OPTIMUM LATERAL SPACING FOR SUBSURFACE DRIP-IRRIGATED CORN

F. R. Lamm, L. R. Stone, H. L. Manges, D. M. O'Brien

ABSTRACT. *A two-year study was initiated in the spring of 1990 on a Keith silt loam soil (*Aridic Argiustoll*) in northwest Kansas to determine the optimum dripline lateral spacing for irrigated corn (*Zea mays *L.) using subsurface driplines installed at a depth of 40-45 cm in a direction parallel to the corn rows. Average corn yields were 13.6, 12.8, and 12.2 Mg/ha for dripline spacings of 1.5, 2.3, and 3.0 m, respectively, for a seasonal-irrigation amount of 462 mm. Yields decreased to 10.8 and 9.3 Mg/ha when irrigation was reduced by 33 and 50% for the wider 2.3- and 3.0-m dripline spacings, respectively. The wider dripline spacings resulted in nonuniform horizontal distribution of available soil water. As a result, yields decreased with horizontal distance from the dripline. The highest yield, highest water use efficiency, and lowest year-to-year variation were obtained with the 1.5 m dripline spacing. An economic analysis indicated that because yield reductions were so great, the wider dripline spacings would be justified only at very high dripline costs and or very low corn grain prices.*

Keywords. *Microirrigation, Water use efficiency, Irrigation uniformity, Water redistribution.*

Declining groundwater supplies and increased competition for available water resources in the Central Great Plains have resulted in an increased need for efficient irrigation systems. Subsurface drip irrigation (SDI) represents the state-of-the-art in efficient irrigation systems. Numerous studies have shown that drip irrigation can increase the water-use efficiency of crop production.

Clark (1979) compared the relative efficiencies of microirrigation, sprinkler, and furrow irrigation for corn production in Texas and found water use efficiencies of 0.0140, 0.0119, and 0.0115 Mg/ha-mm, respectively. In a limited study in Italy, Safontas and di Paola (1985) reported yield increases of up to 35% with drip irrigation as compared to sprinkler irrigation for corn. Camp et al. (1989) evaluated drip irrigation for corn production in the Southeastern Coastal Plain of the United States. They found that subsurface drip irrigation required less water than surface drip irrigation. Lamm et al. (1995a) evaluated the water requirement of subsurface drip-irrigated corn and found water savings of approximately 25% which were achieved primarily through reductions in deep percolation and evaporation from the soil surface.

The initial installation costs for SDI are high, and in the Central Great Plains, it has not been considered a viable economic option for traditional row crops, such as corn. Increasing the spacing of dripline laterals would be one of the most significant factors for reducing the high overall investment costs of SDI.

Camp et al. (1989) evaluated surface microirrigation for corn planted in a configuration of twin rows spaced 0.24 m apart and each pair of twin rows spaced 0.76 m apart. A dripline spacing of 1.5 m centered between the pairs of twin rows was compared to a dripline spacing of 0.76 m centered between the twin rows. The wider dripline spacings resulted in significantly lower yields in one of three years. They attributed this to extremely dry soil conditions during the early part of the growing season.

Powell and Wright (1993) evaluated dripline spacings of 0.91, 1.83, and 2.74 m for corn production on loamy sand soils in Virginia (USA). They recommended that subsurface driplines installed in alternate corn row middles (1.83 m) or under every third row (2.74 m) would be the most cost effective of the dripline spacings evaluated.

Spurgeon and Manges (1990) reported no significant differences in corn yields among dripline spacings ranging from 0.75 to 3.0 m in a wet season (1989). However, a 1.3 to 3.8 Mg/ha range in yields occurred in 1990 and 1991, respectively (Spurgeon et al., 1991). The driplines in that study on silt loam soils at Garden City, Kansas, were perpendicular to the corn rows. As a result, a corn plant could be as much as 1.5 m from a dripline for the 3.0-m dripline spacing. Manges et al. (1995) presented corn yield prediction equations related to both dripline spacing and plant population. They found higher yields with narrower

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The authors are **Freddie R. Lamm**, ***ASAE Member Engineer***, Associate Professor, Northwest Research-Extension Center, Kansas State University, Colby, Kans.; **Loyd R. Stone**, Professor, Department of Agronomy, Kansas State University, Manhattan, Kans.; **Harry L. Manges**, ***ASAE Member Engineer***, Professor Emeritus, Department of Biological and Agricultural Engineering, Kansas State University, Manhattan, Kans., and **Daniel M. O'Brien**, Assistant Professor, Northwest Research-Extension Center, Kansas State University, Colby, Kans. **Corresponding author:** Freddie R. Lamm, Northwest Research-Extension Center, Kansas State University, 105 Experiment Farm Rd., Colby, KS 67701; tel.: (913) 462-6281; fax: (913) 462-2315; e-mail: <flamm@oznet.ksu.edu>.

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dripline spacings ranging downward from 3.0 to 0.76 m. In general, the narrower the dripline spacing, the higher the optimum plant population. At a dripline spacing of 1.5 m, corn yield was maximized at a plant population of approximately 80,000 plants/ha.

Kruse and Israeli (1987) examined subsurface drip irrigation using a 1.5 m dripline spacing for corn production in Colorado. They found considerable yield variation with distance from the dripline and concluded that centering driplines between corn rows was important to assure good production.

A dripline spacing study was initiated in 1990 at the KSU Northwest Research-Extension Center at Colby, Kansas, to determine the optimum spacing for subsurface driplines installed parallel to the corn rows.

PROCEDURES

Field studies were conducted during 1990 and 1991 on a deep, well-drained, loessial Keith silt loam soil (Aridic Argiustoll). This medium-textured soil, typical of many western Kansas soils, is described in more detail by Bidwell et al. (1980). The 1.8-m soil profile holds approximately 445 mm of available water at field capacity, which corresponds to a volumetric soil water content of approximately 0.37 and a profile bulk density of approximately 1.3 gm/cm^3.

The continental climate in the region can be described as semi-arid with an average annual precipitation of 474 mm and approximate annual lake evaporation of 1400 mm (Bark and Sunderman, 1990). Daily climatic data used to schedule irrigation were obtained from a NOAA weather station located approximately 450 m northeast of the study site.

The study was conducted on an approximately 1.1-ha tract, 115 m wide, 100 m long, and with a land slope of approximately 0.7%. The field length (100 m) was divided into three ranges of approximately 33 m. Each range contained one randomized complete block of five spacing/irrigation treatments. Each plot was 33 m long × 9 m wide and included twelve 0.76 m corn rows.

The study utilized a subsurface drip irrigation system installed during the summer of 1989. The system was constructed with dual-chamber drip tape installed at a depth of 0.40 to 0.45 m. The capacity of the drip tape was 1.86 L/h-m. The construction and design of the irrigation system are described in detail by Lamm et al. (1990). Three dripline spacings (1.5, 2.3, and 3.0 m) were examined. The corn was planted parallel to the driplines, with each dripline centered between two corn rows. Using this installation procedure assures that every corn row is within 1.14 m of the nearest dripline, with some rows as close as 0.38 m. This is in contrast to a study conducted at the KSU Southwest Research-Extension Center at Garden City, Kansas, where corn rows were planted perpendicular to the dripline laterals (Spurgeon and Manges, 1990).

The study included treatments in which water was applied at full and reduced levels for the various spacings. In essence, the study tried to determine if the irrigation amount should be applied on a land-area basis (full) or in relation to the number of driplines in a plot (reduced). Some spacing treatments received water strictly on a land-area basis, in which case, the total volume of irrigation water received was the same. This meant that the treatments with the wider dripline spacings received a greater volume of water in the immediate vicinity of the dripline. Other treatments received water in relation to the number of driplines in each plot. For example, the 2.3- and 3.0-m spacings in the latter category received 66 and 50% of the irrigation received by the fully irrigated 1.5-m spacing. The five treatments can be summarized as follows:

1. 1.5-m dripline spacing with full irrigation (Control)
2. 2.3-m dripline spacing with 66% of full irrigation
3. 2.3-m dripline spacing with full irrigation
4. 3.0-m dripline spacing with 50% of full irrigation
5. 3.0-m dripline spacing with full irrigation

Irrigations were scheduled using a water budget to calculate the root zone depletion, with precipitation and irrigation water amounts as deposits and the calculated daily corn water use (AET) as a withdrawal. If the root-zone depletion became negative, it was reset to zero. All calculations of the root zone depletion were based on fully irrigated conditions. Treatments receiving full irrigation were irrigated to replace 100% of the calculated root-zone depletion when the depletion was within the range of 19 to 51 mm, with most irrigations performed at a depletion of approximately 25 mm. The irrigation event for all treatments began on the same day but ended on different days and times because of the different spacings and irrigation amounts. An irrigation event that applied 25 mm for Treatment 1 (1.5-m spacing) lasted approximately 20 h; whereas, the same event for Treatment 5 (3.0-m spacing with full irrigation) lasted 40 h. These irrigation amounts and length of events may seem high when compared to traditional microirrigation on higher value crops on sandier soils. However, Caldwell et al. (1994) found that weekly irrigation worked as well as daily irrigation on the deep silt loam soils of western Kansas when full irrigation was practiced. Irrigation water was metered separately onto each plot with commercial, municipal-grade, flow accumulators with an accuracy of ±1.5%. Irrigation volumes were converted into an equivalent depth for the plot area.

The reference evapotranspiration (ET_r) was calculated using a modified Penman combination equation similar to the procedures outlined by Kincaid and Heerman (1974). The specifics of the ET_r calculations used in this study are described fully by Lamm et al. (1987). Basal crop coefficients (K_{cb}) were generated by equations developed by Kincaid and Heerman (1974) based on work by Jensen (1969) and Jensen et al. (1970, 1971). The basal-crop coefficients were calculated for the region by assuming 70 days from emergence to full canopy for corn, with physiological maturity at 130 days. This method of calculating actual evapotranspiration (AET) as the product of K_{cb} and ET_r has been applied in past studies at Colby and has been found to accurately estimate AET (Lamm and Rogers, 1983, 1985). In constructing the irrigation schedules, no attempt was made to modify AET with respect to soil-evaporation losses or soil-water availability as outlined by Kincaid and Heerman (1974).

Conventional tillage was used in the corn production. The stalks were shredded and double-disked in the fall for increased residue decomposition. The study area was fertilized in the fall of 1989 and 1990 with 245 kg/ha of nitrogen and 45 kg/ha of P_2O_5, surface applied as a solution. Following fertilization, the area was corrugated to prevent overwinter wind erosion and to provide 0.76 m ridges for planting in the spring. Corn (Pioneer 3162) was planted parallel to the driplines at a rate of 67,950 plants/ha on 23 April 1990 and at a rate of 71,900 plants/ha on 7 May 1991. The corn emerged on 15 May each year.

A neutron probe was used to measure volumetric soil water contents in 0.3 m increments to a depth of 1.8 m on an approximately weekly basis each season. Soil water was measured in one of the corn rows 0.38 m from the dripline for Treatment 1 (1.5 m dripline spacing). Treatments 2 and 3 had three corn rows between driplines, so estimating an integrated-soil water amount for these treatments involved measuring soil water in two corn rows, one being 0.38 m and the other 1.14 m from the nearest dripline. Treatments 4 and 5 had four corn rows between driplines. Using symmetry, soil water measurements in two adjacent corn rows (0.38 and 1.14 m from the dripline) allowed estimation of an integrated soil water amount for these treatments.

The seasonal field-water supply for each treatment was calculated as the sum of precipitation, irrigation, and measured soil water depletion between the initial (6-07-90 and 5-31-91) and the final (9-20-90 and 9-19-91) soil water measurements. The term field-water supply should not be confused with actual measured crop water use (ET). Field-water supply, as expressed here, includes any runoff and deep percolation that occurred. It would be reasonable to assume that deep percolation might be a significant component for the fully irrigated treatments with wider dripline spacings (Treatments 3 and 5).

A 6-m row length was harvested from the center of each plot at physiological maturity (9-20-90, 9-20-91) for yield determination. To examine yield distribution between driplines, yield samples from representative rows were taken similar to the individual row measurements described for soil water. The yield distribution, when integrated, gave the average yield for the treatment.

The combination of yield and soil water distribution was used to determine the performance of each dripline spacing/irrigation treatment performed. Water use efficiency was calculated as the integrated corn grain yield divided by the field-water supply.

A partial-budget economic analysis was conducted by comparing the total income generated by the various dripline spacing treatments to their investment costs. The analysis was limited to the primary differences in dripline costs for the various treatments, although some minor differences could also occur in other components because of hydraulic design differences. It does not include analysis of any operating costs or total investment costs, only the differential costs between the dripline spacings. The annual amortized costs for the dripline were calculated using a 10-year life and 10% interest. The break-even dripline costs for the wider 2.3 and 3.0 m dripline spacings as compared to the standard 1.5 m dripline spacing were calculated for corn grain prices ranging from $0.06 to $0.12/kg using the two-year mean corn yields for the various dripline spacings.

RESULTS AND DISCUSSION

CLIMATIC CONDITIONS

Seasonal precipitation (May to September) was 309 and 332 mm for 1990 and 1991, respectively, which was very near the long-term (99-year) mean of 321 mm. However, in both years, May precipitation was significantly greater than the 99-year mean. The corn emerged on 15 May in each year so crop water use from the available May precipitation was low. In each year, one or more of the principal growth months (June, July, or August) had less than normal precipitation.

The cumulative calculated evapotranspiration (AET) for the 120-day period beginning on 15 May was 594 and 600 mm for 1990 and 1991, respectively, as compared to the 20-year mean of 587 mm.

The average net irrigation requirement for corn in Thomas County of northwest Kansas is 391 mm with an 80% chance precipitation (Soil Conservation Service, 1977). In this study, the net irrigation requirement was 462 mm in both years for the full irrigation treatments. In 1990, extremely high AET during the mid-June to mid-July period coupled with low precipitation resulted in greater irrigation needs than most irrigation systems in northwest Kansas could provide. Nearly 44% of the seasonal irrigation requirement was applied before corn silking (7-18-90). Fortunately deep soils with stored available water buffered the corn from excessive water stress during the period. The crop year 1991 was characterized by slightly above-normal precipitation in June and July but appreciably below-normal precipitation in August and September, resulting in 72% of the seasonal irrigation amount being applied after corn silking (7-18-91).

The climatic conditions for the two years can be summarized overall as being near normal. However, the irrigation requirements were generally above normal because of the timing of high evapotranspiration periods and precipitation. Of course, the timing of irrigation events with respect to when precipitation occurs also can affect the overall amount of irrigation applied.

EFFECT OF DRIPLINE SPACING ON INTEGRATED CORN YIELDS AND WATER USE

Integrated corn yields varied widely among treatments (table 1) for the two years of the study ranging from a low of 6.7 Mg/ha for Treatment 4 in 1991 to a high of 14.1 Mg/ha for Treatments 1 and 3 in 1990.

Although seasonal crop water use (ET) was higher than normal in 1990, the pollination and grain filling stages of the corn occurred during periods of extremely mild temperatures. Because of these climatic conditions, much of the plant water stress was buffered and overall excellent grain yields were obtained. The mean yields were high for all treatments, with less than a 3% difference between the spacings for the fully irrigated Treatments 1, 3, and 5. When irrigation water was reduced in relation to the reduction in the number of driplines for each plot, the yield differences increased, resulting in a 15% difference between the control 1.5-m dripline spacing and the 3.0-m spacing with reduced irrigation. There were no statistically significant differences in yields in 1990 with the exception of Treatment 4, which had significantly lower yields.

The results from 1991 contrasted sharply with the results from 1990. Yields from the wider 2.3- and 3.0-m dripline spacings with full irrigation were significantly lower, being reduced 12 and 18% compared to those from the standard 1.5-m dripline spacing. At the high overall yield levels, these reductions were economically

Table 1. Integrated corn yields and water use data from a dripline spacing study, KSU Northwest Research-Extension Center, 1990-1991

Dripline* Spacing	Irrigation Regime	Irrigation Amount (mm)	Corn Grain Yield 1990	Corn Grain Yield 1991	Corn Grain Yield Mean	Field Water Supply 1990	Field Water Supply 1991	Field Water Supply Mean	Water Use Efficiency 1990	Water Use Efficiency 1991	Water Use Efficiency Mean
			(Mg/ha at 15.5 wb)			(mm)	(mm)	(mm)	(Mg/ha-mm)	(Mg/ha-mm)	(Mg/ha-mm)
1. 1.5 m	Full	462	14.1a	13.1a	13.6a	693a	659b	676a	0.0203a	0.0199a	0.0201a
2. 2.3 m	66% of Full	308	13.4a	8.3c	10.8c	616b	565c	590b	0.0217a	0.0147bc	0.0182a
3. 2.3 m	Full	462	14.1a	11.5b	12.8ab	701a	680ab	691a	0.0202a	0.0169b	0.0185a
4. 3.0 m	50% of Full	231	11.9b	6.7d	9.3d	541b	462d	501c	0.0220a	0.0146c	0.0183a
5. 3.0 m	Full	462	13.6a	10.7b	12.2b	697a	693a	695a	0.0196a	0.0155bc	0.0175a
Mean			13.4	10.1	11.7	650	612	631	0.0207	0.0163	0.0185
Least Significant Difference (P = 0.05)			0.9	1.4	1.0	31	31	20	0.0021	0.0023	NS

* Within columns, means followed by the same letter are not significantly different according to LSD means separation at P = 0.05.

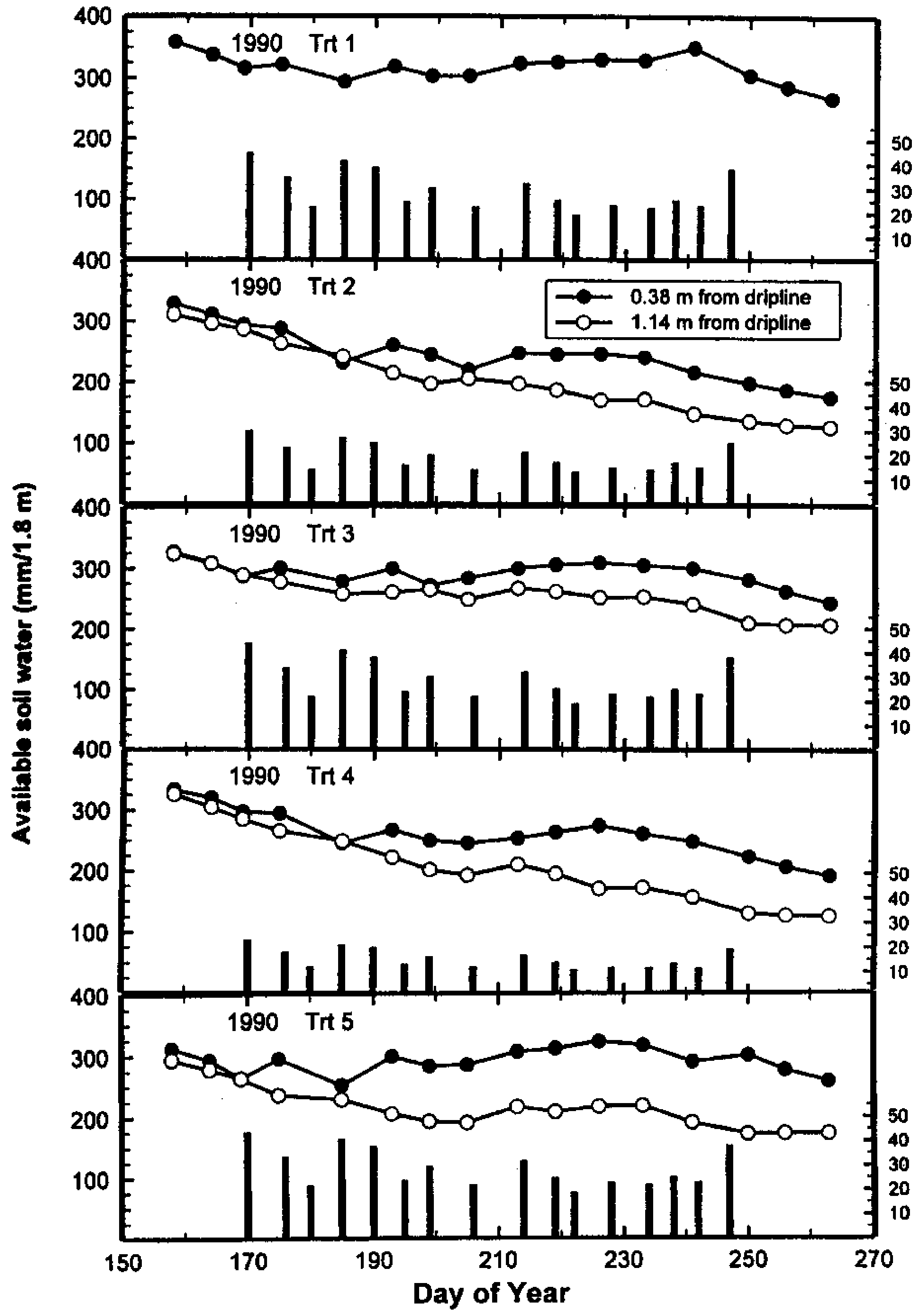

Figure 1–Seasonal progression of profile available soil water at 0.38 and 1.14 m from the dripline (lines and symbols) and irrigation amounts (vertical bars) for various treatments in a dripline spacing study, Colby, Kansas, 1990.

significant. At the reduced irrigation level, yields were reduced 36 and 49% for the 2.3- and 3.0-m spacings. At the wider dripline spacings with reduced irrigation, corn yields were near zero for the rows 1.14 m from the dripline.

Lamm et al. (1995b) compared the corn yield results of this study with parallel corn row and driplines to those obtained by Spurgeon et al. (1991) for driplines perpendicular to corn rows. Soil types and climates were similar for these two Kansas (USA) locations. Yields for comparable dripline spacings were nearly identical. The accumulation or integration of corn yield for the two orientations was quite different, but both orientations produced similar results. The parallel corn row and dripline orientation might provide more management flexibility when using saline waters and/or fertigation. Ayars et al. (1995) reported that salinity distribution was increased in the center of the bed beneath the crop row when driplines were not matched with bed location. Mechanical damage from tillage also was much more evident when driplines were not centered under the bed.

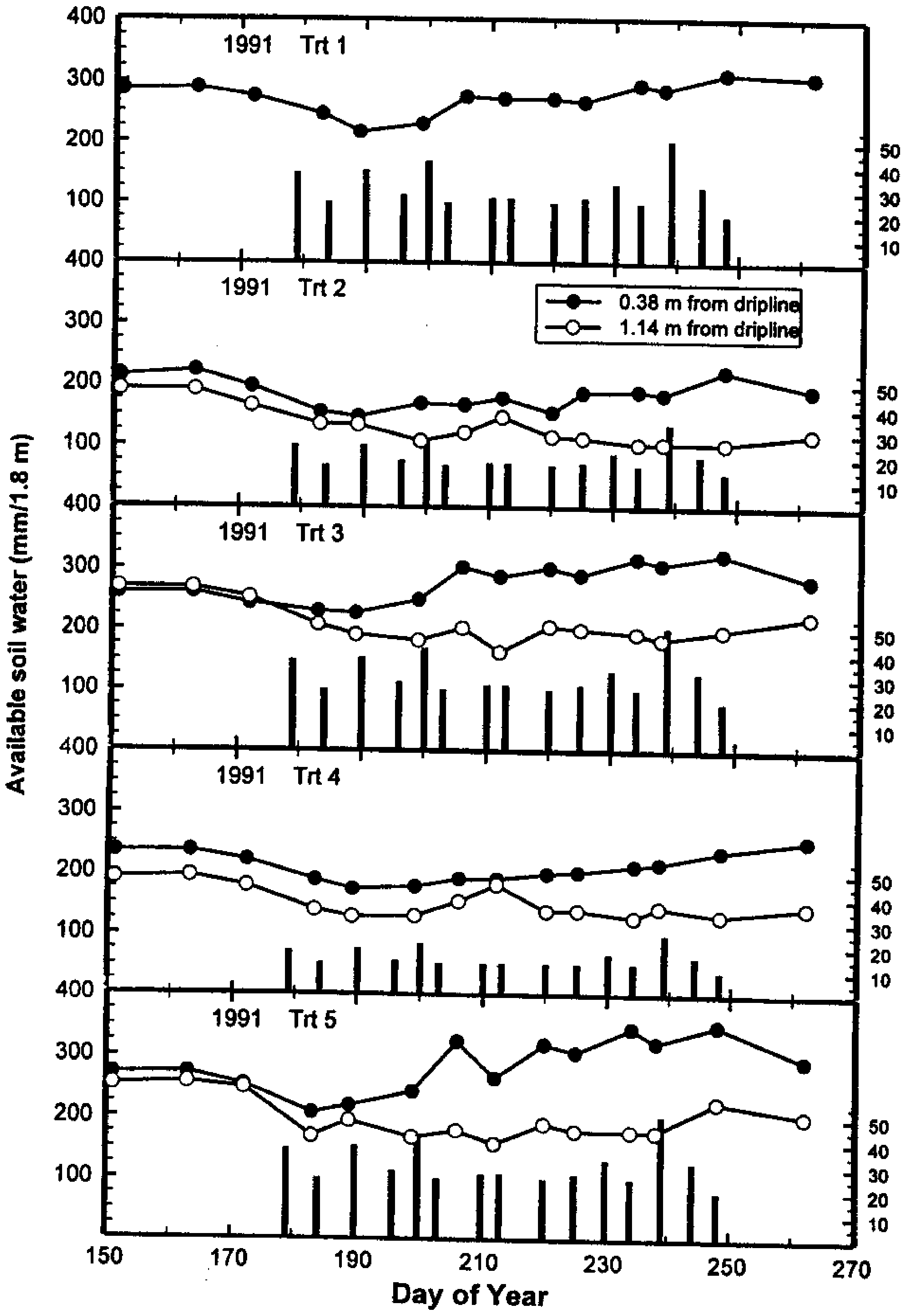

Figure 2–Seasonal progression of profile available soil water at 0.38 and 1.14 m from the dripline (lines and symbols) and irrigation amounts (vertical bars) for various treatments in a dripline spacing study, Colby, Kansas, 1991.

In 1990, the 155 mm reduction in irrigation water for Treatment 2 resulted in a field-water supply reduction of only 77 mm as compared to the fully irrigated Treatment 1. This indicates increased depletion of soil water reserves by

Treatment 2. The 50% irrigation reduction for Treatment 4 was 231 mm but resulted in a field-water supply reduction of only 152 mm. As a result of the extremely mild temperatures during the pollination and grain filling stages of the corn in 1990 which allowed gradual depletion of soil water reserves, the decreased irrigation amounts for Treatment 2 and 4 resulted in little loss of yield.

In 1991, the 33 and 50% reductions in irrigation for Treatments 2 and 4 resulted in field-water supply reductions of 94 and 197 mm, respectively, compared to the fully irrigated Treatment 1. There was less compensation for the decreased irrigation amount by increased depletion of soil water reserves. Treatments 2 and 4 started the 1991 season with soil water reserves at approximately 50% of field capacity for the 1.8 m soil profile, primarily because the low amount of overwinter precipitation (October through April, 113 mm) did not recharge reserves depleted by the 1990 crop.

In 1990, there were no significant differences in water use efficiency among treatments (table 1). In 1991, the highest average water use efficiency was obtained by Treatment 1, which was considerably higher than that for the wider spacing treatments. The lower average water use efficiencies for Treatments 2 and 4 were due primarily to low corn yields in 1991. In contrast, the lower average water use efficiencies for Treatments 3 and 5 were due to higher field-water supply values, which probably included excessive deep percolation.

EFFECT OF DRIPLINE SPACING ON SOIL WATER

In both years, irrigation and precipitation maintained the profile available soil water at a relatively constant and high level with the standard 1.5 m dripline spacing (Treatment 1) for the corn row that was 0.38 m from the dripline (figs. 1 and 2). This indicates that the 1.5 m dripline spacing were adequately supplying the water needs of the crop.

Treatments 3 and 5 also maintained relatively constant and high profile available soil water for the corn row 0.38 m from the dripline (figs. 1 and 2). However, soil water was lowered an additional 20 to 40% by the corn row growing 1.14 m from the dripline, indicating that water distribution was inadequate for the wider dripline spacings, even with the same volume of water applied (full irrigation).

In 1990, reduced irrigation amounts for Treatments 2 and 4 resulted in heavy depletion of the profile soil water at both corn row locations, with an approximately 65 to 70% depletion at a distance 1.14 m from the dripline. Decreased soil-water reserves for these two treatments were carried over into 1991, partly because of low overwinter precipitation. The reduced irrigation amounts in 1991 could not replenish soil water reserves, and, as a result, severe water stress occurred early in the season. An estimated 80 to 90% of the plants in the corn rows 1.14 m from the dripline died before tasseling in Treatments 2 and 4. These results indicate that a proportional reduction in irrigation amount and the number of driplines for the wider spacings greatly increases the chance for crop failure, unless preseason irrigation can be used to recharge the soil profile with water. Such preseason irrigation using a SDI system would be impractical on this soil type, because of the poor horizontal distribution of water for the wider dripline spacings.

EFFECT OF DRIPLINE SPACING ON INDIVIDUAL CORN ROW YIELDS

The effect of dripline spacing on individual corn row yields is shown in figure 3. A mirror image of corn yields about a line halfway between driplines was used to illustrate the yield distributions of the various treatments.

Large yield variations between rows occurred as distance from the dripline to the row increased from 0.38 m to 1.14 m. In 1990, the row-to-row difference exceeded 32% for the 3.0 m dripline spacing with reduced irrigation (Treatment 4). This row-to-row difference was reduced to 22% when water was applied on a land area basis (Treatment 5). In 1991, corn yields for the interior rows were reduced 98 and 41% for Treatments 4 and 5, respectively.

An unanticipated result occurred for the wider dripline spacings. The corn yields for the rows 0.38 m from the dripline were almost always higher for Treatments 2, 3, 4, and 5 than for the standard 1.5 m dripline spacing (figs. 3 and 4). The reason for this is unknown. However, it probably was not caused by extra water available for the rows nearest the dripline, because yields generally were

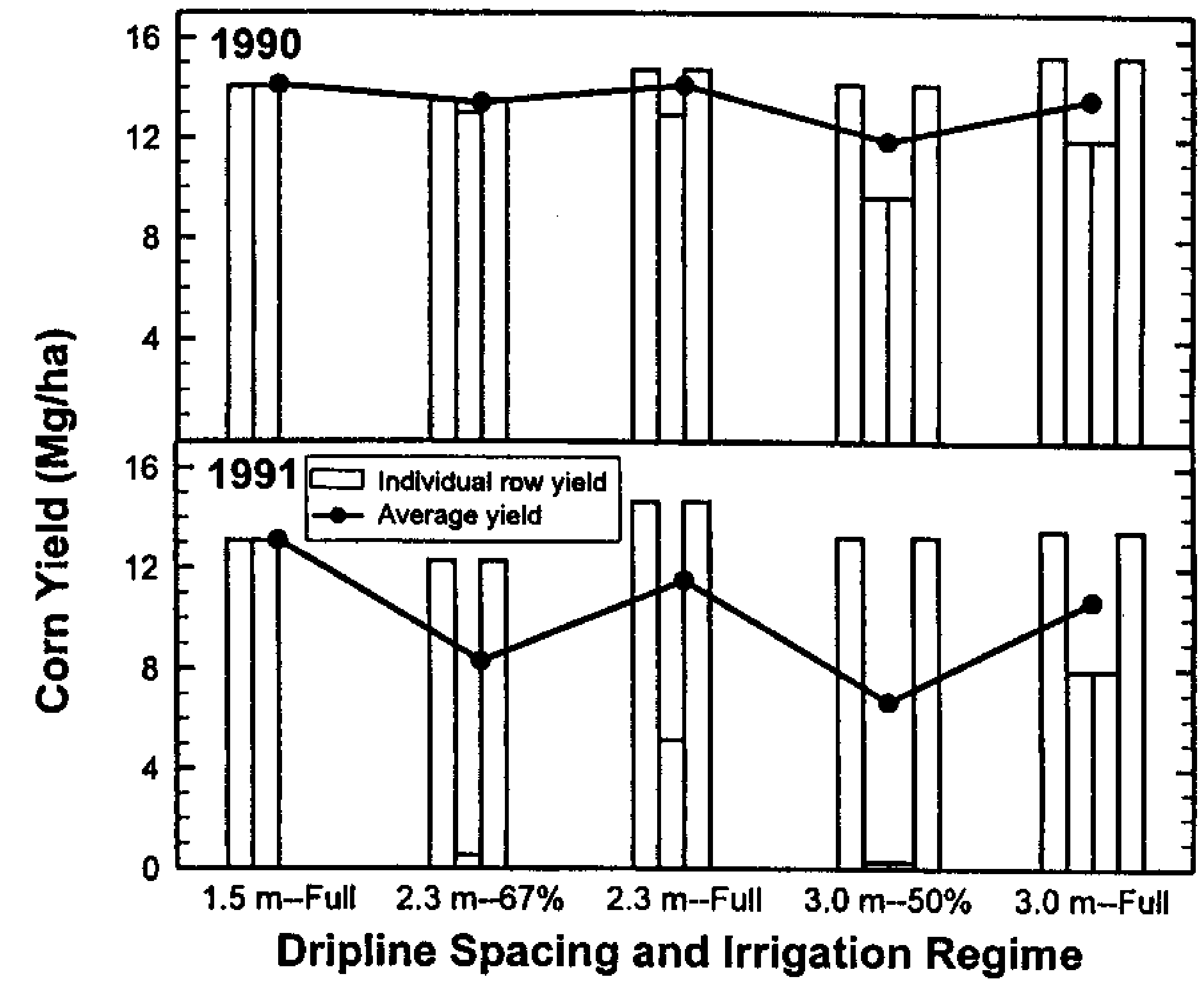

Figure 3–Corn yield distribution as affected by dripline spacing and irrigation regime, KSU Northwest Research-Extension Center, Colby, Kansas, 1990-1991. Note: Individual row yields are mirrored about a centerline half way between two adjacent driplines for display purposes.

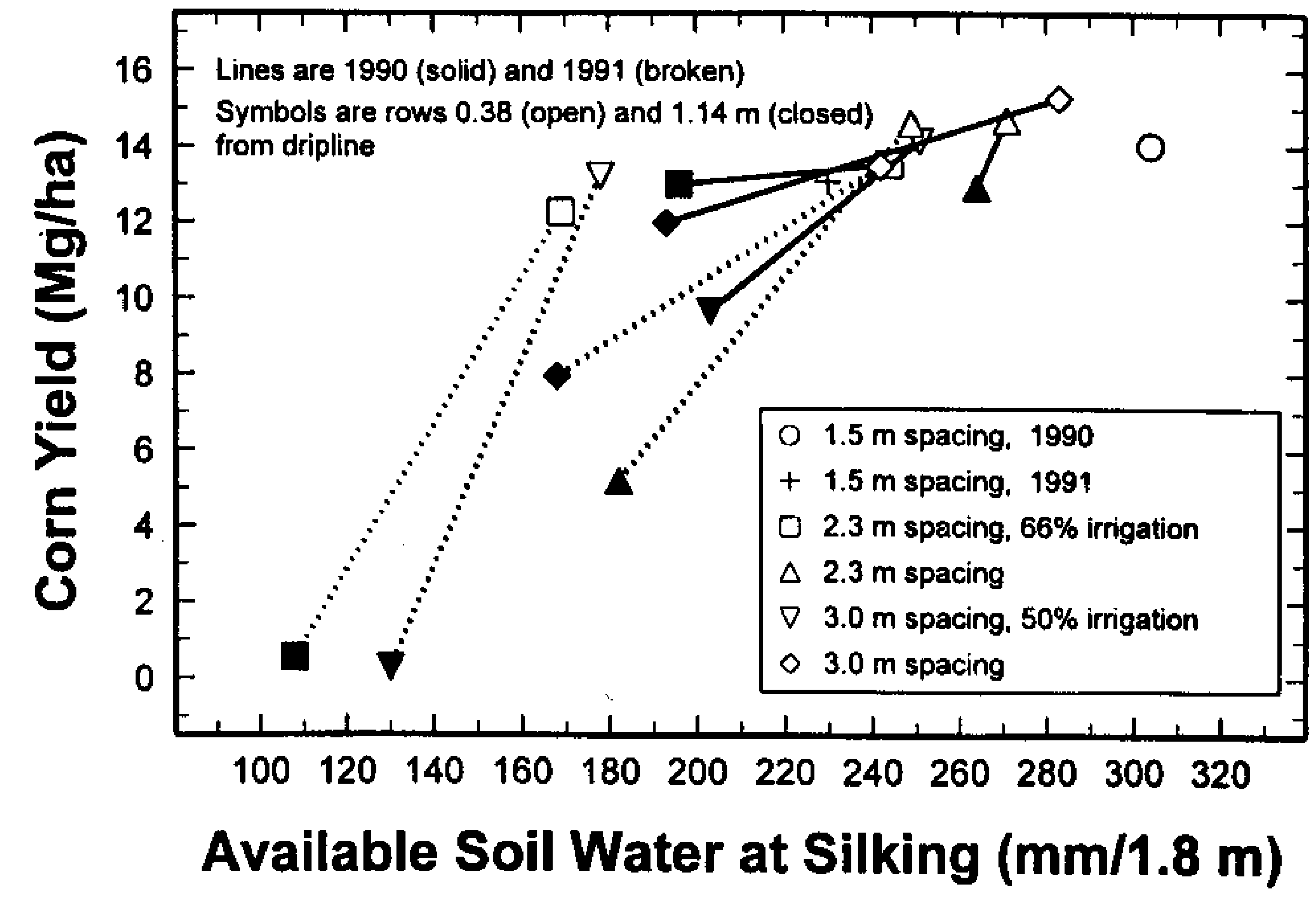

Figure 4–Relationship of individual corn row yields to the available soil water at silking for a dripline spacing study, KSU Northwest Research-Extension Center Colby, Kansas, 1990-1991.

reduced by overirrigation in another SDI corn study at Colby (Lamm et al., 1995a). The interior rows for the wider dripline spacings were stunted in height by water stress during the vegetative stage in both years. This may have allowed more sunlight into the crop canopy of the rows nearest the dripline, resulting in higher yields. Another possibility is that the rows nearest the dripline, having more favorable soil water conditions, scavenged more nutrients.

Individual row yields were roughly positively linearly related to the availability of soil water at corn silking for available soil-water levels below 230 mm/1.8 m (fig. 4). A distinct plateauing of corn yields occurred when the profile available soil water at silking reached approximately 230 mm value, indicating an adequate supply of soil water. In years when the profile soil water (1.8 m depth) for the interior rows remains at approximately 50% of field capacity at the end of the vegetative stage, the wider spacings may perform acceptably, at least in terms of corn yields. Of course, this statement also reflects the fact that seasonal precipitation in the corn reproductive period buffered a portion of the shortfall in irrigation water redistribution. This buffering may explain why Powell and Wright (1993) in the wetter climate of Virginia (USA) obtained adequate results with a 2.74 m dripline spacing for corn production.

ECONOMIC COMPARISON OF THE VARIOUS SPACING TREATMENTS

A partial budget analysis was used to compare the relative economic rankings of the various dripline spacings assuming the mean corn yield response obtained in the two-year study. This analysis was limited to comparing the total income from the harvested grain to the differential amortized dripline costs for the various spacings. Equivalent break-even dripline costs for the wider 2.3 and 3.0 dripline spacings as compared to the standard 1.5 m spacing were calculated for various corn prices (fig. 5). The average corn yield differences for the various dripline spacings obtained in this study were relatively high, and as a result, the wider spacings were justified only at very high dripline costs and/or very low corn prices. No realistic scenarios were indicated where the wider spacings would be economically justified using the assumptions of this analysis.

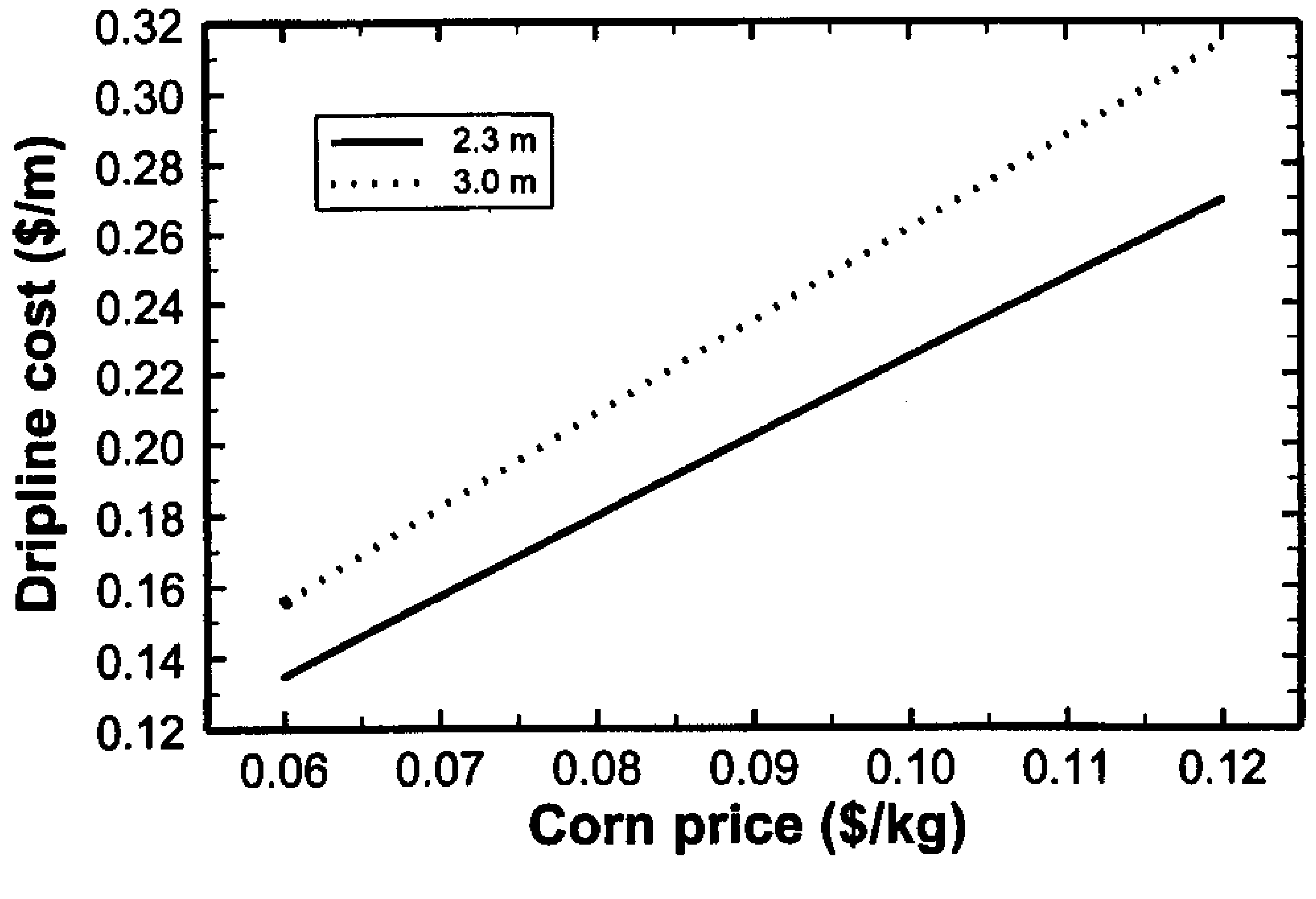

Figure 5–Break-even dripline costs for the wider 2.3 and 3.0 m dripline spacings as compared to the standard 1.5 m dripline spacing as a function of corn grain price, KSU Northwest Research-Extension Center, Colby, Kansas, 1990-1991.

CONCLUSIONS

A dripline spacing of 1.5 m with full irrigation resulted in the highest two-year average corn yield (13.6 Mg/ha) and also the highest water use efficiency (0.0201 Mg/ha-mm). The next highest-yielding treatment (2.3 m dripline spacing with full irrigation) had a 6% lower yield and an 8% lower water use efficiency but these differences were not statistically different at $P = 0.05$.

The lower water use efficiencies for the wider 2.3- and 3.0-m dripline spacings were related to lower average corn yields from reduced-irrigation treatments and to higher field-water supply values for the full-irrigation treatments.

A time-series comparison of the profile available soil water amounts for the wider dripline spacings indicated inadequate water distribution. At a distance of 1.14 m from the dripline, the profile was depleted increasingly during the course of the season. Severe soil water depletions for the reduced-irrigation treatments in 1990 were not replenished by overwinter precipitation, resulting in crop failure for the rows 1.14 m from the dripline in 1991. Risk-averse producers probably would want to avoid using the wider dripline spacings because of the variation in year-to-year performance.

The combined factors of a tendency to lower yields, lower water use efficiencies, increased year-to-year yield variation, and lower economic returns indicate that the wider 2.3- and 3.0-m dripline spacings are not justified for subsurface drip-irrigated corn on the silt loam soils of western Kansas.

REFERENCES

Ayars, J. E., C. J. Phene, R. A. Schoneman, B. Meso, F. Dale and J. Penland. 1995. Impact of bed location on the operation of subsurface drip irrigation systems. In *Proc. 5th Int. Microirrigation Congress*, Orlando, Florida, 2-6 April 1995, 141-146. St. Joseph, Mich.: ASAE.

Bark, L. D. and H. D. Sunderman. 1990. Climate of northwestern Kansas. Report of Progress 594. Manhattan, Kans.: Kansas Agricultural Experiment Station.

Bidwell, O. W., E. E. Banbury, W. L. Barker and G. E. Muilenburg. 1980. The Colby Branch Experiment Station and agriculture in northwest Kansas with special mention of soils. Bulletin 635. Manhattan, Kans.: Kansas Agric. Exp. Station.

Caldwell, D. S., W. E. Spurgeon and H. L. Manges. 1994. Frequency of irrigation for subsurface drip-irrigated corn. *Transactions of the ASAE* 37(4):1099-1103.

Camp C. R., E. J. Sadler and W. J. Busscher. 1989. Subsurface and alternate-middle micro irrigation for the Southeastern Coastal Plain. *Transactions of the ASAE* 32(2):451-456.

Clark, R. N. 1979. Furrow, sprinkler, and drip irrigation efficiencies in corn. ASAE Paper No. 79-2111. St. Joseph, Mich.: ASAE.

Jensen, M. E. 1969. Scheduling irrigation using computers. *J. Soil and Water Cons.* 24(8):193-195.

Jensen, M. E., C. E. Franzoy and D. C. N. Robb. 1970. Scheduling irrigations using climate-crop-soil data. ASCE, *J. Irrig. and Drain.* 96(IRI):25-38.

Jensen, M. E., B. J. Pratt and J. L. Wright. 1971. Estimating soil and moisture depletion from climate, crop and soil data. *Transactions of the ASAE* 14(5):954-959.

Kincaid, D. E. and D. F. Heerman. 1974. Scheduling irrigation using a programmable calculator. USDA Publication ARS-NC-12. February.

Kruse, E. G. and I. Israeli. 1987. Evaluation of a subsurface drip irrigation system. ASAE Paper No. 87-2034. St. Joseph, Mich.: ASAE.

Lamm, F. R. and D. H. Rogers. 1983. Scheduling irrigation using computed evapotranspiration. ASAE Paper No. MCR 83-109. St. Joseph, Mich.: ASAE.

Lamm, F. R. and D. H. Rogers. 1985. Corn yield response to different irrigation regimes. ASAE Paper No. MCR 85-131. St. Joseph, Mich.: ASAE.

Lamm, F. R., D. A. Pacey and H. L. Manges. 1987. Spreadsheet templates for the calculation of Penman reference evapotranspiration. ASAE Paper No. MCR 87-106. St. Joseph, Mich.: ASAE.

Lamm, F. R., H. L. Manges, D. H. Rogers, W. E. Spurgeon and M.H. Farmer. 1990. Design and installation of a drip irrigation system for research purposes. ASAE Paper No. 90-2530. St. Joseph, Mich.: ASAE.

Lamm, F. R., H. L. Manges, L. R. Stone, A. H. Khan, D. H. Rogers. 1995a. Water requirement of subsurface drip-irrigated corn in northwest Kansas. *Transactions of the ASAE* 38(2): 441-448.

Lamm, F. R., W. E. Spurgeon, D. H. Rogers and H. L. Manges. 1995b. Corn production using subsurface drip irrigation. In *Proc. 5th Int. Microirrigation Congress*, Orlando, Fla., 2-6 April 1995, 388-394. St. Joseph, Mich.: ASAE.

Manges, H. L., W. E. Spurgeon, Z. M. Huang and D. J. Tomsicek. 1995. Subsurface dripline spacing and plant population for corn production. In *Proc. of the 5th Int. Microirrigation Congress*, Orlando, Florida, 2-6 April 1995, 388-394. St. Joseph, Mich.: ASAE.

Powell, N. L. and F. S. Wright. 1993. Grain yield of subsurface microirrigated corn as affected by irrigation line spacing. *Agron. J.* 85:1164-1170.

Safontas, J. E. and J. C. di Paola. 1985. Drip irrigation of maize. Vol. 2 of *Drip/Trickle Irrigation in Action, Proc. 3rd Int. Drip/Trickle Irrigation Congress*, Fresno California, 575-578. St. Joseph, Mich.: ASAE.

Soil Conservation Service. 1977. Kansas irrigation guide. Salina, Kans.: Soil Conservation Service,

Spurgeon, W. E. and H. L. Manges, 1990. Drip line spacing and plant population for corn. In *Proc. 3rd Nat. Irrig. Symp.*, Phoenix, Arizona, 28 October - 1 November 1990, 217-222. St. Joseph, Mich.: ASAE.

Spurgeon, W. E., H. L. Manges and T. P. Makens. 1991. Drip line spacing and plant population for corn. ASAE Paper No. 91-2592. St. Joseph, Mich.: ASAE.