Response of Sunflower to Deficit Irrigation

Abdel Berrada, Senior Research Scientist and Manager

Colorado State University, Southwestern Colorado Research Center, Yellow Jacket, CO 81335

Joel Schneekloth, Water Resources Specialist

Colorado State University Extension, Akron, CO 80720

Abstract. A study was conducted in 2010-2012 in SW Colorado to quantify the response of sunflower to water deficit. Water was applied pre-plant only (Pre-P), during the growing season (Full), at bud initiation through flowering (R1-6), or during flowering (R4-6). Another treatment was added to mimic irrigation with siderolls (Veg). The Full irrigation treatment outperformed the other treatments in 2010 and 2011 but was similar to R1-6 in 2011. Seed yields of Veg, R4-6 and R1-6 were similar in 2010 while R4-6 ≡ R1-6 in 2011. In 2012, Mycogen 8H449CLDM had greater seed yield than the short stature hybrid Triumph s870HCL, except at Full. The latter is more suitable to irrigation with siderolls, which are prevalent in SW Colorado. Irrigation plus rain closely matched sunflower ET at Full. Season rainfall was greatest in 2010, with 3.3 in. recorded in August. Precipitation use efficiency was generally highest with Pre-P and lowest with Full. In contrast, seed oil content of Full was significantly more than that of the other treatments. The treatment that received little or no irrigation after planting (Pre-P) had the lowest seed oil content in 2010 and especially in 2011. Full irrigation and Veg had the tallest plants while Pre-P and R4-6 had the shortest plants. Applying water mostly during bloom did not affect seed yield or oil content in 2010 and 2011 compared to R1-6. Substantial water conservation and use efficiency can be achieved with limited but targeted irrigation of sunflower.

Keywords. Sunflower, irrigation scheduling, seed yield, oil content, plant height.

Introduction

Contrary to popular belief, sunflower may use as much or more water than other field crops such as corn to produce maximum yield (Meyer at al., 2009). With its deep taproot (Stone, 2002), sunflower can extract water down to 7 or 8 ft., thus reducing the need for additional water from rain or irrigation to meet evapotranspiration (ET).

At Akron, CO, Nelson (2007) derived the following response of sunflower to irrigation:

Yield (lb/acre) = 150.6*(inches water use – 6.9)

Seed production started at 6.9 in. of water consumption. Each additional inch of water produced approximately 151 lb/acre.

Long-term average precipitation from May through September in Yellow Jacket is 6.7 in. Assuming 6.0 in. of effective rainfall during the growing season and 4.0 in. of available soil moisture at planting, it would take an additional 2.2 in. of water to produce 800 lb/acre of sunflower seeds, which was about the average dryland yield in SW Colorado in 2006-2008. It would take another 5.3 in. to double the yield.

Sunflower is most sensitive to water stress "just before flowering through seed development" (Meyer et al., 2009). Schneekloth (2007) achieved 60% water saving compared to full irrigation when he applied water at the R-4 to R-5 stage. Seed and oil yields were equal or higher to those obtained with full irrigation in two (2003 and 2005) out of the four-year period (2002-2005) of the study. There was plenty soil moisture (field capacity in 0- to 6-ft) at planting in 2002 and 2003. When there was less water available at planting or during the growing season, full irrigation outperformed the limited irrigation treatments. Withholding irrigation until R-6 to R-7 increased oil concentration significantly compared to full irrigation. Conversely, applying water at R-1 to R-3 (bud stage) *only* reduced seed oil concentration. Seed yield was similar to that of when irrigation was withheld until R-6 to R-7.

The area where this study was conducted is within the Dolores Irrigation Project, which provides irrigation water to approximately 62,000 acres of crop land in Dolores and Montezuma counties. Pressurized water of excellent quality is delivered to each farm in the full service area (FSA) of the project. Each farmer is allocated close to 2.0 acre feet of water per season. The total FSA annual water allocation was reached or exceeded several times since irrigation began in 1987. Reasons for this include frequent droughts and the predominance of alfalfa (> 80% of the irrigated acreage), which is a high water user. Wheel-line sprinkler systems (siderolls) prevail in the FSA. The price FSA irrigators pay for water has been on the rise due to increases in pumping and maintenance costs. Thus conserving water and enhancing its efficiency is important to the long-term sustainability of the FSA.

Alfalfa ground is usually planted to dry bean, oat or spring wheat for one to two years before reseeding it to alfalfa. Sunflower would be a good crop to plant after alfalfa e.g., to mine the residual water and nitrogen that may be available beyond the reach of dry bean or spring cereals. Moreover, it appears that sunflower responds well to deficit irrigation.

The main objective of this study was to determine the response of sunflower to irrigation deficit.

Materials and Methods

A field trial was conducted at the Southwestern Colorado Research Center in Yellow Jacket, CO in 2010, 2011, and 2012. The soil at the study site is Wetherill loam (fine-silty, mixed, superactive, mesic Aridic Haplustalfs). Normal annual precipitation is 15.9 in., with June being the driest month (0.5 in.), and Aug., Sept., and Oct. the wettest months (1.7 to 1.9 in.). The elevation at the site is 6900 ft. Approximately 40% of the annual precipitation comes from snow.

Sunflower planting dates and irrigation scheduling are shown in Tables 1 and 2, respectively. Sunflower was planted in 30-in rows with a 4-row Monosem NG Vacuum Planter. Row length varied from 50 to 100 ft. The two middle rows were harvested in full or partially for yield estimates. There were four replications in 2010 and 2011 and three in 2012.

Table 1. Sunflower planting dates and rates

	2010	2011	2012	
Sunflower hybrid	Mycogen 8H449CLDM	Mycogen 8H449CLDM	Mycogen 8H449CLDM	Triumph s870HCL
Planting date	4-Jun	1-Jun	1-Jun	1-Jun
Planting rate (seeds/acre)	15,488 & 22,082	22,082	25,344	25,344
Harvest date	11-Nov	Oct. 17-20	Oct. 31 & Nov. 1	

Table 2. Irrigation treatments and amounts

Irrigation treatment	**Description**	**Net post-planting irrigation depth (in.)**[1]		
		2010	2011[2]	2012
Pre-P	Pre-plant irrigation (PPI) only	0.0	2.5	0.0
Full	PPI + Full-season irrigation[3]	11.4	18.1	16.2
R1-6	PPI+ Irrigation at R-1 to R-6[3]	3.1	11.7	8.7
R4-6	PPI + Irrigation at R-4 to R-6[3]	2.6	7.2	4.5
Veg	PPI + Sideroll Irrigation[4]	6.6	4.9	NA
PPI (with sideroll)		1.8	0.8	2.5
Rainfall		7.1	4.2	4.4
Full irrigation treatment crop ET		19.8	21.9	20.5

[1] Depth of irrigation after planting. Post-planting water was applied with subsurface drip irrigation (SDI) at approximately 90% efficiency.
[2] Two irrigations were applied early in the season to all the treatments to enhance seed germination and seedling emergence.
[3] Irrigation to meet crop ET during the designated treatment period. R-1: The terminal bud forms a miniature floral head, R-4: The inflorescence begins to open, R-6: Flowering is complete.
[4] Treatment to mimic irrigation with sideroll. Irrigation is terminated when sunflower interferes with the movement of the sideroll, which usually occurs at R-1 for standard-height sunflower.

Results and Discussion

2010

Irrigation scheduling had a significant impact on seed yield, oil yield, and plant height. The full irrigation treatment (Full) produced the highest seed yield of approximately 3000 lb/acre while pre-plant irrigation only (Pre-P) produced the lowest yield of 2334 lb/acre (Fig. 1). Treatments R1-6 and R4-6 received a total of 3.1 and 2.6 in. of net irrigation amount (in addition to pre-plant irrigation), respectively, which is about half the amount (6.6 in) received by Veg and yet, all three treatments had similar yields of approximately 2600 lb/acre. The sideroll-alike treatment (Veg) received most of the irrigation water during the mid-vegetative to early reproductive growth stages or until sunflower plants were too tall to irrigate with the sideroll.

In general, sunflower production in 2010 was enhanced by good water availability at planting and timely and above average rainfall during the reproductive growth stages. Precipitation use efficiency (lb of seeds/in. of rain plus irrigation) was highest at Pre-P and lowest at Full and Veg (Fig. 1). R4-6 and R1-6 had similar precipitation use efficiencies of around 280 lb/in.

The Full treatment had the highest seed oil content, significantly more than the other irrigation treatments, although the range in seed oil content values (39.9 to 41.3%) was small (Fig. 5). The Full and Veg treatments had the tallest plants on average, followed by R1-6. Pre-P and R4-6 had similar plant height of 55 in. (Fig. 8).

Increasing seeding rate from 15,488 to 22,082 seeds/acre increased seed yield by only 121 lb/acre on average (Data not shown). A larger increase (454 lb/acre) was observed at R4-6.

2011

Irrigation treatments that received water during reproductive growth (Full, R4-6, and R1-6) outperformed Pre-P and Veg (Fig. 2). The Full irrigation treatment and R1-6 produced around 3100 lb seeds/acre while R4-6 averaged 2878 lb/acre. The pre-plant irrigation treatment had the lowest yield (1854 lb/acre) followed closely by Veg. All the treatments received 2.5 in. of irrigation water shortly after planting due to dry conditions at planting. Precipitation use efficiency was highest with Pre-P and R4-6 and lowest with Full (Fig. 2).

Seed oil content increased in a near linear fashion with increasing irrigation amounts (Fig. 6). The Full irrigation regime averaged 41.3% followed by R1-6 and R4-6. The Pre-P treatment lagged behind with 37.5%. Sunflower plants averaged 45.7 in. in height with Pre-P and R4-6 and 51.4 in. with the other treatments. As in 2010, restricting irrigation mostly to the flowering period (R4-6) reduced plant height but it did not negatively impact seed yield or oil content when compared with R1-6.

2012

Seed yield increased significantly with increasing irrigation amounts (Fig. 3). Mycogen H449CLDM outperformed Triumph s870HCL at all irrigation levels, except at Full. Mycogen H449CLDM had higher precipitation use efficiency (PUE) at Pre-P and R4-6 and similar PUE at R1-6 and Full (Fig. 4).

On average, Full had the highest seed oil content of 43.8%, significantly more than that of R4-6 and R1-6. Treatment Pre-P had the lowest seed oil content of 41.7% (Fig. 7). Mycogen 8H449CLDM and Triumph s870HCL averaged 43.2% and 41.9%, respectively. Plants of both hybrids were tallest at Full followed by R1-6. Treatments R4-6 and Pre-P had similar plant heights (Fig. 10). As would be expect, s870HCL was much shorter than 8H449CLDM.

Conclusion

The full irrigation treatment outperformed the other treatments in 2010 and 2011 but was similar to R1-6 in 2011. Seed yields of Veg, R4-6 and R1-6 were similar in 2010 while R4-6 ≡ R1-6 in 2011, at P=0.05. In 2012, Mycogen 8H449CLDM had greater seed yield than the short stature

hybrid Triumph s870HCL, except at Full. Mycogen 8H449CLDM appears to respond better to deficit irrigation than Triumph s870HCL, possibly due to its more extensive root system. The latter is more suitable to irrigation with siderolls, which are prevalent in SW Colorado.

Irrigation plus rain closely matched sunflower ET at Full. Season rainfall was greatest in 2010, with 3.3 in. recorded in August (Fig. 11). Precipitation use efficiency was generally highest with Pre-P and lowest with Full. In contrast, seed oil content of Full was significantly more than that of the other treatments. The treatment that received little or no irrigation after planting (Pre-P) had the lowest seed oil content in 2010 and especially in 2011. The full irrigation and the sideroll-alike (Veg) treatments had the tallest plants while Pre-P and R4-6 had the shortest plants.

Applying water mostly during bloom did not affect seed yield or oil content in 2010 and 2011 compared to R1-6.

Literature Cited

Meyer, R., D. Belshe, J. Falk, S. Patten, and D. O'Brien. 2009. High Plains Sunflower Production Handbook. MF-2384, Kansas State Univ. Agric. Exp. Sta. & Coop. Ext. Service.

David Nielson. Estimated yield of some alternative crops under varying irrigation in Northeast Colorado. Agronomy News 26 (1): 8-9, April 2007, Colorado State University, Ft. Collins.

Joel Schneekloth. Yield impact of growth stage irrigation of sunflowers. Agronomy News 26 (1): 10-11, April 2007, Colorado State University, Ft. Collins.

Stone, L.R., D.E. Goodrum, A.J. Schlegel, M.N. Jaafar, and A. H. Khan. 2002. Water depletion depth of grain sorghum and sunflower in the central high plains. Agron. J. 94: 936-943.

Acknowledgments

This study was sponsored by the National Sunflower Association with additional support from Colorado State University Agricultural Experiment Station.

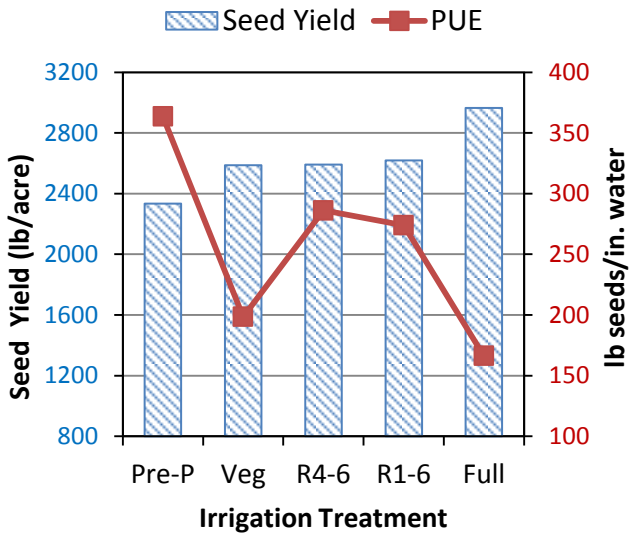

Figure 1. Seed yield and precipitation use efficiency (PUE) in 2010 as affected by irrigation scheduling.

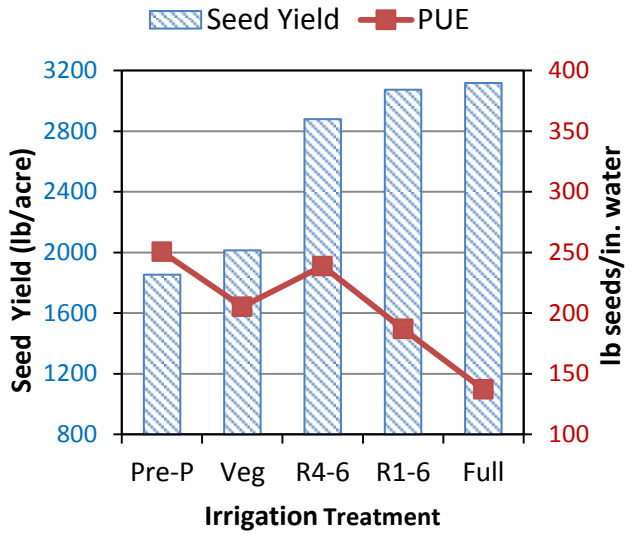

Figure 2. Seed yield and precipitation use efficiency (PUE) in 2011 as affected by irrigation scheduling.

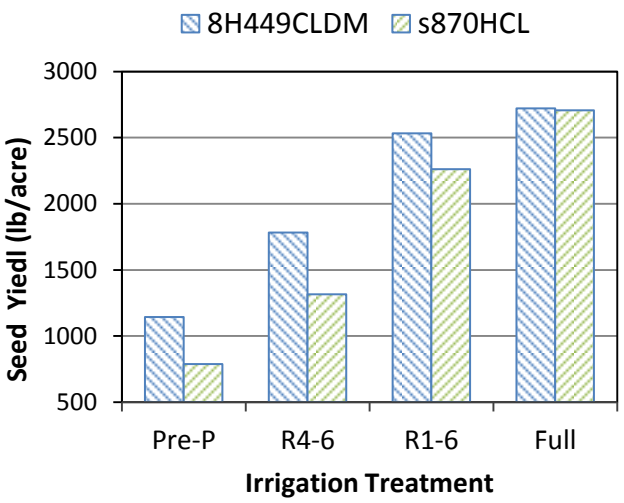

Figure 3. Seed yield of two sunflower hybrids in 2012 as affected by irrigation scheduling.

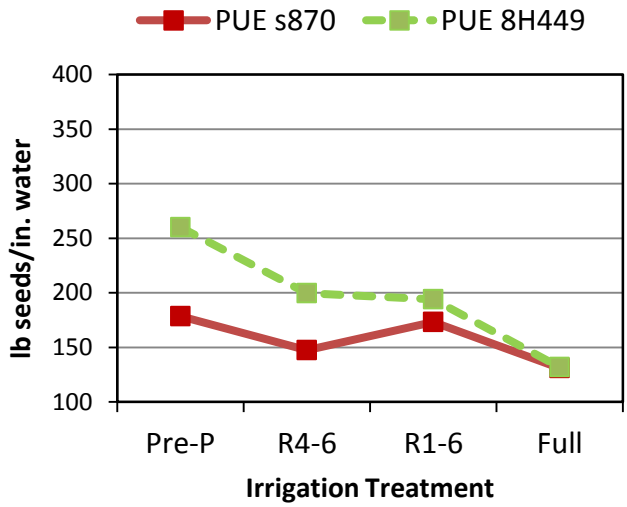

Figure 4. Precipitation use efficiency (PUE) of two sunflower hybrids in 2012 as affected by irrigation scheduling.

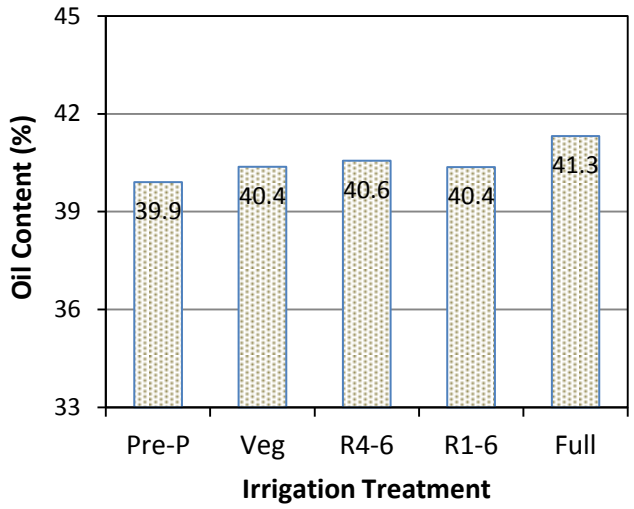

Figure 5. Oil content of sunflower hybrid 8H449CLDM in 2010 as affected by irrigation scheduling.

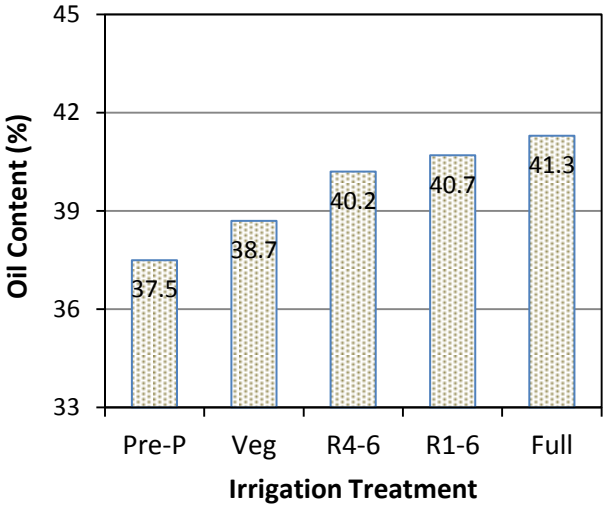

Figure 6. Oil content of sunflower hybrid 8H449CLDM in 2011 as affected by irrigation scheduling.

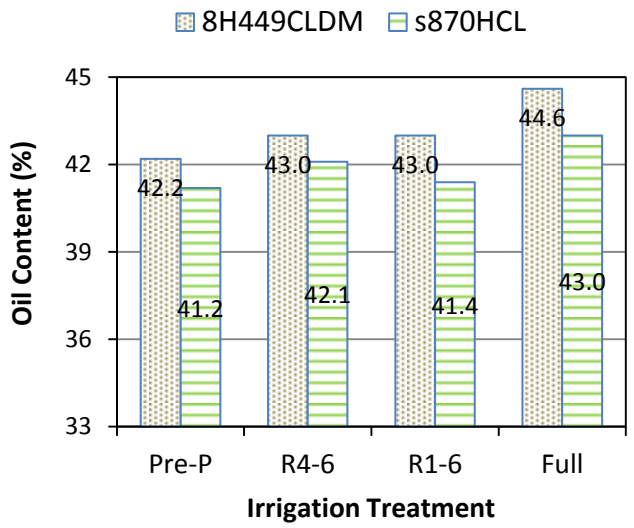

Figure 7. Oil content of two sunflower hybrids in 2012 as affected by irrigation scheduling.

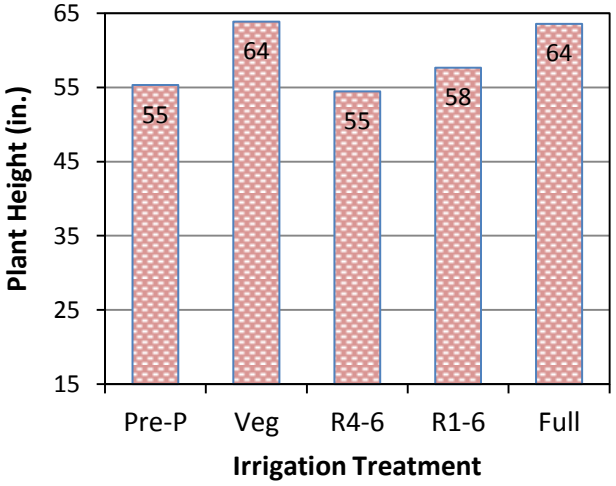

Figure 8. Plant height of sunflower hybrid 8H449CLDM in 2010 as affected by irrigation scheduling.

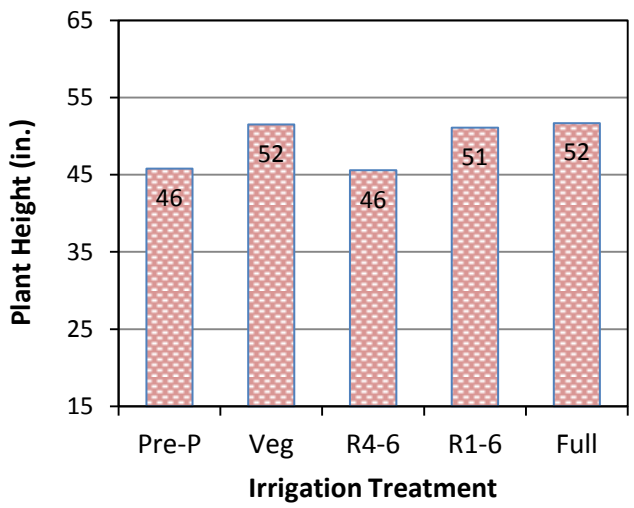

Figure 9. Plant height of sunflower hybrid 8H449CLDM in 2011 as affected by irrigation scheduling.

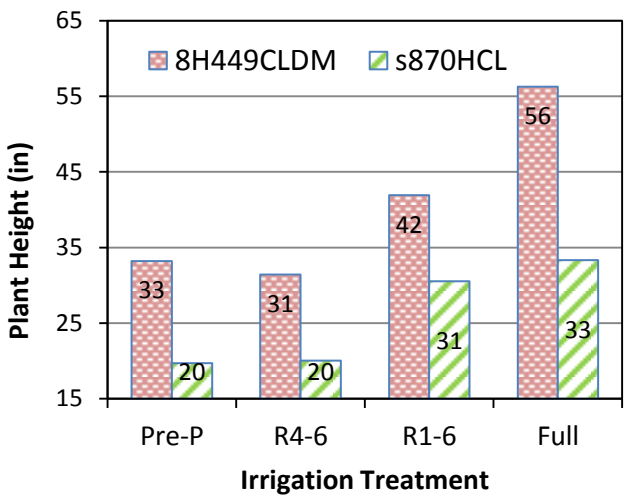

Figure 10. Plant height of two sunflower hybrids in 2012 as affected by irrigation scheduling.

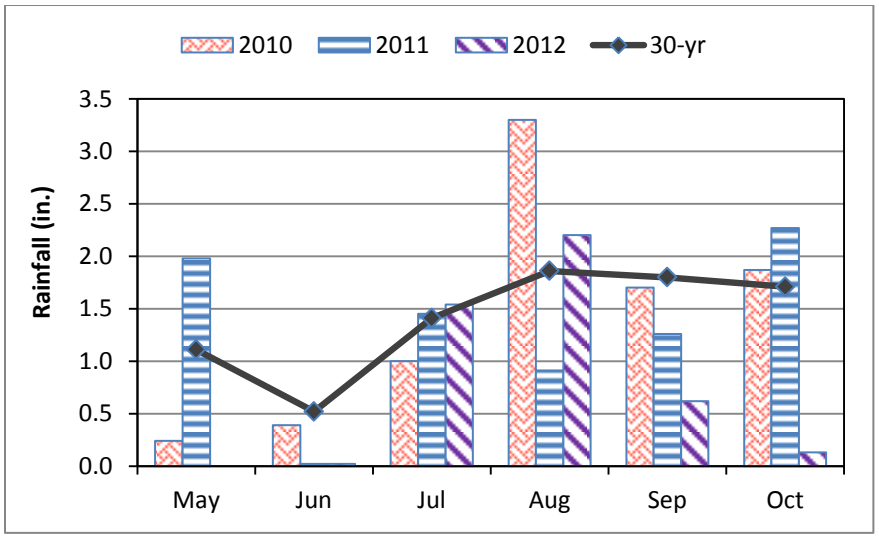

Figure 11. Rainfall in May through September at the study site.