Growth Biometrics Response of Silage Corn and Forage Sorghum to Hybrid Vigor under Multiple Irrigation Treatments

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Abstract:- Hybrids affect vegetative development in silage corn and forage sorghum. Investigations were conducted on the hybrid selection and impact on vegetative development for multiple irrigation treatments in Jordan. The study was carried out under the Norman Borlaug Fellowship during the 2017 season which demonstrated a suitable selection for forage growers. The first step required the selection of drought-tolerant hybrids. Five commercial seed lots (three of corn and two of sorghum) were tested. The second step involved planting hybrids under field conditions at Florida Agricultural and Mechanical University using a designed irrigation treatment and then evaluating the vegetative growth and development by measuring emergence rate index, seedling dry weight, tissue water content percentage, total leaf count, plant height, and fodder yield of the first harvest. Silage corn (6640VT3P) seed had lower water uptake and higher seedling dry weight aligned with a suitable seedling tissue water content and fodder yield of the first harvest. The superiority of silage corn (6640VT3P) may be attributed to hybrid vigor and its efficient water usage habit. These findings suggest that silage corn (6640VT3P) had a high impact on the vegetative development that could be selected and grown using irrigation treatment under extreme drought conditions identical to Jordan.

Key-words:- Biology, Crops, Drought, Heterosis, Meteorology, Seeds.

1 Introduction

Silage corn hybrids have predominantly been major silage forages for livestock in Jordan (Massimi et al., 2017). 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 heterosis (hybrid vigor) and drought-tolerance offer potential in areas where water is scant and will continue in the future to be in decreasing supply. The total count for dairy cows in the Zarqa region is about 29,820 heads in 2016-2017 (Department of Statistics, 2018). Because of global warming and expectations for drought stress conditions characterized by lower rainfall, higher temperatures and less water for irrigation in some regions, for example, eastern arid parts of Zarqa and Mafraq in Jordan with its large dairy cattle industries, there is a vital need for alternative hybrid 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 entities, for example, agriculture, human population, and domestic animals and wildlife.

Heterosis, hybrid vigor, or out-breeding enhancement, is the improved or increased function of any biological quality in a hybrid offspring. An offspring exhibits heterosis if its traits are enhanced as a result of mixing the genetic contributions of its parents. (Sleper and Poehlman, 2006) defined hybrid vigor as an increase in vigor, size, or productivity of a hybrid plant over an average or mean of its parents.

Nearly all field corn grown in most developed countries exhibits heterosis. Heterosis in corn was paramount in raising the yield ceiling seven decades ago when the first commercial hybrids were introduced (Tollenaar and Lee, 2006). Heterosis has also been reported to help corn to better adapt to diverse stress conditions (Tollenaar et al., 2004); (Tollenaar, and Lee, 2006). Thus, differences in grain yield between hybrids and their parental inbred lines increased in plants grown under drought (Betra´n et al., 2003a,b,c). Modern corn hybrids substantially over yield conventional cultivars and respond better to fertilizer.

Agronomists and plant breeders should study different variables to improve vegetative growth and development. One of these important crop variables is heterosis or hybrid vigor. It has been reported that selecting hybrid improved crop growth under water stress. (Araus et al., 2010) concluded that hybrid vigor in tropical corn seems to be mediated by improved water use, irrespective of the water conditions during growth.

Water for crop use is the primary factor controlling corn yield (Anandhi, 2016). The vegetative growth and development of hybrid corn seeds are greatly impacted by water availability. For example, the early stages of plant development are sensitive to water availability. Generally, corn vegetative parameters such as plant height, and leaf area were significantly affected by water shortage and stress (Cakir, 2004). Agronomists and seed technologists generally concur that a great seedling vigor leads to greater seedling dry and fresh weights. This could have a greater impact on vegetative growth and crop biomass. (Massimi et al., 2018) reported that silage corn hybrid (6640VT3P) improved the seedling vigor and water use efficiency among different hybrids when estimated by seedling vigor index, and water use efficiency. The study suggests 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 growth and yields under extreme drought conditions of Jordan. (Massimi,2018) studied and reported relation between seed vigor in barley varieties of (Rum) and (ACSAD 176) and seedling vigor under terminal drought stress.

(Prasad and Staggenborg, 2009) stated a positive relationship between the number of tillers in sorghum and hybrid. The plant can tiller depending upon the hybrid. (Zahid et al., 2002) reported the superiority of two hybrids of Sorghum × Sudangrass in terms of high tillering capacity, and leaf area index and hence high yielding green matter yield under irrigated rain-fed conditions of the Potwarbasin of Pakistan.

Even though heterosis or hybrid vigor is most evident in adult traits such as plant or crop biomass and yield, it is also apparent during embryo (Meyer et al., 2007) and early seedling development (Hoecker et al., 2006) and (Massimi et al., 2018). Thus, differences in performance and establishment of seedlings between inbreds and hybrids have been reported (Hoecker et al., 2006, 2008).

The objectives of this study were to evaluate the response of vegetative growth biometrics of silage corn and forage sorghum to the hybrid vigor and to develop recommendations regarding whether to import specific hybrid seeds or not. This experimental simulation was an attempt to study mainly the response of emergence rate, seedling dry weight and green fodder yield to drought-tolerant hybrid vigor under irrigation modeling and simulated extreme drought conditions identical to Jordan.

2 Materials and Methods

2.1 Hybrid Seeds Materials and Sources:

Seed lots from silage corn hybrids namely (6640VT3P), (DKC70-01), and (P1197YHR) were used in this study. Seed lot (6640VT3P) hybrid was produced by Win Field Solutions company, the lot (DKC70-01) was produced by Monsanto company, and the lot (P1197YHR) seeds were obtained from the University of Florida and produced by Du Pont Pioneer Company.

Forage sorghum lot hybrid seeds (ss2010) were obtained from the Southern State Cooperative Company and the hybrid lot of sorghum × sudangrass namely (Sugar Graze II) were obtained from Tucker Seeds Company.

2.2 Water Uptake Percentage Laboratory Evaluation:

The seeds of each hybrid were randomly selected based on the uniformity of size. Ten seeds from each hybrid were placed in a 9 cm Petri-dish lined with double filter papers (Whatman Brand). The filter papers were moistened with 10 ml of distilled water using a specific syringe (laboratory self-refilling syringe) (SOCOREX company Swiss) model number (DOSYS 174) and then incubated in room temperature at 20 ◦C for 24 hours to measure the percentage water uptake. The experiment was placed in a split completely randomized design, in which hybrids of silage corn and hybrids of forage sorghum were replicated five times. The water uptake percentage was recorded for 24 hours. It was calculated by formula according to (Mu-jeeb-ur-Rahman et al., 2008):

The water Uptake Percentage (WU%) = Weight of Seed After Absorbing Water in a Particular Time – Initial Weight of Seed / Initial Weight of Seed………………………………………...…(1).

2.3 Field Experiment:

Hybrids were sown on April 12, 2017, in an open field. The experiment was conducted at the Center for Viticulture and Small Fruits Research (CVSFR), Florida A&M University (FAMU), Tallahassee, Florida, U.S.A. The soil of the experimental area had clay texture. The soil moisture characteristics of field capacity percentage and permanent wilting point percentage were determined according to (Saxton and Rawls, 2006).

The experiment was laid out in a Split Completely Randomized Design, where 3 hybrids of silage corn and 2 hybrids of forage sorghum were replicated three times. The net block size was 30 m × 0.75 m, with a row-to-row distance of 1.83 m and a seed rate of 12 seeds for each hybrid per block (Diagram 1).

5.91-m

0.75-m

Block 1		**Block 2**		**Block 3**
6640VT3P		P1197YHR		ss2010
6640VT3P		P1197YHR		ss2010
6640VT3P		P1197YHR		ss2010
6640VT3P		P1197YHR		ss2010
6640VT3P		P1197YHR		ss2010
6640VT3P	**Space**	P1197YHR	**Space**	ss2010
DKC70-01	**1.83-m**	6640VT3P	**1.83-m**	6640VT3P
DKC70-01		6640VT3P		6640VT3P
DKC70-01		6640VT3P		6640VT3P
DKC70-01		6640VT3P		6640VT3P
DKC70-01		6640VT3P		6640VT3P
DKC70-01		6640VT3P		6640VT3P
ss2010		ss2010		P1197YHR
ss2010		ss2010		P1197YHR
ss2010		ss2010		P1197YHR
ss2010		ss2010		P1197YHR
ss2010		ss2010		P1197YHR
ss2010		ss2010		P1197YHR
S Graze II		DKC70-01		S Graze II
S Graze II		DKC70-01		S Graze II
S Graze II		DKC70-01		S Graze II
S Graze II		DKC70-01		S Graze II
S Graze II		DKC70-01		S Graze II
S Graze II		DKC70-01		S Graze II
P1197YHR		S Graze II		DKC70-01
P1197YHR		S Graze II		DKC70-01
P1197YHR		S Graze II		DKC70-01
P1197YHR		S Graze II		DKC70-01
P1197YHR		S Graze II		DKC70-01
P1197YHR		S Graze II		DKC70-01

5.91-m

Diagram 1: An illustration for a field experiment layout (block length is 30 meters, it the longitudinal arrow with two heads).

2.4 Irrigation Model:

The Trickle-drip irrigation was used during vegetative growth and development, and irrigation was scheduled once every 4 days based on a mathematical model of 36.4 [mm (meter Sq)-1] for 71 seconds (Table 1). The net irrigation depth was 32.76 [mm (meter Sq)-1]. Drip irrigation involves dripping water onto the soil at a specified flow rate of (1.02 liters/hour) from a small-diameter plastic piping system fitted with outlet emitters or drippers. Emitters were spaced at a distance of 0.3 m. Zero soil evaporation was assumed due to the use of plastic mulch, and the irrigation efficiency was 90%. The water requirement of corn and forage sorghum is greatest at the tasseling through ear fill stages. It was assumed that forage sorghum like corn required up to 0.33 inches of water per day (8 mm) (Wright et al., 2003).

A rain gauge instrument (Stratus company) was used to collect and measure the amount of precipitation over a specific period of experiment time. Two data loggers were used. A data logger (model HOBO H08-032-08) was used to monitor the relative humidity and air temperatures, and the data logger (model HOBO UA-001-64) was used to monitor soil temperature during the emergence of seedlings and vegetative development (ONSET Company).
Table 1 shows multiple irrigation treatments in the same experiment. But, the addition of rainwater amount between each irrigation and the other (specifically for the next irrigation event) gives a fixed amount of 819 [mm (22.5-meter Sq)-1]. This amount is equivalent to 36.4 [mm (m Sq)-1]. The gross irrigation depth multiplied by the irrigation efficiency (90%) giving a net irrigation depth of 32.76 [mm (m Sq) -1]. For the crop to take its daily requirements of 8 mm (Wright et al., 2003), the irrigation intervals must be 4 days.

Between April, 28 and May 2 2017 the total rainfall fell by 2.62 [mm (meter Sq)-1] which equals 58.95 [mm (22.5-meter Sq)-1]. This value is subtracted from the gross irrigation depth of 819 [mm (22.5 m Sq)-1], so the next irrigation on May 2 2017 was 760.05 [mm (22.5-meter Sq)-1].

The multiplying product of row-to-row distance (1.83 m) with emitters space (0.3 m) produces an area of 0.546 m (Sq) -1. In drip irrigation, the application rate is equal to the emitter flow rate in 1 hour which is 1020 [mm (hr)-1] divided by 0.546, where is the result 1858 [mm (hr)-1]. Finally, the irrigation running time is equal to the result of dividing the gross irrigation depth 36.4 [mm (Sq) -1] by the application rate 1858 [mm (hr)-1] which is 71 seconds. Running time has been adjusted in case of rain.

Table 1. Irrigation model used during seedling establishment and early vegetative development, 2017, Tallahassee, Florida. U.S.A

Day	Irrigation Depth (mm/block *)	Running Time (Seconds)	Rain (mm)
April, 12	819	71	0
April, 16	819	71	0
April, 20	819	71	0
April, 24	786	68	1.47
April, 28	819	71	0
May, 2	760	66	2.62
May, 6	178	15	28.51
May, 10	819	71	0
May, 14	657	57	7.21
May, 18	Harvest Date		

*Block is 22.5 m^2

2.5 Field Weather Data:
Remote sensing and past weather measurements were taken from an observation site at the Tallahassee airport, which was located about 14

miles from the (CVSFR), FAMU open field experiment site. This data is then analyzed to look for outliers, produce averages and graphs for interpretation (Table 2). Weather data were taken from the Tallahassee Regional Airport. It was retrieved from (www.underground.com, 2017). Table 2 shows relative humidity means among (2007-2016) and means among (2007-2016) for total monthly rainfall records during corn and sorghum season in Tallahassee.

Table - 2. Average weather parameters which are taken from a weather station in Tallahassee, Florida, U.S.A (2006-2017)

2007-2016	**Relative Humidity (%)**	**Total Rainfall (mm)**
March	64.9	115.23
April	65.4	134.57
May	63.9	58.99
June	68.2	171.10
July	71.3	166.17

2.6 Biometrics of Seedling Emergence:

Emerged seedlings were counted 3 and 8 days after planting. The emergence counts were used to calculate the emergence rate index using the formula developed by (Maguire, 1962) and cited by (Massimi, 2005):

Emergence Rate Index (ERI) =

Number of Normal Seedlings / Days of the First Count + …….. + Number of Normal Seedlings/ Days of the Final Count…………..…………….(2).

The last day count was used to determine the final percentage of emergence. Five seedlings were randomly sampled from each hybrid to measure its dry weight by weighting the seedlings after drying in an oven at 70 ºC for 48 hours. The tissue water content percentage was calculated using the formula of (Black and Pritchard, 2002):

Tissue Water Content Percentage (TWC %) = (Fresh Weight – Dry Weight / Fresh Weight) × 100…………………………………………….(3)

2.7 Growth Biometrics of Vegetative Growth and Development:

Plants were thinned to 1 plant. Fertilizer (33-0 -2) was applied at the end of emergence and prior to vegetative development at the rate of 200 g of nitrogen per block (0.606 kg) (Mylavarapu et al., 1997). The fertilizer was applied below the soil surface across an entire block through the manual application at the rate of 20.2 g per hole.

9 [Kg (1000 meter Sq)-1] …..………………….(4)

On May 11, 2017, total leaf count, and plant height were recorded from 5 randomly-selected plants for each hybrid at vegetative development (just prior to the first harvest). At harvest time on May 18, 2017, 5 plants were randomly sampled from each hybrid and fodder green yield was measured using a balance.

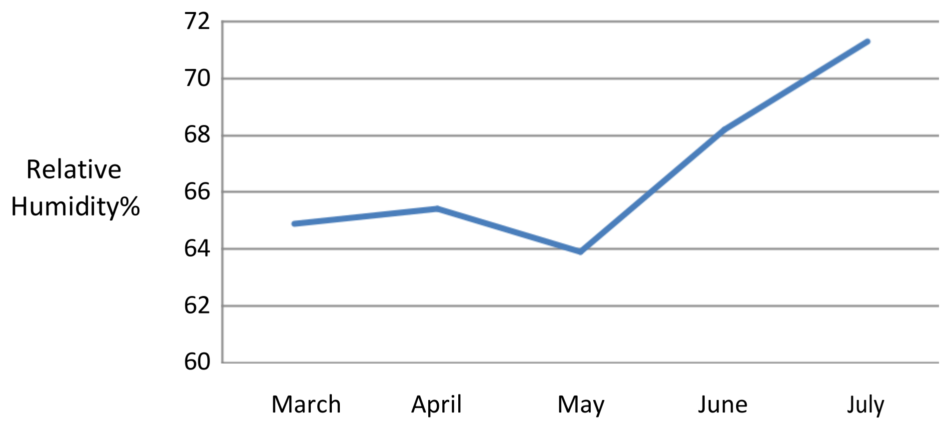
2.8 Statistical Analysis:

A single-factor analysis of variance was used to measure the parameters following the analysis by (Carlberg, 2014). Means were separated according to the Least Significant Difference (LSD) at a probability level of 0.05.

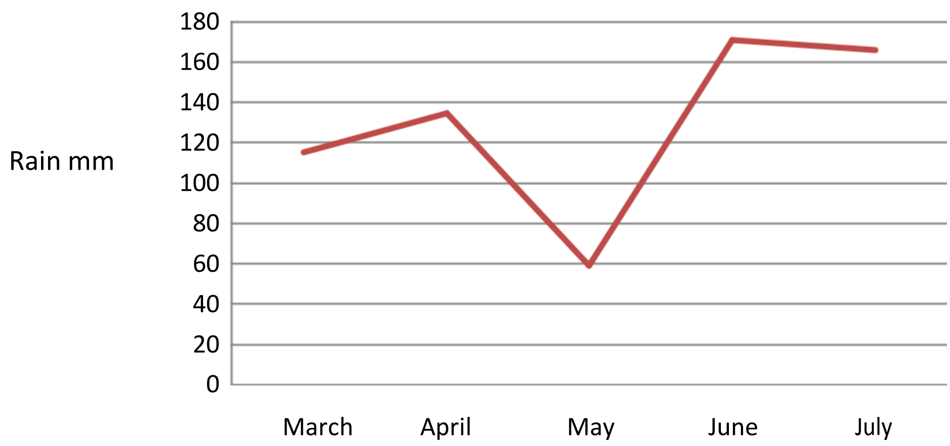
3 Results

During the 2006-2017 period, average relative humidity decreased during March to May (Table 2). The maximum and minimum relative humidity were high during June to July (Graph 1). In 2006-2017, the average maximum total rain was around 171.1 mm in June. Minimum total rain records were around 58.99 mm through May (Table 2). The highest amount of rainfall was reported in June (Graph 2). Scarce rainfall was reported in May.

Both mean relative humidity and rainfall data indicate that relative drought stress occurs in May (Table 2).



Graph - 1. Monthly average relative humidity (2006-2017) during corn and sorghum season in Tallahassee, Florida, U.S.A



Graph - 2. Total monthly rainfall means (2006-2017) during corn and sorghum season in Tallahassee, Florida, U.S.A

Table 3 shows the impact of hybrids on water uptake percentage. The lowest water uptake percentage was observed in silage corn hybrid (6640VT3P), while the highest was recorded in forage sorghum (ss2010).

Table - 3. Hybrid water uptake percentage

Hybrid	**WU %**
6640VT3P	37.23794413 a
DKC70-01	38.13592083 a
P1197YHR	41.56497696 a
SS2010	103.1966273 b
Sorghum × Sudan	49.94811061 b
Significance	S

Means in columns sharing the same letters are not significant at the 5 Percent (%) LSD probability level.
NS: Non-Significant & S: Significant.

Silage corn hybrid (6640VT3P) seed had the lowest water uptake percentage among all tested hybrids, where it was not significantly different from other silage corn hybrids of (DKC70-01) and (P1197YHR). Table 3 shows the lowest water uptake percentage (37.23794413 %) was observed in silage corn hybrid (6640VT3P).

Emergence rate index, seedling dry weight, and tissue water content percentage were compared for different hybrids (Table 4). Silage corn hybrid (6640VT3P) had the highest emergence rate index, where it was not significantly different from other hybrids. Silage corn hybrid (6640VT3P) had higher seedling dry weight, where silage corn hybrid (6640VT3P) was not significantly different from other silage corn hybrids (Table 6) . The lowest seedling dry weight (0.0.684g) and tissue water content percentage (76.3357857%) were observed in forage sorghum hybrid (ss2010).

Table 5 shows the analysis of variance (ANOVA) for the effect of hybrid vigor on the seedling dry weight of five tested hybrids. Table 6 shows ANOVA for the effect of silage corn hybrids on the seedling dry weight. Table 4 and table 6 show that all silage corn hybrids tested were significantly higher for seedling dry weight than sorghum × sudangrass hybrid (sugar graze II) and forage sorghum (ss2010).

Plants produced from silage corn hybrids of (6640VT3P) and (P1197YHR) had the highest biological and fodder green yields (Table 7). Forage sorghum hybrid (ss2010) had shorter plants and had the lowest yield per plant than all other hybrids. For all hybrids, plant height per plant was not significantly different (Table 7). Silage corn hybrid (6640VT3P) had higher total leaf counts per plant than other silage corn hybrids (P1197YHR), and (DKC70-01).

Table - 4. Hybrid emergence rate index, seedling dry weight (g/plant) and tissue water content percentage

Hybrid	**ERI**	**SDW (g)**	**TWC %**
6640VT3P	3.928 a	0.4746 a	83.51855982 a
DKC70-01	3.925 a	0.4388 a	86.05000356 a
P1197YHR	3.928 a	0.3148 a	83.40194256 a
SS2010	3.788 a	0.0684 b	76.3357857 a
Sorghum × Sudan	3.595 a	0.2072 b	78.73116415 a
Significance	NS	S	NS

Means in columns sharing the same letters are not significant at the 5 Percent (%) LSD probability level.
NS: Non-Significant & S:Significant.

Table - 5. Analysis of Variance (ANOVA) for the impact of hybrid on seedling dry weight (g/plant)

Analysis of Variance (ANOVA)

Hybrid Groups	Count	Sum	Average	Variance
6640VT3P	5	2.373	0.4746	0.035366
DKC70-01	5	2.194	0.4388	0.005081
P1197YHR	5	1.574	0.3148	0.01397
SS2010	5	0.342	0.0684	0.001799
Sorghum × Sudan	5	1.036	0.2072	0.006182

Analysis of Variance (ANOVA)

Source of Variation	SS [1]	df [2]	MS [3]	F [4]	P-value	F crit [5]
Between Groups	0.561086	4	0.140271	11.24011	6.0618E-05	2.866081402
Within Groups	0.249591	20	0.01248			
Total	0.810677	24				

1 SS: Sum of Squares, 2 df: Degrees of Freedom, 3 MS: Mean of Squares, 4 F: Statistical, 5 F Crit: F Critical.

Table - 6. Analysis of Variance (ANOVA) for the impact of silage corn hybrids on seedling dry weight (g/plant)

Analysis of Variance (ANOVA)

Silage Corn Hybrid Groups	Count	Sum	Average	Variance
6640VT3P	5	2.373	0.4746	0.035366
DKC70-01	5	2.194	0.4388	0.005081
P1197YHR	5	1.574	0.3148	0.01397

Analysis of Variance (ANOVA)

Source of Variation	SS [1]	Df [2]	MS [3]	F [4]	P-value	F crit [5]
Between Groups	0.070323	2	0.035161	1.938435	0.18642243	3.885293835
Within Groups	0.217669	12	0.018139			
Total	0.287992	14				

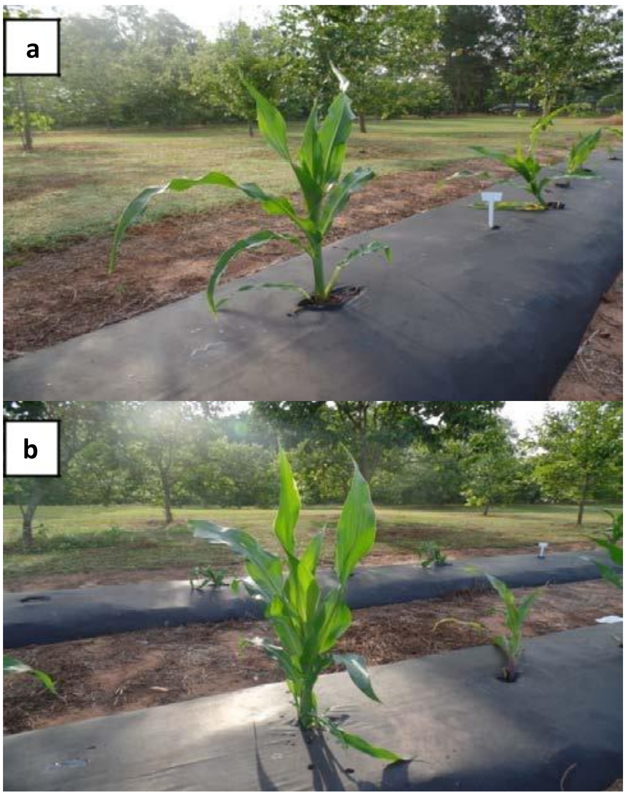
1 SS: Sum of Squares, 2 df: Degrees of Freedom, 3 MS: Mean of Squares, 4 F: Statistical, 5 F Crit: F Critical

Table - 7. Impact of hybrid on plant total leaf count, plant height (cm) and fodder yield (kg/plant)

Hybrid	TLC	PLH (cm)	FY (kg)
6640VT3P	9 b	70.612 a	0.306628 a
DKC70-01	8 b	66.04 a	0.239497 a
P1197YHR	8.2 b	71.374 a	0.325679 a
SS2010	14.8 b	48.006 a	0.227703 a
Sorghum × Sudan	39.8 a	64.262 a	0.234053 a
Significance	S	NS	NS

Means in columns sharing the same letters are not significant at the 5 Percent (%) LSD probability level.
NS: Non-Significant & S:Significant.

Photos (1 a and b) show both silage corn hybrids of (6640VT3P) and (P1197YHR) respectively during vegetative growth and development.



Photos – 1 (a and b): Silage Corn Hybrids of (6640 VT3P) and (P1197YHR) respectively during vegetative development.

4 Discussion

The results from the present study revealed that the importance of silage corn breeding to develop drought-tolerant hybrids which can improve forage yield and production. Therefore, the selection may be fruitful to improve drought-tolerance in silage corn. Higher broad sense heritability indicated that the selection of hybrids to develop forage production may be helpful to improve the green fodder yield. The hybrid vigor will also be increased due to the higher dominance effects of genes (Ali et al., 2014).

Generally, silage corn hybrid (6640VT3P) seed imbibed water with the lowest ratio (WU%) among all other hybrids. This indicates that it has superior water use efficiency (Table 3) and this result was confirmed by (Massimi et al., 2018).

A positive effect was recorded between hybrid vigor seeds and seedling emergence biometrics such as emergence rate index (ERI), seedling dry weight (SDW), and tissue water content percentage (TWC%) (Tables 4-6). In our study, higher heritability was found in silage corn (6640VT3P) for seedling dry weight, which suggested the selection of drought-tolerance genotypes on the basis of seedling dry weight may be helpful to improve forage crop yield. Dry shoot weight showed a higher genetic advance, that suggested selection on the basis of shoot weight may be helpful to develop drought-tolerant corn genotypes (Ahsan et al., 2013).

The beneficial role of silage corn hybrid vigor (6640VT3P) on seedling vigor was reflected and continued in subsequent vegetative growth and development of the crop. Increase the hybrid seed vigor at planting was found to be beneficial in terms of leaf count per plant, plant height, and fodder yield (Table 7). Seeds of silage corn hybrid (6640VT3P) produced more dry matter due to large initial capital food reserve, and increased mitochondrial protein in seedlings indicates higher respiratory rates, biochemical activity, greater energy production, growth rate, and seedling vigor. This was reflected in the vigor of seedlings and their growth behavior (Massimi et al., 2018) . The significant correlation between total fresh weight and total dry weight shows that the traits are important for selection against drought stress conditions (Khan et al., 2014). If the heterosis of a hybrid is higher and positive, it will indicate that its selection may be helpful to improve forage yield.

The results of this study clearly explained the positive effects of hybrid vigor on seed quality, emergence, and vegetative growth. Hybrid not only affects the emergence rate, and seedling dry weight under field conditions but also affect fodder yield during vegetative growth and relative drought stress period. Thus, introduction of silage corn hybrid (6640VT3P) seeds from United State of America, Florida, to Jordan or Middle East countries will be an efficient, and useful method of improving consistency, uniformity, and providing high-quality seed with the potential for improved vegetative yields under drought environmental conditions in Jordan. This will certainly sustain cattle production and provide food security to drought areas.

5 Conclusions

These results indicate that silage corn and forage sorghum hybrids are highly variable in simulated extreme drought conditions of Jordan, where the amount and distribution of rainfall or irrigation are highly variable. These differences among hybrids emphasize the importance of the selection process to maintain higher vegetative growth and development of hybrid crops. Silage corn hybrid (6640VT3P) improved the seedling dry weight, vigor and water use efficiency among the different hybrids, where hybrid vigor had significantly higher seedling dry weight, aligned with a suitable tissue water content and fodder yield of the first harvest. As a final conclusion, results reported in this study suggest that introduction of silage corn hybrid (6640VT3P) seeds from the United States to Jordan or Middle East countries will be an efficient and useful method of improving consistency, uniformity, and providing superior vegetative growth and development under extreme drought conditions of Jordan.

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