



Corn (*Zea mays* L.) Response to Hybrid, Row Spacing, and Plant Populations in the Blacklands of Central Texas

W. J. Grichar^{1*} and Travis W. Janak²

1. Texas A&M AgriLife Research, Corpus Christi, TX 78406, USA
2. B-H Genetics, Ganado, TX 77962, USA

w-grichar@tamu.edu

ABSTRACT

Field studies were conducted during the 2013 and 2014 growing seasons in central Texas near Taylor (30.5326° N; 97.4548° W) to determine the effect of hybrid, row spacing, and plant populations on corn growth and yield. Two corn hybrids (BH 8844 and BH 8900) were compared at 53,000, 62,000, and 71,000 plants ha⁻¹ planted one row on a single bed or twin rows (spaced approximately 20 cm apart) on a single bed. Plant counts were taken 4 to 6 wk after planting while ear height measurements were taken approximately four wk prior to corn harvest. Crop yield was determined by harvesting all eight rows of each plot with a combine. Weights were adjusted to 12% moisture. Experimental design was a factorial arrangement using a randomized complete block design with corn hybrid (2), row spacing (2), and seeding rates (3) as factors. Data were analyzed using PROC GLM with SAS (SAS Institute, Inc., Cary, NC) and treatment means separated by Fisher's protected least significant difference test at P = 0.05. Plant height was not affected by plant populations or row spacing as only hybrid response was significant with BH 8900 being taller in both years. Row spacing affected ear height in one of two years with the twin row spacing having a taller ear placement in the dryer year. No differences were seen with ear placement with respect to plant populations. In the dry year, yield of BH 8844 decreased as plant populations increased; however, no differences were noted with BH 8900. In the wet year, the inverse was seen with increased yield with higher populations with both hybrids. The twin row system increased BH 8900 yield in 2013. In 2014, with BH 8844, the single row system out yielded twin row and no differences noted with BH 8900. The results were quite variable and this was due in part to rainfall events in the two years. Plant and ear height was influenced by hybrid while yield response was somewhat affected by population and row spacing. A hybrid x row width response was noted indicating that certain hybrids will respond to row spacing more than others.

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INTRODUCTION

Corn or maize (*Zea mays* L.) producers are constantly questioning variables such as hybrids, row spacings, and plant populations that play an important role in yield and subsequently the net returns they receive since the demand is constantly increasing for food, fuel and feed and corn is a common crop grown both in the U S and globally that is often used to meet these demands. The world population reached 6.9 billion people in 2010 (Population Reference Bureau, 2010). Although the rapid growth has slowed, continuously decreasing mortality due to improved health, increased access to education and economic growth coupled with slower than expected declines in birth rates guarantee continued growth for years to come (Bremner *et al.*, 2010). Increasing use of food crops such as corn for biofuel production will worsen the risk of hunger for the world's poor. The challenge to agriculture is to produce enough food to meet the demands of an increased population and biofuel production demand.

Optimizing harvestable corn grain yield requires matching the best corn hybrids with optimal plant populations and row spacing. Research indicates that plant populations have increased dramatically in corn production over the past 40 years (Hodgen, 2007). Duvick (1997) reported that older hybrids out-yielded newer hybrids at lower plant populations, while at higher plant populations the reverse occurred. The major genetic contribution to the increase in yield has been to increased 'crowding stress' tolerance (Duvick and Cassman, 1999). This tolerance has resulted in increased grain yield through planting higher corn plant populations. The introduction of multiple sources of insect resistance through biotechnology and plant breeding have resulted in improved plant health which has resulted in increased corn populations.

Row crop yields are also influenced by row spacing. Although optimal plant densities for grain sorghum (*Sorghum bicolor* L. Moench) differ from region-to-region, previous research has indicated that grain yield generally increases as plant populations increase (Conley *et al.*, 1995; Jones and Johnson, 1991; Staggenborg *et al.*, 1999). At lower than suggested plant densities, grain sorghum head number per plant or seed number per head increased when compared to the recommended plant density (Gerik and Neely, 1987; LaFarge and Hammer, 2002 a, b). Also, Grichar (2007a) reported mixed results on the effects of seeding rates on soybean (*Glycine max* L.). The effect of seeding rate on soybean yield varied from year-to-year depending on variety and rainfall received during the growing season.

Row spacing in a crop can also have an effect on crop yield potential (Besler *et al.*, 2008; Bryant *et al.*, 1986; Conley *et al.*, 1995; Grichar, 2007b; Jones and Johnson, 1991; Limon-Ortega *et al.*, 1998; Staggenborg *et al.*, 1999). Staggenborg *et al.* (1999) reported that crop row spacings of less than 76 cm would increase grain sorghum yield in areas with high yield potential with little risk of reduced yield in areas with lower yield potential. Grichar (2007b) reported that soybeans in a single-row system out yielded the twin-row configuration 50% of the time. Shibles *et al.*, (1966) observed a 1.5% yield increase in corn yield in Iowa for 76-cm row spacings compared with 102-cm row spacings and an additional 3.5% yield increase for 51-cm spacings. Brown *et al.* (1970) found a 34% yield increase for corn grown in 51-cm row spacing. Ottman and Welch (1989) reported no differences in grain yield between 76-cm and 12-cm twin-row on 76-cm center in an irrigated high yield system while Kratochvil and Taylor (2005) found no yield increase in corn grain yield with the twin-row spacing. Fulton (1970), in Canada, reported with respect to yield, a significant plant population x row spacing (50 cm) interaction in only one of four experimental years. This interaction showed that the effect of narrow row spacings was greater at higher plant populations (54000 plants ha⁻¹) than lower populations (40000 plants ha⁻¹) provided that adequate soil moisture was available. Rossman and Cook (1966) also reported that higher plant population was found to have a greater effect on yield than row width or planting pattern.

Reducing the distance between rows can also improve weed control by increasing crop competitiveness and reducing light transmittance to the soil (Tharp and Kells, 2001). Johnson *et al.*, (2005) reported that total weed densities were less when peanut rows were spaced 30 cm apart compared with rows spaced 91 cm apart. Seedlings in close proximity to each other express phytochrome-mediated responses by developing narrow leaves, long stems, and less massive roots (Kasperbauer and Karlen, 1994). Planting a crop in a pattern that reduces the spacing of plants within and between rows can increase plant biomass and leaf area index (Bullock



et al., 1988). Work in the late 1980's, showed that reduced row spacing increased the total interception of photosynthetic active radiation by the corn canopy and redistributed the radiation toward the top of the canopy (Kasperbauer and Karlen, 1994). Reduced row spacing is also thought to increase weed control by increasing the competitiveness of a crop with weeds and by reducing light transmission to the soil surface (Teasdale, 1995). He showed that reduced row spacing and increased corn populations decreased weed growth in the absence of herbicides and shortened the time of canopy closure by one week.

Since very little research has been reported on twin-row vs single row planting in Texas on corn, the central Texas corn production area was selected to compare these two planting configurations along with plant populations and hybrid effect. Therefore, the objectives of this study were to determine the effect of corn hybrid, plant density, and row spacing on corn growth and yield.

MATERIAL AND METHODS

Study site

Corn was planted in central Texas near Taylor (30.5326° N, 97.4548° W) on 1 March, 2013 and 20 February, 2014. Soils at this location were a Burselson clay (fine, montmorillonitic, thermic Udic Pellusterts) with less than 1% organic matter and 7.6 pH. Treatments were replicated three times with corn hybrid, plant population, and row spacing (single vs twin) plot size of 8 rows by 378 m long. The test area was maintained with a wide raised seedbed for ease of planting twin rows. Fertilizers were applied prior to the planting of the corn crop according to soil test recommendations provided by the Texas A&M AgriLife Extension Soil and Plant Testing Laboratory.

Corn hybrids

Two commonly used hybrids, BH 8844 and BH 8900, were planted. BH 8844 is a medium-short hybrid with low ear placement and semi-determinate ear type. It has above average stress tolerance ratings and has impressive stability across environments (BH genetics, 2016). BH 8900 is a medium-high hybrid with high ear placement and semi-flex ear type. It has a top-end yield potential and good choice for high rainfall or irrigated areas (BH Genetics, 2016).

Plot setup and planting

Row spacings were single rows spaced 96 cm apart on a bed or twin rows spaced approximately 20 cm apart on a single bed with plant populations of approximately 53000, 62000, and 71000 plants ha⁻¹. Corn was planted using two separate vacuum planters, one equipped for single row planting and another equipped for twin-row planting. Both units were equipped with precision seed meters calibrated to deliver the desired seeding rate.

Plant counts, ear height measurements, and harvest

Plant counts were taken 4 to 6 wk after planting to assured that each plot was within the desired plant populations. Glyphosate (Roundup Maxx®) was applied postemergence at 2.3 L ha⁻¹ two times during the growing season as needed for weed control.

Ear height measurements were taken approximately four wk prior to corn harvest. Measurements were taken at three locations throughout the plots and averaged across the three locations. Measurements were taken from the ground line up to the point where the ear attaches to the stalk.

Corn was harvested 26 July, 2013 and 15 July 2014. Crop yield was determined by harvesting all eight rows of each plot with a combine and then placed in a weight wagon to determine plot weight. Weights were adjusted to 12% moisture.

Data analysis



Data were analyzed using PROC GLM with SAS (SAS Institute Inc., 2007) and a model statement appropriate for a factorial design. Treatments means were separated by Fisher's protected least significant difference test at $P = 0.05$. Data for the two years were analyzed separately due to variations in rainfall from year-to-year.

RESULTS AND DISCUSSION

Rainfall

Rainfall amounts were variable for the two years especially for May, June, and July (Table 1). Rainfall in 2013 was below normal for most of the growing season with above normal rainfall for July while rainfall in 2014 followed the same pattern as seen in 2013 for March, April, and June; however, rainfall in May and July were above average (National Climatic Data Center, 2016). The above normal rainfall for July in both 2013 and 2014 came too late to be of any help during those growing seasons but the May rainfall in 2014 greatly helped the crop. The extremely low rainfall in March and April of 2013 greatly affected yield since it occurred during pollination and fertilization.

Table 1. Monthly rainfall at the study location near Taylor, TX.

Month	2013	2014	30 yrs. average ^a
	Mm		
March	30.2	26.9	70.1
April	24.6	23.4	52.1
May	114.8	162.8	121.9
June	24.6	51.8	110.0
July	138.2	210.1	42.9
Total	332.4	475.0	397.0
^a 30-year average, Source: US Climate Data - usclimatedata.com			

Water stress during pollination and fertilization has a great effect on corn yield (Nielsen, 2007; Lauer, 2006). Stress during pollen shed and silking can cause more yield loss than almost any other period in the crop's development (Nielsen, 2007). Inadequate plant water potentials can slow down silk elongation, resulting in delay or failure of the silks to emerge from the ear shoot. Silks that do emerge may desiccate rapidly when the plant is enduring severe moisture deficits, becoming non-receptive to pollen (Nielsen, 2007).

Van Roekel and Coulter [33] noted that, over time, corn hybrids have been bred for increased tolerances to stress associated with higher plant populations and hybrids introduced since the 1990's tolerate high plant populations much better than those used in the past. Hybrid yields were examined from 1930s to the 2000s by Hammer *et al.* [34] and they concluded that much of the yield increase associated with newer hybrids was due to increased stress tolerance, which allowed growers to plant higher plant populations and thus obtain higher yields.

Plant height

No interactions were noted. Row spacing and plant populations had no effect on plant height, only corn hybrid was significant (Table 2). BH 8900 resulted in taller plants in both years regardless of rainfall and this has been seen in other field studies with this hybrid (author's personal observations). McFarland (2013)



reported similar results with other hybrids. In a two-year study, plant height decreased for only two of six hybrids for one of two years as populations increased across single and twin-row plantings.

Table 2. Plant height as influenced by hybrid, row spacing, and plant populations.

	Height (cm)	
	2013	2014
Hybrid		
BH 8844	173.7	170.2
BH 8900	189.0	208.3
LSD (0.05)	5.8	7.1
Row spacing		
Single	179.8	188.5
Twin	182.9	190.0
LSD (0.05)	NS	NS
Plants ha⁻¹		
53,000	182.9	188.0
62,000	182.9	190.3
71,000	179.8	189.0
LSD (0.05)	NS	NS

Ear height

No interactions were noted and plant populations had no effect on ear height (Table 3). Only hybrid (both years) and row spacing (2013) affected ear height. Ear height with BH 8900 was taller in each year of the study. In 2013 ear height was taller with twin-row spacing compared with the single row; however, no differences in ear height were noted with row spacing in 2014. Plant population did not affect ear height. McFarland (2013) reported that plant population had no effect on the majority of hybrids in each year (affecting only one hybrid in each year of a two-year study) and that row width had no effect on ear height with any hybrid.

Corn yield

Hybrid x plant population and hybrid x row spacing affected corn yield. With BH 8844 in 2013, as plant population increased, yield decreased while in 2014 the opposite occurred with an increase in the yield of BH 8844 when population was increased from 53000 to 62000 and 71000 plants ha⁻¹ (Table 4). With BH 8900, no differences in yield were noted with plant populations in 2013; however, yield did increase in 2014 as population increased from 53000 to 62000 and 71000 plants ha⁻¹.

Hybrid x row spacing also influenced yield (Table 5). With BH 8844, no effect on yield was seen in 2013 but in 2014 the single row spacing resulted in an increase in yield over the twin-row spacing. With BH 8900, the twin row system out yielded the single row system in 2013 while in 2014 no differences in yield were noted between row spacings.



It has been reported that the yield response to narrow rows in corn is affected by many environmental, spatial, and temporal field interactions (Thelen, 2006) and been suggested that a positive yield response to narrow rows is more likely to occur in the presence of environmental yield-limiting factors. Andrade *et al.*, (2002) reported that the narrow-row yield response was inversely proportional to the radiation interception achieved with wider rows. Under very favorable growing conditions, when radiation interception for wide rows was optimized, the yield response to narrowing the rows was minimized.

Test weight

Test weight was not affected by row spacing; however, hybrid and plant population did affect test weight (Table 6). In both years, BH 8844 produced a higher test weight than BH 8900. Higher test weights with BH 8844 have been noted in other trials (author's personal observations).

Table 3. Ear height as influenced by hybrid, row spacing, and plant populations.

Hybrid	Height (cm)	
	2013	2014
BH 8844	57.9	50.6
BH 8900	64.0	61.0
LSD (0.05)	6.1	0.2
Row spacing		
Single	57.9	55.4
Twin	61.0	55.9
LSD (0.05)	3.1	NS
Plants ha⁻¹		
53,000	61.0	54.9
62,000	61.0	56.1
71,000	61.0	56.1
LSD (0.05)	NS	NS

Table 4. Grain yield as influenced by hybrid and population.

		Yield (kg ha ⁻¹)	
Hybrid	Plants ha ⁻¹	2013	2014
BH 8844	53,000	4264	9644
	62,000	4037	10175
	71,000	3503	10888
BH 8900	53,000	5247	9490
	62,000	5325	10108



	71,000	5229	10532
LSD (0.05)		467	390

Table 5. Grain yield as influenced by hybrid and row spacing.

Hybrid	Row spacing	Yield (kg ha ⁻¹)	
		2013	2014
BH 8844	Single	5241	10471
	Twin	5294	10001
BH 8900	Single	3851	10108
	Twin	4018	9980
LSD (0.05)		166	282

Plant populations did affect test weight in one of two years (Table 6). In 2013, test weight decreased as the plant population increased while in 2014 no differences were noted. In a study by Widdicombe and Thelen (44) the opposite was noted. In their study, test weight increased slightly as plant populations increased from 56000 to 90000 plants ha⁻¹.

Table 6. Corn test weight as influenced by hybrid, row spacing, and plant populations.

	Test weight(kg/m ³)	
	2013	2014
Hybrid		
BH 8844	757.2	772.7
BH 8900	713.4	736.6
LSD (0.05)	1.3	12.9
Row spacing		
Single	735.3	757.2
Twin	735.3	753.4
LSD (0.05)	NS	NS
Plants ha⁻¹		
53,000	739.2	753.4
62,000	736.6	757.2
71,000	730.1	755.9
LSD (0.05)	7.7	NS



CONCLUSION

The results from this study were quite variable and this was due in part to rainfall events in the two years. Production under ideal moisture conditions may favor narrow rows. Under ideal moisture conditions, soil is generally moist and the twin-rows result in more equidistant plant spacing therefore increasing leaf area and early-season interception of solar radiation, and increased soil shading. This can result in reduced evaporative water loss. This contrasts with low moisture conditions where with the dry soil surface, evaporative water loss is low to begin with; thus, narrow rows do not reduce soil surface evaporation but rather increases water loss by transpiration. This transpiration increase negates any benefits from improved spacing. The twin-row system provided inconsistent results as seen in other studies (Haegele *et al.*, 2014; Lee, 2006; Thelen, 2006; Van Roekel and Coulter, 2012). Twin row corn production has been compared to the traditional 76 to 96 cm rows across a broad range of geographies and few differences have been detected between these row arrangements (Balkcom *et al.*, 2011; Nelson and Smoot, 2009; Novacek *et al.*, 2013). However, in this study, plant and ear height was affected by hybrid while yield response was somewhat affected by population and row spacing.

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