Growth and Yield Assessment of Two Types of Sorghum-Sudangrass Hybrids as Affected by Deficit Irrigation

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Abstract**—**In order to evaluate the growth and yield properties of two Sorghum-Sudangrass hybrids under different irrigation levels, an investigation was done in the experiment site of Collage of Agriculture, University of Duhok, Kurdistan region of Iraq (36°5′38″ N, 42°52′02″ E) in the years 2015-16. The experiment was conducted under Randomized Complete Block Design (RCBD) with three replications, which main factor was irrigation treatments (I_{100}, I_{75} and I_{50}) according to evaporation pan class A and type of Sorghum-Sudangrass hybrids (KH12SU9001, G_1) and (KH12SU9002, G_2) were factors of subplots. The parameters studied were: plant height (cm), number of green leaves per plant; leaf area (m^2/m^2), stem thickness (mm), percent of protein, fresh and dry biomass ($ton.ha^{-1}$) and also crop water productivity. The results of variance analysis showed that KH12SU9001 variety had more amount of leaf area, percent of protein, fresh and dry biomass yield in comparison to KH12SU9002 variety. By comparing effects of irrigation levels on vegetative growth and yield properties, results showed that amount of plant height, fresh and dry biomass weight was decreased by decreasing irrigation level from full irrigation regime to 5 $_0$% of irrigation level. Also, results of crop water productivity (CWP) indicated that improvement in quantity of irrigation would impact fresh and dry biomass yield significantly. Full irrigation regime was recorded the highest level of CWP (1.28-1.29 $kg.m^{-3}$).

Keywords**—**Deficit irrigation, growth, Sorghum-Sudangrass hybrid, yield.

I. Introduction

According to the shortage of water resources around the world, drought is one of the most threatening factors for food security, and crop yield [1]. In the other word, the most important challenge for agriculture is supplying enough water for food production especially in arid and semi-arid areas [2]. Sorghum is a C_4 species and it is one of the most important plants as a forage plant for livestock. Drought resistant and function of sorghum makes this plant to be so useful for semi-arid regions [3]. This plant can produce high amount of yield in dry condition with extreme temperature while maize and some of other cereals cannot be so productive. According to the shortage of water for plants to grow, finding a proper genotype which is more efficient with this condition is one of the priorities for researches [4]. Hybrids of sorghum originate from some types of fodder sorghum and sudangrass [5]. Compared to maize or sorghum, the hybrids have a smaller leaf area with waxy bloom owing to which they are more tolerant to drought. One beneficial property of the hybrids is an increased number of acquisitive roots to absorb water in deeper soil depth when faced with water stress and let the plant to continue growing and increase biomass. Another beneficial characteristic of the hybrids is that they grow faster than sorghum, and therefore, they are more competitive and hinder the weeds growth [6]. The most significant feature of the hybrid varieties is their ability to regrowth when cut, a property comes from sudangrass. In comparison to maize or sorghum, the hybrids can be harvested several times a year and therefore they fulfill the shortages of roughage during the growing period. Sorghum-Sudangrass hybrids are one of the hybrids which are characterized by relatively small diameter stems, high tillering capacity, rapid re-growth potential and low grain yield. Sorghum-Sudangrass hybrids can produce good quality silage, but are best suited for grazing or hay production.

The amount of irrigation reduction depends on crops, and usually, it is not effective on yield reduction [7]. Reference [8] investigated on Gizani variety of Sorghum with three irrigation intervals (6, 9 and 12) and concluded that by increasing irrigation interval, crop function and yield was affected significantly and the most grain yield was reported in interval 6 of irrigation. Reference [9] reported that by reducing irrigation, amount of grain yield decreased. Reference [4] studied on three genotype of forage sorghum (KFS_2, KGS_6 and KGS_{17}) under deficit irrigation and stated that KGS_6 had highest range of physiological properties, while the highest yield is related to KFS_2 and KGS_{17}. In another research, an investigation was done on KFS_3 variety which produced the highest amount of wet and dry yield (132.9 and 16.4 ton/ha respectively) and it was selected as a most suitable genotype for draught stress condition [10]. Reference [11] investigated on seven genotypes of grain sorghum under water stress and stated that KGS_3 selected as the most tolerant genotype to water stress condition.

There is not enough research that has been done on the growth and yield properties of Sorghum-Sudangrass hybrids as effected by different irrigation regimes [12]. Therefore, the

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objective of this study was aimed to investigate the effects of different irrigation levels on growth rate and yield properties of two genotypes of Sorghum-Sudangrass hybrids (KH12SU9001 and KH12SU9002).

II. Procedure

This research was conducted in the field of Agriculture College at Duhok University, Duhok province, Kurdistan region of Iraq (36°5′38″ N, 42°52′02″ E) in August 2016. The climate of the study area is arid to semi-arid, with hot and dry summer and cold and wet winter. The temperature in winter is characterized by below zero and a hot summer with temperature elevating up to 40 °C. Before starting the study, some soil samples were taken in the field from 0-30 cm soil depth. Some physical and chemical soil properties and some of the chemical characteristics of irrigation water from well are represented in Tables I and II, separately.

TABLE I
Some Physical and Chemical Soil Properties of the Studied Area

Soil texture	EC (dS m^{-1})	pH	O.M ($g.Kg^{-1}$)	CEC ($Cmol_ckg^{-1}$)	Available N (mg. Kg^{-1})	Available P (mg. Kg^{-1})	K^+ ($mmol_cL^{-1}$)	Ca^{2+} ($mmol_cL^{-1}$)	Mg^{2+} ($mmol_cL^{-1}$)
Silty clay	2.3	7.9	1.77	31.3	105	4.88	0.2	1.66	1.03

TABLE II
Some Chemical Properties of Irrigation Water

pH	SAR	Na^+ (mmolec L^{-1})	HCO3- (mmolec L^{-1})	Cl- (mmolec L^{-1})	TDS (ppm)
7.95	1.77	105.95	4.88	0.2	1.66

The experiment is laid out as RCBD comprised of factorial combination of three irrigation levels and two Sorghum-Sudangrass hybrids with three replications. Main plot was irrigation regimes (D1, D2 and D3 with receiving 100%, 75%, and 50% soil moisture depletion respectively) and subplot were types of Sorghum-Sudangrass hybrids (B1, KH12SU9001 genotype and B2, KH12SU9002 genotype). Each genotype of sorghum was cultivated in plots with dimensions (2.1*2.5 m) with 5 cm depth of cultivation and the distance between two seeds was 20 cm and the space within the rows was 70 cm. Each treatment was replicated three times. The area of cultivation was equipped with drip irrigation system. No fertilizer was used during growing of Sorghum-Sudangrass hybrids.

Growth properties of sorghum genotypes were measured on plants from every plot before cutting. The properties that were measured in this study includes plant height (cm), number of green leaves per plant, leaf area, stem thickness, fresh and dry yield. Also, water productivity assessment [13] was calculated for parameters include: CWP (kg/m^3), irrigation crop water productivity (ICWP, kg/m^3) and irrigation water saving.

Statistical analysis was done using SPSS software version 16 by applying the general linear procedure to test for significant irrigation treatment effects on measured parameters.

III. Results and Discussions

A. Plant Height

The statistical analysis of ANOVA variance in Table II showed that there was no significant difference between irrigation levels and type of genotype on plant height. Table III indicated that the average of plant height in KH12SU9001 variety (118.88 cm) was more than KH12SU9002 variety, but the difference between hybrids is not significant because physiological and biochemical mechanisms of plants may be the same and could be changed when plant are grown in different nutrition conditions [14] and [15]. Also, according to Table IV, irrigation level in 100% had the highest plant height while irrigation level in 50% had the lowest plant height, and their differences were significant. It was shown that by increasing irrigation level, plant height will increase. That is because of drought stress dramatically impact, stem height during vegetative stage and it makes a competition between aerial shoots and roots to absorb water. This result is in compatible with the other researches about effecting irrigation levels on plant height [16] and [17]. The interaction effect between irrigation levels and Sorghum-Sudangrass varieties indicated that applying 100% irrigation regime resulted in a significant increase in plant height for variety KH12SU9001, while there is significantly lower plant height with application of 50% irrigation level for the same variety.

B. Number of Green Leaves

According to variance analysis results in Table II, there were no significant differences between irrigations levels and type of hybrids on number of green leaves. Number of green leaves in 100% irrigation was about 11 leaves per plant and in 75% and 50% was about 10 leaves per plant but the differences was not significant. Also, interaction results between irrigation levels and Sorghum-Sudangrass hybrids on number of green leaves in Table V indicated that there were no significant differences. Reference [10] investigated a research on water stress effects on number of green leaves in different type of sorghum genotypes and showed that there was a significant difference among different irrigation levels on number of green leaves. Reference [8] conducted a study on Gizani variety of sorghum with three irrigation intervals (6, 9, and 12 days) and reported that by increasing irrigation interval, all vegetative growth was affected significantly, and the maximum vegetative growth was recorded in irrigation interval 6 days.

C. Leaf Area

Leaf area is the parameter as an indicator for production. Table II showed that irrigation regimes did not affect on leaf area significantly but by increasing irrigation level, amount of leaf surface area could be increased. The result is in compatible with previous studies which emphasize that 50%

decrease in irrigation level in maize could lead to significant reduction of leaf area and growth rate [18]. Also, by decreasing soil moisture, leaf area and leaf area index will decrease [19]. Reference [20] studied on environmental effects (water stress) on leaf area factor and suggested that leaf area decreases because of sharp increase of aging leaves. Results of Table III showed there was a significant difference between types of genotype on leaf area parameter and genotype KH12SU9001 has a priority in leaf area amount (250.92 cm^2) in comparison to KH12SU9002 hybrid (223.83 cm^2). Therefore, depending on these results, it can be claimed that the response of leaf area depends on the types of Sorghum-Sudangrass varieties. On the other hand, no significant interaction ($P > 0.05$) between irrigation levels and Sorghum-Sudangrass hybrids was recorded on leaf area amount (Table VI), meaning that the date of leaf area for each studied variety is not affected by the irrigation regimes.

D.Stem Thickness

Regarding genotypes, KH12SU9001 had more stem thickness than genotype KH12SU9002, but the differences between them was not significant (Table IV). Based on the results of Table V, the most amount of stem thickness was related to 100% irrigation regime, while the lowest amount related to 50% irrigation level but there were not significant differences among applied irrigation regimes. Also, the interaction of irrigation regimes × Sorghum-Sudangrass hybrids indicated that hybrid varieties responded not differently to irrigation levels.

E. Protein Percent

According to Table IV, there was a significant difference between types of genotype in percent of protein. In genotype KH12SU9001, amount of protein was more than genotype KH12SU9002. This difference may be related to contribution of kernels to produce protein. Results of Table V indicated irrigation regime did not affect protein yield, and there was no significant difference among irrigation levels. Reference [21] indicated that by decreasing irrigation level, amount of protein increased in some cereals. Also, water stress effects on grain sorghum, and percent of protein in grain of sorghum were increased by decreasing irrigation level [22]. Based on Table VI, there was a significant difference between irrigation levels and types of hybrids in percent of protein. Therefore, maximum percent of protein (12.17%) was observed by the interaction of 75% irrigation regime × KH12SU9002, while lowest protein yield (7.70%) was observed with interaction of 75% irrigation regime × KH12SU9001 hybrid (Table IV).

F. Total Nitrogen Percent

Table II showed that amount of nitrogen percent in leaf and stem of Sorghum-Sudangrass hybrids was not different among irrigation levels and also between types of hybrids. According to Table III, nitrogen percent in KH12SU9001 hybrid was more than KH12SU9002 but their difference was not significant. On the other hand, maximum concentration of nitrogen percent was observed in 100% irrigation level (1.63%), while the lowest was related to 50% irrigation regime (1.40%), but their difference was not significant (Table V). The results of interaction in Table VI presented no significant differences for nitrogen percent between two sorghum hybrids under different irrigation levels.

G.Fresh Biomass

Results of variance analysis in Table III showed that irrigation regimes, type of Sorghum-Sudangrass hybrids and their interaction had significant difference at 5% significant level. According to Table IV, KH12SU9001 variety with 6472.11 kg/ha fresh biomass was more than KH12SU9002 variety with 6281.75 kg/ha in fresh biomass, and their difference was significant. Also, by comparing irrigation regime effects on fresh biomass weight, 100% irrigation had maximum amount (7131.85 kg/ha), while 50% irrigation level had the lowest amount of fresh biomass weight (5818.03 kg/ha) and their differences was significant. This decrease of fresh weight contributed to limitation of areal part of plant for photosynthesis [23]. Sorghum-Sudangrass hybrids which meet full irrigation regime, reached to the maximum weight of fresh biomass sooner, while 75% and 50% of irrigation levels take much longer time to reach maximum fresh biomass. Also, in growing stage, when the plant does not meet sufficient water, it leads to decrease in plant height and leaf area and finally fresh biomass weight. Even though, most of vegetative parameters of Sorghum-Sudangrass hybrids individually did not decrease notably by decreasing irrigation level, but the consequence of decreasing vegetative parameters led to reduces the yield of fresh biomass weight by decreasing irrigation level with significant difference. Table VI shows that there was a significant difference in interaction between irrigation levels and type of Sorghum-Sudangrass hybrids and KH12SU9001 with full irrigation regime had the priority to KH12SU9002 variety with the same irrigation regime to produce fresh biomass.

H.Dry Biomass

There were significant effects among different irrigation regime, between two types of genotypes and their interactions for dry biomass weight (Table III). With regards to types of hybrids, KH12SU9001 variety had drier biomass weight (3226.78 kg/ha) than KH12SU9002 plants (3192.48 kg/ha). Also, Full irrigated Sorghum-Sudangrass hybrids had the driest biomass weight compared to 75% and 50% irrigation regimes (Table V). It seems, decreasing dry biomass weight by decreasing irrigation level, is due to water stress and less supply of required nutrients for plant. Dry biomass weight depends on total input of sun distribution radiation, leaf area index, physiological structure of plant and the rate of photosynthesis [24]. The interaction between irrigation regime and type of Sorghum-Sudangrass hybrids was significant at a 5% level for dry biomass weight. The interaction of (KH12SU9001* 100% irrigation regime) produced the highest dry biomass weight (3462.84 kg/ha).

I. CWP and ICWP

CWP is a key to evaluate deficit irrigation strategies, and it is defined as the ratio between seed yield and volume of water applied [25]. The following equation was used to calculate the crop water productivity (WP):

$$\text{WP (kg.m}^{-3}\text{) = seed yield (kg/ha)/water applied (m}^{3}\text{/ha)} \quad (1)$$

The estimated CWP and ICWP (fresh biomass basis) for each treatment are presented in Table VII. The CWP ranged from 1.28 to 2.49 kg m^{-3}. On average, the highest and lowest CWP values were observed for treatment (KH12SU9002*50% irrigation regime) and (KH12SU9002*100% irrigation regime) respectively. Generally, CWP are influenced by crop yield potential, crop environment, and climatic characteristics of a region. Data from the table show that ICWP increased with decreasing irrigation amount, being higher in 50% irrigation regime. In the both varieties ICWP was within range of 1.17 and 1.93 kg m^{-3}. Again, the higher values related to lowest irrigation level. The values estimated for both the CWP and ICWP have some very important implications. Under a limited water supply situation where the goal may be to achieve the highest possible ICWP, utilizing a water application IR_{50} at each irrigation event offers opportunities for water savings. In other words, utilizing this water application depth offers water savings of 42% (Table VII) compared to the fully irrigated treatment but with significant difference in fresh and dry biomass weight. Similarly, utilizing an application of IR75 compared to the IR100 is another viable alternative for improving farm level water use given the average 21% in water savings. If the objective is to maximize yield, crop ET would need 42% greater than the water use at maximum CWP.

TABLE III
ANALYSIS OF VARIANCE OF SORGHUM-SUDANGRASS HYBRIDS VARIETIES, IRRIGATION LEVELS AND INTERACTION BETWEEN VARIETIES AND IRRIGATION LEVELS ON STUDIED AREA

Variables	Irrigation levels		Varieties		Varieties × irrigation levels	
	$F_{1,12}$	P	$F_{2,12}$	P	$F_{2,12}$	P
Plant height (cm)	1.24	0.32	0.23	0.63	1.16	0.34
Number of green leaves	0.98	0.40	0.83	0.37	0.56	0.58
Leaf area (cm^3)	0.51	0.61	5.23	0.04	0.08	0.92
Stem diameter (mm)	1.98	0.18	1.54	0.23	0.53	0.6
Protein (%)	0.13	0.88	17.59	0.001	18.75	0.000
Total Nitrogen (%)	1.15	0.35	0.65	0.43	0.16	0.85
Fresh biomass (kg/ha)	14012140.91	0.000	827711.16	0.000	488609.16	0.000
Dry biomass (kg/ha)	2836173.82	0.000	47135.01	0.000	24625.08	0.000

TABLE IV
EFFECT OF SORGHUM-SUDANGRASS HYBRIDS VARIETIES ON STUDIED AREA

Varieties	Plant height (cm)	Number of green leaves	Leaf area (cm^3)	Stem diameter (mm)	Protein (%)	Total Nitrogen (%)	Fresh biomass (kg/ha)	Dry biomass (kg/ha)
KH12SU9001	118.88a	10.37a	258.88a	12.64a	10.81a	1.59a	6472.11a	3226.78a
KH12SU9002	114.79a	10.08a	223.83b	12.25a	9.28b	1.49a	6281.75b	3192.48b

Means having the same letters in the same column are not significantly difference at P – value > 0.05.

TABLE V
EFFECT OF IRRIGATION LEVELS ON STUDIED VARIETIES OF SORGHUM-SUDANGRASS HYBRIDS

Irrigation levels	Plant height (cm)	Number of green leaves	Leaf area (cm^3)	Stem diameter (mm)	Protein (%)	Total Nitrogen (%)	Fresh biomass (kg/ha)	Dry biomass (kg/ha)
%100	126.00a	10.04a	250.92a	12.82a	10.16a	1.63a	7131.85a	3457.44a
%75	115.83b	10.12a	241.25a	12.46a	10.5a	1.59a	6180.98b	3203.46b
%50	109.00c	10.54a	231.90a	12.06a	9.93a	1.40a	5818.03c	2967.99c

Means having the same letters in the same column are not significantly difference at P – value > 0.05.

TABLE VI
INTERACTION BETWEEN IRRIGATION LEVELS AND SORGHUM-SUDANGRASS HYBRIDS VARIETIES ON VEGETATIVE GROWTH AND YIELD CHARACTERISTICS

Irrigation levels	Varieties	Plant height (cm)	Number of green leaves	Leaf area (cm^3)	Stem diameter (mm)	Protein (%)	Total Nitrogen (%)	Fresh biomass (kg/ha)	Dry biomass (kg/ha)
I_{100}		131.87a	10.16ab	264.98a	12.79a	9.50b	1.51a	7133.40a	3462.84a
I_{75}	*KH12SU9001*	122.70ab	10.08ab	258.40a	12.34a	7.70c	1.65a	5942.36d	3211.48c
I_{50}		102.08c	10.91a	253.26a	12.79a	10.64b	1.62a	5769.48f	3012.51e
I_{100}		119.79abc	9.91b	236.85a	12.86a	10.60b	1.30a	7130.30b	3452.42b
I_{75}	*KH12SU9002*	116.87abc	10.16ab	224.11a	11.78a	12.17a	1.61a	6419.59c	3201.55d
I_{50}		107.70bc	10.16ab	210.54a	12.12a	9.68b	1.56a	5866.58e	2923.37f

Means having the same letters in same rows and column are not significantly difference at P – value > 0.05.

TABLE VII
TOTAL CWP, ICWP AND WATER SAVINGS FOR DIFFERENT IRRIGATION REGIMES

Irrigation levels	CWP (kg/m)		ICWP (kg/m)		Irrigation water saving (%)
	KH12SU9001	KH12SU9002	KH12SU9001	KH12SU9002	
IR100	1.29a	1.28a	1.17a	1.17a	0
IR75	1.46b	1.58b	1.30bc	1.40b	21.0
IR50	2.45e	2.49e	1.89c	1.93c	42.0

Means having the same letters in the same column are not significantly difference at P – value > 0.05

IV. CONCLUSION

This study aimed to investigate the effects of different irrigation levels on growth and yield properties in two varieties of Sorghum-Sudangrass hybrids. Results showed that KH12SU9001 variety had the priority in producing more amount of leaf area, percent of protein, fresh and dry biomass yield. On the other hand, by decreasing irrigation level from IR100%, to IR50%, plant height, fresh and dry biomass weight were decreased significantly, while other measured parameters did not affect noticeably. As far as we know, the main limiting factor in agricultural productivity is water supplement. Knowledge about crop response to water and environmental factors can help us to improve water management and crop productivity. According to the results of CWP and ICWP, the data clearly show that improvement in quantity of irrigation would impact fresh and dry biomass yield significantly. This attributed to the low available soil water in the root zone. CWP would be helpful for determining the profitability and productivity of Sorghum-Sudangrass hybrids under different irrigation regimes. Thus, IR100 was recorded the highest level of productivity (1.28-1.29 $kg.m^{-3}$). With greater amount of irrigation, farmers would be able to optimize the irrigation dosages in each watering and give adequate number of watering including watering at critical stages of plant growth. This would not only increase the yield, but also reduce non-beneficial depletion.

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