Limited and Full Irrigation Comparison for Corn and Grain Sorghum

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The current high cost of irrigation pumping and areas of declining well capacities in the Southern High Plains Groundwater District in Southeastern Colorado, prompt a review of irrigation practices in this region.

The importance of limited irrigation (supplemental irrigation) has traditionally been associated with very low capacity irrigation wells. The current high fuel prices and associated pumping costs, combined with the low commodity prices, places new emphasis on limited irrigation as a replacement for full irrigation. We define limited irrigation on corn and grain sorghum as applying one in-season furrow irrigation of less than 9 A-in./A or a similar amount of water applied with a sprinkler. Applying less than 9 A-in./A as an in-season irrigation assumes that the soil water profile is full from sufficient winter moisture, or, if winter moisture is lacking, the soil water profile is filled by pre-irrigation.

An extensive study by McLaughlin Water Engineers (Anderson and Edwards, 2001) of the aquifers for the Southern High Plains Groundwater District in Southeastern Colorado revealed that fully two-thirds of the irrigation wells in the district have an average expected life span of 50 years at the current extraction rates. This, of course, means that the pumping capacity of affected wells will continue to taper off until the wells are no longer economical to pump. As more and more wells become smaller capacity irrigation wells, economics will favor limited irrigation compared to full irrigation.

Procedure

All our yield information is from studies conducted at the Plainsman Research Center at Walsh, Colorado. The average dryland grain sorghum yield of 56 Bu/A is from the dryland grain sorghum hybrid performance tests for the 15-year period 1986 to 2000. The average dryland corn yield of 54 Bu/A is from corn borer resistant (Bt) and nonresistant hybrid comparison studies during the 5-year period 1996 to 2000. The average full irrigation corn yield of 182 Bu/A is from sprinkler irrigated hybrid comparison studies of Bt and nonresistant hybrids during the 4-year period 1996 to 1999. The full irrigation grain sorghum yield of 151 Bu/A is derived from the 17% yield difference between limited sprinkler corn and grain sorghum. We used this calculated yield because there were no full sprinkler irrigation grain sorghum studies conducted at Plainsman Research Center.

The following table (Table 1) is a summary of limited irrigation applications and resulting yields obtain at Plainsman Research Center at Walsh Colorado during 1996 to 2000. We selected yield averages with similar water application amounts as the limited furrow and sprinkler irrigation systems. They averaged 9.1 A-in./A of supplemental irrigation and ranged from 8.3 A-in./A to 9.6 A-in./A. The limited irrigation yields and applied irrigation amounts used for the full and limited irrigation cost and variable net income comparisons (Table 2 and 3) were taken from Table 1. The grain yield we used for limited irrigation corn was 123 Bu/A with 9.6 A-in./A of water applied using furrow, and 144 Bu/A with 9.0 A-in./A of water applied using sprinkler. We selected 93 Bu/A with 9.4 A-in./A for limited furrow irrigation grain sorghum and 123 Bu/A with 8.3 A-in./A for limited sprinkler irrigation grain sorghum.

Table 1.-Season Rainfall, Grain Yield, and Applied Irrigation for Full Irrigation Sprinkler Corn and Limited Furrow and Sprinkler Irrigation Corn and Grain Sorghum, Plainsman Research Center, Walsh, Colorado, 1996-2000.

Year	May to Sept. Rainfall	Furrow Corn Yield	Furrow Corn Irrigation Applied	Sprinkler Corn Yield	Sprinkler Corn Irrigation Applied	Furrow Grain Sorghum Yield	Furrow Grain Sorghum Irrigation Applied	Sprinkler Grain Sorghum Yield	Sprinkler Grain Sorghum Irrigation Applied	Full Sprinkler Corn Yield	Full Sprinkler Corn Irrigation Applied
	in.	Bu/A	A-in./A	Bu/A	A-in./A	Bu/A	A-in./A	Bu/A	A-in./A	Bu/A	A-in./A
1996	19.43	109	15.1	161	16.5	81	15.4	124	9.5	160	18.0
1997	11.13	123	13.5	183	13.0	99	14.2	121	7.0	184	19.0
1998	18.55	159	5.7	201	12.0	129	4.8	131	3.0	195	13.5
1999	12.69	138	6.4	154	7.5	79	5.6	97	4.5	190	17.5
2000	5.81	84	7.3	78	7.5	79	6.9	85	7.0	98 *	15 *
Average	13.52	123	9.6	155	11.3	93	9.4	112	6.2	182	17.0
1996 & 1997 Avg.		116	14.3	172	14.8	90	14.8	123	8.3		
1998 to 2000 Avg.		127	6.5	144	9.0	96	5.8	104	4.8		

The limited furrow irrigated sites for 1996 and 1997 were pre-irrigated with approximately 8 A-in./A of water.

* Yield and irrigation application averages for full irrigation sprinkler corn do not include year 2000.

Results and Discussion

Our average limited sprinkler irrigation corn yield of 144 Bu/A with 9.0 A-in/A of applied water was only 1 Bu/A less than the projected yield reported by Kansas State University researchers at the Northwest Research-Extension Center in Colby, Kansas (O'Brien, et al., 2000) using the same amount of water applied and 85% application efficiency with a center pivot sprinkler system. In their report they used the irrigation requirements and yields of corn based on 1972 to 1998 climate data from Colby, Kansas.

The best management practices for irrigation published by Colorado State University states that irrigated corn requires 26 in. of water and irrigated grain sorghum requires 21.5 in. of water (Waskom, 1994). Our fully irrigated corn surpassed its crop water needs from 1996 through 1999 by 1.6 in., using a water use efficiency of 85% for May to September rainfall and irrigation (Table 1).

Grain yields increased 17% for corn and 32% for grain sorghum with limited sprinkler irrigation compared to limited furrow irrigation. The increased application efficiency for sprinkler compared to furrow undoubtedly contributed to these yield increases. The 17% increase in yield for sprinkler corn compared to furrow corn from our study is close to the 15% average increase in application efficiency reported for sprinkler compared to furrow (Waskom, 1994). The 32% yield increase for sprinkler irrigated grain sorghum compared to furrow irrigated grain sorghum is nearly twice the 17% yield response obtained with corn, even though we used similar irrigation application systems (Low Drift Nozzles (LDN) for sprinkler, surge valves for furrow). This indicates that grain sorghum is more responsive to sprinkler applied limited irrigation than is corn. Researchers at Kansas State University (O'Brien, et al., 2000) concluded that converting from furrow irrigation to sprinkler irrigation was a profitable undertaking for smaller capacity irrigation wells, 600 gpm and less. With this in mind, we focused on sprinkler systems for our comparison between full and limited irrigation.

The May to September rainfall average of 13.52 in. for the 5-year period from 1996 to 2000 at Plainsman Research Center was 30% above the 100 years average of 10.41 in. recorded in Baca County, Colorado for 1897 to 1996. Last year was the only below average growing season precipitation for this limited sprinkler and furrow irrigation study. Rainfall during May through September for 2000 was 5.81 in., which was 54% less rainfall than in 1999. Grain yield was 49% less in 2000 than in 1999 for limited sprinkler irrigated corn. The low yield obtain for limited irrigation in 2000 with below normal precipitation suggests that limited irrigation may not be a viable irrigation option without above average rainfall. Moreover, the full sprinkler irrigation corn test in 2000 was 48% lower yielding than in 1999 even though it received twice the amount of irrigation than the limited irrigation site. This suggests that doubling the amount of limited irrigation water may be inadequate to overcome a below average rainfall season.

From conversations with area growers, we were able to set an approximate pumping cost for a typical 500 gal/min capacity well at $5/A-in. for the 2000 growing season. The $5/A-in. pumping cost contains both fuel cost, $3200 per 28 day pumping month (2.5 days off per month for maintenance and repair), and $525 per month maintenance and repair costs. Furthermore, calculating the energy cost of our full irrigation sprinkler system (based on a 500 gpm well with an electric pump), we figured the energy cost to be $4.38/A-in. using the energy cost equation presented by Colorado State University for a center pivot with an electric pump (Broner, 1998):

$$\text{Energy Cost (\$)} = (A \times I \times P \times C \times 0.2)/(Ei \times Ep)$$

Where:
- A = irrigated area (acres)
- I = applied water (inches)
- P = pressure for lift and pressurization of the pivot (psi) (to convert lift from feet to psi divide by 2.31)
- C = cost of electricity ($/kwh)
- Ei = irrigation system efficiency (fraction)
- Ep = pump plant efficiency (fraction)

We used these values in the above equation: A, 124 acres; I, 17 in.; P, 220 psi (450 ft. lift and 25 psi); C, $0.055/kwh; Ei, 0.85; Ep, 0.65. If we further assume $525 per month for maintenance and repair cost, our pumping cost becomes $5.08/A-in. The $5/A-in. pumping cost is utilized in Table 2 and Table 3.

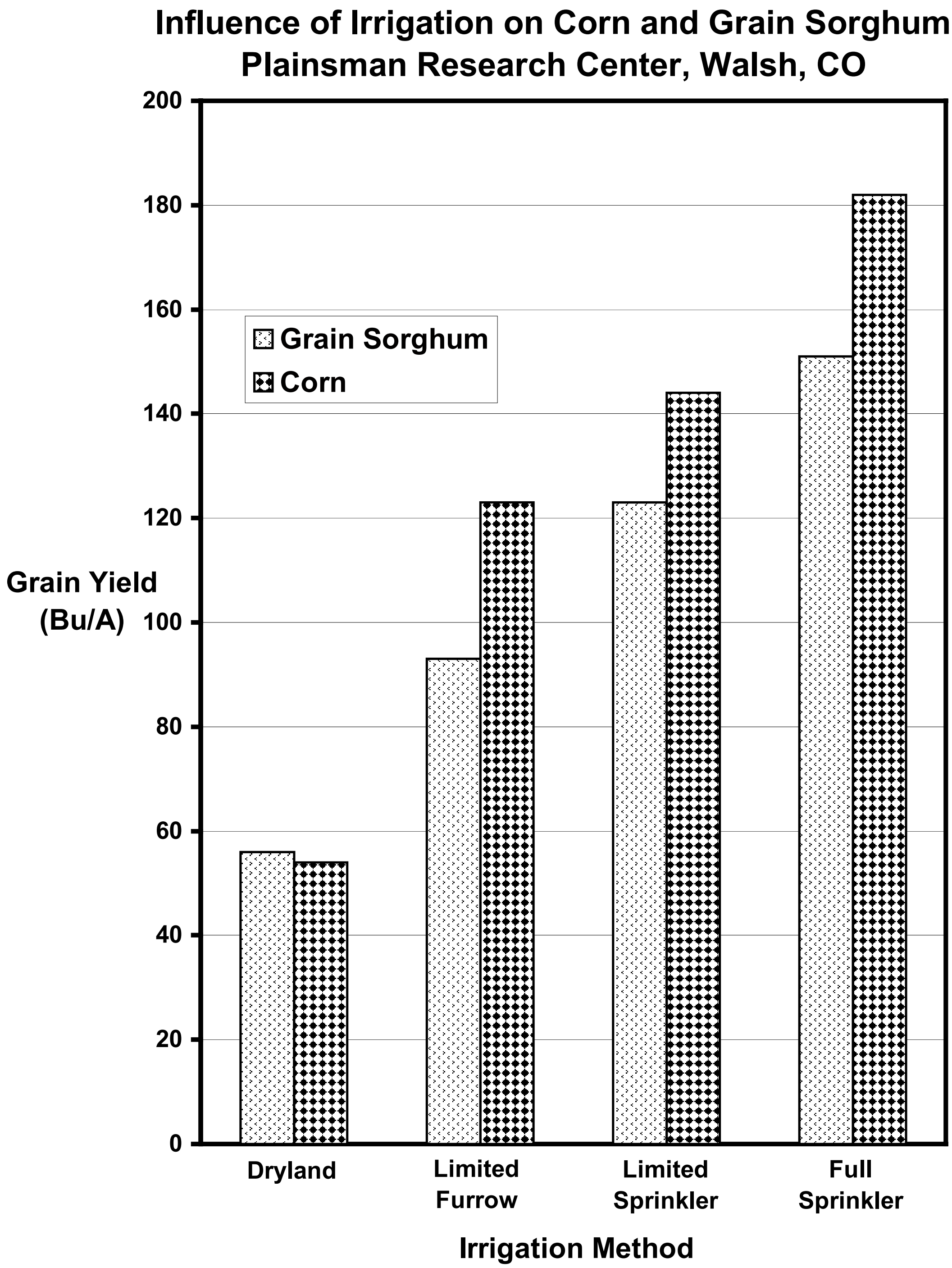

Fig. 1. Influence of irrigation on corn and grain sorghum yields. Yields are average yields at Plainsman Research Center at Walsh, Colorado. Limited furrow and sprinkler irrigation regimes averaged 9 A-in./A of irrigation. Full sprinkler irrigation averaged 17 A-in./A of irrigation.

Table 2.-Full and Limited Irrigation Comparison of Costs and Returns for Sprinkler Irrigated Corn at Walsh, 2000.

Full Irrigation Gross Income	$/A
182 Bu/A @ $2.17/Bu =	394.94
Full Irrigation Variable Cost	
N: 228 Lb N/A (1.25 Lb N/Bu * 182 Bu/A) @ $0.15/Lb =	34.20
P: 40 Lb P2O5/A @ $0.325/Lb P2O5 =	13.00
Seed: 34,000 seeds/A @ $1.00/1000 seeds =	34.00
Irrigation: 17 in./A (11.3 weeks * 1.5 in./A/week) @ $5.00/A-in.=	85.00
Harvest: 182 Bu/A @ $0.25/Bu =	45.50
Interest: $211.70/A @ 10% =	21.17
Total Variable Cost of Full Irrigation =	232.87
Total Non-Variable Cost of Full Irrigation =	121.50
Total Cost of Full Irrigation =	354.37
Gross Income of Full Irrigation =	394.94
Net Income of Full Irrigation =	40.57
Limited Irrigation Gross Income	
144 Bu/A @ $2.17/Bu =	312.48
Limited Irrigation Variable Cost	
N: 166 Lb N/A (1.15 Lb N/Bu * 140 Bu/A) @ $0.15/Lb =	24.90
P: 20 Lb P2O5/A @ $0.325/Lb P2O5 =	6.50
Seed: 24,000 seeds/A @ $1.00/1000 seeds =	24.00
Irrigation: 9 in./A @ $5.00/A-in.=	45.00
Harvest: 144 Bu/A @ $0.25/Bu =	36.00
Interest: $136.40/A @ 10% =	13.64
Total Variable Cost of Limited Irrigation =	150.04
Total Non-Variable Cost of Limited Irrigation =	121.50
Total Cost of Limited Irrigation =	271.54
Gross Income of Limited Irrigation =	312.48
Net Income of Limited Irrigation =	40.94

Non-Variable Costs include tillage, pesticides, applications, and sprinkler lease based on local custom rates and practices (Tranel, et al., 1997).

Table 3.-Full and Limited Irrigation Comparison of Costs and Returns for Sprinkler Irrigated Grain Sorghum at Walsh, 2000.

Full Irrigation Gross Income	$/A
151 Bu/A @ $1.78/Bu =	268.78
Full Irrigation Variable Cost	
N: 166 Lb N/A (1.1 Lb N/Bu * 145 Bu/A) @ $0.15/Lb =	24.90
P: 20 Lb P2O5/A @ $0.325/Lb P2O5 =	6.50
Seed: 110,000 Seeds/A, 7.5 Lb/A @ 1.00/Lb =	7.50
Irrigation: 17.0 in./A @ $5.00/A-in.=	85.00
Harvest: 151 Bu/A @ $12/A, $.10/Bu over 20 Bu, $.10/Bu =	40.20
Interest: $164.10/A @ 10% =	16.41
Total Variable Cost of Full Irrigation =	180.51
Total Non-Variable Cost of Full Irrigation =	84.10
Total Cost of Full Irrigation =	264.61
Gross Income of Full Irrigation =	268.78
Net Income of Full Irrigation =	4.17
Limited Irrigation Gross Income	
123 Bu/A @ $1.78/Bu =	218.94
Limited Irrigation Variable Cost	
N: 135 Lb N/A (1.1 Lb N/Bu * 123 Bu/A) @ $0.15/Lb =	20.25
P: 20 Lb P2O5/A @ $0.325/Lb P2O5 =	6.50
Seed: 110,000 Seeds/A, 7.5 Lb/A @ 1.00/Lb =	7.50
Irrigation: 8.3 in./A @ $5.00/A-in.=	41.50
Harvest: 123 Bu/A @ $12/A, $.10/Bu over 20 Bu, $.10/Bu =	34.60
Interest: $110.35/A @ 10% =	11.04
Total Variable Cost of Limited Irrigation =	121.39
Total Non-Variable Cost of Limited Irrigation =	84.10
Total Cost of Limited Irrigation =	205.49
Gross Income of Limited Irrigation =	218.94
Net Income of Limited Irrigation =	13.45

Non-Variable Costs include tillage, pesticides, applications, and sprinkler lease based on local custom rates and practices (Tranel, et al., 1997).

Net Income and Pumping Cost for Limited and Full Irrigation Corn and Grain Sorghum

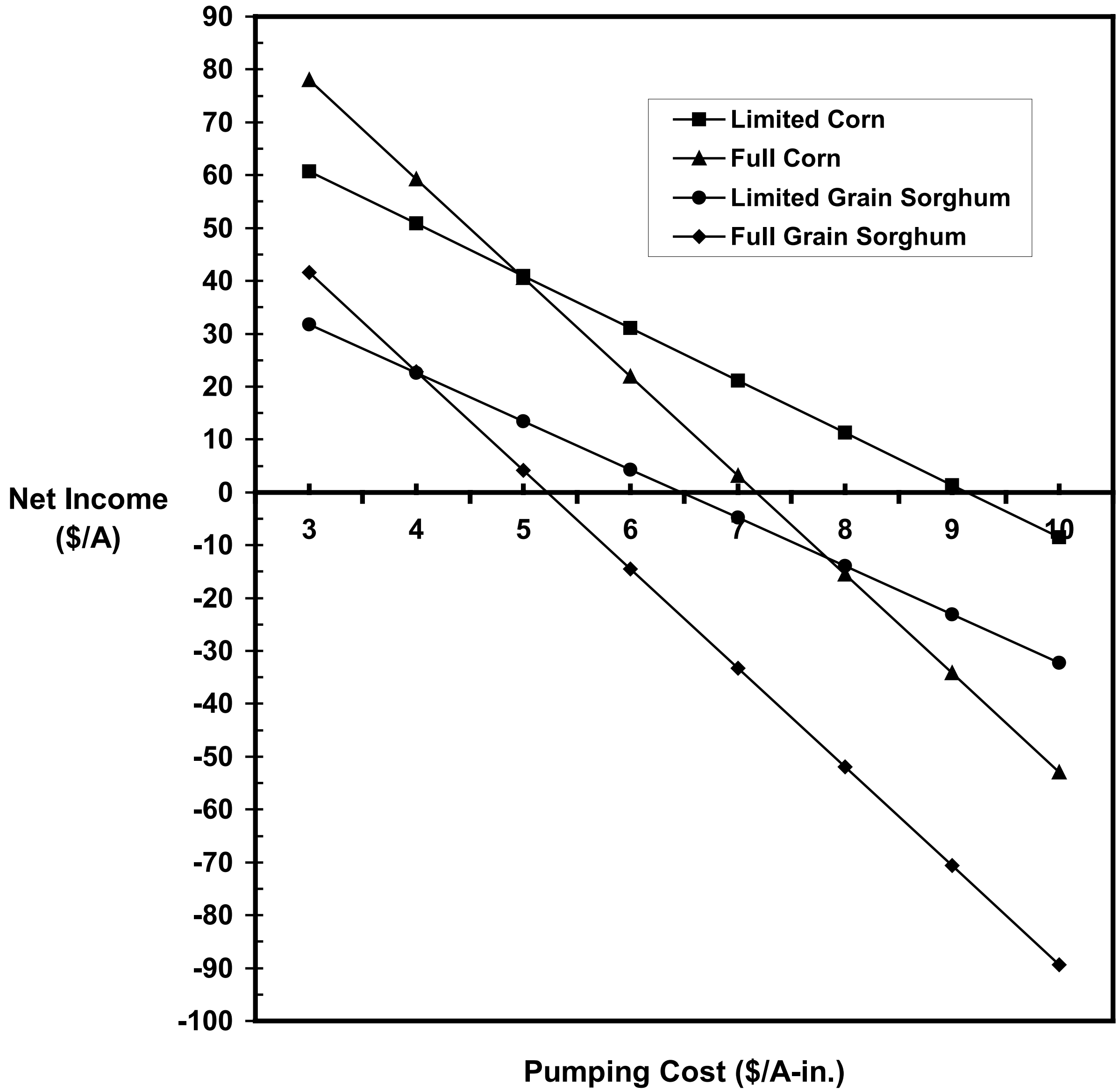

Fig. 2. Full and limited sprinkler irrigation comparison of net income for corn ($2.17/Bu) and grain sorghum ($1.78/Bu). Assumptions: yield: 182 Bu/A (corn) and 151 Bu/A (grain sorghum) for full irrigation, 144 Bu/A (corn) and 123 Bu/A (grain sorghum) for limited irrigation; irrigation: 17 A-in./A for full irrigation, 8.3 A-in./A (grain sorghum) and 9 A-in./A (corn) for limited irrigation; production costs: pumping cost varies from $3 to $10/A-in., all other costs remain constant.

Net Income and Grain Price for Limited and Full Irrigation Corn and Grain Sorghum

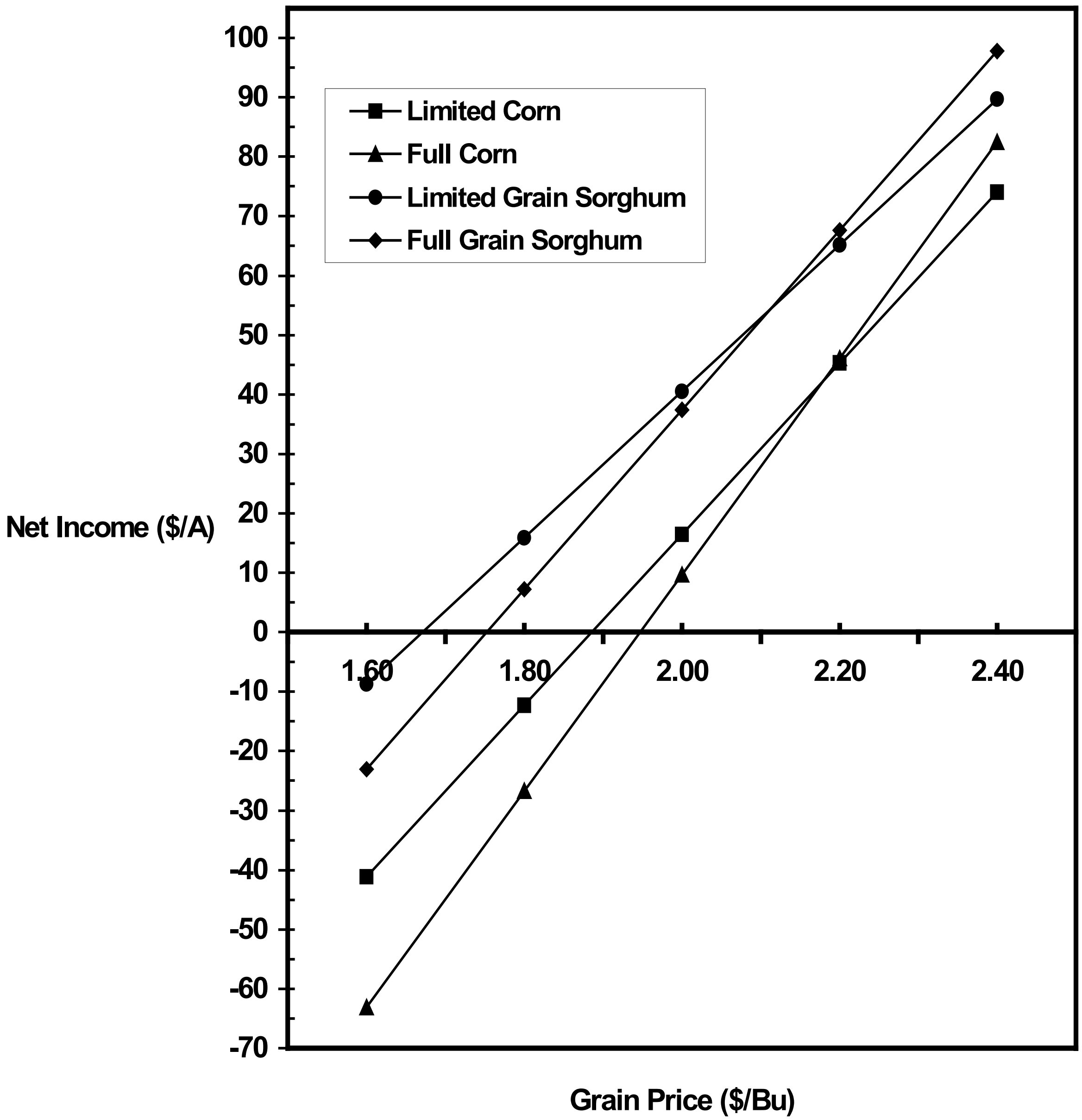

Fig. 3. Full and limited sprinkler irrigation comparison of net income for corn and grain sorghum with $5/A-in. pumping cost. Assumptions: yield: 182 Bu/A (corn) and 151 Bu/A (grain sorghum) for full irrigation, 144 Bu/A (corn) and 123 Bu/A (grain sorghum) for limited irrigation; irrigation: 17 A-in./A for full irrigation, 8.3 A-in./A (grain sorghum) and 9 A-in./A (corn) for limited irrigation; production costs: remain constant; corn price: varies from $1.60/Bu to $2.40/Bu.

Table 2 compares full and limited irrigation corn cost and net income and focuses on the production costs that change with conversion from full to limited irrigation. Field-wide costs that remain constant regardless of irrigation regime were combined in the analysis under non-variable costs, such as, tillage, planting, herbicides, insecticides, pesticide applications, and sprinkler lease. The grain sorghum table (Table 3) includes seed cost and P fertilizer cost which do not change between full and limited irrigation for grain sorghum production but are left as a comparison to corn production where these two production costs did differ with irrigation change.

Limited irrigation becomes a more profitable choice as fuel costs increase. Last year pumping cost for natural gas in Southeastern Colorado doubled. Many irrigated growers expect that fuel costs will be higher for the upcoming irrigation season. If our predictions are correct, the projected income provided by limited irrigation will greatly exceed the income from full irrigation. Our research suggests that the decision point for conversion from full irrigation to limited irrigation with our current costs and returns is $5/A-in. pumping cost for corn production and $4/A-in. for grain sorghum. We spoke to several growers who irrigate their crops and they confirmed that last year in our area many wells with capacities of 500 gal/min and less reached or exceeded these pumping costs.

Decreases in commodity prices give limited irrigation the income advantage over full irrigation. Predicting commodity prices is equally as mystifying as predicting fuel prices. Corn and grain sorghum prices were below their loan rates, $2.17/Bu and $1.78/Bu, respectively, at harvest last year. There has been speculation that the national loan rate could drop $0.20/Bu for corn and $0.10/Bu for grain sorghum for the upcoming season. If the current or lower loan rates become the price growers receive for their corn and grain sorghum crops next season and irrigation costs remain high, limited irrigation will continue to be more profitable than full irrigation for smaller capacity wells.

Summary and Conclusions

Full irrigation is the standard when pumping costs are low and commodity prices are high. More water equals more income: more is more. But when pumping costs are high and commodity prices are low, limited irrigation becomes the new paradigm. Less water equals more income: less is more. Intuitively everyone understands the concept more is more, but less is more appears counterintuitive, illogical. Full irrigation produces higher yield, but the yield increase does not compensate for the higher pumping cost.

The current high cost of fuel makes pumping cost the most responsive variable driving conversion from full to limited irrigation. Nonetheless, inputs such as fertilizer and seed, which differ between full and limited irrigation regimes, favor limited irrigation when these input costs increase.

Limited irrigation performs best in conjunction with good dryland practices. Moisture saved with dryland practices lowers the irrigation water needed for crop production. All soil water conserved saves on pumping costs. In addition, the use of water application efficient equipment such as LEPA or low drift nozzles for sprinkler and gated pipe and surge valves for furrow increases water application efficiency and reduces pumping costs. Proper irrigation timing with limited irrigation is critical for optimum yields. Crop water use requirements for corn and grain sorghum are greatest during flowering and grain fill. Timely irrigations during flowering will provide maximum return on irrigation inputs. Timing or scheduling irrigations to coincide with flowering is a recommended initial step, but we also recommend measuring available soil water to get a more complete available water/water-use picture. This can be accomplished inexpensively with gypsum blocks.

Since we found that limited irrigation may not be economical without adequate rainfall, more studies are needed to determine the optimum economic balance between irrigated crop acreages and applied water. These studies will reduce the risk of unprofitable yields during dry years.

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