	71.3	
ature (°F)	1962	75.4												
Average daily	1960	21	23	21	24	29	25	22	18	17	17	11	15	
3 p.m. relative	1961	13	15	9	26	31	27	23	21	17	13	12	10	
humidity (percent)	1962	22												

three days after rain. Holes were sunk with a two-inch Jarrett soil auger at the bottom of furrows and in the interfurrow space. Differences in depth of penetration were calculated from eight holes per treatment.

Soil Moisture Content: This was determined gravimetrically at depths of zero to one inch, one to two inches, and two to three inches both at the bottom of furrows and in the interfurrow space, there being four samples for each furrow depth. Samples were taken late in the afternoon as well as early morning until diurnal fluctuations ceased to be significant.

Depth of Infill: This was measured with an array of steel markers set at zero at the bottom of the appropriate furrows at the commencement of the trial. There were four markers per treatment.

The furrows with V-trenches which had slumped showed the same moisture characteristics as their counterpart six and twelve inch furrows. Data from these treatments are omitted.

Results

Climate

Climatic records for 1960, 1961 and January 1962 are set out in Table 1. The rainfall during this period was exceptionally low and the main sampling was restricted to five out of seven significant falls in January, February, May and October 1960 and January 1962. The temperatures were, if anything, slightly above normal possibly because of the drier conditions.

Water Accumulation

Water penetrated more deeply in furrows than in the interfurrow areas in most instances. The results have been expressed as the difference, and thus the increment, in moisture penetration beneath the furrows (Table 2). Increments exceeding four feet

Table 2. Increase in depth of water penetration under furrows as compared with interfurrow spaces.

Sampling Date	Furrow depth (inches)	Plow (3-4)				6				12			
	Furrow spacing (yards)	2	5	10	Mean	2	5	10	Mean	2	5	10	Mean
		(Inches)											
Jan. 20, 1960	Burnt	3.1	2.0	2.8	2.6	9.1	13.4	5.9	9.5	7.9	10.6	8.7	9.1
	Burnt and cultivated	2.8	2.8	2.8	2.7	6.3	10.6	6.3	7.7	4.7	6.7	6.7	6.0
	Mean	3.0	2.2	2.8	2.7	7.7	12.0	6.1	8.6	6.3	8.7	7.7	7.6
Feb. 1, 1960	Burnt	3.5	7.9	21.7	11.0	2.0	24.0	13.4	13.1	-2.8	17.3	12.2	8.9
	Burnt and cultivated	5.1	10.2	2.0	5.8	1.2	17.3	20.9	13.1	12.6	29.1	24.0	21.9*
	Mean	4.3	9.1	11.9	8.4	1.6*	20.7	17.2	13.1	4.9*	23.2	18.1	15.4
May 4, 1960	Burnt	3.1	7.5	8.3	6.3	23.6	29.9	7.9	20.5	22.0	31.1	10.6	21.2
	Burnt and cultivated	7.9	1.2	2.8	4.0	6.7	8.7	22.4	12.6	35.8	30.3	33.5	33.2*
	Mean	5.5	4.4	5.6	5.2	15.2	19.3	15.2	16.6	28.9	30.7	22.1	27.2
Oct. 14, 1960	Burnt	3.1	3.5	3.5	3.4	9.1	7.5	4.3	7.0	4.3	4.7	6.7	5.2
	Burnt and cultivated	2.4	1.2	3.9	2.5	7.1	8.3	3.9	6.4	4.7	3.1	13.0	6.9
	Mean	2.8	2.4	3.7	3.0	8.1	7.9	4.1	6.7	4.5	3.9	9.9	6.1
Jan. 18, 1962	Burnt	11.8	16.1	-2.0	8.6	24.8	9.8	13.0	15.9	40.6	39.4	49.2	43.1
	Burnt and cultivated	0.8	5.5	17.7	8.0	32.7	31.5	21.7	28.6*	14.6	36.2	48.4	33.1
	Mean	6.3	10.8	7.9	8.3	28.8	20.7	17.4	22.3	27.6	37.8	48.8	38.1

*Significant

Table 3. Time taken for soil moisture to reach 15 atm tension in furrows and between furrows

Furrow Depth	October, 1960 Soil 0-1	Depth 1-2	(Inches) 2-3	January, 1962 Soil 0-1	Depth 1-2	(Inches) 2-3
(Inches)	(Hours)					
0 (Interfurrow)	30	78	84	26	108	*
3-4	30	72	92	26	60	104
6	30	48	76	26	72	106
12	30	68	84	26	54	60

*Not determined but exceeds five days

Table 4. Depth of material deposited in furrows.

Furrow Depth	Clearing Method: Burnt and Cultivated — Furrow Spacing (Yards) 2	5	10	Burnt 2	5	10	Mean
	(Inches)						
3-4	1.7	2.0	1.7	1.4	1.2	1.5	1.6
6	1.7	1.7	1.8	1.3	1.3	0.9	1.5
12	2.2	2.3	2.1	1.8	2.0	1.9	2.1
Mean		1.9			1.5		

and total depths exceeding six feet were measured. One foot of soil moisture storage is equivalent to approximately 1.2 inches of rain.

The six and 12 inch furrows consistently accumulated more moisture than the plow furrows. During the heavy rains of May 1960 and January 1962 the 12-inch furrows accumulated more than the six inch furrows. From two to four-fold increases in depth of penetration from the plow to six inch furrows are shown in Table 2. Increases from the six to 12 inch furrows were less.

The effects of wider furrow spacing and of cultivating after burning are inconclusive. Increased penetration occurred in a minority of instances. On the occasions when treatment effects were significant penetration increased from the two to five yard spacing and also was greater in the cultivated area.

The depth to the wetting front was very variable due to variations in micro-relief, to small rivulets depositing water in low troughs in the furrows and to inherent variations in the permeability of the soil mass. Greater replication may have given more stringent comparisons which were significant on five instances. Mean negative increments on two occasions may have resulted from sampling at 'high spots' in the furrows. They fall within intra-treatment variability encountered in the experiment.

After 0.98 inches of rain in October 1960 deeper penetration of moisture occurred under all furrows.

Topsoil Drying

Routine sampling during the earlier part of the experiment showed that topsoil was drying in less than two or three days. Drying appeared equally rapid at the bottom of furrows. Consequently, intensive frequent sampling was planned for the next wet periods to plot more detailed drying curves. Occasions arose in October 1960 and January 1962. The times taken for each soil layer to dry to the 15 atm tension after rain ceased was determined by interpolation from graphed data and are given in Table 3.

In October the top inch of soil dried to 15 atm tension in about

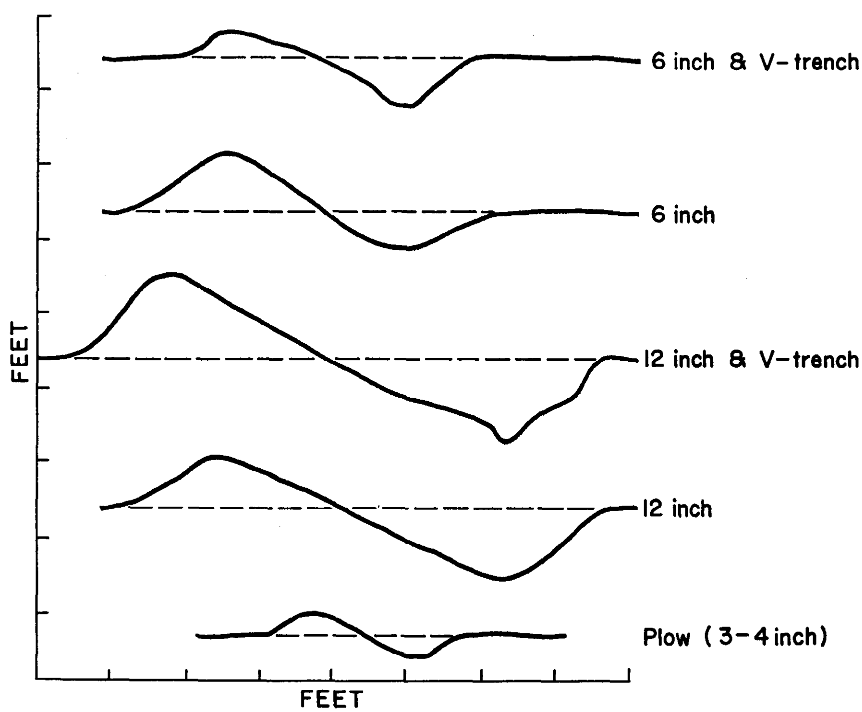

FIGURE 1. Cross sectional outlines of the five furrow designs three months after being formed.

30 hours after rain ceased. The soil moisture was above this tension for just over four days. In January two moist periods, one of 64 hours during which rain fell, the other of 26 hours were approximately 24 hours apart. Times are the same for all furrow depths and the interfurrow area.

Times for drying increased with soil depth. In the one to two-inch layer this ranged from 18 hours to more than three days, with a mean of one day 18 hours, longer than for the top one inch. The mean increase in the two to three-inch layer was two days ten hours. The results show that the drying of the soil at these depths was not affected by furrow depth.

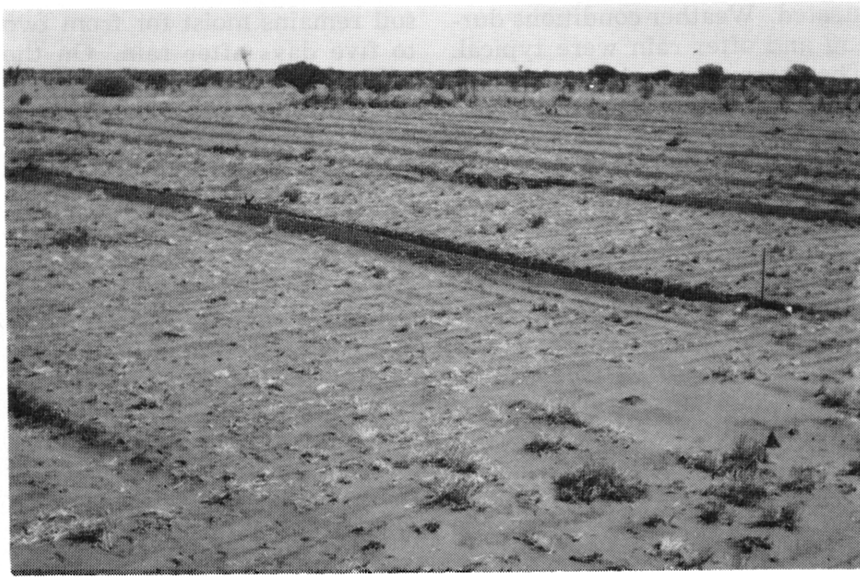

FIGURE 2. A portion of the burned and cultivated experimental area. Remains of burned spinifex tussocks, surface litter and the sparse cover of annuals are evident. A wall of untreated spinifex and shrubs can be seen in the background.

Infilling of Furrows

Periodic measurements were made to determine the rate of deposition of material, almost entirely sand, in the furrows. The depths of the deposits after two years and four months are shown in Table 4. Spacing had no effect but there was a highly significant increase in deposition in the cultivated area as a whole and in the 12 inch furrows. The filling represents about ½, ¼ and one-sixth of the depth of the plow, six and 12 inch furrows respectively.

Discussion

The results have shown conclusively that furrows accumulate appreciable quantities of surface run-off water even from falls of rain of about one inch. This water is stored at depth beneath the furrow and laterally for a short distance on either side of the furrow. If perennial species were established in furrows over a wide area and were capable of using soil moisture to depths of six feet and more it is likely that productivity would be enhanced.

More water was stored under six and 12 inch furrows than under plowed furrows. This could be due to either or both their greater depth and their larger spoil banks which form appreciable catchment surfaces. These effects cannot be differentiated in the present data. Spacing effects also are influenced by run-off from spoil banks. The results strongly suggest that run-off from the banks form an appreciable proportion of the total, perhaps equal to and exceeding that from the interfurrow space.

Cultivating up and down the slope did not consistently increase run-off. Other factors, relating to the regeneration of native communities, may need to be considered in a pasture improvement programme. Evidence exists that after burning, cultivation has desirable effects on the sequence of several communities which will inevitably occupy the inter-furrow areas.

Regenerating vegetation may decrease run-off during rain and increase the rate of depletion of soil moisture after rain. During this experiment a sparse scatter of ephemeral and annual plants, together with occasional new spinifex shoots, appeared on all areas. These were considered to have a very minor influence on soil moisture. Hence it was possible that residual moisture affected the depth of penetration in February and May 1960. After two years, deposits in furrows in the cultivated area were about 0.5 inch deeper than in the uncultivated area. This cannot be regarded as serious in the deeper furrows. These results apply to empty furrows and as wind is probably the main agent in soil movement deposition would be greater if the furrows carried rows of plants. Should the furrows fill up, the main result would be reduction of the surface area of the spoil banks with a reduction of run-off.

The above discussion shows the possibility of increasing the moisture supply to established perennial plants with deep root systems by growing them in spaced furrows. In the crucial germination and early growth stages attention is focussed on the moisture regime of the uppermost few inches of soil in the furrows immediately following wet periods.

The rapidity of soil drying and the ineffectiveness of furrows to retard this was amply demonstrated. Weather conditions during and after rain were typical. The furrows were aligned east-west with the banks on the southern side, and thus during summer shading of the bottom was negligible. In situations where the slope is east-west it is possible that shading would be more effective, but it seems unlikely that orientation will give any practical reduction of either radiation or advective effect. Steep sided trenches along the bottom of furrows were expected to create a shaded, more humid and cooler micro-climate but they were eliminated by sheer mechanical instability.

The top one inch of soil, where seed has usually been sown, remains below 15 atm moisture tension for the duration of the wet period plus one day. Assuming that germination is severely limited at tensions exceeding 15 atm then rain periods of at least four to five days duration would seem necessary to ensure seedling emergence. This may account for poor results in previous range seeding trials. Observations during them indicate the minimum time for emergence at about five days.

The one to three-inch layer of soil remains moist for from two to five days after rain. On the average it remains above the 15 atm tension for two days longer than the soil above which is acting as a mulch. This strongly suggests that deeper sowing will enhance emergence provided coleoptile extension is not retarded. Humphreys,[2] using seed of *Cenchrus ciliaris* (buffel grass) in well-watered pots found only slight retardation of germination rate at a sowing depth of two inches. Sowing at this depth may also allow germination after shorter rain periods which occur more frequently.

Summary

Furrows were formed on a gently sloping spinifex sand-plain in central Australia. Furrows three, six and 12 inches deep were spaced two, five and ten yards apart across the slope. During five rainy periods in two years surface flow water accumulated in the furrows resulting in increased depth of penetration in the soil profile under them. Spacing effects were inconclusive and greater accumulation in the deeper furrows is possibly due to their larger and steeper banks. Soil moisture increments were obtained from rain falls of only one inch. From heavier falls increases in storage under furrows reached the equivalent of five inches of rain. The results indicate the possibility of increasing the moisture supply to perennial pasture plants with deep root systems by growing them in furrows.

The time taken for soil to dry to 15 atm moisture tension was the same at the bottom of furrows as between furrows. The top one inch of soil reached this tension just over one day after rain ceased. Seed has usually been sown in this layer in range seeding trials. The one to three inch layer remains moist from two to five days after rain. Assuming that germination is severely limited at tensions exceeding 15 atm it is suggested that deeper sowing may be necessary for satisfactory seedling emergence.

[2] *Unpublished M. Sc. Ag. Thesis.*

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