

Final Report to Delaware Soybean Board

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Evaluating the Response of Full Season and Double Cropped Soybeans in Narrow and Wide Rows to Various Soil Moisture Levels

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OBJECTIVES

- 1) Evaluate the effects of various soil moisture levels and row widths on growth and yield of full season and double cropped soybeans.
- 2) Determine the optimal irrigation management strategy for full season and double cropped soybeans to maximize yield and profitability.
- 3) Determine the optimal row width for irrigated full season and double cropped soybeans to maximize yield and profitability.

INDIVIDUAL SUMMARY OF 2012, 2013, AND 2014 TRIALS

2012 (1st year of trials). In 2012, rainfall totals in May (0.5"), June (2.5"), July (2.5"), and September (2.8") were below average, but rainfall was well above average in August (10.6").

In the full season study, average yield in plots that received irrigation ranged from 63 to 70 bu/A compared to 54 bu/A in plots that received no irrigation. The amount of water applied based on the irrigation strategy ranged from 5.3" to 9.6". The irrigation strategy that produced the greatest yield (70 bu/A) was when irrigation was applied at a reduced amount (>30% available soil moisture) until the R5/R6 growth stage and then >50% available soil moisture until maturity. This irrigation strategy also required the least amount of water applied (5.3"). There was no yield advantage in irrigating to maintain >50% available soil moisture until Mid-August this year. Soybeans in all row widths responded similarly to each irrigation strategy, but there was an overall yield difference between row widths. Average soybean yield was 67 bu/A in 15" rows, 64 bu/A in 7" rows, and 61 bu/A in 30" rows.

In the double crop study, average yield in plots that received irrigation ranged from 58 to 61 bu/A compared to 58 bu/A in plots that received no irrigation. The amount of water applied based on the irrigation strategy ranged from 2.2" to 6.6". The above average rainfall in August had a significant effect on soybean yield. Soybeans in all row widths responded similarly to each irrigation strategy, but there was an overall yield difference between row widths. Yield was greatest in the 15" rows at 64 bu/A, followed by the 30" rows at 58 bu/A, and then the 7" rows at 55 bu/A. Final stand in the 7" rows was 107,000 plants/A compared to 169,522 plants/A in the 15" rows, and 154,427 plants/A in the 30" rows. The reduced plant stand in the 7" rows compared to the 15" and 30" rows may have limited yield potential.

2013 (2nd year of trials). In 2013, rainfall totals in June (10.4”), July (6.9”), August (6.5”) and October (6.1”) were above average, but rainfall was well below average in September (0.7”).

In the full season soybean study, soybeans were planted on May 19. Average yield in plots that received irrigation ranged from 65 to 73 bu/A compared to 69 bu/A in plots that received no irrigation. The amount of water applied based on the irrigation strategy ranged from 4.3” to 7.0”. The irrigation strategy that produced the greatest yield (73 bu/A) was when irrigation was applied at a limited amount (>30% available moisture) until the R3/R4 growth stage and then applied to maintain available soil moisture >50% until maturity and was also the irrigation strategy with the least amount of water applied (4.3”). However, yield attained by this irrigation strategy was not statistically different from the no irrigation treatment and strategies that applied no irrigation until R1/R2 and limited irrigation to R1/R2 and R5/R6, where yields ranged from 69 to 71 bu/A. The two irrigation strategies, full season irrigation (65 bu/A) and an ET based program (66 bu/A), that maintained soil moisture >50% all season were the only two strategies that produced less yield than the no irrigation treatment. Soybeans planted in 7.5”, 15”, and 30” row widths yielded similarly to each irrigation strategy, but there was an overall yield difference between row widths. Average soybean yield was 72.8 bu/A in 7.5” rows, 68.6 bu/A in 15” rows, and 66.4 bu/A in 30” rows.

In the double crop study, soybeans were planted on July 19. Average yield in plots that received irrigation ranged from 38 to 45 bu/A compared to 31 bu/A in plots that received no irrigation. The amount of water applied based on the irrigation strategy ranged from 4.7” to 6.7”. The irrigation strategy that produced the greatest yield (45 bu/A) was when irrigation was applied to maintain soil moisture >50% all season. Yield from irrigation strategies where soil moisture was maintained >50% available moisture at R1/R2 until maturity, except the treatment of limited irrigation to R1/R2 then >50% available moisture to R3/R4 then >70% available moisture to maturity, yielded similarly at 42 to 45 bu/A. The limited irrigation to R3/R4 then >50% available moisture to maturity, limited irrigation to R5/R6 then >50% available moisture to maturity, and limited irrigation to R1/R2 then >50% available moisture to R3/R4 then >70% available moisture to maturity strategies produced the lowest yields at 39, 38, and 37 bu/A, respectively. Soybeans planted in 7.5”, 15”, and 30” row widths yielded similarly to each irrigation strategy, but there was an overall yield difference between row widths. Average soybean yield was 41 bu/A in 7.5” rows, 41 bu/A in 15” rows, and 37 bu/A in 30” rows.

2014 (3rd year of trials). In 2014, rainfall was above average in July (6.76”) and August (5.76”), but below average in June (2.05”) and September (3.99”). In June, July, and August, rainfall in the last 2 weeks of each month was less than 0.88 in. There was a 4 week period from 8/16 to 9/15, where Harbeson received only 1.56” of rainfall.

In the full season soybean study, soybeans were planted on May 20. Average yield in plots that received irrigation ranged from 73 to 77 bu/A compared to 73 bu/A in plots that received no irrigation. There was no significant difference between any irrigation treatments this year. The amount of water applied based on the irrigation strategy ranged from 1.9 in. to 9.0 in. Soybeans planted in 7.5 in., 15 in., and 30 in. row widths yielded similarly to each irrigation strategy, but there was a slight yield difference between row widths. Average soybean yield was 76 bu/A in 7.5 in. rows, 74 bu/A in 15 in. rows, and 74 bu/A in 30 in. rows.

In the double crop study, soybeans were planted on July 9. Average yield in plots that received irrigation ranged from 50 to 55 bu/A compared to 42 bu/A in plots that received no irrigation. The amount of water applied based on the irrigation strategy ranged from 3.4 in. to 5.4 in. There was only a slight difference in yield between irrigated treatments. Soybeans planted in 7.5 in., 15 in., and 30 in. row widths yielded similarly to each irrigation strategy, but there was an overall yield difference between row widths. Average soybean yield was 56 bu/A in 7.5 in. rows, 51 bu/A in 15 in. rows, and 50 bu/A in 30 in. rows.

THREE YEAR AVERAGE YIELD TREND

In research conducted at the University of Delaware Warrington Irrigation Research Farm from 2012 to 2014, trends in soybean response to irrigation strategies are developing. Averaged over three years, there were only slight differences in yield between irrigation strategies in both full season (*Table 1a*) and double cropped (*Table 2b*) soybeans. However, there is a trend that full season and double cropped soybeans may require different irrigation strategies to maximize yield. In full season soybeans, yield with strategies of limited irrigation (>30% soil moisture) to later growth stages were comparable to or higher than strategies that provided full irrigation (>50% soil moisture) all season (*Table 1a*). In double cropped soybeans, yield with strategies that provided full irrigation (>50% soil moisture) all season were typically higher than strategies of limited irrigation (>30% soil moisture) to later growth stages (*Table 2b*).

Based on research results from the last 3 years, there may be a possibility to completely delay irrigation until later growth stages (R3 to R5) at least in full season soybeans. Although, strategies where irrigation was completely withheld until later growth stages was not included in this research. In addition, due to the inability to control rainfall in irrigation research in Delaware, more years of research are required to become confident in determining the optimum irrigation management strategy to maximize full season and double cropped soybean yield and profitability.

Table 1a. Full Season Study – Irrigation treatment effect on soybean yield averaged over 3 years and in 2012, 2013, and 2014.

Irrigation Treatment ¹	Yield			
	3 yr Avg.	2012	2013	2014
	bu/A			
No Irr.	65 e ²	54 d	69 abc	73 b
KanSched2 (ET) >50%	68 cd	65 bc	66 cd	73 b
Full Season Irr. >50%	67 de	63 bc	65 d	74 ab
No Irr. to R1/R2 then >50%	70 bc	63 bc	71 ab	76 ab
Limited Irr. to R1/R2 then >50%	70 abc	67 ab	69 abc	75 ab
Limited Irr. to R3/R4 then >50%	72 a	66 abc	73 a	77 a
Limited Irr. to R5/R6 then >50%	72 ab	70 a	71 ab	73 b
Limited Irr. to R1/R2 then >50% to R3/R4 then >70%	70 bc	63 c	71 ab	75 ab

¹Treatments with limited irrigation were kept at >30% available soil moisture (0% moisture = dry; 100% moisture = wet).

²Treatment means followed by the same letter are not significantly different.

Table 2b. Double Crop Study – Irrigation treatment effect on soybean yield averaged over 3 years and in 2012, 2013, and 2014.

Irrigation Treatment ¹	Yield			
	3 yr Avg.	2012	2013	2014
		bu/A		
No Irr.	44 d ²	58 a	31 e	42 d
KanSched2 (ET)	52 ab	59 a	43 ab	55 a
Full Season Irr.	53 a	60 a	45 a	54 ab
No Irr. to R1/R2 then >50%	51 bc	58 a	42 bc	52 bc
Limited Irr. to R1/R2 then >50%	53 a	61 a	42 abc	55 a
Limited Irr. to R3/R4 then >50%	49 c	59 a	39 cd	50 c
Limited Irr. to R5/R6 then >50%	50 bc	59 a	38 d	54 ab
Limited Irr. to R1/R2 then >50% to R3/R4 then >70%	50 c	59 a	37 d	53 ab

¹Treatments with limited irrigation were kept at >30% available soil moisture (0% moisture = dry; 100% moisture = wet).

²Treatment means followed by the same letter are not significantly different.

MATERIALS AND METHODS

Two studies were conducted in 2014 to determine the response of full season and double cropped soybeans to various soil moisture levels and row widths. Both studies were conducted under a variable rate four tower center pivot irrigation system located on the University of Delaware’s Warrington Irrigation Research Farm in Harbeson, DE.

Treatments. In both projects, the plots measured 30 ft by 30 ft and consisted of soybeans planted in 3 row widths. The row widths were 7.5 in., 15 in., and 30 in. Each plot received one of the following irrigation treatments. All treatments were replicated five times.

Irrigation Treatments:

1. No irrigation.
2. KanSched2 - Evapotranspiration (ET) based irrigation management using the Delaware Environmental Observing System’s weather station located on the research farm and the commonly accepted soybean crop coefficients.
3. Full season irrigation (>50% soil moisture throughout the season).
4. No irrigation until flowering (R1 to R2) then >50% soil moisture.
5. Limited irrigation (>30% soil moisture) until flowering (R1 to R2) then >50% soil moisture.
6. Limited irrigation (>30% soil moisture) until flowering (R1 to R2) then >50% soil moisture until pod development (R3 to R4) then >70% soil moisture.
7. Limited irrigation (>30% soil moisture) until pod development (R3 to R4) then >50% moisture.
8. Limited irrigation (>30% soil moisture) until seed development (R5 to R6) then >50% soil moisture.

Field Operations. The entire study area was treated identically for all production inputs except irrigation. Fertilizer was applied based on the University of Delaware recommendations for soybean.

Soybeans in both studies were grown under conventional tillage practices. Soybeans were planted in 7.5 in. rows with a Great Plains 1520P drill and in 15 in. and 30 in. rows with a Kinze planter with brush meters. Planting dates, soybean varieties, seeding rates, pesticide applications, and harvest dates for both studies are presented in *Table 1*.

Table 1. Planting date, variety, seeding rate, pesticide applications, and harvest date for the full season and double crop soybean studies.

Operation	Full Season Study	Double Crop Study
Planting Date	5/20/14	7/9/14
Variety	Asgrow 4232	Asgrow 3931
Target Seeding Rate/A	165,000	185,000
<i>Pesticide Applications</i>		
Glyphosate 28 oz/A + Canopy 4 oz/A	5/22/14	--
Glyphosate 32 oz/A	--	7/16/14
Glyphosate 28 oz/A + Reflex 1.5 pt/A	6/27/14	8/8/14
<i>Harvest Date</i>	10/31/14	11/10/14

Soil Moisture Monitoring to Trigger Irrigation Treatments. Soil moisture was monitored in each plot using Watermark soil moisture sensors placed at 4 in., 10 in., and 16 in. below the soil line. Sensors were placed in the 15 in. row width section of each plot. A Watermark 950T transmitter was used at all moisture monitoring locations to wirelessly transmit data to a Watermark 950R data logging receiver. Moisture data was viewed and interpreted daily to determine if any treatments required irrigation. Irrigation was applied to plots when soil moisture at the 4 in., 10 in., or 16 in. depth reached the specific irrigation treatment requirement. KanSched2, an irrigation scheduling program, was used to trigger the ET based irrigation treatment. ET data was obtained from a Delaware Environmental Observing System (DEOS) weather station located on the irrigation research farm.

Data Collected. Plant stand counts were recorded in each row width and were averaged within each row width (*Table 2*). In-season plant heights, canopy development, and growth stages (*Table 3*) were recorded on multiple dates. In addition, lodging and green stem were recorded at harvest. Soybean yield, moisture, and test weight were determined by harvesting the middle rows of each plot (11 rows in the 7.5 in. width, 5 rows in the 15 in. width, and 3 rows in the 30 in. width) with a Massey Ferguson 8XP plot combine. Soybean yield was adjusted to 13% moisture.

Table 2. Final average plants per acre by row width in the full season and double crop soybean studies.

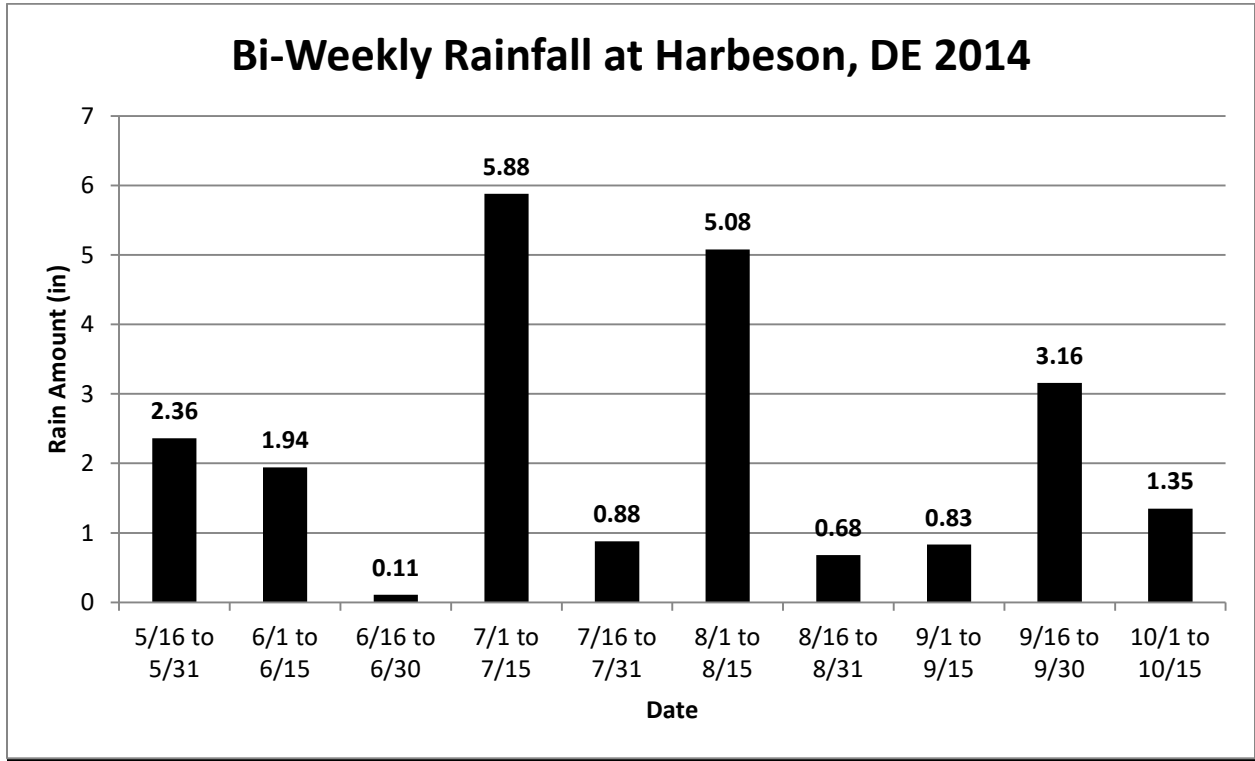
Row Width	Full Season Study	Double Crop Study
	Avg. Plants/A	
7.5 inch	178,470	173,520
15 inch	137,650	122,840
30 inch	144,475	124,000

Table 3. Soybean growth stages by date for the full season and double crop soybean studies.

Growth Stage	Growth Stage Description	Full Season Study	Double Crop Study
		Date	
V2	2-trifoliolate	6/19/14	7/28/14
V4	4-trifoliolate	6/24/14	8/7/14
V6	6-trifoliolate	6/30/14	--
R1	Begin Flower	7/1/14	8/14/14
R2	Full Flower	7/12/14	8/21/14
R3	Begin Pod	7/23/14	8/28/14
R4	Full Pod	8/5/14	9/2/14
R5	Begin Seed	8/14/14	9/8/14
R6	Full Seed	9/4/14	9/18/14
R7	Begin Maturity	9/25/14	10/16/14
R8	Full Maturity	10/5/14	10/31/14

Data Analysis. Data was analyzed using the Proc GLM procedure in SAS and treatments means compared using the Least Significant Difference (LSD) test at the 5% probability level. There were no significant irrigation treatment by row width interactions for any data. Therefore, data for each row width was combined and analyzed by irrigation treatment. Total water applied for each irrigation treatment was determined and the economic implications of each irrigation management strategy were calculated based on soybean yield, soybean selling price, and irrigation energy costs.

Figure 1. Bi-weekly rainfall total at the study site in Harbeson, DE in 2014.



RESULTS AND DISCUSSION

In-Season Rainfall. *Figure 1* shows the bi-weekly rainfall at the study site in Harbeson, DE in 2014. Overall, rainfall was above average in July (6.76”) and August (5.76”), but below average in June (2.05”) and September (3.99”). In June, July, and August, rainfall in the last 2 weeks of each month was less than 0.88”. There was a 4 week period from 8/16 to 9/15, where Harbeson received only 1.56” of rainfall.

Irrigation Applied. Bi-weekly and total irrigation applied for each treatment in the full season and double crop studies are shown in *Figure 2* and *Figure 3*, respectively.

Full Season Study – Irrigation applied for all irrigated treatments ranged from 1.9 in. to 9.0 in. (*Table 6*).

Double Crop Study – Irrigation applied for all irrigated treatments ranged from 3.4 in. to 5.4 in. (*Table 9; Figure 3*).

Soybean Growth.

Full Season Study – Soybean heights were measured on 6/30, 7/9, 7/16, 7/28 and 10/31. Canopy development was recorded on 6/30 and 7/9.

Plant Height by Irrigation Treatment. There were no significant differences in plant height between any irrigation treatments on 10/31 just before harvest. Plant height ranged from 45.2 in. to 48.7 in. (*Table 4*).

Plant Height by Row Width. There were no significant differences in plant height between any row widths on 10/31 just before harvest. Plant height ranged from 45.9 in. to 47.4 in. (*Table 5*).

Canopy Closure by Irrigation Treatment. Plant canopy closure was not significantly different between irrigation treatments on any collection date (*Table 4*).

Canopy Closure by Row Width. On 7/9 at stage R1, soybeans in the 7.5 in. and 15 in. row widths had achieved full canopy and the 30 in. row widths were 6.5 in. from full canopy (*Table 5*).

Double Crop Study – Soybean heights were measured on 8/14, 8/28, 9/12, 9/24 and 11/10. Canopy closure was recorded on 8/14, 8/28 and 9/12.

Plant Height by Irrigation Treatment. There were no significant differences in plant height between any irrigation treatment up to the R3 growth stage on 8/28 (*Table 7*).

Plant Height by Row Width. On 11/10 just before harvest, plant height by row width was 29.9 in., 27.7 in., and 28.9 in. in 7.5 in., 15 in., and 30 in. row widths, respectively (*Table 8*).

Canopy Closure by Irrigation Treatment. Canopy closure on 8/28 at growth stage R3 ranged from 1.4 in. to 2.5 in. between all treatments (*Table 7*).

Canopy Closure by Row Width. On 7/28 at stage R3, soybeans in the 7.5 in. and 15 in. row width had achieved full canopy and the 30 in. row widths were 5.6 in. from full canopy (*Table 8*).

Lodging and Yield.

Full Season Study – Soybeans were harvested on 10/31. Lodging ratings were taken before harvest.

Lodging by Irrigation Treatment. There were only slight differences in lodging between all treatments, which ranged from 2.3 to 3.4 on a scale of 0 to 5 (0=no lodging; 5 =maximum lodging) (*Table 6*).

Lodging by Row Width. Lodging ratings by row width ranged from 2.6 to 3.0. Lodging at harvest was slightly higher in the 7.5 in. row width compared to the 15 in. and 30 in. row widths (*Table 5*).

Yield by Irrigation Treatment. Yield in the irrigated treatments ranged from 73 to 77 bu/A compared to 73 bu/A in the no irrigation treatment (*Figure 2; Table 6*). Although, there were no significant differences in yield, the highest yielding treatment was limited irrigation to R3/R4 then >50% irrigation.

Yield by Row Width. Yield between row widths ranged from 74 to 76 bu/A (*Table 5; Figure 4*). Yield in the 7.5 in. row was greatest at 76 bu/A. Yield in the 15 in. and 30 in. row widths were similar at 74 bu/A.

Double Crop Study – Soybeans were harvested on 11/10. There was no lodging to rate.

Yield by Irrigation Treatment. Yield in the irrigated treatments ranged from 50 to 55 bu/A compared to 42 bu/A in the no irrigation treatment (*Figure 3; Table 9*).

Yield by Row Width. Yield ranged from 50 to 56 bu/A by row width (*Table 8; Figure 4*). Yield was greatest in the 7.5 in. row width at 56 bu/A. Yield in the 15 in. and 30 in. row widths were similar at 51 and 50 bu/A, respectively.

SUMMARY

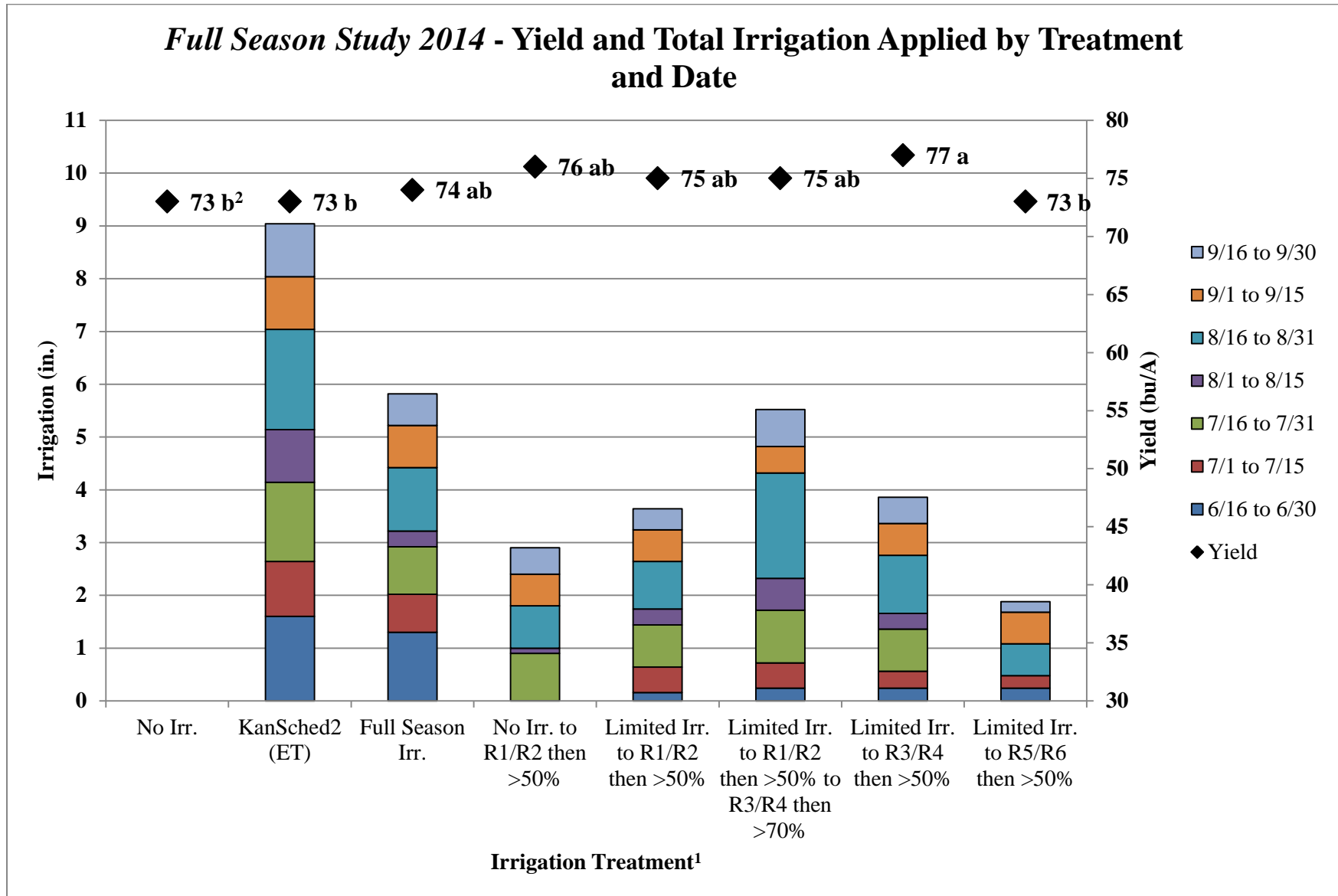
Full Season Study – Effect of Irrigation Treatment. Average yield in plots that received irrigation ranged from 73 to 77 bu/A compared to 73 bu/A in plots that received no irrigation. The amount of water applied based on the irrigation strategy ranged from 1.9 in. to 9.0 in. There was no significant difference in yield between irrigation treatments, however, the highest yielding treatment was limited irrigation to R3/R4 then >50%.

Effect of Row Width. Soybeans planted in 7.5 in., 15 in., and 30 in. row widths yielded similarly to each irrigation strategy, but there was an overall yield difference between row widths. Average soybean yield was 76 bu/A in 7.5 in. rows, 74 bu/A in 15 in. rows, and 74 bu/A in 30 in. rows.

Double Crop Study – Effect of Irrigation Treatment. Average yield in plots that received irrigation ranged from 50 to 55 bu/A compared to 42 bu/A in plots that received no irrigation. The amount of water applied based on the irrigation strategy ranged from 3.4 in. to 5.4 in.

Effect of Row Width. Soybeans planted in 7.5”, 15”, and 30” row widths yielded similarly to each irrigation strategy, but there was an overall yield difference between row widths. Average soybean yield was 56 bu/A in 7.5 in. rows, 51 bu/A in 15 in. rows, and 50 bu/A in 30 in. rows.

Figure 2. Full Season Study – Soybean yield and total irrigation applied bi-weekly by treatment. Each color represents the total amount of irrigation applied during the date range listed. The top of the bar column represents the total irrigation applied for the season.



¹Treatments with limited irrigation were kept at >30% available soil moisture (0% moisture = dry; 100% moisture = wet).

²Treatment means followed by the same letter are not significantly different.

Figure 3. Double Crop Study – Soybean yield and total irrigation applied bi-weekly by treatment. Each color represents the total amount of irrigation applied during the date range listed. The top of the bar column represents the total irrigation applied for the season.

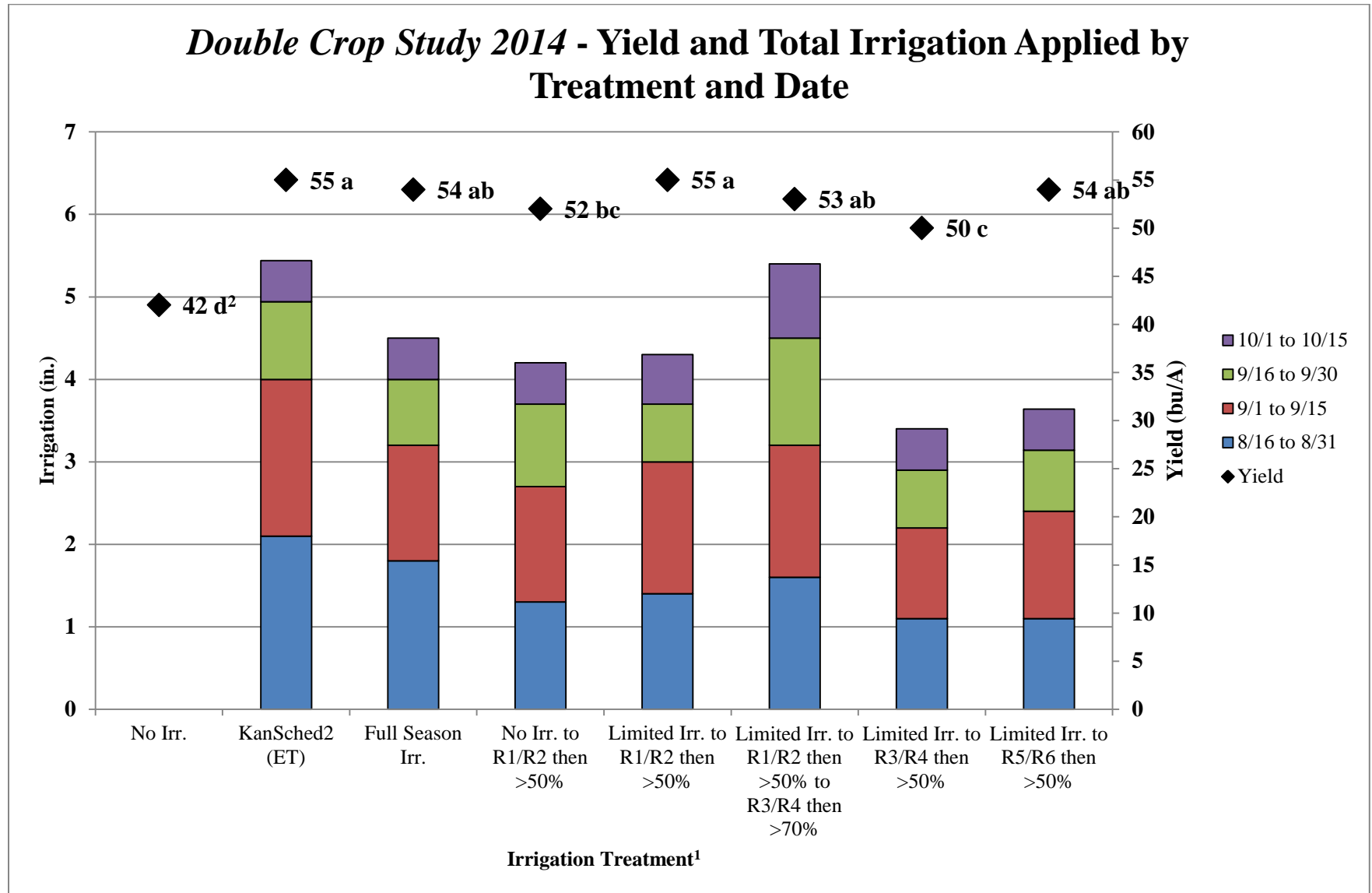
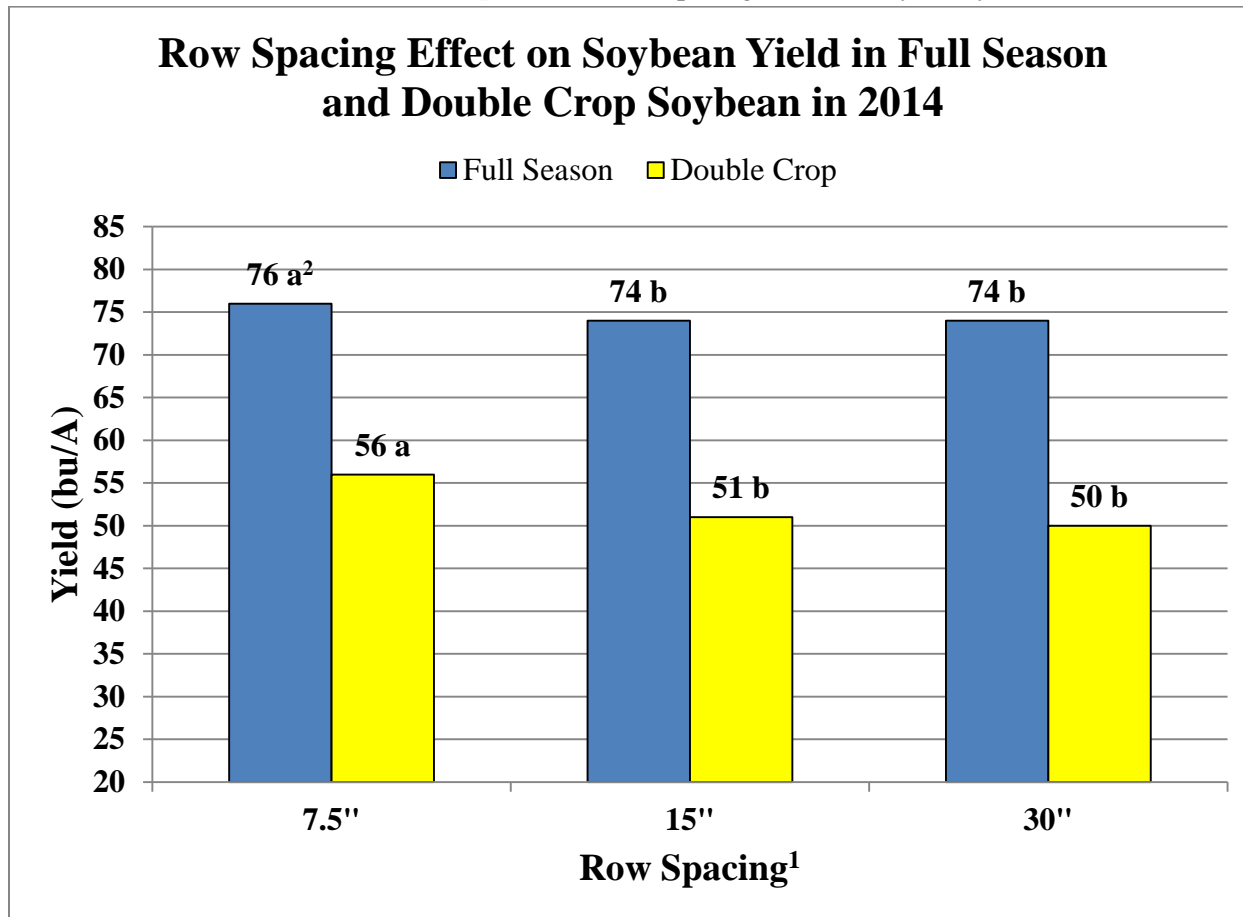


Figure 4. Full Season and Double Crop Study – Row spacing effect on soybean yield.



¹Average plant stand/A for full season study in 7.5 in. = 178,470; 15 in. = 137,650; 30 in. = 144,475.
Average plant stand/A for double crop study in 7.5 in. = 173,520; 15 in. = 122,840; 30 in. = 124,000.

²Treatment means followed by the same letter are not significantly different.

Table 4. Full Season Soybean Study - Irrigation treatment effect on soybean plant height and canopy closure.

Irrigation Treatment ¹	Plant Height					Canopy ²	
	6/30/14	7/9/14	7/16/14	7/28/14	10/31/14	6/30/14	7/9/14
	in.					in.	
No Irr.	7.6 c ³	14.6 abc	20.6 bcd	36.6 abc	46.2 bc	4.4 ab	2.3 ab
KanSched2 (ET)	8.4 a	15.7 a	21.8 abc	37.8 a	48.7 a	3.7 b	1.6 ab
Full Season Irr.	8.3 ab	15.7 a	22.1 a	36.6 abc	46.9 abc	4.5 a	2.1 ab
No Irr. to R1/R2 then >50%	7.3 c	13.6 c	19.5 d	34.6 c	45.2 c	4.9 a	2.5 a
Limited Irr. to R1/R2 then >50%	7.6 c	14.0 bc	20.1 d	35.2 bc	46.1 bc	4.7 a	2.4 a
Limited Irr. to R1/R2 then >50% to R3/R4 then >70%	7.8 bc	15.0 ab	21.9 ab	37.2 ab	47.7 ab	4.4 ab	2.0 ab
Limited Irr. to R3/R4 then >50%	7.7 c	13.9 bc	20.0 d	36.4 abc	47.3 ab	4.4 a	2.5 a
Limited Irr. to R5/R6 then >50%	7.6 c	14.5 abc	20.4 cd	36.8 abc	45.9 bc	4.3 ab	2.1 ab
LSD	0.6	1.1	1.5	NS	NS	NS	NS

¹Treatments with limited irrigation were kept at >30% available soil moisture (0% moisture = dry; 100% moisture = wet).

²Canopy was measured as the width between adjacent rows. A canopy measurement of zero would indicate that plants were at full canopy.

³Treatment means followed by the same letter are not significantly different.

Table 5. Full Season Soybean Study – Row width effect on soybean plant height, canopy closure, lodging, and yield.

Row Width ¹	Plant Height					Canopy ²		Lodging ³	Yield
	6/30/14	7/9/14	7/16/14	7/28/14	10/31/14	6/30/14	7/9/14		
	in.					in.		#	bu/A
7.5 in.	7.3 b ⁴	15.4 a	21.7 a	37.3 a	47.4 a	0.0 c	0.0 b	3.0 a	76 a
15 in.	7.6 b	14.5 b	19.8 b	35.7 b	46.9 ab	2.1 b	0.0 b	2.6 b	74 b
30 in.	8.4 a	14.0 b	20.9 a	36.2 ab	45.9 b	11.1 a	6.5 a	2.7 b	74 b
LSD	0.4	0.7	0.9	NS	NS	0.4	0.5	0.3	1.9

¹Average plant stand/A for 7.5 in. = 178,470; 15 in. = 137,650; 30 in. = 144,475.

²Canopy was measured as the width between adjacent rows. A canopy measurement of zero would indicate that plants were at full canopy.

³Lodging was rated on a scale of 0 to 5 (0 = no lodging; 5 = maximum lodging).

⁴Treatment means followed by the same letter are not significantly different.

Table 6. Full Season Soybean Study – Irrigation treatment effect on soybean lodging and yield, total irrigation applied, irrigation energy cost per acre, and gross income at multiple soybean prices.

Irrigation Treatment ¹	Lodging ² — # —	Yield bu/A	Total Irrigation Applied — in. —	Irrigation Energy Cost ³ - \$/Acre -	Gross Income minus Irrigation Energy Cost ⁴		
					\$8.00/bu ⁵	\$12.00/bu	\$16.00/bu
No Irr.	2.8 bc ⁶	73 b	0.0 e	0.00 f	584 abc	876 ab	1168 abc
KanSched2 (ET)	3.2 ab	73 b	9.0 a	54.00 a	530 d	822 c	1114 c
Full Season Irr.	2.6 cd	74 ab	5.8 b	34.80 b	557 c	853 bc	1149 bc
No Irr. to R1/R2 then >50%	2.6 cd	76 ab	2.9 cd	17.40 d	590 ab	894 ab	1198 ab
Limited Irr. to R1/R2 then >50%	2.3 d	75 ab	3.6 c	21.60 cd	578 abc	878 ab	1178 ab
Limited Irr. to R1/R2 then >50% to R3/R4 then >70%	3.4 a	75 ab	5.5 b	33.00 b	567 bc	867 ab	1167 abc
Limited Irr. to R3/R4 then >50%	2.9 bc	77 a	3.9 c	23.40 c	592 a	900 a	1208 a
Limited Irr. to R5/R6 then >50%	2.7 cd	73 b	1.9 d	11.40 e	572 abc	864 ab	1156 abc
LSD	0.5	NS	1.4	4.5	26	39	51

¹Treatments with limited irrigation were kept at >30% available soil moisture (0% moisture = dry; 100% moisture = wet).

²Lodging was rated on a scale of 0 to 5 (0 = no lodging; 5 = maximum lodging).

³Irrigation energy costs were calculated assuming the cost to pump 1 acre-inch of water is \$6.00.

⁴Gross income was calculated based on soybean price, yield, and irrigation cost.

⁵Gross income minus irrigation energy cost at the expected soybean selling price.

⁶Treatment means followed by the same letter are not significantly different.

Table 7. Double Crop Soybean Study - Irrigation treatment effect on soybean plant height and canopy closure.

Irrigation Treatment ¹	Plant Height					Canopy ²	
	8/14/14	8/28/14	9/12/14	9/24/14	11/10/14	8/14/14	8/28/14
	in.					in.	
No Irr.	10.2 a ³	18.3 abc	25.4 b	25.7 c	25.9 c	5.4 b	2.1 abc
KanSched2 (ET)	10.7 a	18.6 ab	30.4 a	30.7 a	31.3 a	5.9 ab	1.4 c
Full Season Irr.	10.7 a	18.4 abc	29.6 a	29.6 a	29.5 b	6.7 a	1.7 bc
No Irr. to R1/R2 then >50%	10.4 a	17.2 c	26.9 b	27.5 b	27.6 c	6.3 a	2.2 ab
Limited Irr. to R1/R2 then >50%	10.8 a	18.8 a	29.7 a	30.6 a	30.3 ab	5.9 ab	1.5 bc
Limited Irr. to R1/R2 then >50% to R3/R4 then >70%	10.7 a	18.1 abc	29.5 a	29.5 a	29.7 ab	6.0 ab	1.9 abc
Limited Irr. to R3/R4 then >50%	10.2 a	17.4 bc	26.3 b	26.8 bc	26.0 c	6.4 a	2.5 a
Limited Irr. to R5/R6 then >50%	10.5 a	18.7 ab	29.2 a	29.6 a	30.1 ab	6.2 ab	1.6 bc
LSD	NS	NS	2.0	1.8	1.7	NS	0.7

¹Treatments with limited irrigation were kept at >30% available soil moisture (0% moisture = dry; 100% moisture = wet).

²Canopy was measured as the width between adjacent rows. A canopy measurement of zero would indicate that plants were at full canopy.

³Treatment means followed by the same letter are not significantly different.

Table 8. Double Crop Soybean Study – Row width effect on soybean plant height, canopy closure, and yield.

Row Width ¹	Plant Height					Canopy ²		Yield – bu/A –
	8/14/14	8/28/14	9/12/14	9/24/14	11/10/14	8/14/14	8/28/14	
	in.					in.		
7.5 in.	10.3 b ³	18.4 a	28.9 a	29.0 a	29.9 a	0.0 a	0.0 b	56 a
15 in.	9.9 b	17.4 b	27.5 b	27.9 b	27.7 b	4.5 b	0.0 b	51 b
30 in.	11.4 a	18.8 a	28.8 a	29.3 a	28.9 a	13.8 a	5.6 b	50 b
LSD	0.6	0.8	NS	1.1	1.0	0.5	0.5	1.7

¹Average plant stand/A for 7.5 in. = 173,520; 15 in. = 122,840; 30 in. = 124,000. Planting conditions reduced emergence in 15 in. and 30 in. rows.

²Canopy was measured as the width between adjacent rows. A canopy measurement of zero would indicate that plants were at full canopy.

³Treatment means followed by the same letter are not significantly different.

Table 9. Double Crop Soybean Study – Irrigation treatment effect on soybean yield, total irrigation applied, irrigation energy cost per acre, and gross income at multiple soybean prices.

Irrigation Treatment ¹	Yield - bu/A -	Total Irrigation Applied - in. -	Irrigation Energy Cost ² - \$/Acre -	Gross Income minus Irrigation Energy Cost ³		
				\$8.00/bu ⁴	\$12.00/bu	\$16.00/bu
No Irr.	42 d ⁵	0.0 d	0.00 e	336 e	505 d	673 d
KanSched2 (ET)	55 a	5.4 a	32.40 a	408 abc	628 ab	849 ab
Full Season Irr.	54 ab	4.5 abc	27.00 b	408 abc	626 ab	844 ab
No Irr. to R1/R2 then >50%	52 bc	4.2 bc	25.20 bc	391 cd	599 bc	807 bc
Limited Irr. to R1/R2 then >50%	55 a	4.3 abc	25.80 bc	414 a	635 a	856 a
Limited Irr. to R1/R2 then >50% to R3/R4 then >70%	53 ab	5.4 ab	32.40 a	394 bcd	607 abc	820 ab
Limited Irr. to R3/R4 then >50%	50 c	3.4 c	20.40 d	378 d	577 c	776 c
Limited Irr. to R5/R6 then >50%	54 ab	3.6 c	21.60 cd	414 ab	632 a	850 a
LSD	2.7	1.2	4.00	21	32	43

¹Treatments with limited irrigation were kept at >30% available soil moisture (0% moisture = dry; 100% moisture = wet).

²Irrigation energy costs were calculated assuming the cost to pump 1 acre-inch of water is \$6.00.

³Gross income was calculated based on soybean price, yield, and irrigation energy cost.

⁴Gross income minus irrigation energy cost at the expected soybean selling price.

⁵Treatment means followed by the same letter are not significantly different.