Modeling the hybrid seedling performance of forage sorghum and silage corn under Jordan irrigation conditions

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ABSTRACT

Hybrid seeds influence seedling vigor in forage sorghum and corn. Few investigations were reported on the hybrid effect on vigor for irrigation conditions in Jordan. A new investigation conducted under the Norman Borlaug fellowship during 2017 demonstrated a suitable simulation for growers. The first step required the identification of drought-tolerant seeds. Five commercial seed lots (three of corn and two of sorghum) were used. The second involved planting seeds under controlled and field conditions in the Florida A&M University and then evaluating the vigor by measuring emergence, fresh weight, and water use efficiency. Corn (6640VT3P) had significantly higher fresh weight and vigor. However, it was significantly the highest with water use efficiency in the greenhouse. The superiority of corn (6640VT3P) may be attributed to increased seed weight. Thus, results reported suggest that corn (6640VT3P) had a high impact on the seedling establishment that could be grown under extreme drought conditions.

Key words: Seeds, Vigor, Water Use Efficiency.

INTRODUCTION

With the impact of climate change, increasing population, urbanization and limiting resources, crop production sector is facing the challenge of more food production with less water Liu et al. (2007). In developing countries, the problem of water is acute Karousakis and Koundouri, (2006). Water scarcity and deficit in Jordan projected during 2025 is about 630 million cubic meters (Soazic, 2014). With the variability in rainfall, the situation sometimes gets worst. Forage sorghum, silage corn, sudangrass, barley, wheat, alfalfa, and ryegrass yields sustainability are highly dependent on water availability.

Two approaches solving the issue of water shortage, either by engineering-based approach (construction of water reservoirs and water harvesting techniques) or agronomy-irrigation based approach (on field water management of hybrid crops). Focusing on the agronomy based solution, either we have to cultivate low water requiring crop or apply less water to the crop. Regulated deficit irrigation can be a possible option to get more crop yield per each drop of water Al-Harbi et al. (2015). It helps to reduce water consumption and minimize adverse negative impacts on yield. Irrigating the crop only at drought-sensitive growth stages can help to manage water resources to meet crop water requirements Du et al. (2010). The reduction in yield due to deficit irrigation can be compensated by the yield from the additional irrigated area with the saved water Bashir et al. (2017). Irrigation scheduling can be managed precisely to meet crop water demands, holding the promise of increased yield and quality (Kahlon, 2017).

The total corn yield is highly affected by irrigation management. Greaves and Wang, (2017) concluded that long drought cycles on corn attributed to lower rainfall. Similar results emphasized the negative effect of drought on the growth of corn reported Randhawa et al. (2017). Corn is sensitive to moisture stress during vegetative growth and tasselling stages (Anandhi, 2016). Drought stress at these critical growth stages of corn led to reduced growth represented by plant height and leaf area development (Cakir, 2004). Ali et al. (2007) identified the stages of tillering and stem elongation as one of the moisture sensitive stages in the wheat crop. Limited irrigation water availability can cause an increase in crop failure, defined as the complete loss of crops on a farm (Anandhi and Blocksom, 2017).

Seed is a crucial input for agricultural production and the most affordable external input for farmers. Quality seed is the critical and basic input for agricultural output and accounts for 25-30 percentage of yield increase Kumar et al. (2015). Hybrid seeds greatly influence the seedling vigor under varied irrigation conditions. The availability of water

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during the different stages of crop growth influences the crop’s ability to survive. The early stages of plant development are key processes that are sensitive to water availability. Crop ecologists, physiologists, and agronomists generally concur that a great and positive seedling vigor and establishment leads to greater seedlings fresh and dry weights. This could have a greater impact on vegetative growth and crop biomass. Vara Prasad and Staggenborg, (2009) stated a positive relation between the number of tillers in sorghum and hybrid. The plant can tiller depending upon the variety (or hybrid). Shafiq Zahid et al. (2002) reported the superiority of two hybrids of sorghum × sudangrass called (ST-6E) and (SX-17) in terms of high tillering capacity, plant height, leaf area index and hence high yielding green matter yield under irrigated rain-fed conditions of the Pothwar tract of Pakistan.

Forage sorghum and silage corn hybrids have predominantly been major silage forages for livestock in Jordan (Massimi et al. 2017). The total count for dairy cows in Zarqa region is about 29,120 heads in 2013 (Department of Statistics, 2013). Due to climate change and anticipations for drought conditions characterized by lower rainfall and less water for irrigation in some regions, for example eastern arid parts of Jordan with its large dairy cattle industries, there is a vital need for alternative forages that require less water, to be sustainable for the production system that integrates forage production. In Jordan, water policy is driven by the needs of often competing for entities, for example, agriculture, human population, and natural animal and plant species. Sudangrass is currently of interest as a forage sorghum hybrid because this crop tolerates prevailing drought conditions in the dairy regional areas. Forage sorghum and silage corn hybrids belong to an annual grass group that is drought tolerant and is an excellent choice for livestock feed in arid and relatively dry regions. This tolerance offers potential in areas where water is in scanty and will continue in the future to be in decreasing supply, for example, the eastern arid parts of Jordan. The forage sorghums are further grouped into four types; hybrid forage sorghum, sudangrass, sorghum × sudan hybrids (also known as sudan hybrids), and sweet sorghum (Getachew et al. 2016). In the United States when grain and hay crops are considered, sorghum ranks in the top 10 crops based on the land area of cultivation. However, for Jordan agricultural national strategy considering forage crops like silage corn and forage sorghum with cereal grain crops like wheat (Fardous et al. 2004), barley, triticale as well as green forage crops like alfalfa, and ryegrass (Massimi et al. 2017). Increasing production of these crops will help to improve both the rural demands and the national economy.

This experimental simulation was an attempt to study the response of forage sorghum and silage corn hybrids emergence, seedling establishment and vigor to irrigation modeling under simulated extreme drought conditions of Jordan.

**MATERIALS AND METHODS**

The present study was planned to access the performance of forage sorghum and silage corn drought-tolerant hybrids for irrigation scheduling based on initial growth stages; irrigation at the seedling establishment and emergence during growing season of the year 2017.

First two second steps were to identify and plant drought-tolerant hybrid seeds. Drought tolerant silage corn hybrids (6640VT3P), (DKC70-01) and (P1197YHR) were promising test hybrids sown on April 12, 2017, in open field and on April 18, 2017, in the greenhouse. Further, forage sorghum promising drought-tolerant hybrids sown in the same dates were (ss2010) and (Sugar Graze II).

The experiment was conducted at Agricultural Research Station (ARS), Florida A&M University, Tallahassee situated in humid agro-climatic conditions. The soil of the experimental area had clay texture. The experiment was laid out in split completely randomized design, keeping 3 hybrids of silage corn and 2 hybrids of forage sorghum replicated three times. The net block size was 30 m × 0.75 m, with the row-to-row distance of 1.82 m and seed rate of 12 seeds for each hybrid per block. The drip irrigation was applied through the seedling establishment, irrigation was provided once in every 4 days based on a mathematical model of 36.4 [mm (meter Sq)] for 71 seconds.

Topsoil of the greenhouse experimental trail had loam texture. The experiment was laid in split completely randomized design, keeping hybrids of silage corn and hybrids of forage sorghum replicated five times. Each block represented by 5 plastic pots and seed rate of 2 seeds for each hybrid per block. The surface irrigation was applied through the seedling establishment, irrigation was provided every 24 hours based on a mathematical model of 14 (mm pot⁻¹).

The third step involved evaluating the seeds and seedling vigor. After 10 days of emergence in both field and greenhouse, the final day count of seedlings was used to determine the final emergence percentage. Five seedlings of each hybrid were randomly taken from the open field and greenhouse to measure seedlings fresh weight, seedlings vigor index, and water use efficiency.

Seedling vigor index was calculated following a modified formula of Afrakhte et al. (2013):

Seeding Vigor Index = Germination % × Seedling Dry Weight.

Seeding Vigor Index = Emergence % × Seedling Fresh Weight.

Potential water use efficiency inside the greenhouse was estimated as:

Water Use Efficiency (g mm⁻¹) =
Seedlings Fresh Weight (g pot⁻¹) / [Seedlings Water Supply (mm pot⁻¹) – Evaluated Soil Evaporation (mm pot⁻¹)].

Four Petri dishes (8 cm diameter) were washed with de-ionized water for the water evaporation study. Each Petri dish received 14 ml of water. The experiment was conducted in a greenhouse at an average daily temperature of 25.46 °C for 24 hours. The average daily amount evaporated was 9 mm.

On the other hand, the potential water use efficiency in the open field was evaluated as:

Water Use Efficiency (g mm⁻¹)=

Seedlings Fresh Weight [g (meter Sq)]⁻¹ / Seedlings Water Supply [mm (meter Sq)]⁻¹.

In the open field, soil evaporation was assumed zero due to mulch use. The seedling fresh weight per meter square was simulated to 7.6 plants of corn hybrids per meter square of row plantings (Alberta Agriculture and Food, 2007). Further, the seedling fresh weight of sorghum hybrids was simulated to 131 plants per meter square of the broadcast planting method.

The final step involved analyzing the results. Data were analyzed by using SAS (version 9.2) analysis of variance technique. To check the significance, treatment means were compared by using least significant (LSD) test at 0.05 probability level.

RESULTS AND DISCUSSION

A significant and positive effect was recorded between silage corn hybrids of (6640VT3P) and (DKC70-01) with field performance, such as seedling fresh weight and seedling vigor index (Table 1). Also, a significant effect was recorded between silage corn hybrid of (6640VT3P) and greenhouse seedling establishment represented by seedling fresh weight and seedling vigor index (Table 2). Other research has found that variety had a significant effect on growth vigor of sorghum (Vara Prasad and Staggenborg, 2009). Furthermore, increased mitochondrial protein in crop seedlings from high test weight seeds indicates higher respiratory rates, biochemical activity, greater energy production and growth rate and seedling vigor. In this experiment, there were no consistent differences in the final stands or total emerged seedlings among all silage corn and forage sorghum hybrids (Tables 1 and 2). The beneficial role of silage corn hybrid (6640VT3P) on seedling vigor was reflected in the subsequent growth and development of the crop. An increase in the weight of seed at planting was found to be beneficial in terms of water use efficiency inside the greenhouse (Table 3). Larger seeds of Corchorus olitorius produced more dry matter due to large initial capital food reserve and this was reflected in the seedlings growth behavior (Bhattacharjee et al. 2000).

In the field trial, plants produced from silage corn hybrid (6640VT3P) were not significantly different than those produced from silage corn hybrid (DKC70-01) for seedling vigor, fresh weight and water use efficiency (Tables 1 and 4). Generally, planting silage corn hybrid (6640VT3P) larger seeds produced plants with higher vigor indices and water use efficiency than those produced from silage corn hybrid (DKC70-01) seeds. This result was confirmed by Bhattacharjee et al. (2000) on Jute (Corchorus olitorius) who stated that smaller seeds were traced by poor seedling vigor, establishment, and growth. This was indicated by silage corn hybrid (6640VT3P) growth behavior represented by superior seedling vigor and water use efficiency (Fig. 1) inside the greenhouse trial. This result was in agreement with Saha and Mandal, (2016) on sunflower who reported that among the seed sizes, large seeds showed higher field performance than the other categories of seeds.

The results of this research clearly explain the significant and positive effect of hybrid on seed quality, vigor, field performance, and seedling establishment. Hybrid not only affects viability, seedling vigor in the greenhouse

### Table 1: Overall mean for the effect of hybrids on open field emergence percentages, seedlings establishment vigor parameters, and water use efficiency (g mm⁻¹).

| Crop            | Hybrid       | Field Emergence % | Seedling Fresh Weight (g seedling⁻¹) | Seedling Vigor Index |
|-----------------|--------------|-------------------|--------------------------------------|----------------------|
| Silage Corn     | 6640VT3P     | 90.278 AB         | 3.2804 A                             | 296.14 A             |
| Silage Corn     | DKC70-01     | 89.58 AB          | 3.1930 A                             | 286.04 A             |
| Silage Corn     | P1197YHR     | 100 A             | 1.927 B                             | 192.76 B             |
| Forage Sorghum  | ss2010       | 90.278 AB         | 0.2994 C                             | 27.03 C              |
| Sorghum×Sudangr | Sugar Graze II | 83.33 B     | 0.9678 BC                           | 80.65 BC             |

Means in columns not sharing same capital letters are significant at the 5% LSD probability level.

### Table 2: Overall mean for the effect of hybrids on greenhouse emergence percentages, seedlings establishment vigor parameters, and water use efficiency (g mm⁻¹).

| Crop            | Hybrid       | Greenhouse Emergence % | Seedling Fresh Weight (g seedling⁻¹) | Seedling Vigor Index |
|-----------------|--------------|------------------------|--------------------------------------|----------------------|
| Silage Corn     | 6640VT3P     | 90 AB                  | 2.3364 A                             | 210.28 A             |
| Silage Corn     | DKC70-01     | 90 AB                  | 1.7398 B                             | 156.58 B             |
| Silage Corn     | P1197YHR     | 100 A                  | 1.6806 B                             | 168.06 B             |
| Forage Sorghum  | ss2010       | 80 AB                  | 0.2044 C                             | 16.35 C              |
| Sorghum×Sudangr | Sugar Graze II | 70 B                  | 0.2134 C                             | 14.94 C              |

Means in columns not sharing same small letters are significant at the 5% LSD probability level.
Fig 1: Water use efficiency measured for three silage corn hybrids based on seedling fresh weight in both greenhouse and open field. Vertical bars indicate the (±) standard error of the mean (n=5). The mean of seedlings fresh weight in greenhouse multiplied by a constant factor of (2) and in the field multiplied by a constant factor of (7.6).

Table 3: Overall mean for the effect of hybrids on water use efficiency (g mm⁻¹) inside the greenhouse simulated for two seedlings per each pot.

| Crop            | Hybrid   | Water Use Efficiency (g mm⁻¹) |
|-----------------|----------|------------------------------|
| Silage Corn     | 6640VT3P | 0.93456                      | A |
| Silage Corn     | DKC70-01 | 0.69592                      | B |
| Silage Corn     | P1197YHR | 0.67224                      | B |
| Forage Sorghum  | SS2010   | 0.08176                      | C |
| Sorghum × Sugar Graze II | 0.08536   | C |

Means in columns not sharing same small letters are significant at the 5% LSD probability level.

Table 4: Overall mean for the effect of silage corn hybrids on water use efficiency (g mm⁻¹) in the open field.

| Crop        | Hybrid         | Water Use Efficiency (g mm⁻¹) |
|-------------|----------------|------------------------------|
| Silage Corn | 6640VT3P       | 0.6849                       | A |
| Silage Corn | DKC70-01       | 0.6667                       | A |
| Silage Corn | P1197YHR       | 0.4025                       | A |

Means in columns sharing same small letters are not significant at the 5% LSD probability level.

CONCLUSION

These results indicated that the hybrid of silage corn and forage sorghum is highly variable in simulated extreme drought conditions of Jordan, where rainfall or irrigation amounts and distribution are highly variable. These differences among hybrids emphasized the importance of the selection process after modeling to maintain seedling establishment of hybrid crops. Silage corn hybrid (6640VT3P) improved the seedling vigor and water use efficiency among different hybrids, large seeds had significantly higher seed quality when estimated by seedling fresh weight, seedling vigor index, and water use efficiency. As a final conclusion, results reported in this study suggest that selection of silage corn hybrid (6640VT3P) seeds in Jordan would be an efficient and useful method of improving consistency, uniformity, and providing superior seedling performance with the potential for improved vegetative yields under extreme drought conditions of Jordan.

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