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Reducing Erosion from Surface Irrigation by Furrow Spacing and Plant Position

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ABSTRACT

Erosion is a serious problem in many furrow-irrigated fields. Erosion abatement can be costly or inconvenient. Plant placement, row spacing, and choice of trafficked or non-trafficked furrow have not been thoroughly exploited for furrow erosion control. It was hypothesized that reducing furrow spacing and plant distance to the furrow would reduce erosion for equal amounts of water applied. A study in 1986 and 1987 observed the effect of narrow rows or twin rows with plants in close proximity to the furrow on infiltration, sediment loss, and yields in three crops grown under conventional tillage on a Portneuf silt loam (coarse-silty, mixed, mesic Durixerollic Calciorthids) with 1% slope. Yields of twin-row dry bean (*Phaseolus vulgaris* L.) significantly increased in both years ($P < 0.05$), whereas yield of sugarbeet or corn (*Beta vulgaris* L., or *Zea Mays* L.) were not affected significantly by any planting pattern. Sediment loss, runoff, and the ratio of sediment loss to infiltration were greatly reduced by twin-row configurations, and somewhat reduced, although less consistently, by narrow single-row configurations. The results point the way to a low-cost, low-maintenance method of reducing furrow erosion.

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THERE ARE APPROXIMATELY 10 MILLION HECTARES of surface-irrigated land in the 17 western states with 1.5 million in the three Pacific Northwest states (Washington, Oregon, Idaho) that are mostly furrow irrigated. Soils in the Pacific Northwest are particularly susceptible to furrow erosion because they are typically low in organic matter and clay, and are derived from ash or glacial loess, with weak aggregates and little structure. In these systems, substantial quantities of water are conveyed across the field each season in furrows cut from bare, recently tilled soil, making the systems inherently erosive (Berg and Carter, 1980; Brown 1985a; Everts and Carter, 1981; Brown et al., 1988, and Carter et al. 1985). Farmers are only beginning to use conservation tillage practices on this land.

Soil erosion is the most serious threat to long-term sustainable production in the Pacific Northwest. Erosion commonly removes 5 to 50 t ha^{-1} yr^{-1} from furrow-irrigated fields, and as much as 141 t ha^{-1} yr^{-1} from the inlet (top) ends of fields (Berg and Carter, 1980; Kemper et al., 1985). As much as 50.9 t ha^{-1} has been reported lost from a single 24-hr irrigation of corn (Mech, 1959). Erosion is exacerbated by slopes

Abbreviations: LAI, leaf area index; and *S/I* ratio, ratio of sediment loss to water infiltration.

>1%, but in gravity systems, longer furrow runs usually require fields with greater slopes in order to deliver adequate amounts of water to the bottoms of fields. Consequently, furrow irrigation of Pacific Northwestern soils frequently results in rapid (tens of years) loss of surface soil from inlet ends of fields, and, in many areas, exposure of high calcium-bearing subsurface horizons. The resulting "white soils" have poorer physical and chemical properties that usually reduce crop productivity and can increase required inputs (Carter et al., 1985).

Various approaches have been used to prevent or reduce furrow erosion, usually at some inconvenience to the farmer or requiring specialized machinery, significant capital outlay, or both. Some of these approaches include settling ponds, requiring periodic sediment removal and redistribution (Brown et al., 1981); minibasins and buried-pipe runoff control systems (Carter, 1985); straw placement in furrows (Brown, 1985b; Brown and Kemper, 1987, and Berg, 1984); creation and maintenance of permanently sodded furrows (Cary, 1986); and conservation tillage (Carter, 1990; Carter and Berg, 1991).

Furrow spacing, plant proximity to the furrow, and choice of trafficked or non-trafficked furrow were thought to affect furrow erosion. Managing these effects could offset the need for less convenient sediment retention techniques, or extend the life and/or maintenance intervals of sediment basins. Alternative plant placement has not been systematically explored as a low cost means of reducing furrow erosion. Simple planting configuration changes might be easily incorporated into otherwise conventional cultural practices. A study was therefore initiated near Kimberly, ID to quantify the impact of varied row spacing (canopy configuration) on infiltration, sediment loss, and crop yield under conventional tillage practices for three commonly grown row crops using furrow irrigation.

MATERIALS AND METHODS

Sugarbeet, corn, and dry edible bean were grown in 1986 and 1987 on separate fields in Kimberly, ID. The soils in all fields were classified as a Portneuf silt loam (McDole and Maxwell, 1986). The slopes of the fields in this study were 1.0%. Fields were fall-plowed and, and in the spring, composite soil samples were collected from each field before seedbed preparation. Fields were broadcast fertilized according to Univ. of Idaho soil test recommendations for N, P, and Zn. Following fertilizer application, fields were treated for weeds using standard label rates. Herbicides used were cycloate (*S*-ethyl cyclohexylethylthiocarbamate) for beets, alachlor (2-chloro-2',6'-diethyl-*N*-[methoxymethyl]acetanilide) in 1986 and EPTC (*S*-ethyl dipropylthiocarbamate) in 1987 for corn, and ethalfluralin (*N*-ethyl-*N*-[2-methyl-2-propenyl]-2,6-dinotro-4-[trifluoromethyl]benzenamine) for beans. Following application of herbicides, fields were disked and roller-harrowed before planting.

In 1986 sugarbeet was planted 28 April, corn on 15 May, and bean on 29 May. Irrigation furrows were formed as an integral part of the planting operation. Sugarbeet was the cultivar WS-88[1] grown at a population of 62 000 plants ha^{-1} in either 0.56- or 0.76-m spacings between furrows (B and D, Fig. 1) in a randomized complete block design with three replications. Corn was the hybrid *O*'s Gold 2570 (Asgrow) planted at a population of 62 000 plants ha^{-1} in either 0.56-, 0.76-, or "twin" 1.12-m row spacings (B, D, or A, Fig. 1) in a randomized complete block design with three replications. Two varieties of bean, Viva pink (a bush type) and NW 590 pinto (a vine type) were planted at populations of 346 000 and 173 000 plant ha^{-1} respectively in a randomized split block design with three replications. Bean row-spacing main plots were split for bean variety. Bean row spacings used were 0.56-, 0.76-, or twin 0.76-m spacings (B, D, and C, Fig. 1).

Individual plots were 12 beds wide for beets and corn and eight beds wide for each bean variety (where "bed" designates the raised area between furrows). The first irrigation of all plots was applied to every furrow to help insure uniform field wetting. As with predominant local production practices, subsequent irrigations were in the same alternate furrows all season, except for beans in twin 0.76-m furrows (C, Fig. 1), which were irrigated in all furrows all season in order to provide adequate water to both twin-rows. Irrigations were monitored in wheel track (rear wheels) furrows, except for corn in twin 1.12-m rows. For the twin 1.12-m corn configuration (A, Fig. 1), a wide front tractor with front end weights was used to provide some firming of the furrow between close-spaced twin corn rows for water conveyance across the field (Trout et al. 1991). In this planting configuration, corn plant spacing and use of the non-wheel track furrow were coupled to attempt the maximum reduction of runoff and erosion. Twin corn rows could not be successfully planted adjacent to the wide rear wheel-track because of the disruptive effect of the wide rear tires too close to corn seed at planting and the destructive effect of wheel traffic too close to growing corn at cultivation.

In 1987 sugarbeet, corn, and beans were planted 22 Apr., 12 May, and 29 May respectively. The sugarbeet variety was WS-88; the corn hybrid was Pioneer 3901; and the bean variety was Viva Pink only. Experimental designs, plant populations, and irrigation practices were the same as in the previous year except that bean plots were not split for variety, and 0.76-m twin-row sugarbeet was added as a spacing treatment. The 0.76-m twin-row sugarbeet was irrigated in the same manner as the 0.76-m twin-row beans.

Water applications and runoff monitoring were partially governed by logistical considerations of manpower (to apply water and monitor run-on, run-off, and sediment loss), flume cost, and water availability within the irrigation system. Irrigation occurred at 7–10-day intervals and at no time were crops visibly water stressed. Furrow lengths for all plots were approximately 100 m (measured precisely for each plot to perform related calculations). Calculated maximum allowable (non-erodible) streamflow for this slope is approximately 38 L min^{-1} (Booher, 1974). Experience has shown that this overstates allowable streamflow for the Portneuf soil. For this furrow length, a much lower streamflow was adequate. Furrow inflow was held constant for all furrows and all other variables at 15.1 L min^{-1}. Water applications were adjusted to provide equal depth applications among treatments by varying the irrigation duration proportionally to the furrow spacing.

Runoff was determined from runoff time and runoff flow rate, using calibrated V-notch flumes which were manually read at 1 hr (or shorter) intervals through the course of the irrigation set. The 60° V-notch flumes, originally developed and calibrated by Robinson and Chamberlain (1960), are marketed by Honkers Supreme, Twin Falls, ID, and satisfy the hydraulic requirements for long-throated flumes (Bos et al., 1984) up to a flow depth of 9 cm (a gauge reading of 10 cm, or 100 L/min flow rate). Net furrow infiltration

[1]Mention of trademark, proprietary product, or vendor does not constitute a guarantee of warranty of the product by the US Department of Agriculture and does not imply its approval to the exclusion of other products or vendors that may also be suitable.

values were determined from the difference of inflow and run-off volumes. Sediment samples were collected with each flume reading. Sediment was collected in 1 L of free-flowing discharge from flumes, filtered on preweighed filter paper, dried, and reweighed to determine grams of sediment per liter of discharge. Differences in field infiltration between treatments were minimized by comparing the ratio of sediment weight lost from each plot to volume of water infiltrated in that plot. Runoff, infiltration, and sediment loss were not monitored for the first year of the bean study.

Growth of each crop was monitored periodically by determining leaf area index and dry weight of tops. Sugarbeet yield was expressed as weight of beets, percent sugar, and weight of sugar per hectare. Corn yield each year was determined both as weight of chopped corn per hectare at the time of maximum vegetative expression, and as weight of grain per hectare at maturity. Bean yield was measured as weight of harvested beans per hectare.

RESULTS AND DISCUSSION

The influence of rainfall for the 2 yr of the study was negligible, resulting in no runoff or erosion. Total seasonal (April through August) precipitation for 1986 and 1987 was 98.3 mm and 65.8 mm, respectively, with the largest events each year being 16.3 mm on 8 June, 1986 and 10.7 mm on 17 May, 1987. The impact of these events was further diminished by their

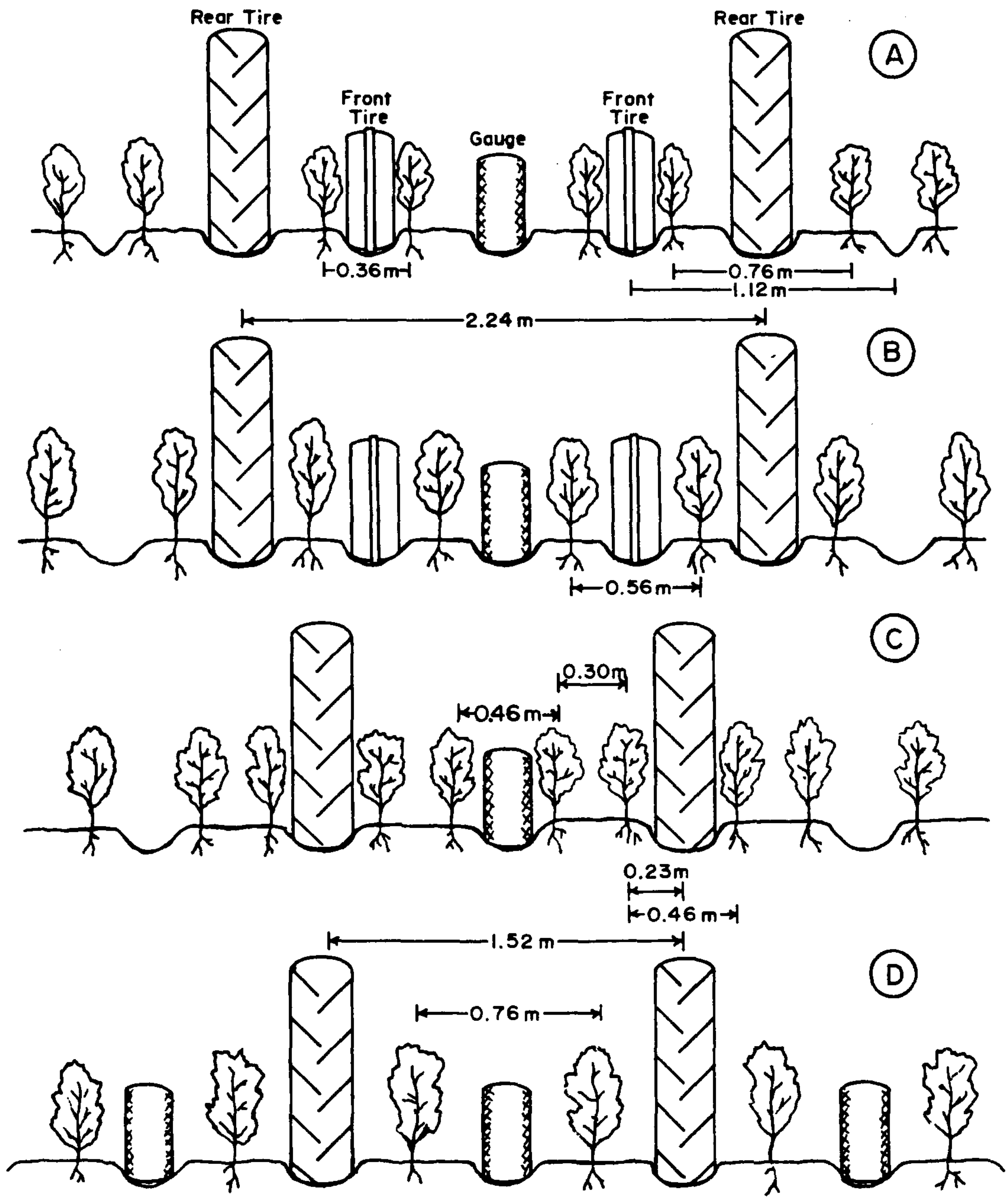

Fig. 1. Schematic showing plant, furrow, and tire placement of four spacing schemes used. All furrows were reshaped to uniform V-shapes with furrow shapers attached to the rear of planters. Patterns as described in text are: A, 1.12 m twin-rows; B, 0.56 m single rows; C, 0.76 m twin-rows; or D, 0.76 m single rows.

occurrence early in the season, before most irrigation was initiated.

Irrigation and Sediment

Table 1 presents summaries of water application, infiltration, sediment removal, and the ratio of sediment loss to water infiltrated (*S*/*I* ratio) for the irrigations monitored in each crop. As many irrigations were monitored over the 2-yr period as logistically possible. On the irrigation dates monitored, all treatments on a given crop were evaluated. Seasonal water application per hectare was nearly identical for all treatments in each crop, except for the sugarbeet crop in 1986. This discrepancy resulted from an application error on an early irrigation. More hardware and personnel in the second year of the study increased the number of observations possible in the cropping sequence. The two most consistent results were the increase in percent of water infiltrated in any of the narrow-row or twin-row configurations compared to wide single-row configurations and the reduction of the *S*/*I* ratio in the twin-row configurations. These effects were more pronounced and more consistent for the twin rows than for narrow single rows. There were several reasons for these occurrences.

If identical flow rates are used to apply water down a given furrow, regardless of the furrow spacing or planting pattern, then the irrigation set duration must vary to apply an equal volume of water per hectare to each spacing treatment. Closer placement of irrigation furrows therefore resulted in shorter irrigation durations. Because furrow infiltration is greatest during the earlier portion of the set (there is less runoff) a greater proportion of the total water applied in the closer spaced furrows infiltrates. This occurs because the less efficient later portion of the set is eliminated. If the duration of the irrigation set is never long enough to allow the wetting fronts of adjacent irrigated furrows to merge, then field infiltration rises inversely proportionally to the interfurrow spacing, reflecting the increase of the wetted perimeter.

Table 1 shows 15% greater infiltration occurred for narrow single-row sugarbeets and 10% greater infiltration occurred for narrow single-row corn compared to wide single rows in 1986. In 1987, however, only one percentage point numerical increase (not significant at $P < 0.05$) in mean infiltration was observed for narrow single rows compared to wide single rows in any of the crops. Twin-row planting patterns produced the highest percent of water infiltrated of all the furrow spacing and planting pattern comparisons.

With twin-row sugarbeets and twin-row beans in 1987 the effect on infiltration of shortening the irrigation duration was maximized. This occurred because beet or bean plants in their twin configurations resulted in one of the twin-rows being 0.53 m from the irrigated furrow center of an alternate-furrow irrigation scheme (C, Fig. 1), necessitating irrigation of every furrow. Irrigating every furrow produced field infiltration comparable to alternate-furrow irrigation of 0.38-m spaced furrows. The twin-row configuration used for corn, however, permitted irrigating only the furrows between the close-spaced twin rows. In this configuration, corn plants were 0.18 m from the irrigated furrow center (A, Fig. 1). The field infiltration pattern was, therefore, comparable to alternate-furrow irrigation of 0.56-m spaced furrows. Furrow infiltration percent, however, showed there was an additional two-year average advantage of 9.5% for the twin-row corn compared to the 0.56-m single row spacing (which had the comparable field infiltration pattern). These infiltration differences were statistically significant for both years in corn. This indicates that for corn there may be one or more additional factors improving the infiltration besides simple set-duration effects. Certainly one factor was the use of the non-trafficked (no rear wheel traffic) furrow to convey water. There were probably both systemic and plant-related factors also, as discussed below.

Reducing irrigation duration for closer furrow spacings can have systematic effects on infiltration and sediment-loss. As a furrow irrigation proceeds, the concentration of sediment carried in the furrow stream usually peaks rapidly after initiation of the set and then gradually declines with time to a near constant rate (Mech 1959; Berg and Carter 1980). Similarly, infiltration decreases over time while runoff increases. Consequently, if irrigation durations of two otherwise identical furrows are varied, the ratio of sediment-loss per hectare to water infiltrated per hectare might be expected to remain nearly constant. This does not appear to be the case for most of the data in Table 1. This suggests that other factors affected infiltration and sediment loss in the altered furrow spacings and planting patterns besides systematic factors associated with the duration of the irrigation set.

Close examination of the furrows in each study revealed that furrow spacing and plant placement altered the proximity of roots and aerial plant parts to the irrigation stream. Presence of the beet leaves in the furrow would have acted in much the same manner as straw or other residues placed in the furrows. This vegetative contact would be expected to have dissipated the energy of the flowing water, reducing its velocity, increasing infiltration because of greater water depth in the furrows, and reducing detachment of sediment from the sides of the furrows.

In 1986 the *S*/*I* ratio of the 0.56-m single-row beets was half that of the 0.76-m single-row beets. Also, the leaves of beet plants in 0.56-m single rows arched almost directly into the center of the irrigated furrows by mid-season. Leaves of these plants could be seen oscillating slightly when in contact with the flowing water. In the 1986 growing season, the leaf area index (Fig. 2a) of 0.56-m beets was similar to the 0.76-m until the measurement on 6 August when their values of 2.24 and 1.75 respectively differed significantly. Probably more important than the leaf area index (LAI) alone was the fact that leaves of beets grown in 0.76-m spaced rows rested on the shoulder of the wider inter-furrow bed when fully arched, and were not capable of interacting with the furrow stream. Closer proximity of sugarbeets to the shoulders of the beds in narrow rows might also be expected to have helped hold soil in the furrow because of greater root proliferation near the furrow.

In 1987 the sugarbeet leaf area index (Fig. 2b) of

Table 1. Cumulative seasonal irrigation and erosion components of monitored irrigations for three furrow irrigated crops grown at differing row spacings at Kimberly, ID in 1986 and 1987. Letters *S* and *T* under spacing refers to single or twin-row configurations.

Crop	Spacing	Dates† pooled	Run-on	Run-off	Infiltration		Sediment	Sed./Inf.‡
	m		m^3ha^{-1}			%	kg ha^{-1}	kg m^{-3}
				1986				
Beet	0.56*S*	5	4137	1781	2356	56.9	10336	4.39
	0.76*S*	5	3531	2053	1478	41.9	15863	10.73
LSD(0.05)			—	445	445	11.8	4654	1.44
	1.12*T*	4	2542	248	2294	90.2	1425	.62
Corn	0.56*S*	4	2542	482	2060	81.0	2659	1.29
	0.76*S*	4	2297	675	1622	70.6	2559	1.58
LSD(0.05)			—	149	149	5.6	589	0.50
				1987				
	0.76*T*	9	6281	1883	4398	70.0	6420	1.46
Beet	0.56*S*	9	6303	2156	4147	65.8	9485	2.29
	0.76*S*	9	6281	2210	4071	64.8	5639	1.39
LSD(0.05)			—	350	350	5.5	1988	0.65
	1.12*T*	8	5380	1627	3753	69.8	4313	1.15
Corn	0.56*S*	8	5602	2236	3366	60.0	9808	2.91
	0.76*S*	8	5583	2274	3309	59.3	8704	2.63
LSD(0.05)			—	492	492	9.0	3027	1.07
	0.76*T*	6	3589	1279	2310	64.4	7109	3.08
Bean	0.56*S*	6	3602	1536	2066	57.4	5046	2.44
	0.76*S*	6	3609	1600	2009	56.7	6882	3.43
LSD(0.05)			—	190	190	5.3	5522	2.75

† The number of irrigations monitored and for which data in the table are cumulatively summarized.
‡ The season-long ratio of cumulative sediment loss to cumulative infiltration.

the 0.76-m single rows was consistently higher than the 0.56-m single rows, whereas the LAI of the 0.76-m single rows and 0.76-m twin started the season together but finished with LAI of the 0.76-m twin rows significantly lower than 0.76-m single rows and with no statistical difference between the final intermediate LAI of the 0.56-m single rows. The LAI pattern of the 0.56-m and 0.76-m single row treatments were essentially the reverse of the 1986 results as were their seasonal *S/I* ratios (Table 1). The twin row S/I ratio was also low (Table 1) suggesting that LAI in the early season may have been more effective in moderating erosion and infiltration than late in the season. This would seem reasonable since early season furrow erosion is usually higher than late season erosion, typically peaking in July (Mech, 1959; Berg and Carter, 1980; Brown, 1985a). However, this interaction of foliage and furrow erosion may be difficult to quantify since timing of erosion and leaf area expansion and proximity of leaves to the furrow stream must all be accounted for.

The foliage of corn did not interact as effectively with the furrow streams as the foliage of sugarbeets. Consequently, in both years the *S/I* ratio of the wide and narrow single row configurations were similar. The close proximity of plants in the 1.12-m twin rows to the irrigated furrow, however, allowed vigorous exploration of the soil volume close to the irrigated furrow by the fibrous root system. Furthermore, this proximity also allowed an overlaying of the furrow walls by the brace roots of many of the corn plants (Fig. 3). No such overlaying was observed in the 0.56- and 0.76-m single rows (plants were too distant from the furrow) in either year. Furrow lining with brace roots was highly variable along the furrows. In some places, as many as six adjacent plants would provide extensive brace root lining. In some places, 10 or more meters were without brace root lining. Estimates

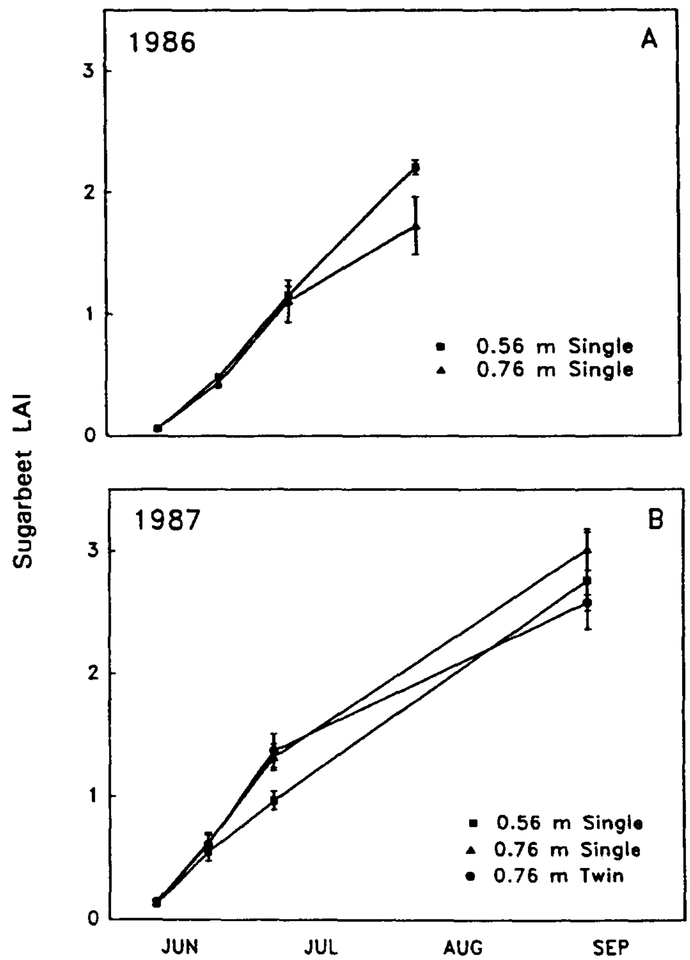

Fig. 2. Time-course of Leaf Area Index development for sugarbeet in two row spacings in 1986 and in three row spacings in 1987.

Fig. 3. Photo of midseason corn roots and corn brace roots covering the soil in the 1.12 m twin row corn planting configuration. The intimate contact of fibrous and brace roots in twin-row planting configurations stabilize soil against erosion from furrow irrigation.

along several rows in 1986 ranged between 1 of 20 and 1 of 10 plants with at least one brace root reaching the furrow stream. Even in the absence of brace roots lining the furrows, the 1.12-m twin corn rows had extensive fibrous root mats at or near (1-2 mm) the soil surface in the furrows. Roots lining the surface of furrows were not apparent in sugarbeet or beans.

Figure 4a, b, and c show the change of sediment/infiltration ratio over the course of an irrigation set for three irrigation dates in corn. This instantaneous *S/I* ratio was nearly the same for all three furrow spacings in the first irrigation throughout the irrigation set. The *S/I* ratio was generally nearly constant throughout an irrigation on a given date for a given treatment. However, there was a low *S/I* ratio in the twin-rows throughout the season, whereas the wider rows produced higher *S/I* ratios later in the season. The fact that the 1.12-m twin-row corn in all three irrigations had low *S/I*s and that in the single rows the latest irrigation produced a lower *S/I* than the mid-season irrigation may further implicate root interactions, since corn roots continue to develop until late in the season, perhaps enough to eventually influence the wider single rows as well.

The bean crop interacted with the furrow irrigation stream in yet another manner. The bean root system and its foliage are not as vigorous or extensive as those of beets or corn. Beans, however, shed flowers and individual leaves during the season. Much of this vegetative litter finds its way into the irrigation furrow if the plant is close to the furrow, and affects sediment

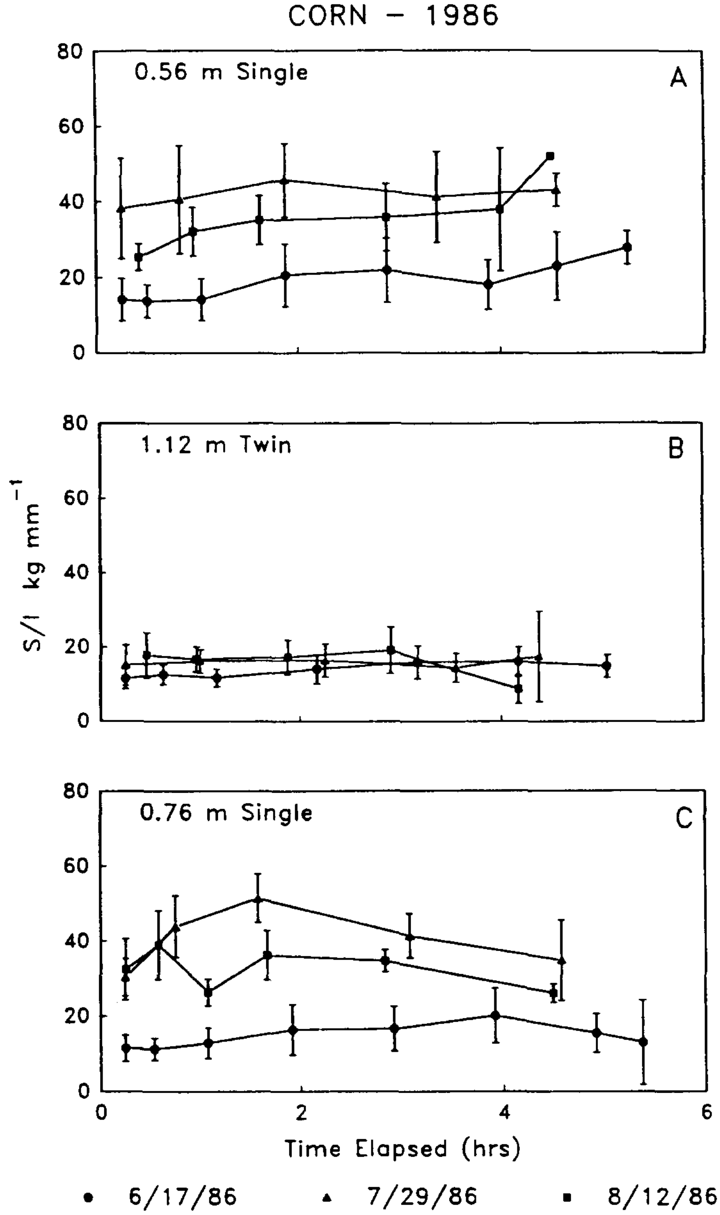

Fig. 4. Time-course of the ratio of sediment loss to infiltration amount on a per hectare basis for three irrigation dates in 1986 for corn growth in (a) 0.56 m single rows; (b) 1.12 m twin-rows; or (c) 0.76 m single rows.

movement similar to straw placement. With both narrow-row and twin-row configurations, this contributed to reducing the *S/I* ratio compared to the wider-spaced beans, whose litter fell largely on the beds without entering the water-carrying furrow.

In all three crops, infiltration and sediment loss were monitored in wheel-track furrows except in the twin 1.12-m corn planting configuration. Furrow infiltration of non-wheel track furrows has been shown to be higher than for trafficked furrows on these soils, especially early in the season (Trout et al., 1991). The twin 1.12-m corn planting configuration resulted in greater infiltration and less erosion by taking advantage of this effect. However, since the infiltration and sediment monitoring of all the other planting configurations in all three crops were from wheel-track rows, it is apparent that spacing and plant interaction effects also contributed to differences. Although both furrow infiltration and sediment accumulation typically have large variances, as seen in this study, it is clear that significant differences can be expected among row spacing and planting configurations and that these factors, along with choice of furrow to irrigate, can be used to manage furrow irrigated systems to minimize furrow erosion in otherwise conventional production systems.

These irrigation and sediment observations should be evaluated in their own context. Furrow lengths at the study site were half to one-third the furrow length of typical northwest production fields. Because soil properties differ, furrow lengths in other parts of the USA are often longer still, whereas furrow lengths in the third world are often shorter (Booher, 1974). The extent of the applicability of these findings depends on the degree to which changes in infiltration limit the length and number of furrows that can be irrigated. Although many farmers are reluctant to irrigate every furrow (because of the danger of excessive irrigation, excess leaching, and the advance time differences between wheel track and non-wheel furrows) this is another way of increasing infiltration. Yet another strategy involves alternating furrows between irrigations, or waiting to irrigate non-wheel furrows until evapotranspirational demand is high, thereby utilizing their higher intake capacities to avoid stress.

Each approach has particular advantages and disadvantages. Changing row spacing and planting patterns is one additional alternative. As with the above alternatives, they should be evaluated as an option within other system constraints.

Yields

Only bean yields (Table 2) were affected ($P < 0.05$) by choice of plant geometry and furrow irrigation. Certain patterns or trends in the overall data among treatments and species are worth noting. Sugarbeet yields, sugar content, and sugar production were greater (at much less reliable probability levels) for 0.56-m single rows in 1986 than for 0.76-m single rows. In 1987, when the 0.76-m twin-row treatment was added to the study, however, the highest yield and sugar production still occurred in the 0.56-m single row configuration. The 0.76-m twin-row configuration produced yields and sugar production numerically intermediate to the two single row spacings. Sugar concentration, however, in 1987, was highest in the 0.76-m twin-row configuration. Except for sugar content in 1986, these row spacing trends both years reflected significance between $P < 0.17$ and 0.23.

In the case of corn, some of the between-year yield response variation may be attributed to the use of two different hybrids. While the change of hybrids would have been expected to have some effect on relative yield performance, it is less likely that this would have had an impact on sediment or infiltration observations. Although no measurements were made to compare the rooting characteristics of the two hybrids, frequent visual observations suggest the abundance and mode of root interaction with furrow streams was similar each year.

For both years, bean yields were nearly unaffected by choice of single row spacing, but yield was significantly greater for 0.76-m twin-row configurations than either single row configuration. In 1986 the 0.76-m twin-row yields were greater for both bean varieties but only yield of the pintos and the variety mean yield were significantly higher. It is likely that two factors improved twin-row yield in 1987. Beans grown in the twin-row configuration were at the same plant population as the single row configurations; therefore, in the twin rows intra-row spacing was twice that of 0.76-m single rows. This means that for the 0.76-m twin-row configuration plants came closest to an "equidistant" spatial distribution, which favors yield in most species (Sojka et al., 1988). This effect may account to some extent for the trends toward improved grain yield of corn in 1987, and of beets in both years as well, although these values were not significant at the 0.05% levels of probability.

Beans grown in the 0.76-m twin configuration also benefitted from a more uniform water distribution relative to the plant. This was the result of irrigating both sides of the bed, rather than alternate furrow irrigation as in the case of the single-row configurations. Furthermore, infiltration percent increased in the monitored furrows of both the sugarbeet and bean crops grown in the 0.76-m twin-row configurations. The infiltration of the non-monitored furrows in these crops were assumed for the sake of calculation to equal the monitored furrows. In reality this is probably a small underestimation of total infiltration, since the non-monitored furrows in these cases were non-wheel track furrows.

Although the primary objectives of this study were to observe effects of canopy configuration on yield and sediment relationships, the impact of the various planting patterns on harvesting considerations is worth noting. Narrow single rows would require only minor equipment changes, or possibly require purchase of existing equipment from geographic areas where narrow rows are already in use. Twin-row sugarbeet harvesting would have to await development of new or modified sugarbeet harvesters. Twin-row corn can be gathered into a single-row crop head if the heads are designed on, or adjustable to, spacings centered on pairs of rows. This approach has been shown successful for corn in other areas (Karlen et al., 1987). Mechanized harvesting of twin-row beans in this study was nearly unaffected, requiring only some assistance with pitch forks to better gather the cut beans while walking alongside the harvester. This suggests that only minor modification or adjustment of knives and windrow equipment would be necessary to allow unassisted mechanized bean harvesting in the normal fashion.

CONCLUSIONS

The use of narrow rows (closer furrows) and/or alternate planting patterns, such as twin-rows planted close to furrows, and the choice of which furrow (trafficked to non-trafficked) to irrigate, offer the potential to improve management of infiltration and to help reduce sediment from furrow irrigation. This strategy may be more effective with some species than others. Different species possess different morphological and phenological development patterns that may interact spatially with furrows. In this study, sediment loss

Table 2. Yield of three crops as affected by furrow spacing and plant placement for Kimberly, ID in 1986 and 1987. Letters *S* and *T* under spacing refer to single or twin-row configurations.

	Sugarbeet			Corn			Beans	
Spacing	yield	sugar conc.	sugar yield	Green Chop @65% H_2O	Grain	Pinks	Pintos	Mean
	kg ha^{-1}	g kg^{-1}	kg ha^{-1}					
1986								
0.56*S*	63 574	133.8	8509	28 003	4667	3616	3468	3542
0.76*S*	55 642	133.2	7410	28 005	5205	3788	3591	3690
1.12*T*	—	—	—	28 441	5062	—	—	—
0.76*T*	—	—	—	—	—	4033	4007	4020
LSD(0.05)	11 763	9.1	1788	3 624	1466	—	—	453
1987								
0.56*S*	60 445	156.9	9485	29 121	7543	3592		
0.76*S*	54 935	154.6	8494	32 299	7577	3504		
1.12*T*	—	—	—	29 532	8041	—		
0.76*T*	56 230	161.4	9074	—	—	4238		
LSD(0.05)	7 078	7.3	1281	4 199	1277	477		

was more effectively reduced with twin-row corn than with sugarbeet or beans regardless of row configuration. This was caused by the combined effects of corn root interactions and greater infiltration of the nonwheel furrow. Success of narrow or twin-row planting patterns can be expected only if accompanied by proper water management, particularly reducing the irrigation duration as inter-furrow spacing decreases. Yields of sugarbeet and corn were not adversely affected by narrow or twin-row planting patterns in this study, and bean yields were enhanced with equal amounts of water applied. These results further suggest that with narrow rows it is possible to reduce irrigation duration and still provide adequate water delivery to maintain or improve yields of sugarbeet, corn, and beans. These options should be considered along with other alternate management practices such as every-furrow irrigation or alternating furrows to non-wheel-trafficked furrows for selectively increasing infiltration. Where furrow lengths are longer and maximum allowable streamflows are less, these approaches would require additional testing to verify their suitability.

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