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Growth Analysis in Sunflower (*Helianthus annus* L.) under Semi-Controlled Conditions

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ABSTRACT. Five sunflower cultivars, *viz.*, Hemus, Amiata, DKS-371, Aia and Vimimilk were evaluated for growth and dry matter accumulation in a plastic house in Al-Baha area in the winter of 1988. Data taken on total (TDW), culm (CDW), leaf (LDW) and head (HDW) dry weights and on LAI at seven sampling dates extending from 25 to 115 days from planting (dfp) revealed high significant differences ($P \leq 0.01$) among sampling dates. Differences among cultivars were significant for TDW and LDW at 85 dfp and for CDW at both 85 and 100 dfp. Differences in HDW and LAI at each sampling date were non-significant. On the average, estimates of 864.6, 315.3, 245.5 and 273.7 g m^{-2} and of 3.108 m^2 m^{-2}, for the respective traits, were recorded for the five cultivars at the final harvesting date (115 dfp). Contributions of LDW and CDW and HDW to TDW during the growing season ranged from 28.3-76.1, 18.3-50.7, and 3.2-31.7%, respectively. Estimates in the ranges of 2.25-17.05 g m^{-2} day^{-1}, 20.5-80.0 mg g^{-1} day^{-1}, 4.16-7.63 g m^{-2} day^{-1}, 42.7-200 cm^2 g^{-1}, 140.3-272.9 cm^2 g^{-1} and 0.315-0.744 g g^{-1}, among the cultivars, indicating high significant differences among sampling dates, were recorded, respectively, for CGR, RGR, NAR, LAR, SLA and LWR during the growing season.

Introduction

The assimilation of dry matter through photosynthesis and its distribution within the plant are important processes to determine crop productivity. The presence of plant organs with a net demand for dry matter (sink) can influence both processes strongly (Gilford and Evans, 1981). Efforts to improve crop yields would be aided by understanding how economically important sinks affect the production and partitioning of dry matter.

In sunflower, the inflorescence (Cabrera and San Jose, 1987) and the partly green culm acts both as a sink and as assimilate source, whereas the leaves act as the major assimilate source. The respective contribution of these organs was reported to account for up to 40, 58 and 60% of total dry matter (TDM) accumulated during the growing season (Losavio *et al.*, 1985). Relatively higher amounts of TDM and seed yield are usually obtained under controlled conditions than under open field conditions. This could be attributed to a number of environmental factors such as abundant water and nutrient supply, uniformity of diffused light distribution within the canopy, favorable temperature regimes and/or absence of negative effects of turbulence and wind speed (Tollenaar and Migus, 1984).

Several studies were conducted in Saudi Arabia (Osman *et al.*, 1988; 1989a; 1989b; 1991) and elsewhere (Losavio, 1985; Cabrera and Jose, 1987; Singh *et al.*, 1987; Sangoi and Silva, 1988) to assess dry matter accumulation and distribution in sunflower under open field conditions. However, the attempts to quantify total dry matter production under semi-controlled conditions are very much limited. This study was, therefore, undertaken to assess the inherent potentialities of five sunflower cultivars in total dry matter production under semi-controlled conditions (plastic house) in the Al-Baha, during the winter season.

Materials and Methods

The present work was conducted at Beljurashi Research Station (41.00°E and 19.52°N) which is located about 31 km south of Al-Baha city at 2400 m above sea level. A plastic house (56 × 9 m); provided with a drip irrigation system (75 cm between lines and 20 cm between drippers), was used. Forty kg of the NPK fertilizer (16:16:8) compound was applied to the whole area, prior to planting. Five sunflower cultivars, *viz.*, Hemus (Cv. 1), Amiata (Cv. 2), DKS-371 (Cv. 3), Aia (Cv. 4) and Vimimilk (Cv. 5) were planted during the first week of November, 1988 using a randomized complete block design with four replications. Each plot consisted of 2 rows (5 m × 1.5 m). The crop plants were kept free from weeds under adequate water conditions.

Destructive sampling started 25 days from planting (dfp) and continued every 15 days until 115 days after planting. Three adjacent plants were taken from each sampling row and separated into leaves, stems and heads (when present) and then oven dried at 70°C for 48 hours and weighed to determine leaf area index (LAI), culm, leaf, head and total dry weights. Leaf area and total dry weight data were used to calculate crop growth rate (CGR), relative growth rate (RGR), net assimilation rate (NAR), leaf area ratio (LAR), specific leaf area (SLA) and leaf weight ratio (LWR) (Radford, 1967; and Hunt, 1982).

Results and Discussion

1. Dry Matter Accumulation

The results of this study indicated that, on the average, TDW, CDW, LDW, HDW and LAI (Fig. 1-5, Table 1) increased steadily throughout the entire growth period. The differences among sampling dates were highly significant for TDW and all its components (Table 3). On the other hand, differences among the cultivars were statistically significant for TDW and LDW at 85 dfp and for CDW at both 85 and 100 dfp only (Table 1).

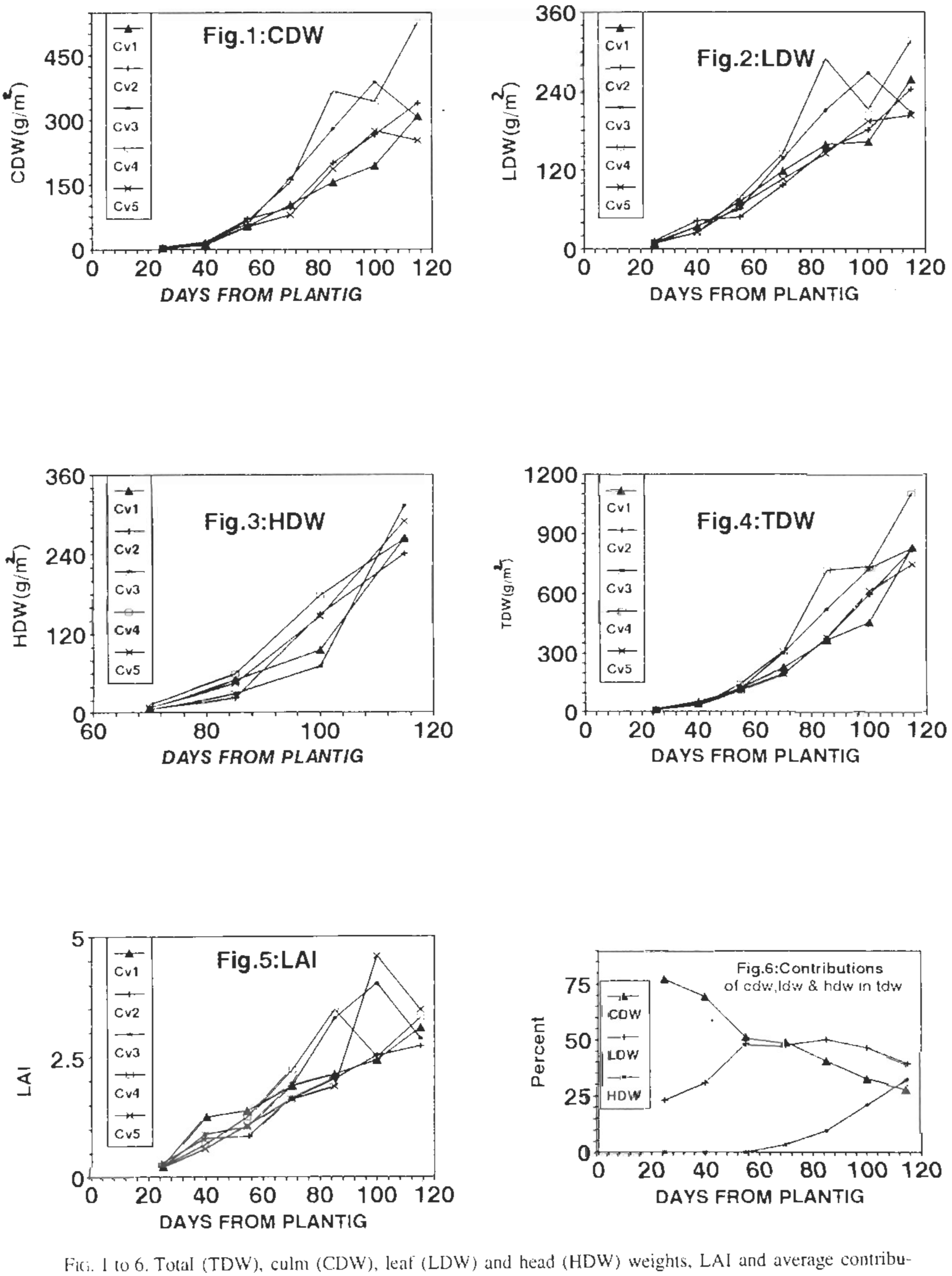

FIG. 1 to 6. Total (TDW), culm (CDW), leaf (LDW) and head (HDW) weights, LAI and average contributions of cdw, ldw & hdw in tdw for the five sunflower cultivars at seven sampling dates.

TABLE 1. Average estimates of five growth parameters in five sunflower cultivars at seven sampling periods.

Growth parameters		Days from planting						
		25	40	55	70	85	100	115
TDW (g / m^2)	Mean	12.3	43.9	125.5	250.3	468.9	616.3	868.3
	S.E. ± a	2.36	13.92	32.27	62.89	77.3*	86.86	188.44
CDW (g / m^2)	Mean	3.1	14.1	60.3	120.0	237.6	292.3	345.9
	S.E. ±	0.72*	6.02	22.62	34.20	41.86*	41.45*	71.72
LDW (g / m^2)	Mean	9.7	32.0	64.4	118.8	190.0	202.8	245.0
	S.E. ±	1.46	11.78	12.41	27.17	32.17*	22.98	54.20
HDW(g / m^2)	Mean	–	–	–	7.8	42.6	128.4	273.7
	S.E. ±	–	–	–	5.85	16.62	43.72	87.42
LAI	Mean	-0.228	0.844	1.127	1.860	2.565	3.213	3.100
	S.E. ±	0.03	0.26	0.76	0.56	0.49	0.48	0.77

a: d.f. for error at each date = 12
* significant at the 5% level.

TABLE 2. Average estimates of six growth parameters in five sunflower cultivars at six growth intervals.

Growth parameters		Days from planting					
		25 - 40	40 - 55	55 - 70	70 - 85	85 - 100	100 - 115
CGR ($g / m^2 / day$)	Mean	2.25	5.44	8.71	17.05	9.86	16.77
	S.E. ± a	0.43	0.80	1.69	2.07*	2.85	4.27
RGR (mg / g / day)	Mean	80.0	78.4	47.7	50.2	21.0	20.5
	S.E. ±	19.0	19.0	19.0	13.0	15.0	13.0
NAR (g / m^2)	Mean	4.34	6.10	5.54	7.53	4.16	5.57
	S.E. ±	1.16	1.55	2.16	1.80	3.06	3.27
LAR (cm^2 / g)	Mean	200.0	133	86.86	64.4	53.3	42.7
	S.E. ±	28.0	16.0	9.0	5.0	6.0	5.0*
SLA (cm^2/g)	Mean	272.9	220.2	166.0	144.1	146.3	140.3
	S.E. ±	40	33	54	37	34	24
LWR	Mean	0.744	0.603	0.506	0.446	0.373	0.315
	S.E. ±	0.033	0.046	0.041	0.027	0.026	0.034

a: d.f. for error each interval = 12
*significant at the 5% level.

As in this study, Osman *et al.* (1988), and Osman *et al.* (1989a and b) observed that dry matter accumulation in various parts of sunflower plants grown in the western region of Saudi Arabia increased steadily with time reaching its peak at the ripening stage. At this stage, San Jose and Cabrera (1988) indicated that 55, 40 and 17% of the assimilate was diverted to the leaves, stems and inflorescence respectively.

Studies on leaf area expansion or LAI indicated that LAI, as in this study, increased with plant age. In this respect, estimate of LAI in the range of 3.1-4.3 $m^2 m^{-2}$ (San Jose and Cabrera, 1988) and as high as 4.73 $m^2 m^{-2}$ (Srojova, 1991) were reported in other studies. In this study, estimates of LAI averaged over cultivars, ranged from 0.23 $m^2 m^{-2}$ at 25 dfp to 3.2 $m^2 m^{-2}$ at 100 dfp. However, estimates of LAI as high as 5.46 and 4.57 $m^2 m^{-2}$, respectively at 85 dfp and 100 dfp were recorded for cultivar Vimimilk in this study (Fig. 5).

The occurrence of maximum leaf area at budding stage or during anthesis was, according to Losavio *et al.* (1985), mostly attributable to the rapid expansion of the existing leaves, production of new leaves and reduced senescence at these stages.

Data on the percentage distribution of TDM among its three components, *viz.*, CDW, LDW and HDW (Fig. 6) indicated that proportionally higher amounts of dry matter were diverted to the leaves during the vegetative stage; whereas equal amounts were diverted to the leaves and stem on the onset of flowering. Following this stage, proportionally higher amounts were diverted to the capitulum. In previous studies, Cabrera and San Jose (1987), similarly, observed three distinct phases for dry matter accumulation and distribution during the lief of the sunflower plant. According to these workers, TDM produced during the first phase (up to 41 days from seedling emergence) was mostly diverted to the leaves, whereas at the second phase (48 days from emergence) dry matter accumulated in the leaves was equal to that in stems. During the third phase, the inflorescence acted as an assimilate source and eventually its dry matter content was significantly increased.

Similar trends were also observed by Osman *et al.* (1988) in sunflower grown under different irrigation regimes in the western region of Saudi Arabia. Studies on partitioning of dry matter in various sunflower cultivars grown in the Mediterranean region (Losavio *et al.* 1985) indicated that peaks of dry matter accumulation in various plant parts differed with the growth stage. In this respect, 58, 60 and 90% were, respectively, diverted to the stems at anthesis, leaves at physiological maturity and to the inflorescence at the waxy stage. In this study, peaks of dry matter accumulation, being 76.1 (leaves), 50.6 (stem) and 31.7% (head), were observed at 25, 85 and 115 dfp for the respective traits.

2. Growth Analysis

Data in Tables 3 and 4 indicated that differences among cultivars for most of the studied growth parameters at each sampling date were generally small and non-significant. Differences among sampling dates, on the other hand, were highly ($P \leq 0.01$) significant (Table 4). Estimates of growth parameters recorded for each of the five cultivars over the growth period are presented in Fig. 1 to 6 and are highlighted hereunder.

Crop Growth Rate

All cultivars showed a steady rate of increase in crop growth rate (CGR) of dry matter accumulation between 25 and 55 dfp (Fig. 7). Following this stage, Aia exhibited (Fig. 7) the highest (32.59 g m^{-2} day^{-1}) CGR estimate, whereas cultivar Hemus exhibited the lowest. Estimates of 13.71, 16.50 and 13.87 g m^{-2} day^{-1} were recorded, respectively, for cultivars Amiata, DKS-371 and Vimimilk, at this stage (Fig. 7). In this respect, estimates as high as 40, 42 and 45 g m^{-2} day^{-1} at 47, 55 and 61 dfp (San Jose and Cabrera, 1988); 20.50 g m^{-2} day^{-1} (Srojova, 1991); and 29.0 g m^{-2} day^{-1} (Cabrera and San Jose, 1987) at the active flowering stage were reported in the literature. Absolute growth rates in the range of 34.55-116.57 g day^{-1} were reported by Osman *et al.* (1989b) under the arid conditions of Saudi Arabia.

TABLE 3. Combined analysis of data on total dry weight and its components.

Source of variation	d.f.	TDW ($g\ m^{-2}$)	CDW ($g\ m^{-2}$)	LDW ($g\ m^{-2}$)	HDW ($g\ m^{-2}$)	LAI
date (D)	6	**	**	**	**	**
cultivars (C)	4	*	**	*	n.s	n.s
D × C	24	n.s	*	n.s	n.s	n.s
Error	84	30987.97	5903.65	3245.50	9864.4	0.898

N.S., * and ** are non-significant and significant at $p \leq 0.05$ and 0.01, respectively.

TABLE 4. Combined analysis of data on growth parameters.

Source of variation	d.f.	CGR	RGR	NAR	LAR	SLA	LWR
Date	5	**	**	**	**	**	**
Cultivars	4	n.s	n.s	n.s	n.s	n.s	n.s
D × C	20	n.s	n.s	n.s	n.s	n.s	n.s
Error	72	114.13	1.1	21.15	0.078	0.189	0.005

N.S., ** are non-significant and significant at $p \leq 0.05$ and 0.01, respectively.

Relative Growth Rate

Although estimates of RGR (Fig. 8) in all cultivars, steadily decreased with plant age, differences among the five cultivars at each of the six sampling intervals were non-significant (Table 4). In previous studies, Koller *et al.* (1970), Scott and Batchelor (1979), San Jose and Cabrera (1988), and Osman *et al.* (1989b) observed relatively high RGR estimates in sunflower during the vegetative stage and progressively lower values as the crop growth advanced. A decrease from 0.110, 0.1, 0.037 to 0.01, 0.007 and 0.028 g g^{-1} day^{-1} respectively, was reported by San Jose and Cabrera (1988) for three sunflower cultivars. A decrease from 156.5 to 21.5 mg g^{-1} day^{-1} was reported by Osman *et al.* (1989b) for cv. Amiata grown under adequate moisture conditions in Jeddah area.

3. Net Assimilation Rate

In spite of the apparent fluctuations reflected by NAR estimates during the growing season (Fig. 9), differences among the cultivars, at each of the six sampling intervals, were non-significant (Table 4). In this respect, San Jose and Cabrera (1988) indicated that NAR estimates generally decreased with the advancement of plant age.

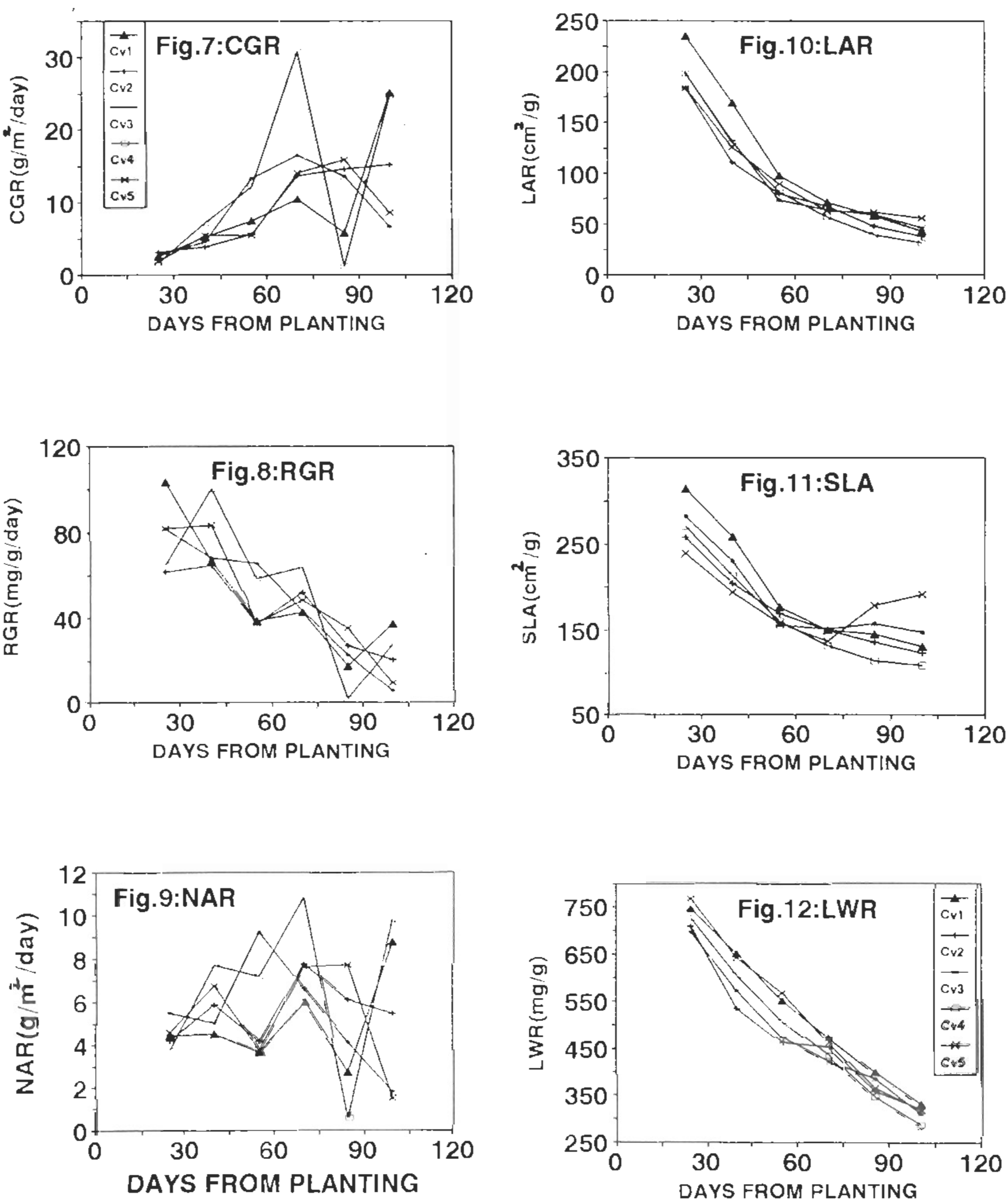

FIG. 7 to 12. Growth parameters for the five sunflower cultivars at six growth intervals.

In contrast to the present findings, Scott and Batchelor (1979) in soybean and Osman *et al.* (1989b) in maize and sunflower, noticed that values of NAR were highest during the vegetative growth and lowest during the reproductive growth. Scott and Batchelor (1979) attributed the decline in NAR to a rise in self-shading and senescence as the season advanced. The stability of NAR estimates observed in this study may be partially attributed to the favourable environment attained under the plastic house conditions. In this study, no leaf senescence was recorded; on the contrary, average estimates of leaf area and leaf dry weight tended to increase as the season advanced.

Leaf Area Ratio, Specific Leaf Area and Leaf Weight Ratio

Estimates of LAR (Fig. 10), SLA (Fig. 11) and LWR (Fig. 12), apart from those of LAR at 100 dfp (Table 3), reflected more or less similar trends for each of the five cultivars. In this respect, highest estimates for each of the three parameters were recorded during the early vegetative stage, whereas lowest estimates were recorded at the late seed-filling stage (Fig. 10-12). Similarly of trends between LAR, SLA and LWR was also observed by Osman *et al.* (1989b) in both corn and sunflower grown under different irrigation regimes. San Jose and Cabrera (1988) indicated that the estimates of LAR in each of the three sunflowers included in their study increased with plant age until 65 dfp and dropped afterwards. Similarly, Cabrera and Jose (1987) reported an increase of LAR with age. However, maximum estimates (120 $cm^2\ g^{-1}$) were recorded only at 29 dfp, whereas lowest estimates ($cm^2\ g^{-1}$) were recorded at the end of the growing season. Estimates in the range of 100.5 $cm^2\ g^{-1}$ (at 42 dfp) and 57.4 $cm^2\ g^{-1}$ (at 64 dfp) were reported for sunflower grown under adequate moisture in Saudi Arabia (Osman *et al.* 1989b).

Since LAR = SLA × LWR, such trends are likely to be observed in various crop plants (Blackman and Wilson, 1951). Differences in LAR estimates (RGR = LAR × NAR), according to these workers, were mostly associated with differences in RGR estimates and apparently, in contrast to this study, not to those in SLA and/or LWR.

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تحليـل النمو في زهـرة الشمس تحت ظروف بيئيـة شبـه محكمة

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المستخلص . استهدف البحث الحالي تقييم النمو وتجميع المادة الجافة في خمسة أصناف (Vimimilk, Aia, DKS-371, Amiata, Hemus) من زهرة الشمس زرعت داخل صوبة بلاستكية في شتاء ١٩٨٨م في منطقة الباحة . أوضحت النتائج التي سجلت عن الوزن الكلي الجاف ، و وزن السوق ، و وزن الأوراق ، و وزن الرؤوس ودليل مساحة الأوراق في الفترة من ٢٥-١١٥ يومًا بعد الزراعة وجود فروقات معنوية بين مواعيد الحشات لكل هذه الصفات . أما الفروقات بين الأصناف فقد اقتصرت على الوزن الكلي الجاف و وزن الأوراق عند ٨٥ يومًا وعلى وزن السوق عند ٨٥ يومًا و ١٠٠ يومًا من الزراعة .

وقد سجلت المعدلات ٨٦٤,٦ ، ٣١٥,٣ ، ٢٤٥,٥ ، ٢٧٣,٧ جم/م^{2} و ٣,١٠٨م^{2}/م^{2} للوزن الكلي ، ووزن السوق ، ووزن الأوراق ، ووزن الرؤوس ودليل مساحة الأوراق على التوالي كمتوسط عام للأصناف عند الحصاد النهائي (١١٥ يومًا) . أما مشاركة الأوراق والسوق والرؤوس في الوزن الكلي خلال الموسم فقد تراوحت ما بين ٢٨,٣-٧٦,١ ، ١٨,٣-٥٠,٧ و ٣,٢-٣١,٧٪ للصفات الثلاثة على التوالي .

أما معدلات النمو فقد تراوحت مابين ١٢,٢٥ إلى ١٧,٥ جم/م^{2}/يوم ، ٢٠,٥ إلى ٨٠ مجم/جم/يوم ٤,١٦ إلى ٧,٦٣ جم/م^{2}/يوم ، ٤٢,٧ إلى ٢٠٠ سم^{2}/جم ، ١٠٤,٣ إلى ٢٧٢,٩ سم^{2}/جم و ٠,٣١٥ إلى ٠,٧٤٤ جم/جم لمعدلات نمو المحصول (CGR) ومعدل النمو النسبي (RGR) ومعدل التمثيل الضوئي (NAR) ونسبة مساحة الأوراق (LAR) والكثافة النوعية للأوراق (SLA) ونسبة وزن الأوراق (LWR) على التوالي ، مما يؤكد وجود فروقات معنوية بين الحشات المختلفة خلال الموسم .