ECONOMICALLY OPTIMAL CORN PLANT POPULATION AT VARIOUS IRRIGATION CAPACITIES USING SUBSURFACE DRIP IRRIGATION (SDI)

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Problem Description

As the Ogallala aquifer continues to decline in areas of the western Great Plains, well capacities have decreased. Producers in these areas of decreasing irrigation system flow rates face difficult irrigated corn cropping decisions. Two important options are to decrease their irrigated area devoted to corn, and/or adopt cropping practices more similar to dryland production (such as planting at reduced populations) and use the available irrigation water for supplemental irrigation. Subsurface drip irrigation (SDI) is an emerging, but valid technology to make wise use of the limited water resource. SDI acres will continue to grow as aging alternative irrigation systems are replaced and because it offers opportunities to extend the life of irrigated production in the western Great Plains. The objective of this research was to define the optimal planting (acreage and population) strategy for irrigated corn production under conditions of limited (but highly efficient) SDI as imposed by limited irrigation well capacity.

Summary of Previous Field Work from 1997-2001

Five years (1997-2001) of field research was conducted at the KSU Northwest Research-Extension Center (NWREC) at Colby, Kansas to determine the optimal corn plant population at various SDI capacities. Corn was grown with SDI under 6 different irrigation capacities (0, 0.10, 0.13, 0.17, 0.20 and 0.25 inches/day) and 4 different average plant populations (32500, 29280, 26360, and 23320 plants/acre, but ranged over the years from approximately 21000 to 35000 plants/acre). Pioneer hybrid 3162 was used in 1997-1998 and 2001 and Pioneer hybrid 31A12 was used in 1999-2000. <u>Irrigation was scheduled using a climatic water budget, but was limited to the specific irrigation capacity treatment.</u> Weather data was collected from the NWREC automated weather station as inputs to the annual water budgets. The SDI driplines were installed at a depth of 17 inches, spaced 60 inches apart, with a 12-inch emitter spacing.

Daily SDI application of even small amounts of water (0.10 inches) doubled corn grain yields (93 to 201 bu/acre) in the extremely dry years of 2000 and 2001. Field results suggested an irrigation capacity of 0.17 inches/day might be adequate SDI capacity when planning new SDI systems in this region. Increasing plant population generally increased corn grain yield. Even when irrigation was extremely limited, there was very little additional penalty for having the higher plant populations. The first four years of the field study were summarized by Lamm and Trooien (2001). Although higher seeding rates do increase production costs somewhat, the higher plant populations allow the producer to take advantage of years with higher precipitation. The results of this follow-up economic study augment the results from the field study, by providing economic planning information and tools for producers.

Publications related to this study

Lamm, F. R. and T. P. Trooien. 2001. Irrigation capacity and plant population effects on corn production using SDI. In Proc. Irrigation Assn. Int'l. Irrigation Technical Conf., Nov. 4-6, 2001, San Antonio, TX. Pages 73-80. Available from Irrigation Assn., Falls Church VA. Also available at http://www.oznet.ksu.edu/sdi/Reports/2001/icpp.pdf

Lamm, F. R. and D. M. O,Brien. 2003. COpt_SDI.XLS. A Microsoft Excel template to determine optimum planned corn area and plant population for SDI. Available at http://www.oznet.ksu.edu/sdi/Software/COpt_SDI.xls

Study Description

A mathematical model was created within a Microsoft Excel spreadsheet template to project corn grain yield, irrigation, nitrogen and phosphorus fertilizer requirements and net returns to land, irrigation equipment and management. The input requirements are irrigation system flowrate, total area of irrigated field, initial planned irrigated corn area, initial planned plant population, seed price, estimated corn harvest price, estimate of net returns to the field area not planted to irrigated corn, estimated corn water use (ET) and estimated precipitation during 120-day corn season. Suggested values or ranges are given to help familiarize producers with the template's operation. The template generates initial estimates of corn yield, irrigation and net returns based on the planning estimates submitted by the user and then suggests alternative plans that might be better. The model selects suggested alternative plans based on the maximization of net returns to land, irrigation systems and management. No fixed costs of land or irrigation systems are included in the model. Projected yield affects fertilizer requirements and also harvest costs, so it was necessary to handle these interactions in the calculations of net returns to land, irrigation systems and management.

The results may appear somewhat surprising to some users in the western Great Plains in that they often indicate higher numbers of planned corn acres and higher plant populations are justified even at fairly low irrigation capacities. It is hypothesized, but remains unproven, that even at low irrigation capacities the small daily applications with SDI are providing some buffer against water stress. It should be pointed out that the model is intended <u>only</u> for deep silt loam soils that have good soil water profiles at planting having been recharged by overwinter precipitation or by any necessary preseason irrigation. The model is a planning tool for near-term decisions in the spring.

As a rule of thumb, the model predicts a maximum increase of 4 bu/acre for each 1000 plants/acre increment over the range of plant populations when irrigation and weather conditions are most favorable. This potential yield increase due to plant population disappears or becomes negative when the irrigation deficit is greater than 12 inches. In this context, irrigation deficit is defined as the corn ET minus the sum of irrigation and precipitation. An irrigation deficit of 12 inches or more only occurs in the western Great Plains for very low capacity systems under extremely dry conditions. Of course net returns may be maximized at a different number of planned acres and different plant population than where grain yields are maximized.

Applied Questions

1. Does it pay to increase plant population under SDI?

In many cases it does up to a final stand count of about 35,000 plants/acre. Exceptions to this rule might be for extremely limited irrigation capacities and under very hot and dry conditions. Table 1 shows that with irrigation capacities ranging down to a very low 0.10 inches/day under very dry conditions that it still was acceptable to use the higher 35000 plants/acre plant population. The Table shows there is essentially little or no difference in net returns at this low irrigation capacity if conditions turn out extremely dry, but that the higher plant population can be beneficial if weather conditions turn out better than expected.

2. Does maximum net returns always occur at the point of maximum yield?

No. It often does, if weather conditions and irrigation capacity are favorable, but as available water becomes more critical, a balancing of planned acres with a lower yield may result in higher net returns. The spreadsheet template will discover that if it is the case.

Table 1. Net returns to land, irrigation systems and management as influenced by irrigation capacity and weather conditions, plant population and the planned number of corn acres in a 160 acre field. These base assumptions apply to the results shown here: Seed price, $1.30/1000 seed; Corn harvest price, $2.35/bushel; and net returns to remaining area in field, $32.50/acre.

Irrigation capacity and Weather conditions	Plant population, p/a	40 corn acres	80 corn acres	120 corn acres	160 corn acres
Irrigation capacity, 0.250 in/day					
Average ET, 23 in. Rain, 12 in.	24,000	$71	$110	$149	$188
	30,000	$80	$128	$176	$224
	35,000	$88	$144	$200	$256
Wet ET, 20 in. Rain, 16 in.	24,000	$79	$125	$171	$217
	30,000	$88	$143	$198	$253
	35,000	$95	$158	$220	$283
Dry ET, 27 in. Rain, 7 in.	24,000	$65	$98	$131	$163
	30,000	$70	$108	$146	$184
	35,000	$75	$118	$160	$203
Irrigation capacity, 0.167 in/day					
Average ET, 23 in. Rain, 12 in.	24,000	$74	$115	$156	$198
	30,000	$80	$128	$176	$224
	35,000	$83	$140	$193	$247
Wet ET, 20 in. Rain, 16 in.	24,000	$80	$128	$175	$223
	30,000	$88	$143	$198	$253
	35,000	$94	$155	$216	$277
Dry ET, 27 in. Rain, 7 in.	24,000	$64	$95	$127	$158
	30,000	$68	$103	$138	$173
	35,000	$71	$110	$148	$187
Irrigation capacity, 0.100 in/day					
Average ET, 23 in. Rain, 12 in.	24,000	$73	$114	$154	$195
	30,000	$77	$121	$166	$210
	35,000	$80	$128	$176	$223
Wet ET, 20 in. Rain, 16 in.	24,000	$81	$129	$177	$225
	30,000	$87	$141	$196	$250
	35,000	$92	$151	$211	$270
Dry ET, 27 in. Rain, 7 in.	24,000	$58	$83	$109	$134
	30,000	$58	$84	$109	$135
	35,000	$59	$85	$111	$137

3. *Does seed price have much effect on the selection of plant population?*

No, only under extremely low irrigation capacities and extremely dry conditions do typical seed costs (range $1.15 to $1.65/1000 seeds) affect selection of plant population. More often than not, before that issue arises, questions will arise about the profitability of growing irrigated corn under such dire irrigation capacity and anticipated weather. It makes more sense to select good quality seed based on your desired characteristics, than to base decision simply on seed costs.

4. Would you expect similar planning results with sandy soils?

No. That scenario remains untested, but the results from the field study (Lamm and Trooien, 2001) indicate the lower irrigation capacities are essentially mining the soil water over an extended period during the corn growing season. Sandy soils would not have such extensive soil water reserves and thus would need to have higher irrigation capacity.

5. Would you expect similar planning results with center pivot sprinklers?

Probably not, but that scenario also remains untested. A safer procedure would be to use the model as a rough guide about how plant population and planned acres interact, and then to act conservatively by trying higher populations on a portion of a center pivot sprinkler. Experience, can then help you move towards an optimal plant population. Also consult your seed professionals and extension specialists about appropriate plant populations. The rationale that the results might not be the same lies in the potential higher efficiency with SDI due to no irrigation runoff, less soil evaporation, less drainage, better infiltration of occasional rains and the ability of SDI to apply small amounts of water on a frequent basis.

6. How accurate are the results of the model?

It is realistic to assume that this model can't predict cropping and economic results perfectly every year. The yield and irrigation amount models are based on linear regression of field data from 5 years. Errors in yield prediction of 15-20 bu/acre would not be uncommon, but alternative plans might equally have similar errors. The linear regression indicated about 80% of the yield variation was explained by the model. That's not bad for a yield model with 4 variables (ET, Rain, Irrigation amount, and Plant population). Small differences in net returns between alternative plans should carry little weight in the decision making process.

7. How can I obtain the Microsoft Excel template?

The template Copt_SDI.XLS is available for free by downloading from the internet at
http://www.oznet.ksu.edu/sdi/Software/SDISoftware.htm

8. Why are there some limitations placed on plant population, crop water use and irrigation capacity in the template?

These limitations are based on the range of data examined in the 5 year field study.

9. Does it make much difference what value is chosen for net returns to the remaining area?

Yes. This can be an important factor in that under some higher value scenarios it may be more profitable to consider planting less corn acres. However, you cannot substitute another irrigated crop during the summer season.

10. Can I change production costs in the template?

Yes, and this is the only place that it is recommended that the user attempt to modify. Production costs could be altered on the ProdCosts Tab by removing the Protection scheme using the Tools menu in Microsoft Excel. Always engage Protection after any changes are made. No password is used. K-State plans to upgrade the template annually with new production costs and features as needed, so it may be useful to check for newer versions each season. The Version and Creation Date is shown on the Main Tab of Copt_SDI.XLS.