Industrial Crops & Products xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Industrial Crops & Products

journal homepage: www.elsevier.com/locate/indcrop

Growing sweet sorghum (*Sorghum bicolor* [L.] moench) in clumps potentially reduces lodging in the arid-southwestern United States

V.H. Teetor[a,*], C. Schmalzel[a], D.T. Ray[a,b]

[a] School of Plant Science, University of Arizona, Tucson, AZ, USA
[b] School of Natural Resources and the Environment, University of Arizona, Tucson, AZ, USA

ARTICLE INFO

Keywords:
Sugar
Planting arrangement
Spacing
Biomass
Yield

ABSTRACT

Sweet sorghum (*Sorghum bicolor* [L.] Moench) is an attractive crop for the biofuel industry in the arid-southwestern United States due to its high yields of fermentable juice as well as fibrous biomass, with lower water requirements and high water use efficiency. Previous work has shown that when planted closer together the resulting stalks are thinner, weigh less, yield less juice, and are more susceptible to lodging, thus affecting yields. The studies examined the effects of planting sweet sorghum in clumps (three to five plants in a hill, spaced 0.5 m apart) compared to conventional rows (planted equidistant with a grain drill).

Four varieties (Cowley, Hodo, M81E, and Mer74-2) were sown on 6 June 2014 and 26 May 2015 in a split-plot design, with arrangement (clump or conventional) as main plot and variety as sub-plot, with five replications in 2014 and four in 2015. Conventional rows were planted with a tractor-driven grain drill at 18 seeds m^{-1}. Clumps were hand-planted as a cluster of three to five seed in a single hole every 0.5 m. Harvest commenced 30 days after half of the plants in a variety were flowering. A 3.05 m section was harvested, and weighed. A subsample of plants was weighed with or without leaves and panicles, stem diameters measured, the stalks pressed, and juice collected and weighed. Sugars in the juice samples were analyzed by HPLC with a refractive index detector.

Individual stems in the clumps were significantly greater in diameter and weight, although field weight showed no significant difference between treatments. Plants in conventional rows were smaller but there were more of them per area than the clump treatments. There were no differences in number of leaves, but the overall leaf weight was significantly greater in the clump treatments, due to increased leaf width and area, but not length. Lodging was significantly lower in the clump treatments in 2015, indicating that the thicker stalks are less susceptible to lodging.

Planting sweet sorghum in clumps resulted in thicker, sturdier stalks with more juice, and did not decrease yields over conventionally planted plots. Planting in clumps has potential under irrigation in the arid southwestern United States to increase yields.

1. Introduction

Sweet sorghum (*Sorghum bicolor* (L.) Moench) is an attractive crop for the biofuel industry in Arizona due to its high yields of fermentable juice as well as fibrous biomass, with lower water requirements and high water use efficiency (Bellmer et al., 2010; Teetor et al., 2011). In Arizona, research has focused on maximizing biomass, sugar yields, and increasing the harvest window in order to supply optimum feedstock to processing facilities (Teetor et al., 2011).

Previous work (Caravetta et al., 1990; Turgut et al., 2005; Worley et al., 1991) has shown that stalks in higher density plantings are thinner, weigh less, and yield less than ones planted at lower density. Others have shown that higher seeding rates result in taller plants with thinner stems, which were more conducive to lodging (Snidera et al., 2012Broadhead and Freeeman, 1980). Godoy and Tesso (2013) suggest that hybrids with thick stems are more resistant to lodging. Higher seeding rates, however, give higher yields because of the increased number of stems per area (Snidera et al., 2012), and thus increased biomass (Ferraris and Charles-Edwards, 1986a,b; Martin and Kelleher, 1984), which is a major component of sugar and ethanol yield (Teetor et al., 2011).

Planting sweet sorghum in clumps has been investigated, but not under marginal environmental conditions with irrigation. Broadhead et al. (1963) in Mississippi showed that 2 plants per clump 16 inches

* Corresponding author.
E-mail address: teetor@email.arizona.edu (V.H. Teetor).

http://dx.doi.org/10.1016/j.indcrop.2017.05.064
Received 31 January 2017; Received in revised form 31 May 2017; Accepted 31 May 2017

Table 1
Temperature maximums, means, and minimums (°C) for 2014 and 2015 sweet sorghum growing season in Tucson AZ.

	Maximum	Mean	Minimum
9 June–22 Nov 2014	40.6	26.1	3.9
26 May–18 Nov 2015	42.0	26.0	0.0

(38 cm) apart and 4 plants per clump 24 inches (58 cm) apart gave the same Brix and yield of stalks as single plants drilled 8 inches (19 cm) apart. They also found that lodging increased with closer spacing.

In the arid southwestern United States, Native American populations have used clump planting for centuries. Corn, beans, and squash are the Three Sisters, and traditionally planted in this manner. By planting the corn in clumps, the stalks are stronger, allowing the beans to climb so that they are not outcompeted by the squash vines (Mt. Pleasant, 2006). Thus, the purpose of the study was to see if in a similar arid environment, planting sweet sorghum in clumps would also result in stronger stalks and decrease the frequency of lodging.

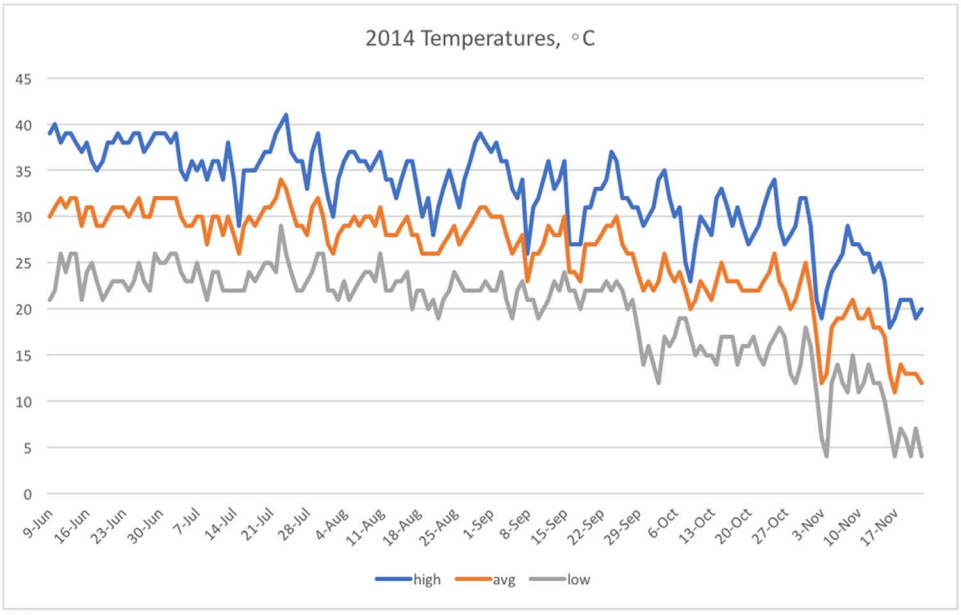
2. Materials and methods

2.1. Varieties, location, and experimental design

Sweet sorghum varieties Cowley, Hodo, M81E, and Mer 74-2 were sown at the University of Arizona, West Campus Agricultural Center, Tucson, Arizona (32.15°N, 111.0°W, Grabe/Pima loam soil; coarse-loamy to fine-silty, mixed, superactive, calcareous, thermic Typic Torrifluvents) on 6 June 2014 and 26 May 2015. In both years, the design was a split-plot, with row arrangement (conventional or clump) as main plot and variety as sub-plot, with five replications in 2014 and four in 2015. Each plot consisted of four rows, approximately 6.1 m long, with short alleys between replications. Variety selection was for high yielding potential from 15 previously tested lines. Temperature maximums, means, and minimums over the growing season are shown in Table 1 and Figs. 1 and 2 . Total precipitation was 28.45 cm in 2014 and 23.0 cm in 2015 (Figs. 1b and 2b).

Nitrogen (18.14 kg) was added to each field at planting, and fields irrigated every two weeks (approximately 100 mm water), for a total of

(a)



(b)

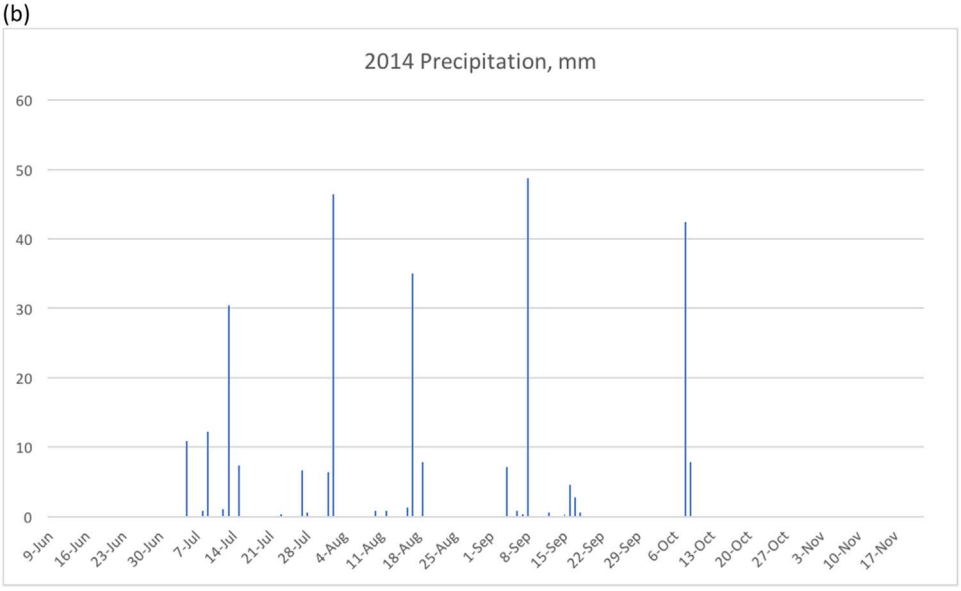


Fig. 1. (a) High, low, and average temperatures; and (b) date and amount of precipitation over the course of the experiment in 2014 in Tucson AZ.