LINE SOURCE SPRINKLER PLOT IRRIGATOR FOR CONTINUOUS VARIABLE WATER AND FERTILIZER STUDIES ON SMALL AREAS

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Abstract

The design details and a sample set of field test results for a line source sprinkler plot irrigation system are presented. The system produces a water application pattern which is uniform along the length of the plot and continuously but uniformily variable across the plot.

By applying a fertility variable along a plot (at right angles to the water variable) planted in some test crop, the system offers a convenient means for developing crop production function data. The system test area and water supply are both small. However, the application of the system may be limited by wind and all water application levels must be supplied at the same irrigation frequency.

KEY WORDS: Water use studies, experimental plot irrigator, water-fertility interactions.

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Introduction

Crop production surfaces as influenced by water and fertility levels are needed for many analyses to relate economic return to soil and water management practices. Fox (1973) and Bauder et al. (1974) have developed and reported on a system for producing these surfaces using a large number of fertility and water levels which vary systematically from one end of a single plot to the other. With the fertility variable increasing in one direction and the water level increasing in the other direction a continuous crop height and production surface is produced in the field. The need for a buffer area around each treatment is eliminated since the incremental change between adjacent treatments is small.

Accurate water control is necessary to produce the numerous water levels required to generate the desired production surface. Bauder, et. al. (1974) used a trickle (drip) irrigation system to obtain the

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high degree of water control needed. The trickle system gave good control of the irrigation water added but was quite expensive and required considerable manpower to operate effectively. Furthermore, periodic and extensive metering and testing of emitters was necessary to determine the exact water application time for the small incremental water availability differences required. An additional problem was the need to filter the water very thoroughly. Because of these problems, alternating schemes of irrigating at varying but consistant levels were tried in an effort to obtain even better and more uniform water control. A system developed in 1973 that seems to work well is a design which used a single line of sprinklers down the center of the plot. The purpose of this paper is to describe the design and layout of this line source sprinkler plot irrigation system and the results obtained with it in 1973. It is interesting to note that this design was successfully used in Arizona, California, Colorado, and Utah for a series of water-fertility interaction studies in 1974.

System Layout

The design criteria for a line sprinkler plot irrigation system is to produce a water application pattern which is:

a. Uniform along the length of the plot.

b. Continuously and uniformly variable across the plot.

c. Approximately 30 m (100 ft.) wide.

d. Consistant and predictable throughout the season.

e. Compact to minimize the size of the required end buffer zones.

Figure 1 shows a schematic layout of the line sprinkler plot design developed in 1973 to meet these criterion. The line of sprinklers is

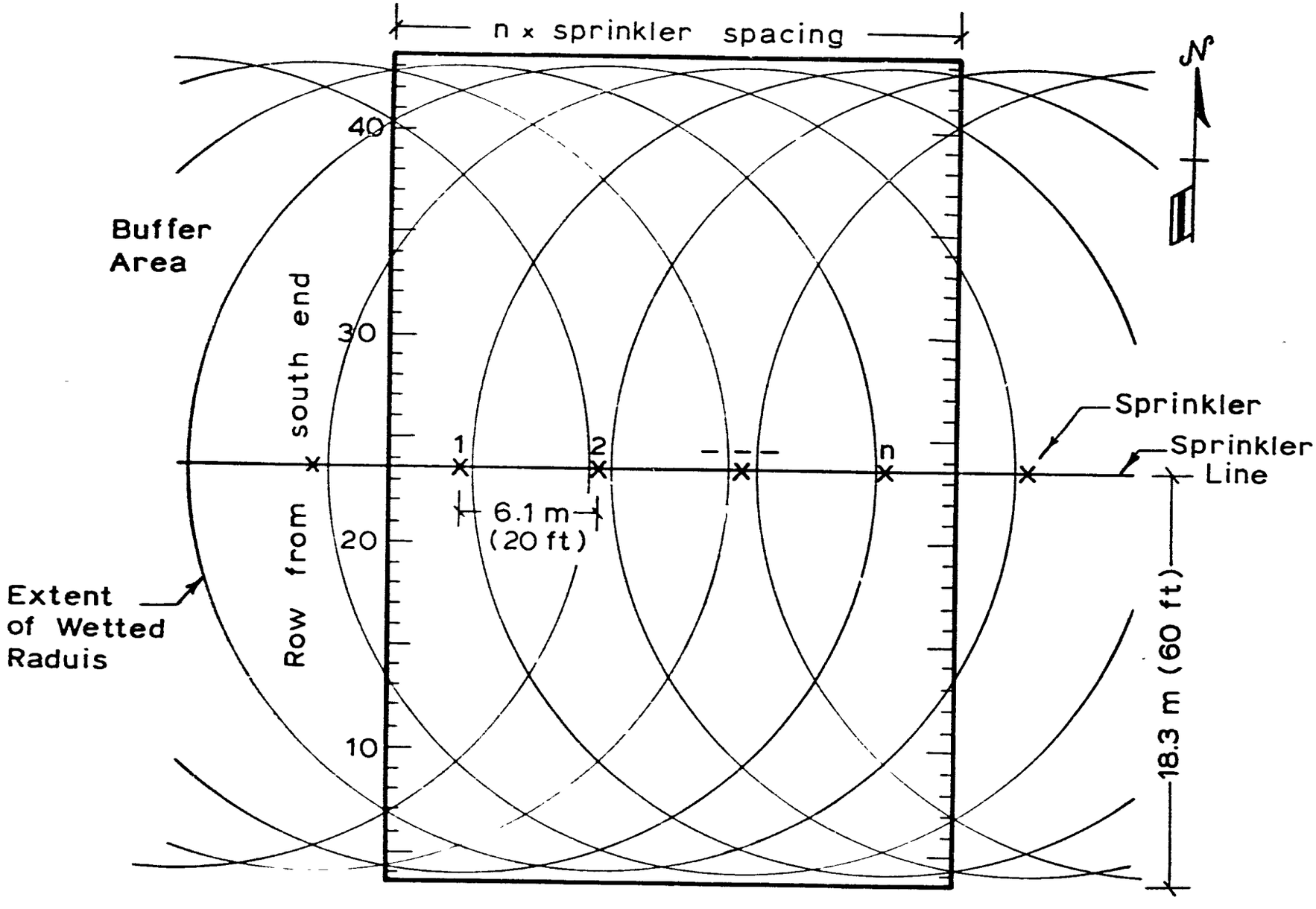

Figure 1. Schematic diagram of the line source sprinkler irrigated test plot.

through the center of the plot and parallel to the row direction. The length of the plot can be increased by adding more sprinklers. However, the width of the plot is governed by the wetted diameters of the sprinklers.

To obtain the "line source" effect, sprinklers should be spaced as closely as practical on the water supply line with the spacing not exceeding 25% of the wetted diameter. Furthermore, the individual sprinklers should produce a triangular shaped profile when operated in low winds at the design pressure.

The 1973 test system had eight sprinklers spaced at 6.1 m (20 feet) which gave an overall usable plot of 24.4 by 24.4 (80 by 80 feet). Model 30 TNT sprinklers with 3/16 inch range by 3/32 inch spreader nozzles produced by Rain Bird Sprinkler Manufacturing Company of Glendora, California, USA, were selected for the layout. The sprinklers were operated at approximately 3 bars (45 psi) and produced a wetted radius of approximately 15 m (50 ft.). Satisfactory results could be obtained with the same sprinklers operated at pressures up to 4 bars (60 psi).

The plot area was essentially level and the sprinklers were placed on 6-foot high by 1-inch risers attached to a 3-inch quick coupling portable aluminum supply line. The supply line had non-drain gaskets and steel fence posts were used to hold the risers in a vertical position. The pressure head difference between the ends of the line was approximately 1 percent of the inlet pressure and each sprinkler discharged 0.54 lps (8.5 gpm) giving a total system discharge of 4.29 lps (68 gpm).

Figure 2 shows the relative sprinkler application rate across the rows. The rows were spaced at 0.76 m (30 in.) and the sprinkler line was laid between rows 23 and 24. To obtain a nearly symmetrical pattern

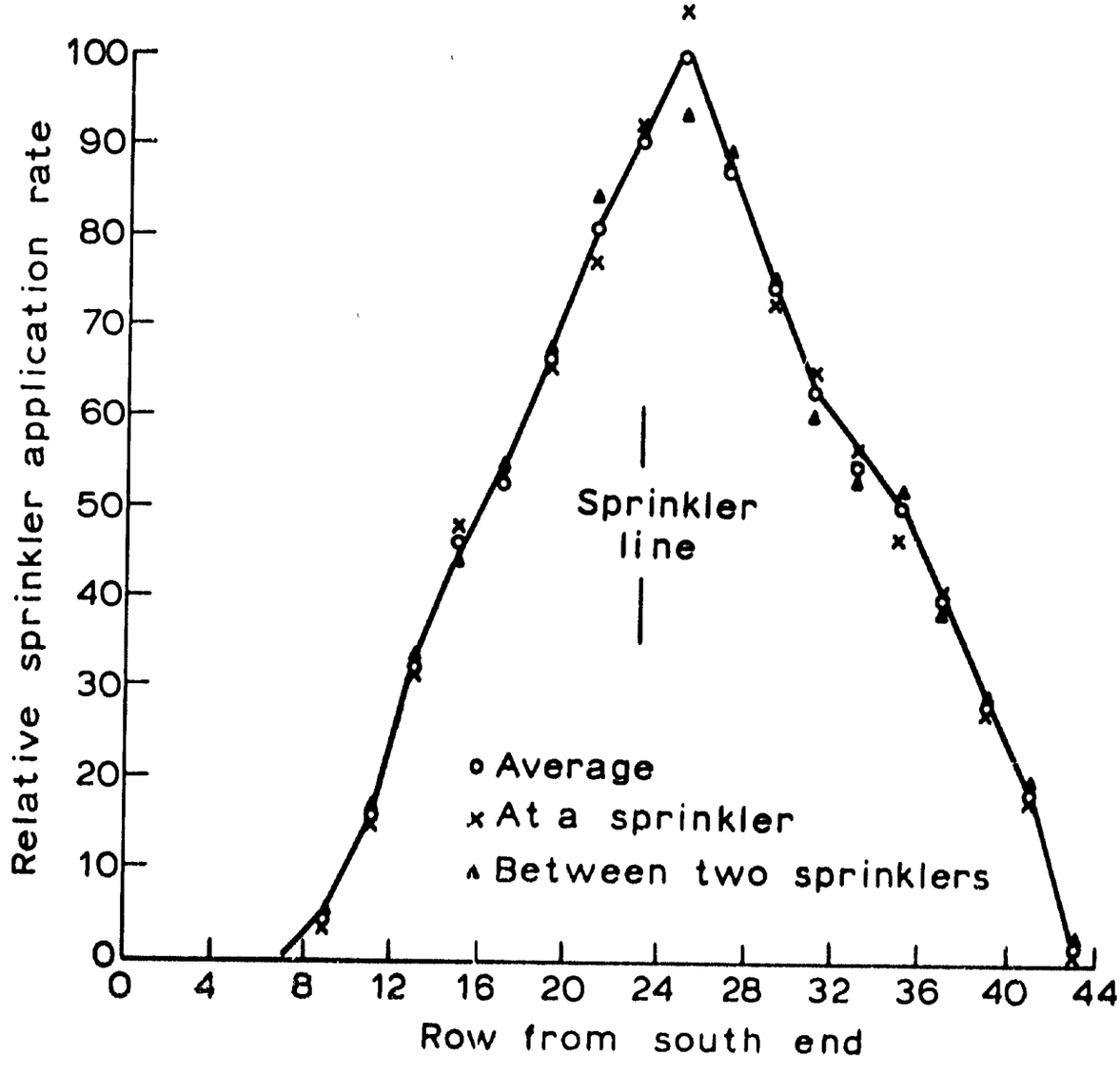

Figure 2. Relative sprinkler application rate as a function of corn row number on June 8, 1973.

as in Figure 2, this system can only be operated when the wind is 0 to 3.2 km per hr. (0 to 2.0 mi per hr.), unless the line of sprinklers is parallel to the wind. Winds up to 8.0 km per hr. (5.0 mi per hr.) can be tolerated where the line is parallel to the wind; however, the width of the pattern will be reduced considerably by the higher wind.

The water distribution data shown in Figure 2 was collected just after planting and periodic checks throughout the growing season produced almost identical results. The relative sprinkler application rate was uniform along the length of each row of the plot. This is demonstrated by the closeness of the application rates at a sprinkler and between two sprinklers in any given row.

Results

The system was set up at the Utah State University field station near Farmington, Utah, and silage corn was planted on May 30, 1973. Irrigation was started on June 26 and water was applied approximately weekly until August 31. The sprinklers delivered water throughout the season at almost the same relative rate along each row as shown in Figure 2. Between June 12 and 21 there was 83 mm of rain. On September 2 there was another 33 mm giving a total of 116 mm of rain for the season. The corn silage was harvested on September 10, by rows in 40 feet sections of the plot to simulate the results that might be expected if the four sections were used for replicates. (There are two sections on each side of the line of sprinklers.) The average yield and water use data for each row are presented in Table 1.

A neutron probe was used to check the soil moisture storage throughout the season to a depth of 1.22 m (48 in.). There was little or no

Table 1. Dry matter corn silage yields, total water use (irrigation, rain and soil moisture decrease) by row numbering from the south end.

Row No. South to North	Yield Kg/ha			Water - mm		
	East	West	Average	Irrigation	Soil	Total *
1	6804	6145	6474	0	-30	146
2	4608	3401	4005	0	-30	146
3	4828	5706	5267	0	-30	146
4	4828	4828	4773	0	-30	146
5	4608	4608	4608	0	-30	146
6	5267	5706	5487	10	-28	154
7	4828	3950	4389	23	-26	165
8	5267	6365	5816	50	-21	187
9	5706	6364	6036	75	-16	207
10	4828	6035	5432	96	-14	226
11	6978	7196	7087	116	-20	252
12	7064	6933	7000	143	-25	284
13	9474	8612	9042	168	-20	304
14	9629	9843	9735	174	-14	304
15	9569	10355	9962	180	-18	314
16	12108	11691	11899	186	-21	323
17	9797	10622	10209	197	-22	335
18	11005	12125	11565	217	-20	353
19	10402	10705	10554	241	-6	363
20	11412	12013	11712	371	+6	371
21	11379	13160	12270	282	+5	393
22	10987	11478	11233	297	+3	410
23	12918	12717	12814	314	0	430
24	11933	12912	12423	314	-2	432
25	11543	11739	11642	314	0	430
26	10791	12066	11428	314	-6	436
27	11117	10625	10871	314	-5	435
28	11345	13023	12185	293	0	409
29	10291	11181	10736	274	-5	395
30	11115	11213	11164	249	-10	375
31	10979	10979	10979	221	-15	352
32	12013	12412	12213	212	-21	349
33	12048	11445	11747	202	-29	347
34	10875	10875	10875	189	-36	341
35	11614	10705	11160	176	-31	373
36	11142	11142	11142	152	-27	295
37	10939	10533	10736	130	-30	276
38	10230	9217	9724	100	-35	251
39	9117	8914	9015	70	-40	226
40	9117	9117	9117	39	-44	199
41	8002	7597	7800	8	-45	169
42	7090	7090	7090	5	-45	166
43	7293	7090	7192	0	-45	161
44	11142	10128	10635	0	-45	161

* Includes 116 mm rain, 1.0 mm = 0.394 in.

change in soil water storage near the center of the plot between June 26 and September 7. Along the outer rows, which received little or no irrigation, the decrease in stored soil water was as much as 45 mm.

Figure 3 shows the smoothed data for the irrigation water applied, total water used, and the yield as a function of the row location parallel to the sprinkler line.

A plot of yield as a function of total water use, Figure 4, shows that there are distinct influences due to the position in the plot as well as to water applied. This effect can be traced to fertility variations within the plot. The south part of the plot was in fallow the previous year with no fertilizer applied and the north side of the plot was in sugar beets which were heavily fertilized. The yields were essentially the same, considering statistical variability, from row 16 through row 37 even though there were large differences in water use in this central region. However, since the water was applied by sprinklers in relatively light amounts it is doubtful that any drainage occurred during the season. Furthermore, the drier rows undoubtedly used water from below 1.22 m (48 in.) which would make the assumed water use too low.

Limitations

There are several limitations of the line source sprinkler plot irrigator which should be considered before laying out an experimental plot. These include the following:

1. As mentioned earlier, even low winds significantly alter the sprinkler patterns. The symmetry of the patterns can best be maintained by either operating the system only during calm periods or laying the line of sprinklers parallel to the

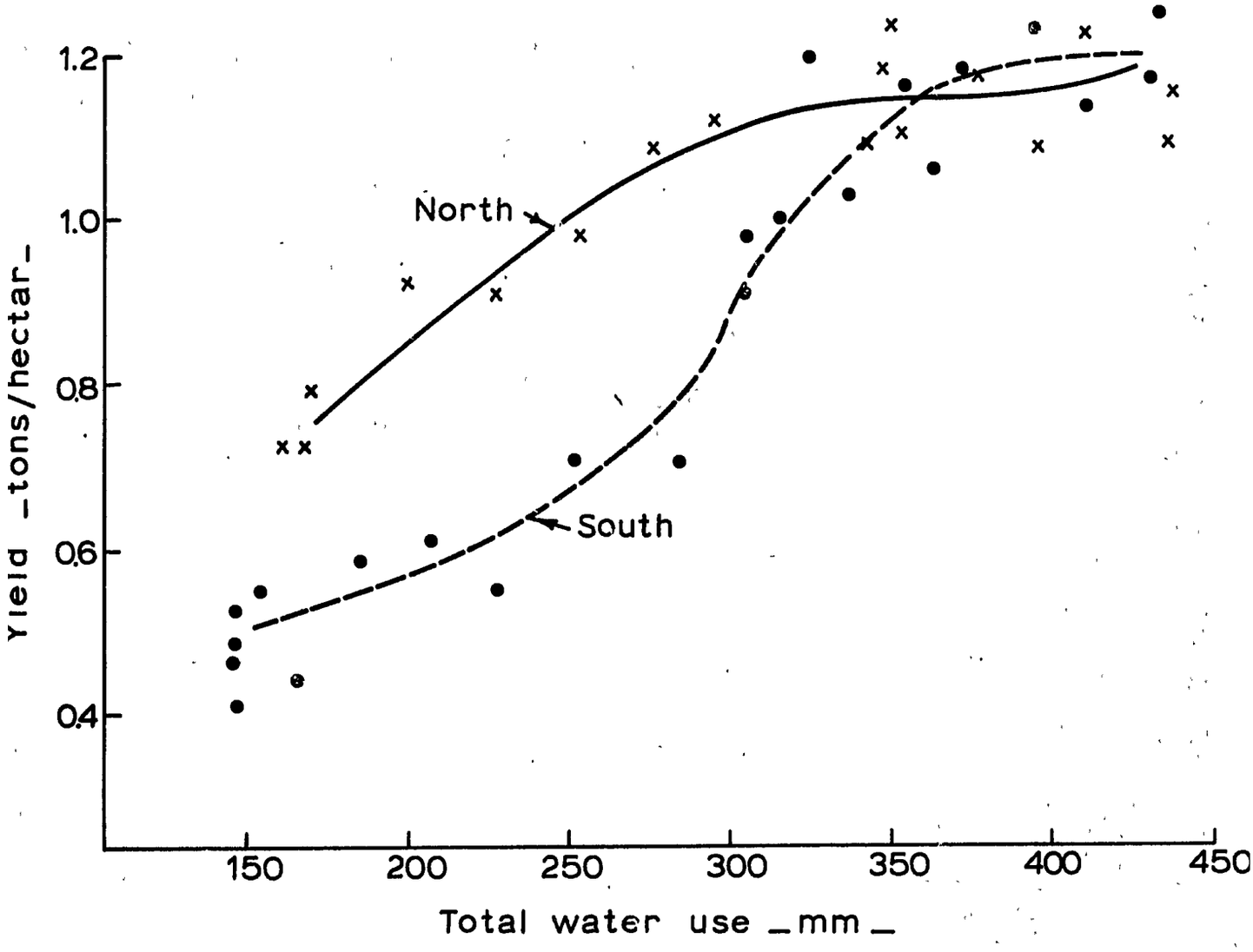

Figure 3. Irrigation water applied, total water used, and corn silage dry matter yield as a function of corn row number.

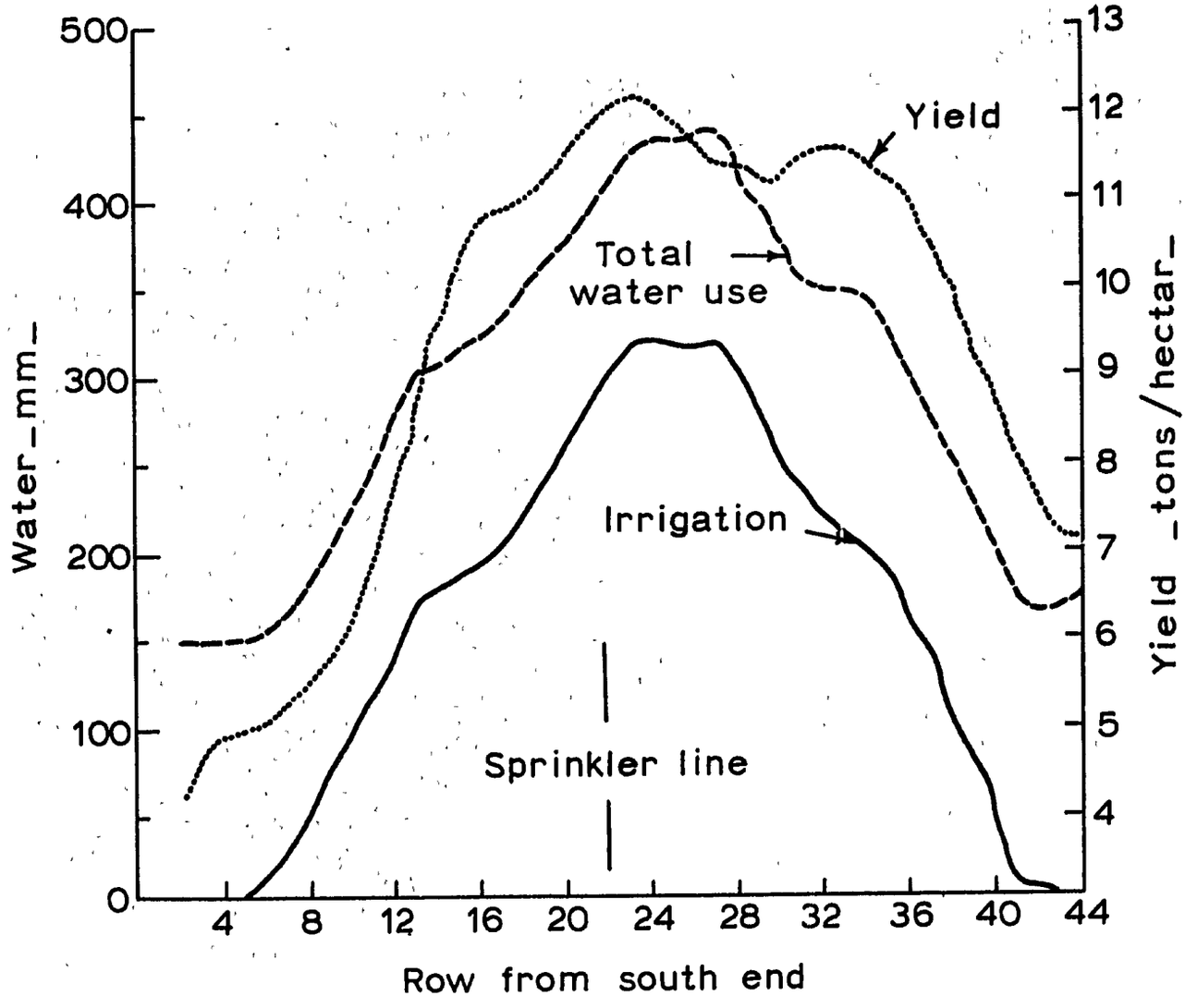

Figure 4. Dry matter corn silage yield as a function of total water use assuming no drainage or water use below four feet.

direction of the wind. During the 1973 study irrigation was applied only when the winds were less than 3.2 km per hr. (2.0 mi per hr.). However, the data show (see Figure 3 or Table 1) that the light general wind from the south caused an average shift of about three rows in the maximum irrigation rate.

2. All the water must be added at the same frequency. This is an inherent feature of the line source concept. However, for some water use studies it may be desirable to manipulate the water availability by utilizing different irrigation frequencies.

3. The maximum application rate along the line of sprinklers for the system design presented is approximately 20 mm per hr. (0.79 in per hr.). While a relatively high application rate provides flexibility for irrigating only during calm wind periods, ponding or runoff may be a problem. However, there are several solutions for these problems which include: Operating the sprinklers intermittently, i.e., 15 minutes on, then 15 minutes off, etc; operating every other sprinkler and after half the total irrigation is applied switch to the in between sprinklers; automatically sequence the sprinklers one at a time; or provide small dams or pits at 1.0 m (3.3 ft. intervals) along the length of the furrows to trap the ponded water and eliminate runoff.

4. Since wind distortion is a problem it is advisable to monitor the water application by collecting a row of can catch data across the plot during each irrigation. For studies on tall crops such as corn this can be a problem. One solution is to

set up a catch container installation with tubing to a read-out station at the side of the plot.

Conclusions

The use of the line source sprinkler plot irrigation system described herein appears to offer a reliable and convenient method for applying a two dimensional continuously uniformly varying level of water to a plot. By applying a fertility variable at right angles to the water variable it appears that this method should be useful for developing crop production function data. The system is economical and simple to install and operate. Furthermore, both the test area and water supply can be relatively small.

REFERENCES

Bauder, J. W., R. J. Hanks and D. W. James. 1974. Crop production function determinations as influences by irrigation and nitrogen fertilization using a continuous variable design. Submitted to Agronomy Journal.

Fox, R. L. 1971. Agronomic investigations using continuous functional experimental designs--nitrogen fertilization of sweet corn. Agronomy Journal, 65:454-456.