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EFFECT OF DEFOLIATION ON GROWTH AND YIELD COMPONENTS OF TWO SORGHUM GENOTYPES

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ABSTRACT

Two field experiments were conducted at Shandaweel Agric. Res. Station in Sohag, Egypt during 2002 and 2003 seasons. The aim was to identify the effect and contribution of individual leaves removal from flag leaf through the 6^{th} leaf and 7^{th} leaf to down (old Leaves) as well as control treatment (without defoliation). These treatments were applied on two sorghum genotypes Dorado and Shandaweel 2 hybrid The obtained results indicated that removing any leaf from plant significantly decreased head dry weight, grain weight/plant, fodder weight/plant, 1000 kernel weight, number of grains/head leaves dry weight, stem dry weight and total biomass compared to control treatment. The highest depressions percentage (DP) in head dry weight, grain weight/plant, fodder weight/plant, 1000 kernel weight, leaves dry weight and total biomass were observed with removing 7^{th} leaf to down while number of grains /head and stem dry weight were highest depressed with removing the 4^{th} leaf treatment. On the other hand, the contribution of leaf area unit (LUC) revealed that the highest contribution displayed by the flag leaf followed by 2^{nd} leaf in head dry weight, grain weight/plant, fodder weight/plant, 1000-kernel weight, number of grains /head and total biomass. While nearly equal LUC values were obtained in leaves dry weight and stem dry weight by removing flag or 2^{nd} leaf. Whereas, the lowest LUC values in head dry weight, grain weight/plant, fodder weight/plant, number of grains/head, stem dry weight and total biomass by removing 7^{th} leaf to down. Also, removing 5^{th} leaf gave lowest LUC values in 1000- kernel weight and leaves dry weight. Shandaweel 2 hybrid was higher than Dorado variety in most growth and yield traits. Partial regression coefficients were significant for grain number/head by removing 4^{th} leaf , grain weight/head by removing each of flag, 4^{th}, 6^{th}, and 7^{th} leaves to down, head weight by defoliation each of , 4^{th} and 7^{th} to down and 1000-kernel weight by removing each of flag, 2^{ed}, 3^{rd}, 6^{th} and 7^{th} leaves to down. Partial regression coefficient was significant for fodder weight/plant while the reverse was true for plant height.

INTRODUCTION

Grain sorghum (*Sorghum bicolor* (L.) Moench) grows in about 0.390 million feddan in Upper Egypt, so it ranks the fourth among cereal crops after wheat, rice and maize in terms of acreage and production. It is usually used for both food and feed over the world including Egypt, where the cereal national production suffers large gap with the total consumption of the explosive population. Despite of the moderate tolerance of sorghum plants to drought and salinity, the old leaves display marked senescence in its cultivated area. This phenomenon encourages farmers to defoliate old leaves as feed for their animals.

Several investigators observed the deleterious effects of defoliation on crop plants. defoliation treatments upon crop plants of sorghum, maize and soybean induce significant reductions in grain yield and seed weight as reported by (*Hanway, 1969; Tufail, 1971; Gates and Mortimore, 1972; Pinter and Kalman, 1979* and *Fehr et al; 1981*). The magnitude of yield reduction associates with time and severity of defoliation. *Hanway (1969)* reported that

50% defoliation at the 10^{th}, 16^{th} leaf and kernel blister stages in corn reduced grain yields to 85, 75 and 80%, respectively, of the non-defoliated control. Removal of all leaves at these stages reduced yield to 0, 2, and 3 % respectively of the control. *Stickler and Pauli (1961)* studied the effect of defoliation during the reproductive stage on sorghum and reported that grain yield showed significant differences after defoliation at boot and anthesis stages, but these differences non-consistent over years.

Both grains number and weight are declined by defoliation in sorghum and corn (*Stickler and Pauli, 1961; Hanway, 1969* and *Tollenaar and Daynard, 1978*). However, early defoliation in corn decreased grain numbers while defoliation post-pollination reduced grain weight. In addition, defoliation reduced the kernel-filling period in corn (*Tollenaar and Daynard 1978; Barnett and pearce 1983* and *Jones and Simmons, 1983*). Kernel growth rates in corn were reduced by complete defoliation at 12^d post mid silking (*Jones and Simmons, 1983*), but not at 24^d post-mid-silking.

Several deleterious effects occur after defoliation. The senescence is accelerated by defoliation so *Pappelis and Katsanos (1966)* observed that defoliation or root injury can increase the rate of cell death in sorghum stem tissues. The incidence of natural infection by *Gibberella zeae* in corn increased with increasing defoliation after mid-silking (*Gates and Mortimore, 1972*). Severe defoliations caused a loss in fertilization, decline in grain yield. On the other hand, defoliation improves pith characteristics and decrease lodging.

Recently, *Haile et al. (1998)* on soybean, *Julio et al. (2001)* on sunflower, *Laur et al. (2004)* as well as *Subedi and Ma (2005)* on maize estimated the reduction in yield and its component by removing individual and group leaves.

In Egypt, *Hammam (1987)* showed that early defoliation (at silking) caused the greatest reduction in all yield components as well as grain yield in the two seasons, whereas shelling percentage was not significantly affected by defoliation. *Salwau and Shams El-Din (1992)* found that stripping treatments significantly decreased ear yield/plant, grain yield/plant, 100-grain weight and grain yield per feddan as compared to without stripping in the two seasons. *EL-Bana (2001)* reported that the highest means of plant height, number of grains /row, ear grain weight and 100-grain weight as well as grain and stover yields/fed. for maize plants were achieved by the control (without stripping) followed by stripping leaves under 1^{st} ear then stripping leaves above 1^{st} ear and stripping all leaves except ear leaf treatment, respectively.

However, trivial information about individual leaf removal effects on grain yield and its components on sorghum are available, so the objective of this study was to determine the effect of each leaf removal beginning from the flag leaf on growth and yield attributes of some sorghum genotypes.

MATERIALS AND METHODS

Two sorghum genotypes significantly have different plant height (the variety Dorado and Sh-2 hybrid) were used to find out their response to defoliation. This investigation was conducted at Shandaweel Agricultural

Research Station during the two successive 2002 and 2003 growing seasons. Eight defoliation treatments were applied in each treatment one leaf was removed except treatment number seven so the treatments were the flag leaf, the second leaf and the sixth leaf for treatments 1, 2 ... and 6, respectively. The treatment number 7 was by defoliation from leaf seventh to down and the treatment number 8 was control (no leaf removal). The split plot design with 4 replications was used. Cultivars represented the whole-plots, while the eight defoliation treatments were allocated in the sub plots.

Sub-Plot area was 3 X 4 m^2 (1/350 fed) each plot included four ridges 60 cm apart. Sowing date were 5 and 16 June in 2002 and 2003 seasons respectively. Planting was in hills spaced 20 cm apart within ridges. Seedlings were thinned to two plants per hill after 20 days from sowing. All treatments were fertilized with phosphorus (150 kg calcium super-phosphate 15.5% P_2O_5) at sowing and 100 kg N/fed as urea 46.5% in two times at 21 and 36 days from sowing before 1st and.2nd irrigation The defoliation process was performed after the complete heading stage at 75 days from sowing. Other cultural practices were applied as recommended for grain sorghum production in Egypt.

Physical and chemical properties of the experimental site at Shandaweel Research Station in Sohag are shown in Table 1.

Table 1: Physical and chemical properties of the experimental site.

Mechanical analysis	
Clay %	21.11
Silt %	29.92
Fined sand %	41.54
Coarse sand %	7.63
Soil type	Sandy loam
Chemical analysis	
O. M. %	1.34
$CaCO_3$ %	1.28
E. C. (m mhos/25°C	1.16
Available nutrients (ppm)	
N	51.20
P	6.93
K	187.6

The data that based on individual plants were recorded on five competitive random plants in each plot on number of green leaves, number of dry leaves, plant height, leaves dry weight, stem dry weight, total biomass, head weight/plant, grains weight/plant, fodder weight/plant, 1000-kernel weight and number of grains / head.

Statistical analysis

Data were statistically analyzed according to (*Steel and Torrie, 1980*). The test of homogeneity showed homogeneous error variances in both seasons. Combined analysis of variance for the two seasons was undertaken using the appropriate analysis of variance and treatment means were compared by least significant difference (LSD) at 5% levels of probability.

Aiming to compute the specific effect of individual leaf removal on the studied traits, the multiple regression technique was used. The trait variable considered the independent and the dependent variables for each constructed of one and zero columns where zero expressed leaf removal and its presence equal one.

Depression percentage (DP):

According to the following equation:

$$DP = \frac{V_C - V_D}{V_C} \times 100 \qquad (1)$$

Where: V_C = Trait value for the control treatment (without defoliation)
V_D= Trait value for the defoliation treatment.

Leaf Unit Contribution (LUC):

According to the following equation:

$$LUC = \frac{V_C - V_D}{RLA} \qquad (2)$$

Where: RLA= Removal Leaf Area (cm^2).
V_C and V_D were mentioned in equation number (1).

Net assimilation rate depression (NARD):

According to Watson (1947), NARD was calculation as follows:

$$NARD = \frac{(W2-W1)*(Log\ L2-Log\ L1)}{L2-L1} = g/cm^2/5weeks \qquad (3)$$

Where: W2=Weight of control (Whole plant). W1=Weight of leaf treatment (defoliation treatment). L2=Leaves area of whole plant. L1=Leaves area in leaf treatment (same defoliation treatment). Time from defoliation to harvest 35 days (110-75=35 days=5 weeks).

The equations number 1 and 2 were used for head weight, grain weight/plant, fodder weight/plant, 1000-kernel weight, number of grains/head, leaves dry weight, stem dry weight, total and total biomass while equation number 3 used for total biomass only.

All data were recorded at harvest time except length and maximum width of removed leaves which were recorded at 75 days after sowing to calculate leaf area according to Stickler *et al.* (1961). The plant samples were portioned head, stem and leaves. Stem and leaves samples dried at 70 ° while heads dried in open air, weighted and then threshed. Grains moisture was adjusted 12% moisture.

RESULTS AND DISCUSSION

The test of homogeneity showed homogeneous error variance for all studied traits in both seasons, therefore the combined data of the both seasons have been discussed.

Morph-physiological traits: Average plant height of the two sorghum genotypes and their response to defoliation were presented in Table 2. As expected, the Sh-2 hybrid was significantly taller than the variety Dorado. These genotypes significantly showed different response to defoliation so that the interaction was highly significant. Plant height of Dorado was significantly shortened after defoliation for any treatments than normal plants. The three upper leaves and treatment number 7 decreased plant heights to about 95% of non-defoliated plants, while leaves number 4, 5 and 6 were decreased plant heights to about 93%. Contrasting to Dorado case, the defoliation significantly elongated plant height of Sh-2 hybrid in all treatments except leaf number 6 which significantly decreased plant height. However, the most increment in plant heights were observed after flag leaf removal.

Data of number of either green or dry leaves shown in Table 2 indicated that defoliation significantly decreased active or green leaves and increased dry or died leaves in both tested genotypes. The most effective treatment on both genotypes was recorded by removing 7^{th} leaf to down. Also, the same trend for number of green leaves was true by removal of flag leaf of Sh-2. So the results indicted that with other different responses of the two cultivars displayed significant interactions. Apparently, the defoliation accelerates leaf senescence which may be due to plant wounded. Plant wounding permits for infections or physiological hurts. In addition, the weight of dry leaves collected from both green and dry leaves were markedly depressed suggesting that either leaf area or the specific weight were decreased as a response for plant hurts, return to Table 2. However, the effects of plant injury on senescence of sorghum tissue were reported by *Pappelis and Katsanos (1966)* and *Pinter and Kalman (1979),* while *Gates and Mortimore (1972)* observed the effect of defoliation on stalk rot in corn. In Egypt same results in corn reported by *El-Bana (2001)*.

Biomass and its portions: Data presented in Tables (2 and 3) indicate that total dry matters and their portions of the two tested cultivars were significantly different, since they have different plant height. Fodder weight/plant was 463.33 and 325.38 g for Sh-2 hybrid and Dorado variety, respectively. After aerial drying, they were 240.36 and 197.48 g, respectively. Total biomass of Sh-2 hybrid partitioned to 32.6, 105.5 and 103.5 g for leaves, stem and grains, while the cultivar Dorado gave 30.8, 104.6 and 57.1 g, respectively.

Defoliation dramatically affected total biomass and its portions. On average, one leaf removal depressed total biomass, leaves weight, stem weight, grains weight by 27.31, 24.68, 38.43 and 13.77%, respectively. Obviously, the stem weight was the most affected portion while grain weight was the least affected portion. However, both leaves and stem dry matters displayed significant interactions between cultivars and defoliation treatments so that the weight depression for leaves and stem were (25.05 and 39.01) and (24.33 and 37.82) for the variety Dorado and Sh-2 hybrid, respectively, the depressions of Sh-2 hybrid more sounded.

Defoliation of leaf number 4 or 7 to down significantly decreased leaves dry weight on the variety Dorado, while all leaves except flag leaf and leaf number 3 decreased leaves dry weight for Sh-2 hybrid. Regarding stem weight, any leaf removal significantly decreased stem dry weight except leaf number 3 for variety Dorado which insignificantly affected stem dry weight. Respecting total biomass and grain weight per plant, the results indicated that any leaf removal on either cultivar significantly depressed both traits. Such depression is due to that any active leaf on plant may play and important role as much as induced reduction which is contributing to total plant growth and yield.

The previous results are in the same line with that reported by Stickler and *Parili (1961) and Tulail (1971)*

Yield Components: The results in Table 3 show that Sh-2 hybrid gave the highest significant grain weight per plant, fodder weight/plant, number of grains/head comparing with same characters in Dorado variety. This may be attributed to that Dorado variety is the male of parent El-Nagouly *et al.* (1997). Removing leaves from 7 to down gave the lowest grain weight/plant, fodder weight/plant and 1000 kernel weight. This may due to higher number and area of leaves from 7 to down which removed. The interaction between genotypes and leaf treatments were significant in fodder weight /plant. The lowest value was by removing flag leaf from short variety Dorado. This result indicates that both defoliation treatments may affect both genotypes a similar by removing leaves from 7^{th} to down or different by removing flag leaf manner in respect of fodder weight. These results concert with that statements reported by *Hanway, 1969; Tufail, 1971; Gates and Mortimore, 1972; Pinter and Kalman, 1979 and Fehr et al., 1981*. In Egypt same results in corn were reported by *Hammam (1987), Salwau and Shams (1992) and El-Bana (2001)*.

Depression percentage (DP): The results in Table 4 showed that the depression percentage in treatment number from 1 to 7 in head dry weight, grain weight/plant, fodder weight/plant, 1000 kernel weight, number of grains/head, leaves dry weight, stem dry weight and total biomass. This table indicate that maximum depression percentage by removing seven to down leaves in head dry weight (19.8 %), grain weight per plant (21.8%), fodder weight per plant (31.%), 1000 kernel weight (15.3%). These may be attributed to decrease leaves area which removed were largest area (1438 cm^2 in Dorado and 1428 in Sh-2 hybrid). Despite of small area of flag leaf was (132 cm^2 in Dorado variety or 94 cm^2 in Sh-2 hybrid), depression percentage for it in most characters approximately equal or even higher than that due to fourth leaf which had larger area (525 cm^2 in Dorado variety and 537 cm^2 in Sh-2 hybrid), since the depression percentage occurred by removing flag leaf and fourth leaf were (18.4%, 16.4%) in head dry weight (16.1%,17.1%) in grain weight/plant, (22.5%, 26.7%) in fodder weight/plant These may be attributed to flag leaf exposes to the sun and light more than other leaves and the contribution of leaf area unit (LUC) was larger in the most studied characters as show in Table 5 as well as NAR decreases. *Haile et al. (1998)* in soybean showed that defoliation caused significant yield reduction (15.70%) in all cultivars. *Julio et al. (2001)* reported that the yield loss increased with increasing level of defoliation. Pre-flowering stage was the most sensitive. At this stage a 100% defoliation of the leaf surface resulted in 92% yield loss, reducing both the number of seeds per head and 1000-seed weight.

Table 2: Average values of growth measures as affected by defoliation of two sorghum cultivars in 2002, 2003 and combined over seasons.

Characters / Treatments	No. of green leaves /plant			No. of dry leaves/plant			Plant height (cm)		
	2002	2003	comb	2002	2003	comb	2002	2003	comb
Effect of genotypes									
Dorado	9.1	8.7	8.9	4.1	3.9	4.0	130.0	111.4	120.7
Sh-2 hybrid	8.6	8.2	8.4	5.7	5.2	5.4	181.1	174.6	177.8
F test	**	*	*	**	***	**	***	***	***
Effect of Leaves removal									
Remove flag leaf	8.2	7.6	7.9	6.7	6.2	6.4	152.5	154.0	153.2
Remove 2 nd leaf	8.5	8.0	8.2	6.8	6.2	6.5	156.7	143.6	150.1
Remove 3 rd leaf	8.8	8.1	8.5	5.8	5.5	5.6	156.9	144.2	150.5
Remove 4 th leaf	9.0	8.3	8.6	4.2	3.9	4.1	156.4	141.3	148.9
Remove 5 th leaf	10.4	9.6	10.0	4.4	4.1	4.2	155.0	142.3	148.7
Remove 6 th leaf	8.9	8.4	8.7	4.8	4.5	4.7	150.4	136.2	143.3
Remove from 7to down	5.5	6.0	5.7	2.4	2.0	2.2	158.7	139.1	148.9
No Remove leaf	11.9	11.3	11.6	4.1	3.8	3.9	158.1	143.3	150.7
LSD 0.05	1.04	0.96	0.68	0.79	0.77	0.53	3.83	5.67	4.43

Characters / Treatments	Leaves dry weight (g)			Stem dry weight (g)			Total biomass (g)		
	2002	2003	comb	2002	2003	comb	2002	2003	comb
Effect of genotypes									
Dorado	29.7	31.9	30.8	97.1	104.6	100.8	211.6	220.1	215.8
Sh-2 hybrid	29.7	35.5	32.6	97.1	114.0	105.6	309.3	250.1	279.7
F test	NS	**	*	NS	**	*	***	**	***
Effect of Leaves removal									
Remove flag leaf	34.6	38.9	36.7	106.5	120.8	113.7	261.1	250.4	255.7
Remove 2 nd leaf	30.4	34.5	32.5	86.9	96.7	91.8	252.6	224.4	238.5
Remove 3 rd leaf	34.8	40.4	37.6	108.8	124.1	116.4	278.3	267.9	273.1
Remove 4 th leaf	25.3	29.2	27.2	66.6	73.6	70.1	232.5	177.6	205.1
Remove 5 th leaf	30.1	34.0	32.1	100.8	114.1	107.4	267.5	237.0	252.3
Remove 6 th leaf	31.0	34.8	32.9	84.8	94.9	89.9	255.1	213.0	234.1
Remove from 7to down	13.1	14.8	14.0	76.3	85.6	80.9	204.1	192.8	198.4
No Remove leaf	38.0	42.8	40.4	146.2	164.7	155.5	332.1	317.7	324.9
LSD 0.05	4.92	6.02	3.74	22.36	6.65	16.35	22.11	30.67	21.98

Effect of the Interaction between genotypes and defoliation treatments for combined analysis

Characters / Treatments	No. of green leaves		No. of dry leaves		plant height		Leaves dry weight		Stem dry weight	
	Dorado	Sh-2	Dorado	Sh-2	Dorado	Sh-2	Dorado	Sh-2	Dorado	Sh-2
Remove flag leaf	10.0	5.8	4.6	8.3	121.7	184.8	35.5	38.0	109.3	118.1
Remove 2nd leaf	9.3	7.2	4.2	8.8	120.3	180.0	31.8	33.2	90.0	93.5
Remove 3rd leaf	8.0	9.0	5.6	5.7	122.0	179.1	36.5	38.7	113.3	119.5
Remove 4th leaf	8.3	8.9	3.7	4.4	119.5	178.2	26.3	28.1	69.2	71.1
Remove 5th leaf	9.8	10.2	4.1	4.4	117.0	180.3	31.1	33.1	105.5	109.3
Remove 6th leaf	9.2	8.3	3.3	6.0	116.6	170.0	32.0	33.8	86.8	93.0
Remove from 7to down	5.7	5.7	2.3	2.1	121.8	176.0	13.5	14.4	79.5	82.3
No Remove leaf	11.0	12.2	4.2	3.7	127.1	174.3	39.4	41.4	153.1	157.8
LSD 0.05	0.96		0.75		6.26		5.65		19.44	

P=probability (* If 0.01<P<=0.05 ** If 0.001<P<=0.01 *** If P<=0.001)

Table 3: Average values of yield and its components as affected by defoliation of two sorghum cultivars in 2002, 2003 and combined over seasons.

Characters / Treatments	Head dry weight (g)			Grain weight /plant (g)			Fodder weight/plant (g)		
	2002	2003	comb	2002	2003	comb	2002	2003	comb
Effect of genotypes									
Dorado	84.8	83.7	84.2	61.9	52.4	57.1	313.5	337.3	325.4
Sh-2 hybrid	182.5	100.6	141.6	133.2	73.7	103.5	495.4	431.3	463.3
F test	***	***	***	***	***	***	***	***	***
Effect of Leaves removal									
Remove flag leaf	120.0	90.7	105.3	87.6	65.5	76.6	371.0	379.5	375.2
Remove 2 nd leaf	135.3	93.2	114.3	98.8	61.1	80.0	407.3	386.5	396.9
Remove 3 rd leaf	134.7	103.5	119.1	98.3	68.9	83.6	414.4	404.5	409.4
Remove 4 th leaf	140.7	74.8	107.8	102.7	48.7	75.7	416.1	294.0	355.1
Remove 5 th leaf	136.6	88.9	112.8	99.7	60.0	79.9	417.0	415.0	416.0
Remove 6 th leaf	139.2	83.3	111.3	101.7	66.2	83.9	419.9	356.2	388.0
Remove from 7to down	114.7	92.4	103.5	83.7	59.1	71.4	336.9	323.0	330.0
No Remove leaf	147.9	110.2	129.0	107.9	74.6	91.3	452.9	515.6	484.3
LSD 0.05	**17.0**	**12.3**	**10.5**	**12.4**	**8.3**	**7.5**	**49.7**	**62.9**	**40.4**

Characters / Treatments	1000-kernel weight (g)			No. of grains/head		
	2002	2003	comb	2002	2003	comb
Effect of genotypes						
Dorado	29.8	26.2	28.0	2083.2	2005.6	2044.4
Sh-2 hybrid	29.9	26.2	28.0	4490.7	2810.6	3650.6
LSD 0.05	NS	NS	NS	***	***	***
Effect of Leaves removal						
Remove flag leaf	27.9	27.6	27.7	3163.2	2414.4	2788.8
Remove 2 nd leaf	30.7	24.8	27.7	3231.8	2488.9	2860.4
Remove 3 rd leaf	30.3	26.7	28.5	3295.5	2558.0	2926.8
Remove 4 th leaf	30.5	26.6	28.6	3392.2	1823.3	2607.7
Remove 5 th leaf	30.2	27.6	28.9	3304.7	2161.9	2733.3
Remove 6 th leaf	31.3	25.4	28.3	3305.6	2605.4	2955.5
Remove from 7to down	26.8	23.1	25.0	3119.8	2541.5	2830.7
No Remove leaf	31.0	28.0	29.5	3482.6	2671.2	3076.9
LSD 0.05	**1.6**	**1.4**	**1.1**	**NS**	**302.8**	**273.1**

Effect of the Interaction between genotypes and defoliation treatments for combined analysis

Characters / Treatments	Fodder weight/plant	
	Dorado	Sh-2 hybrid
Remove flag leaf	272.6	477.9
Remove 2 nd leaf	318.0	475.8
Remove 3 rd leaf	359.1	459.8
Remove 4 th leaf	304.3	405.8
Remove 5 th leaf	353.0	479.0
Remove 6 th leaf	321.5	454.6
Remove from 7to down	285.5	374.4
No Remove leaf	389.0	579.5
	57.1	

P=probability (* If 0.01<P<=0.05 ** If 0.001<P<=0.01 *** If P<=0.001)

100% defoliation when back of head a pale yellow stage caused a 50% yield loss, while at physiological maturity stage defoliation had no effect on yield. *Lauer et al. (2004)* forage yield decreased 16% when 100% defoliation occurred at 7th leaf stage. Likewise 100% defoliation decreased forage yield 43, 70, and 40% at 10th leaf, silking, and dough stages growth stages, respectively. This likely occurred because both increased leaf removal and decreased grain yield combine to reduce forage yield. Also, *Subedi and Ma (2005)* reported that remove all leaves below the maize ear leaf and ear leaf alone in the conventional hybrid caused 19 to 26 % and 17 to 25 % reduction in grain yield, respectively. When all leaves above the ear leaf were removed, kernel number, kernel dry matter were reduced by 84 to 94 % in the leafy hybrid compared with a 40 to 50% reduction in the conventional hybrid.

Leaf Unit Contribution (LUC): Table 4 shows that the contribution of leaf area unit (LUC) revealed that the highest contribution displayed by the flag leaf followed by 2nd leaf in head dry weight (0.25 & 0.06 g/cm^2), grain weight/plant (0.16 & 0.05 g/cm^2), fodder weight/plant (1.16 & 0.37 g/cm^2), 1000-kernel weight (0.02 & 0.008 g/cm^2), number of grains /head (3.07 & 0.90 grains/cm^2) and total biomass (0.52 & 0.41 g/cm^2). While nearly equal LUC values were obtained in leaves dry weight (0.03 & 0.04 g/cm^2) and stem dry weight (0.32 & 0.30 g/cm^2) by removing flag or 2nd leaf. Whereas, the lowest LUC values in head dry weight, grain weight/plant, fodder weight/plant, number of grains/head, stem dry weight and total biomass by removing 7th leaf to down. Thereby, LUC was lowest trend from upper to lower leaf in most traits (Table 4 and Fig. 1, 2 & 3). This may attributed to that upper leaves are intercepting higher light intensity than lower leaves and thereby, higher efficiency per unit leaf area light utilization by upper leaves which appeared as more contribution to most growth and yield traits. Also, removing 5th leaf gave lowest LUC values in 1000- kernel weight and leaves dry weight. These results concert with that statements reported by *Lauer et al. (2004)* and *Subedi and Ma (2005)*.

Net Assimilation Rate Decreases (NARD): The data in Table 5 show that Sh-2 hybrid exceeded Dorado variety in NARD during five weeks from pre-flowering to harvest. Maximum NARD during five weeks were occurred by removing flag leaf or second leaf (0.100 and 0.059 g/g/5week) in total biomass while minimum NARD was by removing Leaves from 7th to down.

Multiple regression analysis results: Aiming to find each leaf removal effects on plant height, fodder weight/plant, head weight, grain yield/plant, 1000-kernel weight and kernels number/plant of the two studied cultivars and the combined data of them, the multiple regression analysis were performed for each cultivar alone, and the results were shown in Table 6. The coefficients of determination of the first seven leaves were estimated about 73.98, 90.63, 76.88, 88.33, 91.24 and 62.00% for plant height, fodder weight/plant, head weight, grain yield/plant, 1000-kernel weight and kernels number/plant for the variety Dorado. Thus the defoliation treatments were reasonably illustrate the variation of 1000-kernel weight, fodder weight per plant and grain yield /plant for this variety, while the coefficients of determination of other traits were quite acceptable.

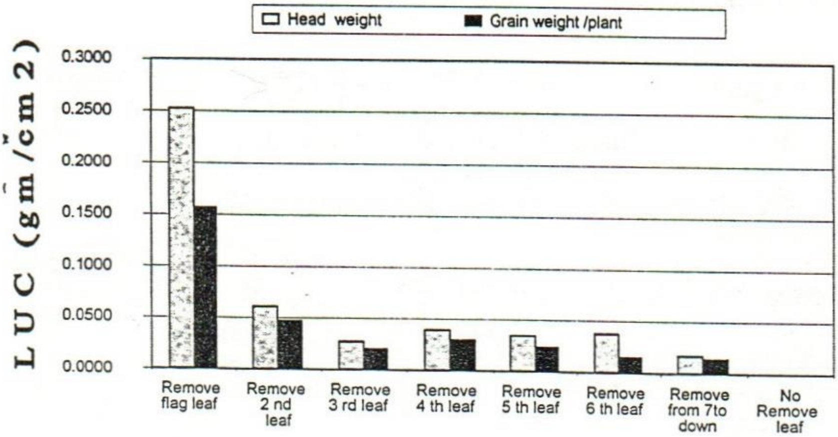

Fig. 1: LUC for head and grain weight (g/cm^2)

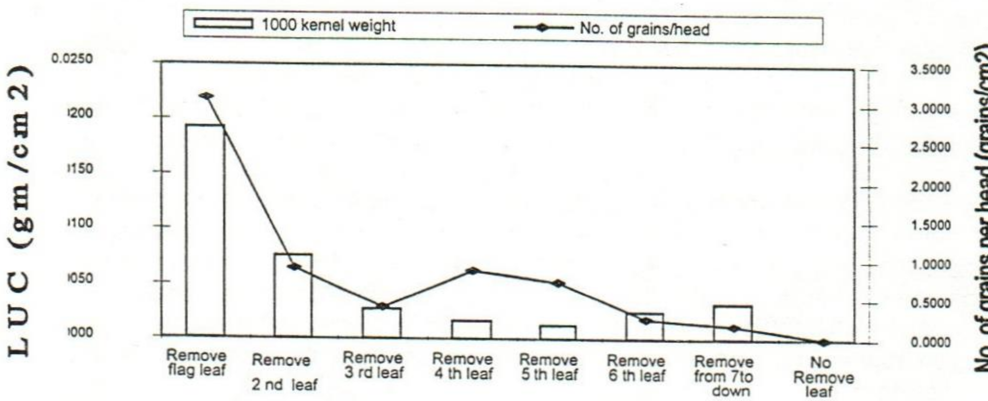

Fig. 2: LUC for 1000 kernel weight and Number of grains

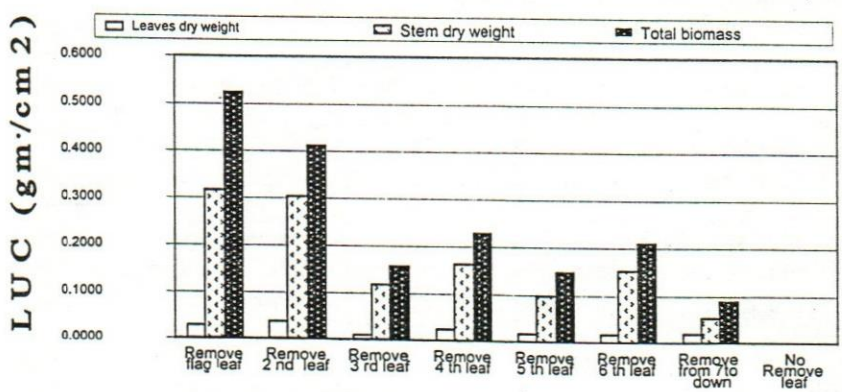

Fig. 3: LUC for leaves, stem and total biomass (g/cm^2)

Regarding the Sh-2 hybrid, the estimates were 85.14, 93.30, 44.47, 64.04, 87.65 and 59.0%, in the same arrangement.

Table 4: Average values of depression percentage and leaf unit contribution (LUC) to some growth and yield components as affected by defoliation combined over genotypes and seasons.

Leaves treatments	Head dry weight		Grains weight /plant		Fodder weight/plant		1000--kernel weight	
	DP	LUC (g/cm)	DP	LUC (g/cm)	DP	LUC (g/cm)	DP	LUC (g/cm)
Remove flag leaf	18.4	0.2528	16.1	0.1568	22.5	1.1637	6.1	0.0192
Remove 2 nd leaf	11.4	0.0613	12.4	0.0471	18.0	0.3646	6.1	0.0075
Remove 3 rd leaf	7.7	0.0268	8.4	0.0209	15.5	0.2030	3.4	0.0027
Remove 4 th leaf	16.4	0.0395	17.1	0.0290	26.7	0.2406	3.1	0.0017
Remove 5 th leaf	12.6	0.0338	12.5	0.0238	14.1	0.1425	2.0	0.0013
Remove 6 th leaf	13.7	0.0372	8.1	0.0155	19.9	0.2022	4.1	0.0025
Remove from 7to down	19.8	0.0179	21.8	0.0139	31.9	0.1081	15.3	0.0032

Leaves treatments	No. of grains/head		Leaves dry weight		Stem dry weight		Total biomass	
	DP	LUC (grains/ cm)	DP	LUC (g/cm)	DP	LUC (g/cm)	DP	LUC (g/cm)
Remove flag leaf	9.4	3.0731	9.2	0.0280	26.9	0.3167	21.3	0.5242
Remove 2 nd leaf	7.0	0.9032	19.6	0.0376	41.0	0.3033	26.6	0.4114
Remove 3 rd leaf	4.9	0.4068	6.9	0.0084	25.1	0.1179	15.9	0.1563
Remove 4 th leaf	15.2	0.8736	32.7	0.0251	54.9	0.1627	36.9	0.2282
Remove 5 th leaf	11.2	0.7170	20.5	0.0169	30.9	0.0978	22.3	0.1477
Remove 6 th leaf	3.9	0.2549	18.6	0.0174	42.2	0.1519	27.9	0.2102
Remove from 7to down	8.0	0.1724	65.3	0.0184	48.0	0.0519	38.9	0.0880

Table 5: Average values of net assimilation rate decrease (NARD) in total biomass as affected by defoliation in 2002, 2003 and combined seasons.

Leaves treatments	2002	2003	Comb.
	Effect of genotype		
Dorado	0.01803	0.02738	0.02271
Sh-2 hybrid	0.05136	0.05681	0.05408
F test	***	**NS**	**
	Leaves treatment		
Remove flag leaf	0.09474	0.10558	0.10016
Remove 2 nd leaf	0.05566	0.06166	0.05866
Remove 3 rd leaf	0.02722	0.03597	0.03160
Remove 4 th leaf	0.03569	0.05813	0.04691
Remove 5 th leaf	0.02635	0.02846	0.02741
Remove 6 th leaf	0.02240	0.03288	0.02764
Remove from 7to down	0.01551	0.01406	0.01478
LSD	**0.029386**	**0.033745**	**0.021978**

P=probability (* If 0.01<P<=0.05 ** If 0.001<P<=0.01 *** If P<=0.001)

The differences between those two cultivars may be due to varied relative importance of plant leaves in those two cultivars. This deduction can be re-suggested from the combined estimates that were 26.22, 90.09, 54.08, 3.90, 94.31 and 2.00%, respectively. However, the reasonable illustration of the variation

Table 6: Partial regression coefficients of defoliation on same agronomic traits of two sorghum genotypes in 2002 and 2003 seasons.

Effects	Grain numbers	Grain weight /head	Green weight /plant	1000 kernel weight	Plant height	Head weight
			Dorado			
Constant	764 NS	1.1NS	-119.8 NS	18.43***	76.1***	2.3NS
Leaf R 1	222*	14.7***	116.4***	1.6*	5.37NS	20.37***
Leaf R 2	204*	8.47**	71***	1.485*	6.87*	11.65*
Leaf R 3	156 NS	1.17NS	29.8 NS	0.495 NS	5.16NS	1.69NS
Leaf R 4	273**	10.92***	84.7***	0.4NS	7.62**	15.06**
Leaf R 5	282**	11.39***	36*	0.71NS	10.08***	16.29**
Leaf R 6	116 NS	8.58**	67.4***	1.39*	10.5***	12.04*
Leaf R 7	209*	11.8***	103.5***	4.88***	5.35NS	16.54**
R^2	0.62	0.88	0.91	0.91	0.74	0.77
			Sh-2 hybrid			
Constant	1719 NS	-1.4NS	-350***	17.38***	202.5***	-2.6NS
Leaf R 1	354 NS	18.92*	101.7***	1.86**	-10.46***	27NS
Leaf R 2	229 NS	12.29 NS	103.8***	2.055**	-5.73*	17.9NS
Leaf R 3	145 NS	12.94 NS	119.8***	1.455*	-4.81NS	18.2NS
Leaf R 4	665**	19.63*	173.7***	1.41*	-3.91NS	27.5NS
Leaf R 5	405 NS	11.38NS	100.5***	0.38 NS	-5.99*	16.3NS
Leaf R 6	127 NS	16.91*	125***	.88NS	4.35NS	23.5NS
Leaf R 7	283 NS	24.28**	205.1***	4.135***	-1.71NS	34.4*
R^2	0.59	0.64	0.93	0.88	0.85	0.44
			Combined			
Constant	1242 NS	-.2 NS	-235*	17.91***	139.3***	-0.2NS
Leaf R 1	288 NS	16.81**	109***	1.73***	-2.54NS	23.7*
Leaf R 2	217 NS	10.38 NS	87.4***	1.77***	0.57NS	14.8NS
Leaf R 3	150 NS	7.06 NS	74.8***	0.975*	0.18NS	9.9NS
Leaf R 4	469 *	15.28*	129.2***	0.905 NS	1.86NS	21.3*
Leaf R 5	344 NS	11.39 NS	68.2**	0.545NS	2.05NS	16.3NS
Leaf R 6	121 NS	12.75*	96.2***	1.135*	7.43NS	17.8NS
Leaf R 7	246 NS	18.04**	154.3***	4.507***	1.83NS	25.5*
R^2	0.02	0.04	0.90	0.94	0.26	0.54

due to defoliation did not elongate for all traits except for fodder plant weight and 1000-kernel weight. So the effect of different leaves defoliations varied from cultivar to other for these traits. But the results for plant fodder weight and 1000-kernel weight can be used for other cultivars or at least for the two studied cultivars.

The partial regression coefficients of plant height on leaves number 2, 4, 5 and 6 were significant for the variety Dorado, while the coefficients on leaves number 1, 2 and 5 were significant for the Sh-2 hybrid; in addition, the effects of the two cultivars had opposite directions. The effect in Dorado was positive so the defoliation shortened plant height; in contrast the effects in

Sh-2 hybrid were negative so the defoliation slightly increased plant height. These results are in the same line with that obtained from traditional statistical analysis Table 2.

Regarding plant fodder weight, any leaf removal showed significant coefficient for both cultivars and their combined data in the same direction toward increasing the weight, so each leaf removed decrease the biomass, the same result was previously obtained (Tables 2 & 3). The partial regression coefficients of head weight on leaves number 1, 2, 3, 5, 6 and 7 were significant for the variety Dorado, while the coefficients of all leaves were insignificant for the Sh-2 hybrid except leaf number 7 that displayed significant effect. The significant effects of the combined data were observed for leaves number 2, 4 and 7.

Despite the insignificant interactions between defoliation and cultivars in the traditional statistical analysis (Table 3), the grain yield/plant and its components displayed different responses in the two cultivars and to different defoliation treatments. The estimates of different leaves effects on grain yield/plant in Dorado were significant, except that of leaf number 3, while leaves number 1, 4, 6 and 7 in Sh-2 hybrid caused significant effects. The effects of defoliation on 1000-kernel weight were significant for upper two leaves 1 and 2 and the lower two leaves 6 and 7. While all leaves of the Sh-2 hybrid showed significant effects on 1000-kernel weight except leaves number 5 and 6. The kernel number/plant was significantly affected by defoliations of leaves number 1, 2, 4, 5 and 7 of Dorado cultivar, while it was insignificantly affected by any leaf removal of the Sh-2 hybrid, except for leaf number 4. The latter result may be due to different time of flowering in the two cultivars, Sh-2 hybrid was slightly earlier than Dorado, and thus the effect of defoliation initiated in Sh-2 hybrid after some time of pollination and fertilization.

Nevertheless, the defoliation caused deleterious effects on plant elongation, caused hurt wound, accelerated leaf senescence, inhibit carbohydrate synthetic factories via decreasing leaf area and leaf senescence, decreasing nutrition sink as the total biomass decreased and ultimately depressed the final grain yield. Two interested points were raised during the course of this, the effects of older leaves than leaf number 7 and the effect of defoliation stage that are plant for further investigation. Same relationship studied by *El-Bana (2001)* which found that positive correlation between grain yield and each of plant height, ear length, ear diameter, number of grains/row, number of grains/ear, ear grain weight, 100 grain yield as well as stover yield/feddan. Also, *Rodney et al. (2004)* which reported that the relationship between percentage defoliation and percentage yield reduction was linear both years.

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تأثير التو ريق على النمو ومكونات المحصول لتركيبين مختلفين من الذرة الرفيعة

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أقيمت تجربتان حقليتان بمحطة بحوث شندويل محافظة سوهاج موسمي ٢٠٠٢ و٢٠٠٣للتعرف على تأثير ومساهمة الأوراق الفردية من ورقة العلم وحتى الورقة السادسة (٦ معاملات) ومساهمة الأوراق تحت الورقة السادسة (من الورقة السابعة وحتى نهاية النبات من أسفل (المعاملة السابعة)) بالإضافة إلى معاملة المقارنة (المعاملة الثامنة) وهى ترك النبات كامل بدون توريق لدراسة تأثير إزالة كل ورقة على حدا من الورقة الأولى وحتى الورقة السادسة وإزالة الأوراق من الورقة السابعة وحتى نهاية النبات من أسفل (المعاملة ٧) وترك النبات كاملا الأوراق للمقارنة (المعاملة ٨ للمقارنة) وذلك على صنفين من الذرة الرفيعة الصنف ورادو قصير الطول وهجين ٢ متوسط الطول.
وتشير النتائج إلى أن:

١. إزالة أي ورقة من أوراق النبات أدى إلى نقص معنوي في وزن القنديل ووزن حبوب القنديل والوزن الغض للنبات ووزن الألف حبة وعدد الحبوب في القنديل والوزن الجاف للأوراق والوزن الجاف للسيقان والوزن الكلى للمادة الجافة بالمقارنة للنبات الكامل الذي لم يتم توريقه.
٢. أدت إزالة الأوراق من الورقة السابعة إلى أسفل النبات إلى أعلى نسبة نقص (DP) في الوزن الجاف للقنديل ووزن الحبوب للنبات والوزن الأخضر للنبات ووزن الألف حبة والوزن الجاف للأوراق وجملة المادة الجافة للنبات بينما أدت إزالة الورقة الرابعة وحدها إلى أعلى نسبة نقص في عدد حبوب الكوز والوزن الجاف للسيقان.
٣. تشير مساهمة وحدة الورقة (LUC) إلى أن ورقة العلم ثم الورقة الثانية كانت أعلى الأوراق مساهمة في الوزن الجاف للقنديل ووزن حبوب النبات والوزن الأخضر للنبات ووزن الألف حبة وعدد الحبوب في القنديل وجملة المادة الجافة للنبات بينما كان هناك تقارب بين مساهمة ورقة العلم والورقة الثانية في الوزن الجاف للأوراق والوزن الجاف للسيقان.
٤. كذلك تشير النتائج إلى أن أقل مساهمة لوحدة الورقة (LUC) كانت بإزالة الأوراق السفلية من الورقة السابعة إلى أسفل النبات في كل من الوزن الجاف للقنديل ووزن الحبوب للنبات والوزن الأخضر للنبات وعدد الحبوب في القنديل والوزن الجاف للسيقان والوزن الكلى للنبات بينما إزالة الورقة الخامسة نتج عنها أقل وحدة مساحة للأوراق (LUC) في صفتي الألف حبة والوزن الجاف للأوراق.
٥. تفوق هجين شندويل ٢ على الصنف دورادو في معظم صفات النمو والمحصول معنويا.
٦. معامل الانحدار الجزئي كان معنويا لصفة عدد الحبوب في القنديل بإزالة الورقة الرابعة بينما كان هذا المعامل لصفة وزن حبوب القنديل معنوي بإزالة الورقة الرابعة والسادسة والأوراق من السابعة إلى أسفل ووزن الكوز كان معنويا بإزالة الورقة الرابعة والأوراق من السابعة إلى أسفل ووزن الألف حبة كان معنويا بإزالة ورقة العلم والثانية والثالثة والسادسة ومن السابعة إلى أسفل كذلك كان معامل الانحدار معنويا في جميع معاملات الأوراق لصفة الوزن الأخضر للكوز ولكنه لم يكن معنويا في جميع معاملات طول النبات.