Evaluation of Deficit Irrigation Strategies in Blackeyes Under Variable Plant Densities

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A study was conducted at the Kearney Research and Extension Center in 2009 to evaluate the effects of two deficit irrigation strategies on blackeye beans. The soil type is a Hanford fine sandy loam. Irrigation response was evaluated for the two most commonly planted blackeye varieties in this area – CB46 and CB50, each planted at densities ranging from 2 to 6 plants per foot. A similar trial was conducted at the Shafter Research and Extension Center under the direction of Blake Sanden. The Shafter trial was initiated almost 3 weeks prior to the Kearney trial. Results from this first year are reported separately, but all information will be summarized and an economic analysis will be prepared following the second year of research.

Irrigation Strategies

Two deficit irrigation strategies were compared with ***conventional*** irrigation management characterized by irrigations every seven to ten days, irrigating every furrow. The ***alternate*** irrigation strategy was irrigated on the same schedule, but only every other furrow was irrigated. Rows that did not have wheel traffic were used for irrigation. This strategy was expected to reduce applied water by 20-30%. The ***extended*** irrigation strategy involved skipping every other irrigation during the season, extending the interval between irrigations. Beans in these plots received 6 out of 10 irrigations during the season with an anticipated water savings of 30-40%. Either of the deficit irrigation strategies could be fairly easily implemented commercially, although alternate furrows would be difficult to manage in some soil types.

Table 1. Irrigation dates and treatments irrigated on each date.

	Treatments Irrigated		
Irrigation Date	**Conventional**	**Alternate Furrow**	**Extended Interval**
6/15	√	√	√
6/25	√	√	
7/2	√	√	√
7/13	√	√	
7/20	√	√	√
7/29	√	√	
8/6	√	√	√
8/17	√	√	
8/27	√	√	√
9/8	√	√	√

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Varieties and Plant Density

Planting recommendations for blackeye beans were developed many years ago for the variety CB5. They were updated when new, more compact varieties CB27 and CB46 were released. Today, the most common planting configuration in the Central San Joaquin Valley is a single-row 30”-bed system with four seeds planted per foot of row. CB50, a new variety released in 2008, has plant size and vigor characteristics similar to CB5, but is more erect and similar to CB46 in that respect. Its high yield and large seed size make it popular for export markets. CB50 needs to be evaluated under a variety of plant densities to determine the optimum planting configuration to maximize yield, bean quality, and economic returns.

Objectives

One objective of this trial was to determine the optimum planting configurations for CB46 and CB50 in terms of plant density. Secondly, these varieties at the given plant densities were evaluated for their response to limited water supplies using two deficit irrigation strategies – alternate furrow irrigation and extended intervals between irrigations. Yield and seed size were evaluated. Insect pressure, weed competition, and disease incidence were not factors in this trial.

Procedures

The field used for this trial had been previously planted to a uniform crop of oats. The trial was planted in single rows on 30” beds with treatments arranged in a split-split plot design. The main plots ran the length of the field and were managed according to one of three designated irrigation strategies (conventional, alternate furrow, extended interval between irrigations). All plots were irrigated at the beginning of the season and then various irrigation strategies were imposed for the duration of the trial. All treatments and all furrows were irrigated at the final irrigation to achieve appropriate soil moisture for cutting the beans prior to harvest. Soil moisture was monitored using gypsum blocks (Watermark sensors) installed at depths from 1 to 5 feet within the plot area. Sensors were placed in the medium density plantings of each variety and irrigation treatment in Rep III and soil moisture information was recorded using a datalogger programmed to read every 8 hours. Sensors placed in plots within other reps were read manually on a weekly basis. Sub plots were planted to one of the two blackeye varieties – CB46 or CB50. Within the subplots, three different plant populations were established by planting seeds 2, 4, or 6 inches apart (high, medium, and low density). Seeding rates were adjusted for the germination percentage of each variety.

Individual plots consisted of eight beds trimmed to a length of approximately 40 feet, replicated five times. Dual and Treflan were applied preplant for weed control. Following pre-irrigation, commercially treated seed (fungicide and rhizobial inoculant) was planted to moisture on 5/21/09. The first irrigation was on 6/15/09. Lannate (6/9/09) and dimethoate (6/19/09) were applied early season for aphid control. Temik 15G (14 lbs/A) was sidedressed on 7/2/09 to limit lygus pressure in the trial area. It was applied to all rows except the plots in the alternate irrigation treatment where the rate was doubled and applied only to the irrigated rows. Weed pressure and disease were not factors in this trial, although canopy cover in the deficit irrigation treatment was much less than in the conventional irrigation treatment and in some situations weed pressure would be expected to be greater in that situation.

First flush yields were estimated by stripping all pods from a 3 ft length of an interior row on 8/25/09, threshing and weighing the beans. Total season yields were obtained by cutting the two center rows of each 4-row planter pass (9/15/09) and threshing them as a single unit (10/6/09). Actual plot lengths were measured following harvest in order to accurately calculate yields on a per acre basis. Beans were cleaned and a 100-g sample was counted to assess seed size. In addition to evaluating early season growth, yield and seed size, an economic analysis will be conducted to determine the optimal planting configuration for each of the varieties.

Results

Plant Density

Prior to imposing the irrigation treatments, stand counts were recorded and averaged from the 4 harvest rows in each of the plots (6/10/09, 20 days after planting). CB50 had a slightly higher plant population compared to CB 46, and the difference (approximately 1 plant per 3 feet of row) was statistically significant. A range in plant density was achieved using variable seeding rates.

Table 2. Average plant densities by variety and seeding rate compared to expected.

	Number of plants/3 feet	**Number of plants/foot**	**Expected number of plants/foot**
Variety			
CB 46	11.6	3.9	4
CB 50	12.8	4.3	4
LSD	*1.05*		
Plant Density			
High	18.2	6.1	6
Medium	10.7	3.6	3
Low	7.8	2.6	2
LSD	*1.36*		

Plots were evaluated subjectively on 7/8/09 (48 days after planting) and significant maturity differences were detected among the irrigation treatments and between varieties, but plant density did not appear to influence maturity. CB50 was slightly more mature than CB46, and beans in plots subjected to either of the deficit irrigation strategies were slightly more mature than beans in the conventional irrigation plots. Canopy coverage was also evaluated and differences were only observed within irrigation treatments. Conventional irrigation management allowed for greater plant growth and coverage compared to the deficit irrigation treatments.

Table 3. Average maturity ratings and canopy coverage ratings.

	Maturity Rating	Canopy Rating
Irrigation Treatment		
Conventional	3.3	5.1
Alternate Row	3.8	4.1
Extended Interval	3.8	4.1
LSD	*0.41*	*0.62*
Variety		
CB 46	3.4	4.3
CB 50	3.9	4.6
LSD	*0.17*	*ns*
Plant Density		
High	3.7	4.6
Medium	3.7	4.4
Low	3.6	4.3
LSD	*ns*	*ns*

Maturity Scale:
1=vegetative, 3=bloom, 5=pods

Canopy Coverage Scale:
0=100% soil exposed furrow to furrow, 10=100% covered by vegetation furrow to furrow.

Irrigation

Plant growth observations during the season suggested that plots closest to the tail end of the field were more stressed than the rest of the plot area, especially within the alternate furrow irrigation treatment. On July 16 plants looked stressed although the field had just been irrigated (7/13). We determined that furrows were not completely filled during irrigations and time had not been allowed for the water to sub across the beds. This was critically important in the alternate furrow irrigation treatment, but it may have resulted in stressed conditions in the conventional and extended irrigation treatments as well. Irrigation management was modified and the field was irrigated again on July 20. From that point forward the water was managed to allow time for subbing across beds.

Soil moisture sensors were used to determine the depth of irrigation and to indirectly indicate the level of plant stress. In all treatments, peak water demand occurred in July, coinciding with bloom and early pod fill. Most of the water uptake was from the top 3 ft of the soil profile. Due to short runs, irrigations were quick, efficiency was high, and deep percolation was limited. When uptake was observed at the 2 ft depth, quick irrigations only served to stabilize the moisture at that level, but were not sufficient to return the soil to field capacity. In none of the treatments was the second foot fully recharged with irrigation. There is a slight indication, which needs to be confirmed by additional research, that CB46 took up water from deeper in the profile than CB50. This observation was based on only one monitoring station per variety in each irrigation treatment. Monitoring soil moisture changes at multiple sites would allow validation of this observation.

In the conventional irrigation treatment, soil moisture sensor readings never exceeded 100 centibars (the higher the value, the drier the soil). Soil moisture was generally recharged with each irrigation at the 1 ft level. In the alternate furrow irrigation treatment, moisture sensor readings at 1 ft often exceeded 120 centibars and moisture was not replenished by irrigation, imposing moderate water stress throughout the season. This was not the case in the extended irrigation treatment where the sensor readings exceeded 120 centibars only once and soil moisture in the top 1 ft was recharged with irrigation. Water stress was imposed between irrigations but was relieved when irrigated soils returned to field capacity at the 1 ft depth.

Yield

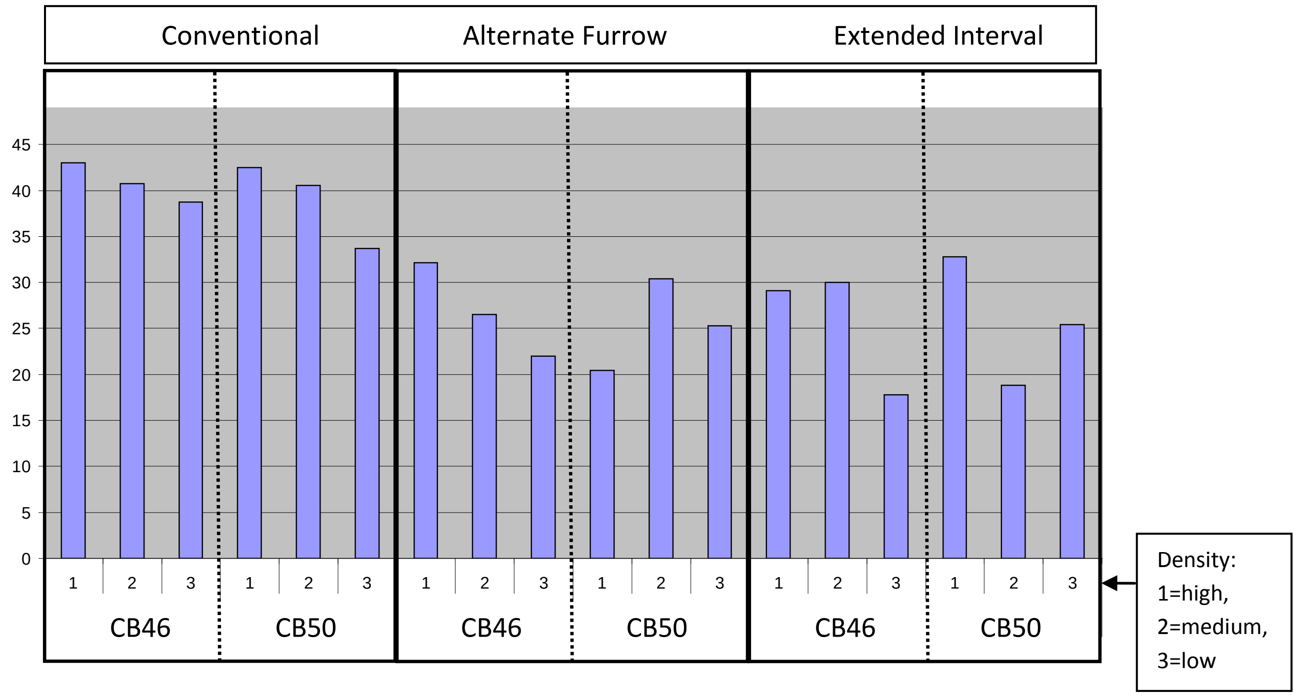
For first flush yield estimates, the only significant differences were from irrigation treatments. The conventional irrigation treatment yielded 26.1 cwt/A while the alternate row and extended interval treatments yielded 19.1 and 18.6 cwt/A, respectively (LSD=3.43). Reducing the available water reduced yields by 7 to 7.5 cwt/A compared to the conventional irrigation treatment.

For total season yields (double flush) there was a significant interaction between irrigation treatment, variety, and plant density. This indicates the two varieties responded differently to the irrigation strategies based on the density of their planting. Yields were higher in the conventional irrigation treatment (40 cwt/A vs. about 26 cwt/A in either of the deficit irrigation treatments) and yields were also generally higher in the more densely planted plots. There was no difference in yield between the two varieties when averaged over all treatments. Data is presented in both table and chart format below.

Table 4. Total Season Yields (cwt/A).

		Irrigation Management		
Variety	**Plant Density**	**Conventional**	**Alternate Row**	**Extended Interval**
CB 46	**High**	43.0	32.1	29.1
	Medium	40.7	26.5	30.0
	Low	38.7	22.0	17.8
CB 50	**High**	42.5	20.4	32.8
	Medium	40.6	30.4	18.8
	Low	33.7	25.3	25.4

Figure 1. Average total season yield (cwt/A) within irrigation, variety, and density.

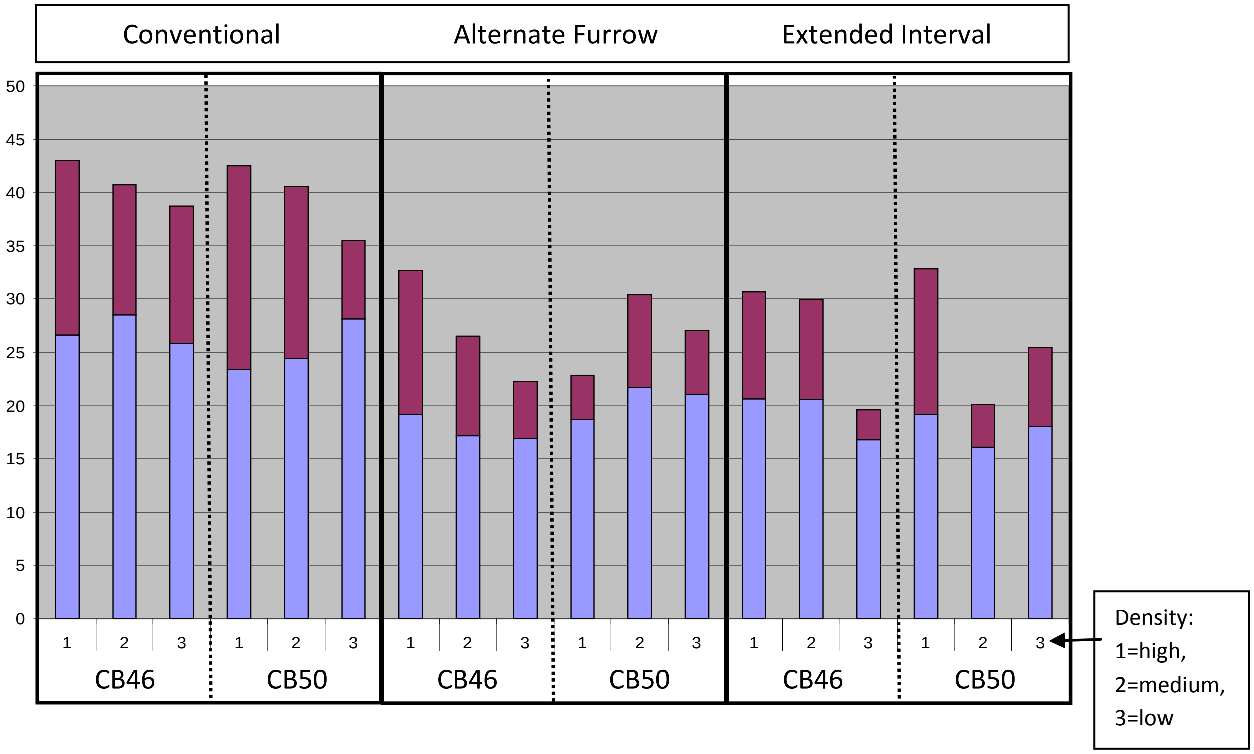


Looking at the contribution of each flush to total season yield showed the conventional irrigation management strategy resulted in a greater yield increase between the first and second flush (14 cwt/A), than the water conserving strategies which averaged close to 8 cwt/A. There was a significant interaction between the treatment variables and the yield difference measured between single and double flush harvests. There was a tendency for higher density plantings to put on more beans during the second flush than lower density plantings.

Table 5. Difference between single and double flush yields (cwt/A).

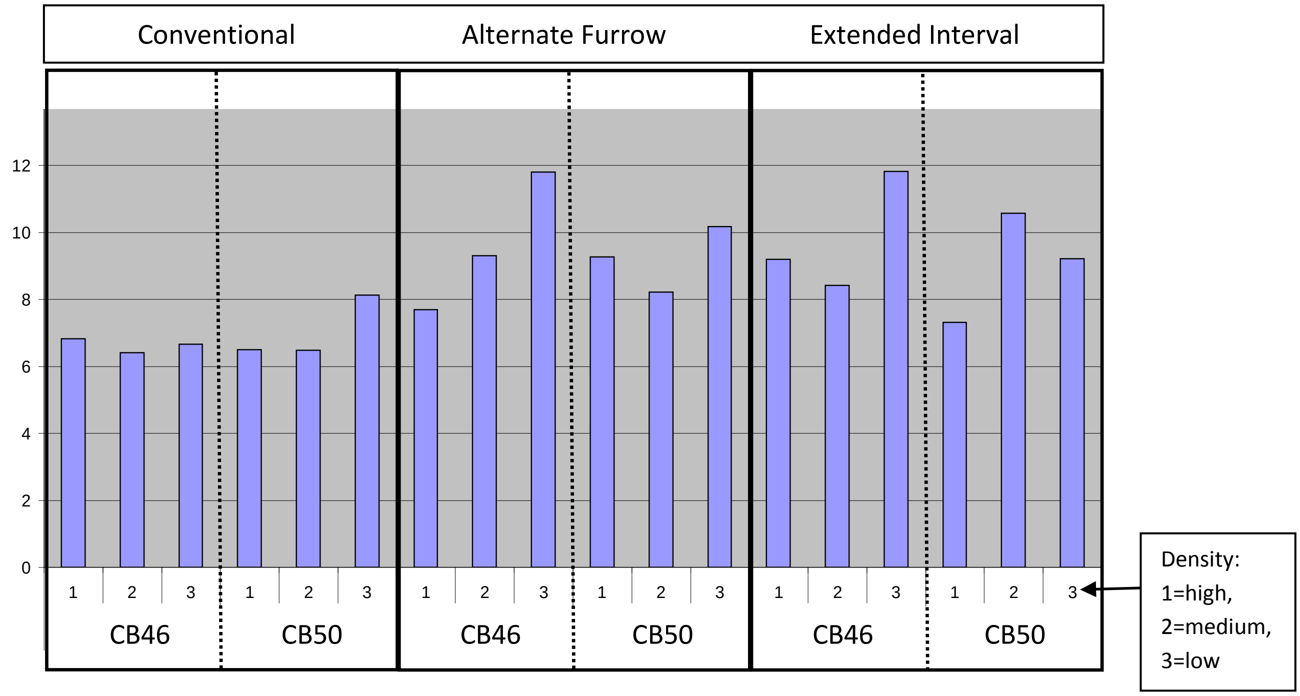
		Irrigation Management		
Variety	**Plant Density**	**Conventional**	**Alternate Row**	**Extended Interval**
CB 46	**High**	16.4	13.5	10.0
	Medium	12.2	9.4	9.4
	Low	12.9	5.4	2.8
CB 50	**High**	19.1	4.2	13.6
	Medium	16.2	8.7	4.0
	Low	7.3	6.0	7.4

Figure 2. Average difference between single and double flush yields (cwt/A) within irrigation, variety, and density.



Cleanout
An estimate of cleanout indicated that the deficit irrigation strategies had higher cleanout percentages than the conventional irrigation strategy. The conventional irrigation strategy resulted in an average 6.8% cleanout and the deficit irrigation strategies both averaged 9.4%. There was no difference between the two varieties.

Figure 3. Estimates of cleanout (%) within irrigation treatment, variety, and density.



Seed Size
Seed size was affected by irrigation treatment, variety, and plant density. There were larger beans in the conventional irrigation treatment compared to either of the reduced irrigation strategies. As expected, CB50, which was selected for large seed size, had significantly larger beans than CB46. Plant density also impacted bean size with the higher density plantings resulting in larger beans as compared to the lower density plantings. Commercially, BE50 tends to run between 400 and 420 beans/100g, while BE46 produced commercially ranges from 460 to 520 beans/100 g. Smaller beans (>450/100g) are marketed domestically while larger beans (<450/100 g) are desirable for the export market.

Table 6. Average number of beans per 100 grams as an indication of seed size within irrigation treatment, variety, and plant density.

	Beans/100 g
Irrigation Treatment	
Conventional	430.6 a
Alternate Row	441.0 b
Extended Interval	446.1 b
LSD	*9.94*
Variety	
CB 46	487.8 b
CB 50	390.6 a
LSD	*9.33*
Plant Density	
High	432.6 a
Medium	440.5 b
Low	444.6 b
LSD	*6.40*

Summary and Conclusions

Reducing the amount of applied water had consequences in terms of both yield and seed size. These important economic losses could be related to reductions in overall plant growth and the potential for maximum production. Plants were slightly more mature and had a smaller canopy under deficit irrigation when compared to the conventionally irrigated plots. Switching from vegetative to reproductive growth earlier in the season, combined with reductions in plant size, may limit the overall potential for bean production. When adequate water was supplied, there was a higher yield potential in both single and double flush systems. Yield were higher initially (26 cwt/A) and increased by 54% if allowed to mature a second flush. When water supplies were reduced, single flush yields of 19 cwt/A only increased by 37% when allowed to mature a second flush.

The two varieties had similar yields when averaged over all treatments, but there was a significant interaction between variety, irrigation and density indicating that the two varieties responded differently to the irrigation strategies based on planting density. The limited monitoring suggested there might be a difference between the varieties in root development and the depth from which water was taken up from soil. Further research is needed to confirm this preliminary observation.

Most of the applied moisture was removed from above the 3 ft soil depth. Short runs in this field allowed rapid and uniform irrigation. Applied moisture remained in the root zone and did not result in deep percolation. Irrigations did not recharge soil moisture to field capacity at the 2 ft depth. Conventional irrigation management kept the soil moisture significantly higher than the deficit irrigation treatments. The alternate furrow treatment imposed a greater level of stress than the extended irrigation treatments and plants exhibited mild to medium stress throughout the season. In the extended irrigation treatment, imposed stress was relieved at the 1 ft depth with each irrigation.

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