IMPACT OF DRIVER ACCURACY IN CORN AND GRAIN SORGHUM YIELDS IN SUB SURFACE DRIP IRRIGATION

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IMPACT OF DRIVER ACCURACY IN CORN AND GRAIN SORGHUM YIELDS IN SUB SURFACE DRIP IRRIGATION

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Title of Study: IMPACT OF DRIVER ACCURACY ON CORN AND GRAIN SORGHUM YIELDS IN SUB SURFACE DRIP IRRIGATION

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Abstract: Water availability from the Ogallala Aquifer is declining in the Oklahoma Panhandle, resulting in dwindling pumping capacities, and the need for water use efficiency. Subsurface drip irrigation (SDI) is a more efficient irrigation system that could be adopted by producers in this region if various management related questions could be addressed. One such question is how crop row placement will impact crop performance, irrigation water use efficiency and yield under SDI. Therefore, a study was established at the Oklahoma Panhandle Research and Extension Center in which drip tape is buried on 152.4 cm rows, allowing two crop rows planted on 76.2 cm to be irrigated with one tape. Corn and Sorghum rows will be offset from equidistance from the drip tape by 0, 8, 15, 23, and 38 cm. This resulted in 5 treatments with 4 replicates. A GPS system will be used to place rows at the offsets mentioned above. For each crop this treatment structure will be imposed on 3 irrigation regimes. Irrigation will be applied to replace 100% of evapotranspiration as determined by the Mesonet irrigation program as well as 75% and 50% of this rate. This project found that offset did not impact sorghum yield. Also, no significant impact on corn grain yield was observed, however, at the 50% irrigation regime a 10% reduction in average yield was observed. This data suggests that SDI can be successful regardless of access to high precision guidance systems.

TABLE OF CONTENTS

LIST OF TABLES

Table Page

LIST OF FIGURES

Figure Page

CHAPTER I

INTRODUCTION

The Ogallala Aquifer underlies more than 45.2 million hectares in the states of South Dakota, Wyoming, Nebraska, Kansas, Oklahoma, Colorado and New Mexico (McGuire 2003). Approximately 27% of the irrigated land in the United States overlies the Ogallala Aquifer within the boundaries of these states. The Ogallala Aquifer is a formation created from sediments deposited from streams carrying material from the Rocky Mountains during the Pleiocene Age. These sediments were more heavily deposited in the western half of the aquifer, and so the landform commonly called the high plains gradually slopes downward from west to east. The eastward flow of the mountain streams was cut off ten thousand years ago with the rising of the Rocky Mountains (Ogallala, 2000) and so this source of recharge for the aquifer was lost forever.

Recharging the Aquifer

Recharge from other sources can occur in several other ways. According to Nativ and Smith (1987), direct infiltration into the aquifer is possible by water moving into outcrops. The Ogallala Aquifer can also recharge from water moving down through layers of soil beneath playa lake beds, sand deposits, and riverbeds. Nativ and Smith

(1987) also discuss how the Oklahoma panhandle region of the High plains contributes minimal recharge from riverbeds due to poor drainage from the soils in the high plains. Another valuable aspect brought up in their findings is that this area receives lower rainfall amounts at inopportune times from May to October, during which time staple summer crops are grown and evapotranspiration (ET) rates are highest. This may negatively affect any infiltration into the profile that could possibly recharge into the aquifer, because evapotranspiration brings water to the soil surface, where it is lost to evaporation from the soil or plant tissue.

The Ogallala Aquifer's saturated thickness ranges from a just few meters thick in places to hundreds of meters in other areas. In the Oklahoma Panhandle, Howell et al (1976) found a range in saturated thickness from 0 m to over 160 m. Changes in saturated thickness for the entire aquifer since large-scale pumping for irrigation began ranged from decreases of twenty-five percent of the thickness to an increase of ten percent or more in the original thickness of saturated formations (McGuire 2013). Once the Ogallala water resource is fully depleted, irrigated production agriculture in the high plains region will slowly disappear and dryland farming practices will have to become more widely adapted in the area.

Irrigation Development in the High Plains Region

The development of irrigation, stemming from the Ogallala Aquifer spurred the surge of agricultural production in the high plains region in the 1950's and brought forth the dramatic change of agricultural production capabilities in the region. The (USGS 2014) shows the Ogallala aquifer's area weighted, average water level has declined by 2.1 ft. from 2011 to 2013. Once depleted, the aquifer will take over 6,000 years to replenish naturally through rainfall with no water being pumped out. The Ogallala aquifer not only supplies irrigation water for the area but also supplies drinking water to 82% of the 2.3 million people who live within the boundaries of the High Plains area according to the 2000 census (USGS 2009). Center pivot irrigation is one of the widest used irrigation methods utilized in the high plains region. In Kansas for example, (O'Brien 1998) found that irrigated areas as reported by producers through annual irrigation water use reports has been approximately 3 million acres since 1990. During the period since 1990, the number of acres irrigated by center pivot irrigation systems increased from 50% of the irrigated acre base to 90% of the base area in Kansas. However, the continued decline of the Ogallala aquifer is driving the need for even more efficient technologies to prolong the life of the aquifer and/or maintain yields.

Sub Surface Drip Irrigation

The main components of a subsurface drip irrigation system include a pump, filtration system, and regulator valves that control the pressure of water flowing to the buried underground tapes. Each tape has a series of emitters that are spaced accordingly for its intended use and based on factors such as crop and soil type. Each tape can be buried at depths and spacing’s appropriate for individual rooting depth and row spacing in different applications. Subsurface drip irrigation systems are ran by a programmable main control box located near the valves. Irrigation schedules can be programmed into the controller to run on a timer or they can be manually started and managed independently. This high level of automation required for most SDI systems lends itself to intensive irrigation management.

There are several benefits of subsurface drip irrigation. Water is used more efficiently by plants, because it is applied to the root zone, and runoff from irrigation is eliminated. Since there is usually no standing irrigation water on the soil surface or crop canopy, it is possible that disease and weed pressure may be reduced (Reich et al, 2014; Payero, et al, 2005). Water can be applied at a variable rate within different zones if needed, in case there are differences in soil properties such as texture and hydraulic conductivity that would require different irrigation rates to achieve the same application amount. Another benefit is that irrigation can occur in conjunction with nutrient management practices, such as swine effluent or fertilizer application. Because the water is subsurface applied, the use of sub surface drip irrigation has the potential to dramatically reduce NH_3 volatilization from swine effluent which can account for as much as 50% of the total N applied (Wu et al, 2003).

Camp (1998) summarized nearly 40 years of subsurface drip irrigation research and reported that studies conducted using subsurface drip irrigation have generally shown that yields can be equal to or in excess of those achieved with other types of irrigation, while requiring less water. However, there are some drawbacks to using subsurface drip irrigation. The main concern is the high initial installation cost. The average cost to install subsurface drip irrigation is $1,000-$2,000 per acre, with current prices suggested to be approximately $1,300 per acre according to Lamm et al. (2001). There are mechanical issues that can occur as well, such as emitters becoming clogged or water flowing at incorrect rates. This can be remedied by flushing the system with an acid or chlorine solutions to remove calcareous scale or biological debris, respectively. It should be noted that clogging could potentially shorten the life of a subsurface drip irrigation system, which may hinder the economic advantage of subsurface drip over center pivot irrigation.

For subsurface drip irrigation to be more economically advantageous than traditional center pivot systems, the subsurface drip system must be operational for 15 to 20 years due to the large initial investment cost (Lamm et al, 2015). Another drawback to sub surface drip irrigation is there are few visual indicators of system operation. If there are problems with the underground drip tape, it will most likely need to be excavated in order to repair. This can be not only costly but time consuming as well. However, many problems such as clogging or leaks can be monitored by consistent assessment of flow rates and pressure differentials throughout the system. Another drawback for subsurface drip irrigation is the potential for rodents to damage the tape and frequently requires repair, however injectable rodenticides are becoming more readily available to help with these management issues.

Row Placement

Visual observation for consistent row placement above the sub surface drip irrigation tape cannot be used or relied upon for consistency of optimum crop row placement. Initial research conducted in the high plains region by (Lamm et al. 2001) used permanent raised beds to maintain accurate placement of the crop rows. However, this requires the beds to be maintained through tillage and presents challenges for narrow row crop production such as wheat. Furthermore, with the continued decline of the Ogallala Aquifer, the utilization of conservation practices such as continuous no-till does not lend itself to bed maintenance. The common utilization of RTK (real time kinematic global positioning) guidance allows for precision return accuracy but no data is currently available to determine if this level of precision is needed for optimum corn and grain sorghum production with SDI. Furthermore, when SDI is used to irrigate pivot corners, it can be installed in straight rows or along the curvature of the pivot depending on the size of the pivot and field equipment use. Cotton research conducted at Texas A&M by Bordovsky et al. (2008) found there were significant differences in individual row yields as row pairs shifted away from their optimum position relative to the SDI tape. However, cotton plants from crop rows closest to the drip tape largely compensated for reduced yield of rows farthest from the tape. Similar data is needed for corn and grain sorghum production utilizing SDI.

Objective

The objective of this study is to evaluate the offset row placement on grain yield of corn and grain sorghum under fully irrigated and limited irrigation conditions. This will provide an assessment of the need for precision guidance for sub surface drip irrigation. The null hypothesis is that the magnitude of row offset will not impact grain yield for corn or grain sorghum. The alternative hypothesis is that as the rows are moved from optimum placement yields will decline as a function of distances away from this equidistance placement.

CHAPTER II

METHODS

This research utilized the SDI system at the Oklahoma Panhandle Research and Extension Center near Goodwell, OK. This series of studies uses 9 irrigation zones, each are 192 m long and 18 m wide. Grain sorghum, corn, and wheat are rotated annually such that each crop is planted on 3 zones. The corn is planted into sorghum stubble, the sorghum is planted into wheat stubble and the wheat is planted directly behind corn harvest. This was done to allow for more successful no-till management to minimize pest pressures. The study presented here is focused on evaluating driver accuracy for corn and grain sorghum and the wheat simply serves as a rotation crop.

Within each zone subsurface drip irrigation tape is located 30 cm below the surface and spaced 153 cm apart such that each tape will supply water to two crop rows when planted 76 cm apart. The tape contains emitters 60 cm apart along the length of the tape, designed to supply 0.68 liters per hour at 68 KPa allowing for 41.6 liters per minute (LPM) being supplied to each zone.

Pressure was adjusted to 89.6 KPa at the inlet of each zone such that instantaneous flow rates of 53 LPM were achieved on each zone. The instantaneous flow was evaluated periodically with manual observations of the flow meters (model # 36M251T, NetifimUSA, Fresno, CA). The flow meters were installed at the inlet of each zone and included totalizers which were used to determine the total water applied during the season.

Experimental Design

The drip tape was installed using real time kinematic global positioning (RTK GPS) Guidance. Therefore, all planting was conducted using this technology to place rows in desired locations relative to drip tape. Within each zone an experiment was established to evaluate the impact of driver accuracy on corn and Grain Sorghum yields under three different irrigation regimes. The experimental design for each experiment was a randomized complete block design with 4 replicates and 5 treatments. The treatments consisted of crop rows being planted at 0, 8, 15, 23, and 38 cm offsets from the drip tape (Figure 1). These offset treatments were applied at planting using real time kinematic global positioning (RTK GPS) Guidance. Each plot was 4.57 m (6 rows) wide and 9.15 m long.

Crop Management

On May 5th, 2014 and April 21st, 2015 corn hybrid Pioneer 1768AMX and on April 15, 2016 corn hybrid Pioneer 1625 was planted in 3 zones and on June 6th, 2014; June 1st, 2015; and June 8, 2016 sorghum Hybrid Pioneer 84G62 was planted in 3 zones. One zone for each crop was designated to receive irrigation at a rate equal to estimated evapotranspiration. In 2014 and 2015 evapotranspiration was estimated by the

Aquaplanner (www.Aquaplanner.net) irrigation scheduling program. In 2016, the Mesonet irrigation scheduling tool was used in combination with adjustments made based on work conducted by Gatlin (2014). The remaining zones were designated to receive irrigation equal to 75% and 50% of this fully irrigated rate. The resulting irrigation applied as well as in season rainfall is presented in table 1. All corn plots received 8 cm of pre-plant irrigation in 2014 and 2015; and 5 cm in 2016. Post planting irrigation was initiated on 5 June, 2014; 4 June, 2015; and 12 May, 2016. The last irrigation events were applied to corn on 26 August, 2014; 25 August, 2015; and 24 August, 2016. Irrigation of the sorghum was initiated on 19 June 2014; 26 June, 2015; and 5 July, 2016. The last irrigation events were applied to the grain sorghum on 11 September, 2014; 28 September, 2015; and 9 September, 2016. Irrigation was applied daily when the soil water deficit was greater than 0.5 cm since the last irrigation event. When rainfall was anticipated irrigation was delayed to allow for optimum rainfall capture.

Fertilization

In 2014, the corn and sorghum received 3.3 L ha^{-1} of 10-34-0 fertilizer applied in row at planting with no in-season nitrogen applications because soil test NO_3-N plus NH_4-N in the surface 30 cm of soil was 200 kg ha^{-1}. In 2015 and 2016, both crops again received starter fertilizer (3.3 L ha^{-1} of 10-34-0) in addition to in-season N fertigation. The corn received 34 kg N ha^{-1} as 32-0-0 liquid fertilizer injected into the irrigation system weekly for 8 weeks starting on 15 June resulting in a seasonal application of 269 kg N ha^{-1}. The sorghum received 34 kg N ha^{-1} as 32-0-0 liquid fertilizer injected into the irrigation system weekly for 6 weeks starting on 8 July resulting in a seasonal application of 202 kg N ha^{-1}. In 2016 the, weekly fertigation of the corn was initiated on 10 June and was applied for 8 weeks; and the grain sorghum fertigation was initiated on 30 June and applied for 6 weeks.

Herbicides and Pesticide Applications

Corn and sorghum ground both received an early pre plant herbicide application of 1qt. Roundup® Weathermax, 1 Quart Aatrex® Atrazine 4L, 1 pint of Rifle® Dicamba, and 2oz of granular Valor® in early April for all 3 data years. At planting, corn and sorghum received a post plant pre emergence herbicide application of 1qt Roundup® Weathermax, 1qt. Aatrex® Atrazine 4L, and 2oz Sharpen®. Post emergence application of 6.4 oz. of Starane® was administered to control any remaining broadleaves in early may for corn and late June for grain sorghum with Huskie® and nonionic surfactant added in. Corn was treated pre tassel, with 3 pints Comite® II miticide at V8 all three seasons. In 2016 grain Sorghum was treated for Sugar cane aphids on August 24th with Silvanto® and LI700 and then followed up with an application of Transform® and Warrior® on September 23rd.

Harvest

Corn grain yield was collected at maturity on 8 October, 2014; 1 October, 2015; and 5 October, 2016. Sorghum yields were collected at maturity on 15 October, 2014; 14 October, 2015; and 29 October, 2016. All grain was harvested using a Kincaid 8-xp small plot combine to harvest the center 2 rows from each plot. In 2015 and 2016 the rows were harvested as individual rows such that the distribution of yield between rows could be utilized.

CHAPTER III

RESULTS AND DISCUSSION

Corn Grain Yield

Table 2 shows that there was no significant impact of offset treatment on corn grain yield. Irrigation regime and year were found to be significant but there was also a significant year by irrigation interaction that is shown in figure 2. In 2014, yield increased with increasing irrigation. In contrast, in 2015 and 2016 there was little or no difference between the 100% and 75%. Table 8 shows that in 2015 rainfall totals nearly doubled when compared to the fifteen-year average. Much of this rainfall occurred early in the season and was assumed to be lost to drainage or runoff. The water budget used to irrigate was based on a soil water balance for the 100% irrigated and therefore estimated drainage and runoff was higher for this treatment compared to the 75 % regime which was more often in a position to capture rainfall because of drier soil conditions. This increased the efficiency of this treatment in the 2015 crop year. In contrast, Table 8 shows in 2016 much of the rainfall received also occurred in the early months of the season but was significantly less when compared to the 2015 early season rainfall totals, therefore irrigation was initiated earlier in 2016. This resulted in excellent growing conditions for both 100% and 75% irrigated treatments. As a result of limited visual differences between the two irrigation regimes, irrigation rates were limited to 0.9, 0.67, and 0.45cm per day for the 100%, 75%, and 50% irrigation treatment in 2016. This was done in an effort to prevent the occurrence of over irrigation of the 75% treatment that occurred in 2015 from occurring again. However, in 2016 lower than normal rainfall occurred during and after flowering. This combined with the estimated ET rates of fully irrigated corn being in excess of 0.9 cm per day caused the 100% irrigation regime to experience more water stress during this critical time when compared to the75% regime which had a visibly more limited canopy and therefore, proportionally lower ET demand. Payero et al. (2006) found that seasonal Et values are linear with irrigation and rainfall in such that more water yields larger biomass and larger biomass yields higher ET rates. Traore et al. (2000) found that the harvest index of corn is affected by water stress when the stress occurred at flowering and that yields are significantly reduced. These findings support the data for the 2016 yield response where the 100% treatment was fully irrigated early on but in an effort to prevent over irrigation of the 75% we did not fully irrigate during reproductive stage and therefore yield was limited in the 100%. In contrast, the 75% was sufficiently stressed early in the season and the canopy size restrictions reduced ET, and water stress on the smaller plants allowing it to apply energy into making grain and producing yields comparable to the 100% irrigation

Table 3 shows the yields resulting from the offset treatments averaged across years for the three irrigation rates. As mentioned above, there are no significant differences resulting from offsets within any irrigation regime. However, it is noteworthy that at the 50% irrigation rate yields were 10% lower at the 38cm offset as compared to 0 cm offset. Furthermore, it is noteworthy that the offset treatments did influence the distribution of yield between the two rows harvested (Table 4). Specifically, at 0cm offsets 50% of the yield was harvested in the north row. However, as this row moved closer to the tape, the percentage of yield it produced increased to 59% in 2016. This is similar to the observations made by Bordovsky et al. (2010) when irrigating cotton with rows offset from equidistance from the tape. Specifically, they found at limited irrigation, rows that moved closer to the tape showed an increase in yield while the rows moving further away produced a declining yield. However, unlike the data collected by Bordovsky et al. (2010), the corn and grain sorghum yields were unaffected by driver accuracy at full irrigation.

Grain Sorghum Yield

Analysis of variance for the grain sorghum yields resulted in the same outcome as was observed in the corn with no treatment affect and a significant year by irrigation interaction. Figure 3 shows that in 2014, the 75% and 100% irrigation regime were higher than the 50%, but that in 2015 and 2016 there was no differences among the irrigation regimes. The lack of yield differences among irrigation regimes in 2015 are apparently in part due to over estimation of ET for grain sorghum as well as over estimation of runoff and drainage as was discussed previously with the corn yield data. Furthermore, there is very limited data available in the literature to validate the ET estimates used by Aquaplanner and the Mesonet software. Similar research conducted at the OPREC research station also showed that grain sorghum produced under limited water conditions was able to extract soil moisture to depths greater than expected prior to the establishment of this study which presented additional challenges (Gatlin et al 2014). Specifically, early season water stress in the limited irrigation regimes (50% and 75%), allowed for more effective rooting and subsoil water extraction. This combined with timely rainfall allowed for comparable yields to the fully irrigated regime, which apparently received excess irrigation due to over estimation of ET. In 2016, these challenges were exacerbated by the fact that grain sorghum in the 100% irrigation regime was later maturing which caused it to be more susceptible to bird damage and sugar cane aphid pressure, explaining why yields were numerically lower than the limited irrigation regimes.

Table 6 shows than not only were there no significant differences between treatments there was very limited numeric difference. Similar to the corn yield distribution between rows, the yield in the northern grain sorghum row increased when it was moved closer to the tape (table 7).

CHAPTER IV

SUMMARY

The results of this study show that row placement does not significantly influence corn or grain sorghum yield regardless of irrigation rate. Harvest of individual row yield found that as the rows were moved, the yield in rows moved closer to the tape would increase, thereby offsetting the yield loss in the rows moved away from the tape. This information is important in allowing producers to understand the driver accuracy required to utilize sub surface drip irrigation.

List of tables

Table 1: Irrigation applied to the 100%, 75% and 50% irrigation zones for corn and sorghum in 2014-16 as well as the pre-plant irrigation applied to all zones and the in-season rainfall.

Water Supply	------Corn-----			-----Sorghum-----		
	2014	2015	2016	2014	2015	2016
	------------------------cm-------------------					
100% In-season	42	51	53	38	33	33
75% In-season	34	39	41	30	25	25
50% In-season	24	28	25	19	18	18
Pre-season irrigation	8	8	5	0	0	0
In-season Rainfall	32	47	26	27	30	14

Table 2: Type III tests of fixed effects of treatment (Trt), irrigation (Irr), and year for corn grain yield

Effect	Num DF	Den DF	F Value	Pr > F
Trt	4	44.68	1.37	0.259
Irr	2	50.15	255.04	<.0001
Trt*Trr	8	57.84	1.05	0.4119
Year	2	50.47	338.93	<.0001
Year*Trt	8	57.73	1.21	0.311
Year*Irr	4	40.91	12.98	<.0001
Year*Trt*Irr	16	54.97	0.86	0.6129

Table 3: Corn grain yields averaged across years from different offsets within each irrigation regime

Offset	50%	75%	100%
cm	--------------------kg ha^{-1}--------------		
0	9865	12291	13280
8	9972	13087	13151
15	9701	12474	13026
23	8985	12394	13228
38	8901	12302	13420

†means followed by the same letter or no letter are not significantly different at the 0.05 probability level

Table 4: Percentage of corn yield produced by the north row.

Offset	2015	2016
cm	--------%---------	
0	51	50a†
8	50	50a
15	51	53a
23	51	53a
38	53	59b

†means followed by the same letter or no letter are not significantly different at the 0.05 probability level

Table 5: Type III tests of fixed effects of treatment (Trt), irrigation (Irr), and year for grain sorghum yield

Effect	Num DF	Den DF	F Value	Pr > F
Trt	4	51.81	1.07	0.3824
Irr	2	48.89	13.25	<.0001
Trt*Trr	8	57.59	0.71	0.6809
Year	2	64.2	83.6	<.0001
Year*Trt	8	54.89	0.46	0.8819
Year*Irr	4	37.67	9.64	<.0001
Year*Trt*Irr	16	50.79	0.44	0.962

Table 6: Sorghum yields averaged across years from different offsets within each irrigation regime

Offset	50%	75%	100%
Inches	--------------------Bu acre^{-1}--------------		
0	8889	9608	9593
8	9126	10003	9444
15	8980	9897	9620
23	9371	9692	9171
38	9055	9498	9175

†means followed by the same letter or no letter are not significantly different at the 0.05 probability level

Table 7: Percentage of grain sorghum yield produced by the north row.

Offset cm	Yield in N Row %
0	51a†
8	53ab
15	53a
23	54a
38	54a

†means followed by the same letter or no letter are not significantly different at the 0.05 probability level

Table 8: Monthly Rainfall Totals for April- October with 15-year Average

Month	2014	2015	2016	15 year avg.
	-------------------cm--------------------			
April	1.19	4.75	9.6	2.3
May	8.68	16.18	3.55	4.72
June	9.47	4.64	6.02	5.76
July	7.36	10.43	4.21	5.28
August	2.46	8.17	8.3	6.4
September	4.14	3.35	.15	3.25
October	3.5	13.05	1.52	4.13
Totals	36.8	60.6	33.35	31.84

List of Figures:

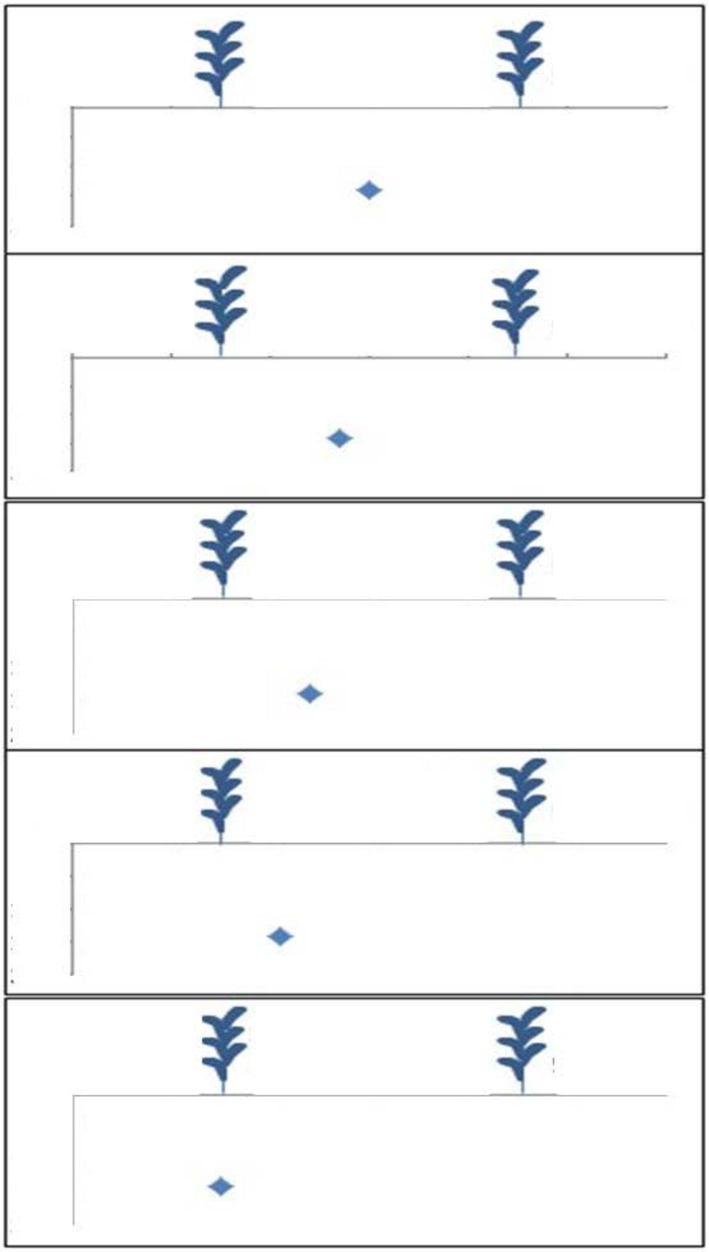

Figure 1: Drip tape offset from sorghum and corn rows.
(Point indicates location of drip tape at each offset).

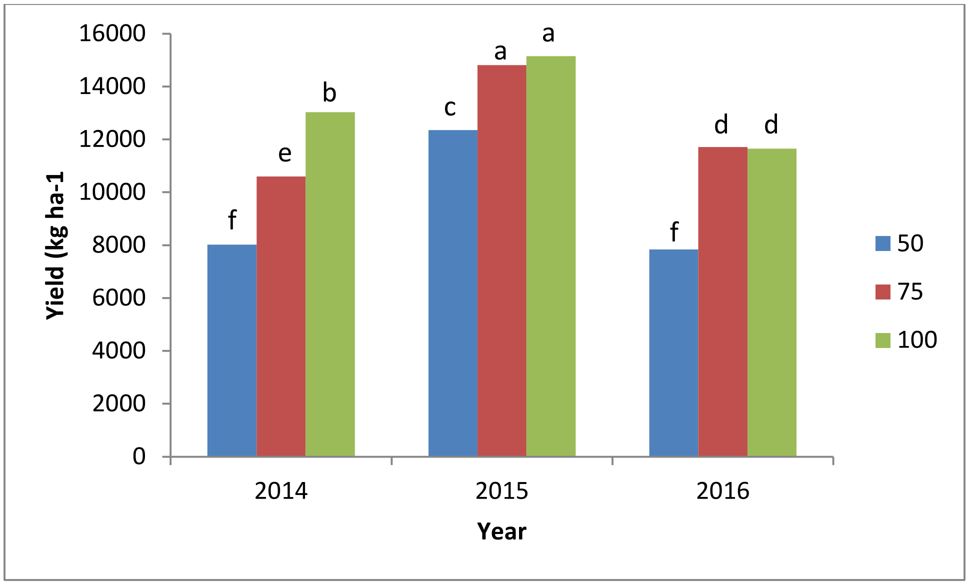

Figure 2: corn grain yield averaged across treatments for each irrigation rate and year. Yields with the same letter are not significantly different at the 0.05 probability level.

Figure 3: Grain sorghum yield averaged across treatments for each irrigation rate and year. Yields with the same letter are not significantly different at the 0.05 probability level.

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