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Growth Analysis of Sunflower (*Helianthus annuus* L.) under Drought Conditions

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ABSTRACT

Two sunflower genotypes *viz.* Hysun 33 (Hybrid) and Gimsun-650 (inbred line) were raised under three moisture levels i.e. 100, 50 and 25% of field capacity. Water stress increased the net assimilation rate whereas it decreased the leaf area ratio. The water stress had no effect on relative growth rate. A very low and negative correlation was found between net assimilation rate, achene yield and oil yield; whereas, relative growth rate had a very low and positive correlation with both achene yield and oil yield. Leaf area ratio had positive and significant correlation with achene and oil yield.

Key Words: Sunflower; Growth analysis; Drought; Leaf area ratio; Relative growth rate; Net assimilation rate

INTRODUCTION

Sunflower (*Helianthus annuus* L.) occupies a prominent place among oilseed crops as it contributes about 12% to the world edible oil production (Anonymous, 1992). Water application plays an important role in improving seed yield and oil quality of sunflower. It has a good potential to withstand drought due to its well developed roots systems.

Water stress on sunflower has been reported to reduce plant height, root length, number of stomata (Vasiliu *et al.*, 1971; Pirjol *et al.*, 1974) and has caused early flowering, early maturity and reduction in seed yield (Hang & Evans, 1985). Sobrado and Turner (1986) observed no change in the time of budding and flowering under mild stress but severe water stress reduced the rate of net photosynthesis, dry weight of leaves and root and also caused reduction of reproductive parts in both wild and cultivated species of sunflower. Ravishankar *et al.* (1990, 1991) reported reduction in sunflower seed yield, 100-seed weight and total dry matter under early water stress. The relative stability in seed oil content under moisture stress was explained partly by its relation to the variation in the kernel-hull ratio. Drought adversely influenced traits of leaf area, days to maturity, leaf diameter, 100-achene weight and achene yield per plant (Hussain *et al.*, 1994), while early flowering genotypes showed no leaf area recovery, the late flowering genotypes showed upto 34.8% recovery in leaf area (Ravishanker *et al.*, 1991). Baldani *et al.* (1993) reported that the wild sunflower species showed a smaller reduction in dry matter production, and suggested that the wild type has a drought avoidance mechanism due to its larger root system and a higher root/shoot ratio under drought conditions.

The purpose of growth analysis is the determination of the increase in dry matter referred to a suitable basis for photosynthetically active tissue, leaf area and amount of leaf protein. The present research is planned to furnish knowledge on growth analysis of yield components and their interrelationship under drought conditions with the help of growth analysis technique. The growth analysis of sunflower will furnish useful information on the response of plant to different levels of moisture treatments.

MATERIALS AND METHODS

The experiments were conducted at the University of Agriculture, Faisalabad during 1996-97. One commercial hybrid, Hysun 33 and an inbred line Gimsun 650 were included in the experiment. The seeds were sown in the earthen pots of 36 cm diameter filled with 8 kg of good quality field soil. During the experiment a single seed was maintained in each pot. The experiment was planned in a randomized complete block design under split plot arrangement with five replications and three moisture levels *viz.*

T1 = 100% moisture level or field capacity
T2 = 50% moisture level
T3 = 25% moisture level

The moisture level at field capacity was taken as 100% and other treatments were adjusted accordingly. There were 25 pots of each genotype in each treatment i.e., five pots per replication and in total there were 150 pots for the experiment.

Treatment levels were maintained according to their water requirement. The fertilizer was calculated at the rate of 86:26 kg N:P per hectare (Chaudhry, 1986) and applied equally to each pot in four doses at one week interval.

Sampling method. Five samplings were done in all, the first sample was taken 30 days after sowing. The interval between samplings was 16 days while the last sampling was taken at maturity. One plant per replication was harvested at the time of sampling making five plants per treatment in total. The leaf area was calculated using an automatic leaf area meter. The plant parts like leaves, stem and flowers were separated and then kept in an oven at 80ºC for 24 hours to determine their dry matter.

Two types of measurements are needed for growth analysis (i) the plant weight; this is usually the oven dry weight (kg) and (ii) the size of the assimilating system; this is usually in terms of leaf area (m^{-2}). The net assimilation rate (NAR), relative growth rate (RGR) and leaf area ratio (LAR) were calculated for growth analysis.

Net assimilation rate (NAR). The net assimilation (NAR) is the increase of plant material per unit of the assimilating material per unit of time. It was calculated for each interval between two samplings by the formula described by Watson (1952) and Radford (1967). The NAR of first harvest could not be calculated because there was no leaf area values before first harvest.

$$\text{NAR} = \frac{(W_2 - W_1) \times \log_e L_2 - \log_e L_1}{(t_2 - t_1)(L_2 - L_1)} = \text{mg/cm}_2\text{/day}$$

Where:

W1 = Initial dry weight

W2 = Dry weight after t1 and t1 days

L1 = Initial leaf area

L2 = Leaf area after t1 days

t1 = Time of first harvest

t2 = Time of second harvest

Relative growth rate (RGR). It is the increase of plant material per unit time. It was calculated for each interval between sampling by the formula given by Radford (1967). The RGR of the first harvest could not be calculated because there was no dry weight before first harvest.

$$\text{RGR} = \frac{\log_e W_2 - \log_e W_1}{t_2 - t_1} = \text{mg/day}$$

Where W_1, W_2, t_2 and t_1 indicate as in case of NAR

Leaf area ratio (LAR). Leaf area ratio (LAR) of a plant at an instant in time (t) is the ratio of the assimilatory material per unit of plant material present. Leaf area was calculated by the following formula:

$$\text{LAR} = \frac{\text{Total leaf area}}{\text{Total dry weight}} = \text{cm}^2\text{/g}$$

Statistical analysis. The data for all the trials were analysed by analysis of variance technique (Steel and Torrie, 1980). Differences for means of various characters were computed using least significance difference test (LSD) at 0.05 level of probability.

RESULTS AND DISCUSSION

Growth analysis of sunflower was conducted with the objectives to investigate the growth and development pattern of sunflower under different moisture regimes to determine as to how the environments affect the magnitude of growth at different developmental stages and to ascertain the physiologically efficient genotypes. The results derived are presented as under.

Net Assimilation Rate. Analysis of variance for the data on net assimilation rate (NAR) (Table I) revealed that moisture level had significant and harvests had highly significant effect on NAR. Genotypes had non-significant effect for NAR. Interactions between moisture level x harvest and harvests x genotype had highly significant effect on NAR.Table II revealed that means for NAR at various moisture levels differed significantly for 100% (field capacity) moisture level

Table I. Mean squares from analysis of variance for net assimilation rate (NAR) and relative growth rate (RGR) of sunflower genotypes evaluated at three moisture levels and three harvests (Harvest No. 1, 2, 3)

S.O.V.	D.F.	Net assimilation rate	Relative growth rate
ML	2	0.157^{*}	0.000^{NS}
Error	8	0.019	0.000
H	2	0.629^{**}	0.017^{**}
ML x H	4	0.368^{**}	0.003^{**}
Error	24	0.082	0.000
G	1	0.008^{NS}	0.000^{NS}
ML x G	2	0.073^{NS}	0.001^{NS}
H x G	2	0.511^{**}	0.002^{*}
ML x H x G	4	0.124^{NS}	0.001^{NS}
Error	36	0.095	0.001

** = Significant at 0.01 probability level; * = Significant at 0.015 probability level; NS = Non-significant

as compared to 50 and 25% moisture level but values at 50 and 25% moisture level were not statistically different. The maximum value for NAR (0.548) was recorded at 25% moisture against 0.405 at 100% and 0.495 at 50% moisture level.

Individual comparison of harvest means for NAR showed that NAR was maximum (0.650 $\text{mg/cm}^2\text{/day}$) at Harvest-2 which was statistically different from Harvest-3 and Harvest-4. There was a reduction of about 66.24% in NAR between 2nd and 3rd harvest

Table II. Individual comparison of treatment means for assimilation rate (mg/cm^2/day)

Harvest	M_1(100%)			M_2(50%)			M_3(25%)					
	G_1	G_2	H x M_1	G_1	G_2	H x M_2	G_1	G_2	H x M_3	H x G_1	H x G_2	H
H_2	0.51	0.57	0.54 BCD	0.83	0.81	0.82 A	0.28	0.87	0.58 ABC	0.54ab	0.75a	0.65 A
H_3	0.28	0.34	0.31 DE	0.11	0.25	0.18 E	0.71	0.62	0.67 AB	0.37 bc	0.41 bc	0.39 B
H_4	0.50	0.19	0.35 CDE	0.66	0.28	0.47 BCD	0.50	0.28	0.39 CDE	0.56 ab	0.25 c	0.40 B
G x M	0.43	0.37		0.54	0.45		0.50	0.59				
M			B			A			A			
			0.40			0.49			0.54			
G				G_1			G_2					
				0.49			0.47					

G_1 = Hysun-33; G_2 = GIMSUN-650; H = Harvest; M = Moisture level; G = Genotype; Treatment means sharing similar letters in different forms are non-significantly different at 0.05 probability level

and it reached to 0.391 mg/cm^2/day) at Harvest-3. There was a minor increase in NAR between 3rd and 4th harvest and it obtained the value 0.408 mg/cm^2/day at Harvest-4.

Harvest x genotype interaction showed that GIMSUN-650 gave maximum NAR value (0.754 mg/cm^2/day) at Harvest-2, while there was a continuous decrease in NAR in the remaining harvests.

Table III. Individual comparison of treatment means for relative growrth rate (mg/day)

Harvest	M_1(100%)			M_2(50%)			M_3(25%)					
	G_1	G_2	H x M_1	G_1	G_2	H x M_2	G_1	G_2	H x M_3	H x G_1	H x G_2	H
H_2	0.06	0.06	0.06 B	0.09	0.07	0.08 A	0.02	0.076	0.05 BC	0.06 a	0.07 a	0.06 A
H_3	0.02	0.02	0.02 DE	0.00	0.01	0.01 E	0.05	0.037	0.04 CD	0.02 b	0.02 b	0.02 B
H_4	0.03	0.01	0.02 E	0.04	0.01	0.02 DE	0.02	0.015	0..02 E	0.03 b	0.01 b	0.02 B
G x M	0.04	0.03		0.04	0.03		0.03	0.043				
M			0.03			0.04			0.03			
G				G_1			G_2					
				0.04			0.03					

G_1 = Hysun-33; G_2 = GIMSUN-650; H = Harvest; M = Moisture level; G = Genotype; Treatment means sharing similar letters in different forms are non-significantly different at 0.05 probability level

At Harvst-3, the value of NAR was 0.410 mg/cm^2/day at Harvest-4 it was 0.256 mg/cm^2/day. Hysun-33 had almost the same (0.545 mg/cm^2/day) and 0.560 mg/cm^2/day at 2nd and 4th harvests, respectively. At Harvest-3, the value was 0.372 mg/cm^2/day.

Harvest x moisture level interaction showed that maximum NAR value (0.822 mg/cm^2/day) was obtained at 50% moisture level at Harvest-2. Minimum NAR (0.188 mg/cm^2/day) was also observed at 50% moisture level at Harvest-3. This interaction showed that at 100 and 50% moisture levels there was a decrease in NAR between 2nd and 3rd harvest. NAR value increased between 3rd and 4th harvest. At 25% moisture level NAR value increased between 2nd and 3rd harvest but was reduced between 3rd and 4th harvest and was found minimum at Harvest-4. The results suggested that water stress increased net assimilation rate. Results also indicated a reduction of NAR from early growth stages to maturity. These results are in full agreement with the findings of Dabre and Bang (1985) and SAN Jose and Cabrera (1988).

Relative Growth Rate. Analysis of variance for the data on relative growth rate (RGR) (Table I) revealed that harvest had highly significant whereas moisture level and genotypes had non-significant effect on RGR. Interaction, moisture level x harvest had highly significant while harvest x genotype had significant effect on RGR whereas other interactions had non-significant effect on RGR.

Individual comparisons of harvest means showed that RGR was maximum (0.068 mg/day) at Harvest-2 (Table III). It reduced to 0,027 mg/day at Harvest-3. The reduction was 151.85% between 2nd and 3rd harvest. Again there was a minor decrease in RGR between 3rd and 4th harvest and it obtained the value 0.025 mg/day at Harvest-4.

Interaction harvest x genotype showed that both genotypes Hysun-33 and GIMSUN-65 produced maximum RGR value 0.061 mg/day and 0.075 mg/day, respectively at 2nd harvest both showed a decline in RGR at 3rd harvest, value was same i.e.

Table IV. Mean squares from analysis of variance for leaf area ratio (LAR) of sunflower genotypes evaluated at three moisture levels and four harvests (Harvest No. 1,2,3,4)

S.O.V.	D.F.	Leaf area ratio
ML	2	4386.876**
Error	8	122.609
H	3	40215.279**
ML x H	6	446.289**
Error	36	121.753
G	1	989.358**
ML x G	2	206.278NS
H x G	3	267.366NS
ML x H x G	6	271.335NS
Error	48	131.910

** = Significant at 0.01 probability level; * = Significant at 0.015 probability level; NS = Non-significant

Table V. Individual comparison of treatment means for leaf area ratio (cm^2/g)

Harvest	M_1(100%)			M_2(50%)			M_3(25%)					
	G_1	G_2	H x M_1	G_1	G_2	H x M_2	G_1	G_2	H x M_3	H x G_1	H x G_2	H
H_1	163.68	152.55	158.12A	136.90	140.25	138.58B	111.95	126.58	119.27C	137.51	139.79	136.65A
H_2	99.89	96.83	98.34D	94.61	76.71	85.66 E	89.55	74.03	81.79 E	94.68	82.52	88.67 B
H_3	88.35	66.49	77.42 E	61.72	61.44	61.58 F	57.51	59.83	58.67 F	69.19	62.59	65.89 C
H_4	64.21	58.94	61.58 F	59.76	51.98	55.87 F	56.44	50.03	53.23 F	60.14	53.65	56.89 D
G x M	104.03	93.70		88.25	82.59		78.86	77.61				
M			A 98.87			B 85.42			78.24			
G				G_1 A 90.38			G_2 B 84.64					

G_1 = Hysun-33; G_2 = GIMSUN-650; H = Harvest; M = Moisture level; G = Genotype; Treatment means sharing similar letters in different forms are non-significantly different at 0.05 probability level

0.027 mg/day. At Harvest-4 RGR of Hysun-33 was 0.036 mg/day and for GIMSUN-650 it was 0.014 mg/day.

Harvest x moisture level interaction showed that maximum relative growth rate value 0.086 mg/day was obtained at 50% moisture level at Harvest-2. Minimum RGR value 0.013 mg/day was also observed at 50% moisture levels at Harvest-3. This interaction showed that at 100 and 25% moisture levels there was a reduction in RGR from Harvest-2 to Harvest-4, whereas at 50% moisture level, RGR decreased between 2nd harvest and 3rd harvest but there was an increase in RGR between 3rd and 4th.

Results of present studies revealed that different moisture levels had no effect on RGR. These results are in agreement with the findings of Lasavio *et al.* (1989). Results also indicated a reduction of RGR value from early growth stages to final stages. These results are in line with the findings of Dabre and Bang (1985).

Leaf Area Ratio. Analysis of variance for the data on leaf area ratio (Table IV) revealed that moisture levels, genotypes and harvests had highly significant effect on LARF. Interaction moisture level x harvest also had highly significant effect on LAR, whereas other interactions had non-significant effect on LAR.

Means for LAR at different moisture levels differed significantly (Table V). Maximum LAR value (98.873 cm^2/g) was obtained at 100% moisture level against 78.243 cm^2 at 25% moisture level. At 50% moisture level LAR was 85.425 cm^2/g. In comparison between genotypes, Hysun-33 attained a high LAR value of 90.385 cm^2/g against 84.642 cm^2/g of GIMSUN-650.

Individual comparison of harvest means for LAR showed that value of LAR was highest (138.656 cm^2/g) in the first harvest and then gradually decreased till the last harvest (Harvest-4). The values of LAR at 2nd, 3rd and 4th harvest were 88.607 cm^2/g, 65.894 cm^2/g and 56.898 cm^2/g, respectively which differed statistically.

Harvest x moisture level interaction showed that at each moisture level, maximum value of LAR was recorded in Harvest-1. LAR gradually decreased from Harvest-1 to Harvest-4 at each moisture level. Reduction in LAR from Ist to 4th harvest was 156.771%, 147.04% and 124.03% at 100, 50 and 25% moisture levels, respectively.

Interaction i.e. moisture level x genotypes, harvest x genotype and harvest x genotype x moisture level had no significant effect on LAR under drought conditions. Results also indicated that a gradual reduction in LAR occurred from Ist to 4th harvest. These results are in line with the findings of Cabrera and Sanjose (1987).

CONCLUSION

Growth analysis was conducted on two sunflower genotypes *viz.* Hysun-33, a commercial hybrid and an inbred line. Gimsun-650 sown in earthen pots filled with 8 kg of food quality field soil under three moisture levels i.e. 100% (field capacity), 50% and 25%. The plants were brought at an interval of 16 days water stress increased the net assimilation. Whereas it decreased the leaf area ratio. The water stress had no effect on relative growth rate. Hysun-33 (Hybrid) showed good results at 100% and 50% moisture level for most of the plant traits whereas Gimsun-650 produced better at greater moisture stress i.e. at 25% moisture level. This showed that Gimsun-650 can be used in the future breeding programme for the development of drought resistant cultivar of sunflower.

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