วารสารเกษตร 10(2) : 114 - 128 (2537)

Journal of Agriculture 10(2) : 114 - 128 (1994)

Responses to Water Strees of Sunflower (*Helianthus annuus* L.)

by

Chalermpone Sampet[1/]

Abstract : Growth and yield of *Helianthus annuus* cv. Hysun 33 was studied under withholding of water at various stages of plant development and irrigation frequencies (every 1, 2, 3 and 4 weeks) at the Faculty of Agriculture, Chiang Mai University during January - April 1987 on paddy soil (clay loam - sady clay loam).

Total dry matter LAI and seed yields were not affected by withholding water treatments when compared with weekly irrigation, but affected by irrigation frequencies. The mean value of seed yield from over all withholding water treatments was 3.37 t/ha. Seed yields and also total dry matter and LAI significantly decreased when irrigation interval increased. The most infrequent irrigation treatment reduced yield by 52 %. The reduction in seed yield was due to decreasing in number of seed per capitulum and seed size. Seed oil content was significantly decreased when irrigation interval increased. The oil content of 42.1 % was observed from the every 4 weeks irrigation treatment compared with 51.4 % observed from the weekly irrigation one. Leaf water potential at predawn, late morning and midday throughout crop cycle are described.

บทคัดย่อ : การศึกษาผลกระทบของความถี่ของการให้น้ำ (ทุก ๆ 1, 2, 3, และ 4 สัปดาห์) และเมื่องดการให้น้ำเป็นเวลา 2 สัปดาห์ ที่ระยะการเจริญต่าง ๆ (V_{10}, R_1, R_5, และ R_7) ที่มีต่อการเจริญเติบโต และผลผลิตของทานตะวันลูกผสม (Hysun 33) กระทำที่ คณะเกษตรศาสตร์ มหาวิทยาลัยเชียงใหม่ ในระหว่างเดือนมกราคม ถึงเดือนเมษายน 2530 ในดินนาซึ่งมีลักษณะเป็น Clay loam - Sandy loam การให้น้ำให้แบบปล่อยระหว่างร่อง

ผลจากการทดลองพบว่า การสะสมน้ำหนักแห้ง ดัชนีพื้นที่ใบ และผลผลิตได้รับผลกระทบอย่างมีนัยสำคัญจากความถี่ของการให้น้ำ กล่าวคือ ทั้งการสะสมน้ำหนักแห้ง ดัชนีพื้นที่ใบ และผลผลิตลดลงเป็นลำดับ

[1/]Agronomy Department, Chiang Mai University

เมื่อความถี่ของการให้น้ำลดลง การให้น้ำทุกสัปดาห์ ให้ผลผลิตเฉลี่ย 2.69 ตัน/เฮกแตร์ และผลผลิตลดลงประมาณ 52 % เมื่อความถี่ของการให้น้ำลดลงเป็นทุก 4 สัปดาห์ การสะสมน้ำหนักแห้ง อยู่ระหว่าง 4.77 - 2.73 ตัน/เฮกแตร์ และดัชนีพื้นที่ใบอยู่ระหว่าง 2.5 - 1.3 ขึ้นอยู่กับความถี่ของการให้น้ำ ส่วนการทดลองการงดให้น้ำที่ระยะการเจริญต่าง ๆ พบว่า การสะสมน้ำหนักแห้ง ดัชนีพื้นที่ใบ และผลผลิตไม่ได้รับผลกระทบจากรรมวิธีต่าง ๆ คือ ให้น้ำหนักแห้งและดัชนีพื้นที่ใบ ผลผลิต (เฉลี่ยจากทุกกรรมวิธี) 5.49 ตัน/เฮกแตร์ 3.0 และ 3.7 ตัน/เฮกแตร์ ตามลำดับ เปอร์เซ็นต์น้ำมันในเมล็ดลดลงอย่างมีนัยสำคัญทางสถิติเมื่อความถี่ของการให้น้ำลดลง เปอร์เซ็นต์น้ำมันเฉลี่ยที่วัดได้จากกรรมวิธีการให้น้ำทุก ๆ 4 สัปดาห์ เท่ากับ 42.1 % เปรียบเทียบกับ 51.4 % เมื่อให้น้ำทุกสัปดาห์ ผลของการวัดศักยภาพของน้ำในใบ (Leaf water potential) ที่เวลาเช้ามืด สาย และเที่ยงวัน ตลอดการทดลองได้บันทึกไว้ในรายงานนี้

Introduction

Sunflower is a crop of increasing importance in northern Thailand, as it can be grown in upland areas as a postrainy season crop or on low-lying areas as an irrigated cool dry season crop. Under such growing conditions, therefore, water stress due to shortage of water can occur during any stage of plant development. The effect of water stress on growth and yield depend on time, severity and duration of stress (Kramer 1983). It has been revealed elsewhere (Connor *et al*. 1985 ; Stegman and Lemert 1981 ; Robinson 1987) that the greatest reduction in yield of sunflower was found when water stress occured in the budding through to anthesis stage. A positive relation between irrigation intervals and yields has also been reported (Kandil 1984).

The objective of this investigation was to determine the critical growth stage when affected by water stress and to evaluate the effect of irrigation frequencies on growth and yields.

Materials and Methods

Two field experiments were conducted on paddy soil at the Faculty of Agriculture, Chiang Mai University during January - April, 1987. The soil is clay loam - sandy clay loam. The data for evaporation pan (E - pan) and rainfall during the experiment period are shown in Appendix 1.

Experiment 1: Effect of withholding water at various stages of plant development on growth and yields. Five water stress treatments were imposed by witholding water 2 weeks during the following stages of plant development :

V_{10} : Beginning at ten leaves stage.

R_1 : As the inflorescence becomes visible (surrounded by immature bracts)

R_3 : Beginning at the inflorescence head above the surrounding leaves.

R_5 : Beginning at anthesis

R_7 : Beginning at seed filling

Control (weekly irrigation) and check (non-irrigation) plots were also incorporated in the experiment (see Appendix 2.). The experimental design was a RCB with four replications. Plot size was 3 x 8 m. Seeds were sown in four rows per plot with spacing 75 cm between rows and 50 cm between plants. Measurements were taken from the two central rows of each plot. Samples to estimate DM and LAI were taken at full bloom stage. Leaf resistance (leaf water potential) and stomatal resistance were measured throughout the crop cycle.

Experiment 2 : Effect of irrigation frequencies on growth and yields. The treatments consisted of four irrigation frequencies (every 1, 2, 3, and 4 weeks) and a check plot (non-irrigation). A randomized complete block design with four replications was used in this investigation. A plot size is the same as experiment 1. Total DM and LAI were measured at full bloom stage. Leaf and stomata resistance were recorded.

Leaf resistance was measured at pre-dawn, late morning (10.00 h) and midday (12.00 h) on the day before watering. Stomatal resistance was measured at midday only on the days before watering. Leaf and stomatal resistance were measured with pressure chamber and a automatic porometer (model MK 3 Delta-T Device) respectively. Both measurements were made on the uppermost fully expanded leaves. A hybrid cultivar (Hysun 33) was used in both experiments. All experimental plots received 350 kg/ha of 15-15-15 and 10 kg/ha of borax before sowing. Irrigation was by flooding and then draining after the soil was saturated.

Results

Leaf water potential and stomata resistance

There was a large difference between predawn and midday leaf water potential from all treatments of both experiments. Leaf water potential gradually declined after sunrise. Both predawn and midday leaf water potential during the 2 weeks of withholding water at any growth stage were found to be lower than that of the control plant (weekly irrigated) (Table 1). The later the withholding of water was imposed, the lower the leaf water potential observed. The observed pre-dawn and midday leaf water potential from the withholding water treatments ranged from -1.0 to -5.6 bars and -9.5 to -16.4 bars respectively. This contrast with -1.0 to 3.6 bars and -7.7 to -10.3 bars respectively observed from the control. The more frequently irrigated the plants, the higher leaf water potential (Table 2). Pre-dawn leaf water potential of the weekly and non-irrigated plants gradually declined as the plant age advanced (Figure 1). The non-irrigated plants gave lower values for leaf water

Table 1 Mean values of leaf water potential of sunflower cv.Hysun 33 after the withholding of water beginning at various stages of plant growth for two weeks.

Treatments	Leaf water potential (- bars)		
	predawn	late morning	midday
Weekly irrigated	2.1 (1.0-3.6)	7.4 (6.6-8.7)	9.3 (7.7-10.3)
V_{10}	1.2 (1.0-1.6)	8.8 (8.4-9.4)	10.0 (9.5-10.5)
R_1	2.5 (2.0-3.0)	9.7 (9.2-11.0)	13.0 (10.6-15.8)
R_3	4.0 (3.0-5.3)	10.3 (7.0-11.8)	13.4 (10.2-16.4)
R_5	4.6 (3.6-5.6)	10.4 (9.6-12.0)	13.5 (13.0-14.3)
R_7	-	-	-
Non-irrigated	4.6 (1.6-7.0)	10.4 (7.6-12.0)	13.2 (10.1-14.9)

Values in brackets were observed throughout the crop cycle.

Table 2 Mean values of leaf water potential of sunflower (measured before rewatering) under different irrigation frequencies.

Irrigation frequencies (week)	Leaf water potential (- bars)		
	predawn	late morning	midday
1	2.1 (0.8-3.2)	6.6 (2.4-9.4)	9.5 (3.5-12.4)
2	4.6 (3.2-5.5)	11.7 (10.0-13.0)	14.4 (13.4-15.8)
3	6.6 (5.4-7.9)	14.3 (12.9-15.7)	16.4 (15.8-16.9)
4	6.6 (3.7-9.7)	14.2 (10.2-17.8)	16.6 (13.7-19.6)
Non-irrigated	5.5 (1.7-8.1)	12.9 (5.2-16.4)	14.9 (7.2-18.0)

Values in brackets were observed throughout the crop cycle.

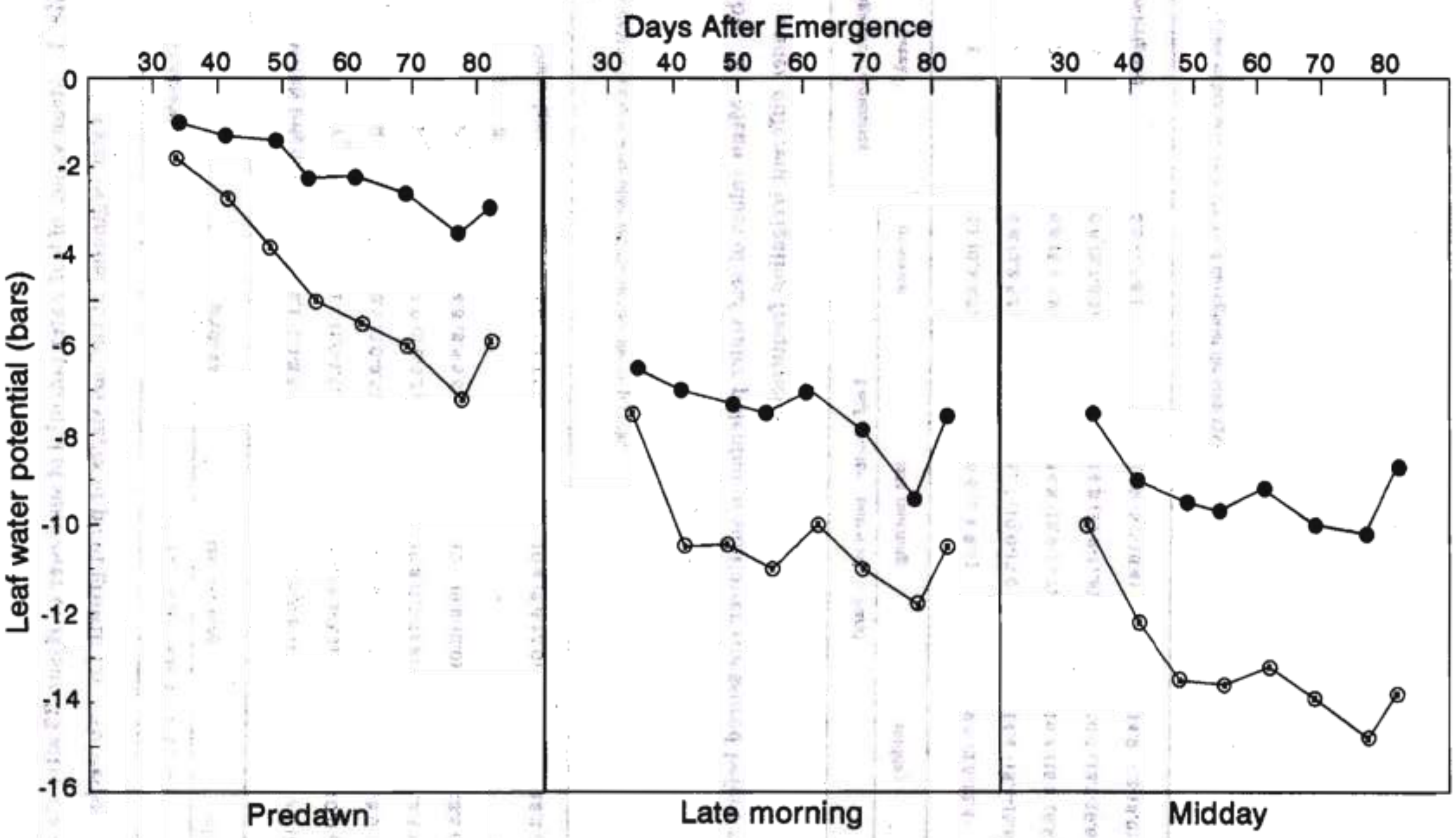

Figure 1 Leaf water potential of sunflower under weekly irrigation (●) and non-irrigation (o)

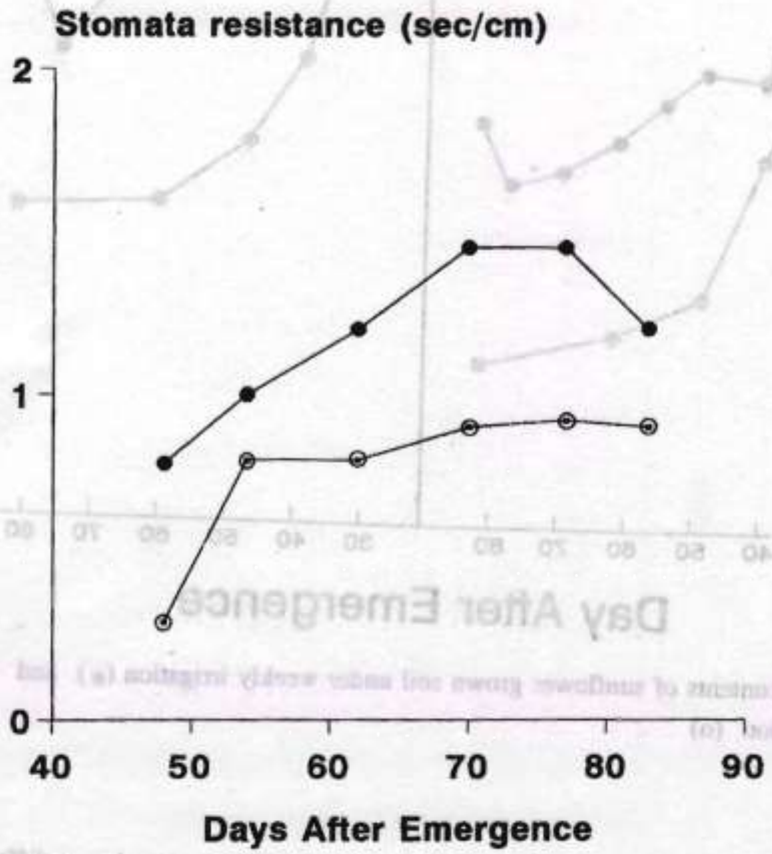

Figure 2 Stomata resistance of sunflower under weekly irrigation (o) non-irrigation (•).

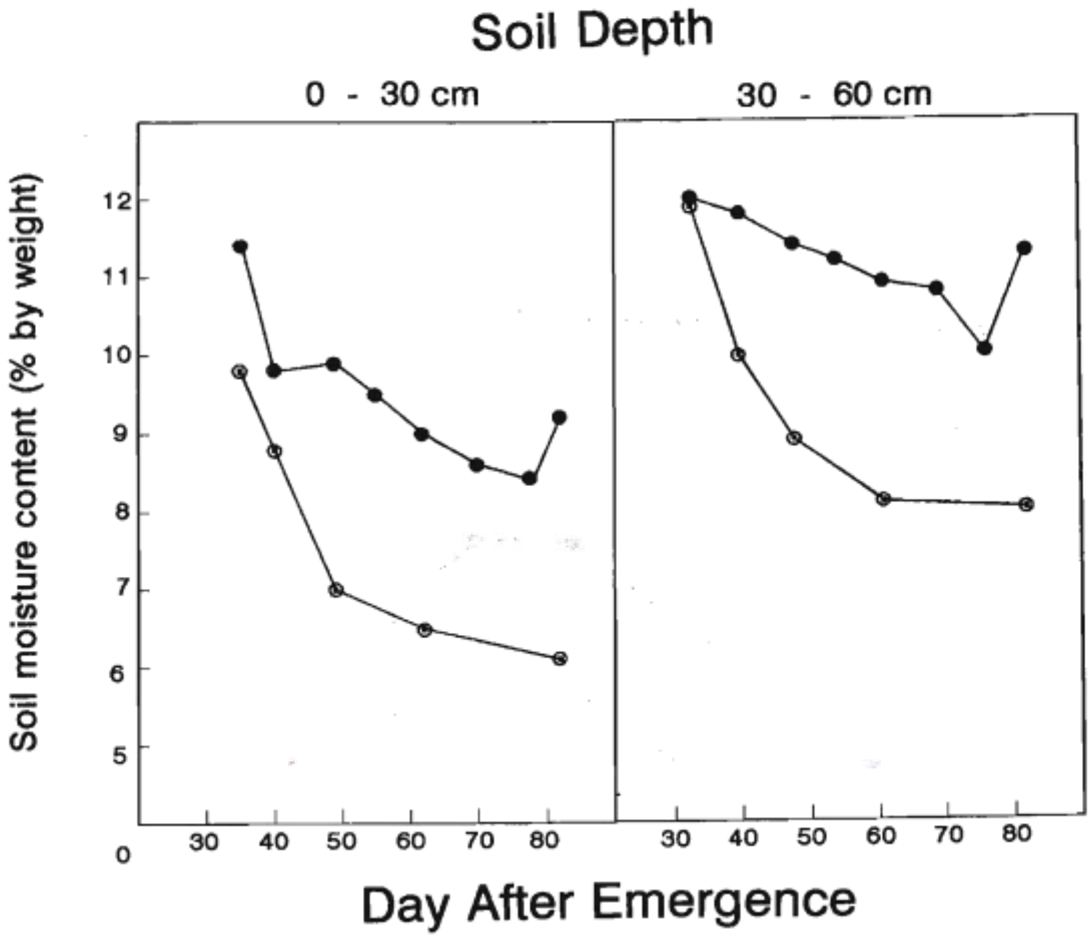

Figure 3 Moisture contents of sunflower grown soil under weekly irrigation (●) and non-irrigation (o)

potential than the weekly irrigated ones.The leaf water potential after weekly irrigated plants also decreased gradually with plant age. However, The leaf water potential of more grown plants were found lower than that of the plants during the young stage. This was due mainly to the higher atmospheric demand (Appendix 1) and larger leaf area at the time of measurement..

There was a small difference and inconsistentcy in stomata resistance among the treatments. However, a larger difference was observed between the weekly and non-irrigated treatments (Figure 2). The plants of the latter showed a higher stomatal resistance indicating that the stomatal opening on the leaf surface became narrower. It is likely that there is a negative relationship between stomata resistance and leaf water potential. The stomatal resistance increased when leaf water potential decreased.

The trend of change in leaf water potential during the crop cycle was similar to that of soil moisture content. The lower the soil moisture content observed, the lower the leaf water potial recorded. Soil moisture content from the non-irrigated treatment was much lower than from the weekly irrigated one, and declined more rapidly during the crop cycle (Figure 3). Moisture content of the soil at 30-60 cm depth was higher than that at 0-30 cm.

Agronomic responses

Experiment 1 There was no significance in growth (Table 3) and seed yield (Table 4) among the treatment means except for the non-irrigated treatment which gave lower results. The observed total DM and LAI of the non-irrigated treatments were 3.46 t/ha and 1.8 t/ha respectively, whereas the other treatments gave values of 5.27 - 5.80 t/ha and 2.7-3.3 respectively. Both withholding water and control treatments yielded ranging values from 3.22 t/ha to 3.54 t/ha, compared with 1.48 t/ha obtained from the non-irrigated one.

Experiment 2 Both growth and yields were significantly affected by the irrigation frequencies (Table 5 and Table 6). Total DM, LAI and yields markedly decreased with the increasing irrigation intervals. The weekly irrigated plants gave the highest yield of 2.69 t/ha and this decreased by 12 %, 33 % and 51 % as the irrigation was applied every 2, 3 and 4 weeks respectively. Non-irrigated plants gave the lowest yield of 0.66 t/ha. The most responsive yield component to water stress was the number of seeds per head and the weight of 100 seeds (Table 6).

Seed oil contents significantly decreased as irrigation intervals increased (Table 7). The observed values varied from 42.1 % - 51.4 % depending on irrigation frequencies. On the other hand, less frequent irrigation tended to increase seed protein content but the differences were not significant.

Table 3 Total dry matter, leaf area index and plant height of sunflower (cv. Hysun 33) after withholding water for two weeks at various stages of plant growth.

Treatments	DM (t/ha)	LAI	Plant ht. (cm)
Weekly irrigated	5.39	2.7	186
V_{10}	5.27	3.0	180
R_1	5.43	3.1	178
R_3	5.80	3.3	187
R_5	5.62	3.1	182
R_7	5.31	2.8	185
Non-irrigated	3.46	1.8	142
LSD (5%)	0.833	0.7	14.6

Table 4 Seed yields and yield components of sunflower (cv.Hysun 33) as affected by withholding water for two weeks at various stages of plant growth.

Treatments	Dry seed wt. (t/ha)	Capitulum size (cm)	No.seed per capitulum	100 seeds wt. (g)
Weekly irrigated	3.55	21.4	1476	6.0
V_{10}	3.22	19.4	1391	5.8
R_1	3.48	20.6	1517	5.6
R_3	3.41	20.9	1525	5.5
R_5	3.53	20.9	1463	6.0
R_7	3.22	20.6	1420	5.6
Non-irrigated	1.48	14.0	864	9.1
LSD (5%)	0.55	2.4	202	0.6

Table 5 Total dry matter, leaf area index and plant height of sunflower (cv. Hysun 33) under different irrigation frequencies.

Irrig. frequency (week)	DM (t/ha)	LAI	Plant ht. (cm)
1	4.77	2.5	171
2	3.59	2.1	160
3	2.84	1.5	146
4	2.73	1.3	133
Non-irrigated	1.68	0.8	90
LSD (5 %)	0.56	0.3	19.8

Table 6 Seed yield and yield components of sunflower (cv.Hysun 33) under different irrigation frequencies.

Irrig. frequency (week)	Dry seed wt. (t/ha)	Head diameter (cm)	No.seed per head	100 seeds wt. (g)
1	2.69	19.1	1308	5.1
2	2.38	17.1	1299	4.5
3	1.79	14.8	967	4.6
4	1.31	12.7	836	3.8
Non-irrigated	0.66	9.5	462	3.5
LSD (5 %)	0.183	0.9	143	0.3

Table 7 **Seed oil and protein contents of sunflower (CV. Hysun 33) as affected by irrigation frequencies.**

Irrig. frequency	% DW	
	Oil	Protein
1	51.4	15.8
2	46.3	16.0
3	46.7	16.1
4	42.1	16.9
Non-irrigated	41.6	16.9
LSD (5 %)	1.8	NS

Discussion

Plant and water relationships

Leaf water potential was affected by the soil water regime. The more severe the stress, the lower the leaf water potential observed. The leaf water potential of all treatments gradually declined from predawn to midday. The idea of using pre-dawn and midday leaf water potential as an indicator of stress was suggested by Slatyer (1969). It is clear from Table 2 that the less frequently irrigated plants were much more affected by water stress. The pre-dawn leaf water potential data for control plants (weekly irrigation) in this investigation indicates that the plants would be more affected by water stress as crop growth advances (Figure 1). This is probably due to a higher atmospheric demand and greater plant growth. Although not much difference was observed between the stomata resistance of the control plants and that of either the plants under the withholding water treatments or that of the less frequent irrigation treatments, greater difference was recorded between the control and the check treatments. It was seen that plants under weekly irrigated treatment were least affected by water stress.

The soil moisture content of the non-irrigated plot was rapidly depleted as time went by (Figure 3), and weekly irrigation was not enough to maintain the soil moisture level throughout the crop cycle at the same level as in early growth phase. A marked increase in soil moisture towards the end of the experiment was due to rain during that time (Appendix 1)

Growth and yields

Withholding water for two weeks at the beginning of any stages of plant growth of sunflower in this investigation was not detrimental to growth and yields. although those plants were under more stress than the control plants as indicated by a lower leaf water potential. This was probably because the stress was not severe and its duration short. A good recover of sunflower after water stress relief has been reported. Sobrado and Rawson (1984) found that the rate of leaf expansion of mildly stressed sunflower was up to three times greater than the normal plant after water stress relief. This could explain why dry matter accmulation and LAI were not affected by the 2 weeks water withholding. However, there was a positive relationship between growth and yield and irrigation frequencies. The less frequently the plants were irrigated, the more severe the stress. An average minimum and maximum midday leaf water potential of -13.4 bars and -19.6 bars respectively, were observed in all irrigation frequency treatments except for the weekly irrigation treatment which gave respective values of -3.5 bars and -12.4 bars (Table 2). These leaf water potential values were below level of -12 to -15 bars, and this affected growth and yields (Stegman 1983). Decreasing yield was mainly due to decreases in the yield components: the number of seeds per head and seed weight. The plants from the irrigation frequency experiment should be under a longer and more severe stress than those plants from the withholding water experiment.

The results from experiment 2 showed a good linear relationship between seed yields and between LAI or DM (Figure 4) but seed yield tended to decline with higher DM although the linear trend explained a high variation in yield. It is possible that seed yields can be increased if such linear relationship with LAI up to 5 is reported (Cox and Joliff, 1986). In the case of the DM aspect, Donald (1962) stated that an economic yield (seed yields) depends on biological yield if increasing such a biological yield does not decrease the harvest index.

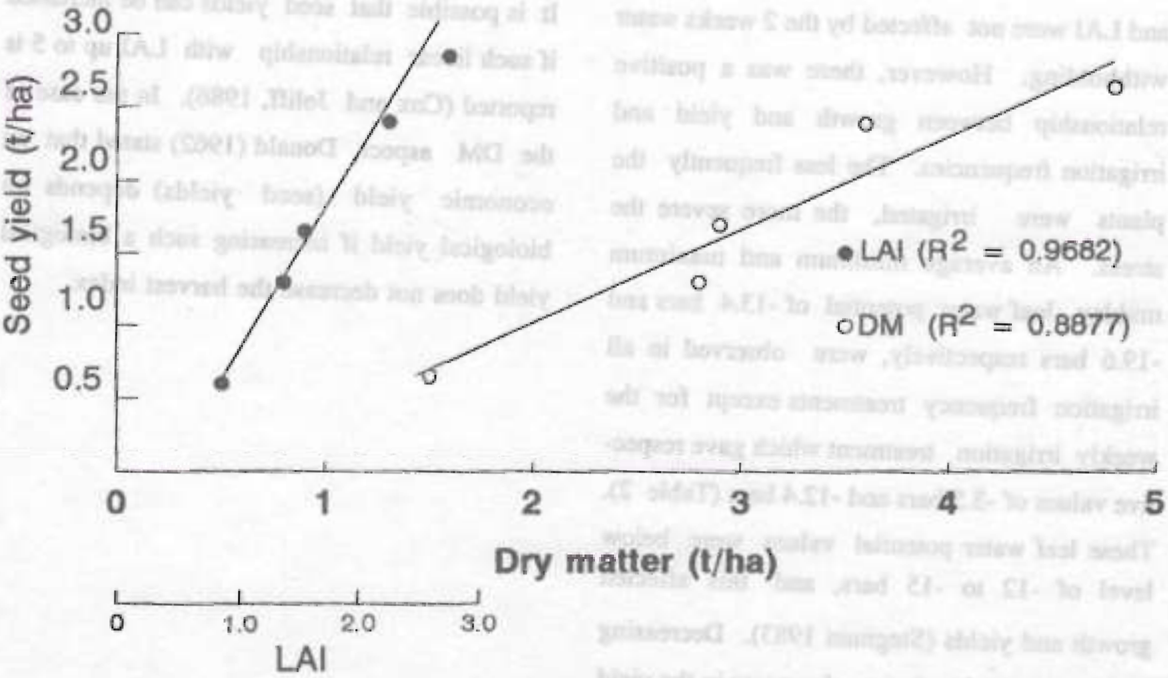

Figure 4 Relationships between seed yields, dry matter and LAI of sunflower cv.Hysun 33.

References

Connor, D.J., T.R.Jones, and J.A.Palta. 1985. Response of sunflower to strategies of irrigation. I. Growth, yield and the efficiency of water-use. Field Crop Research. 12:15-361.

Cox, W.J. and G.D Jolliff. 1986. Growth and yield of sunflower and soybean under soil water deficits. Agron. J. 18:226-230

Donald, C.M. 1962. In search of yield. J. Aust. Inst. Agric. Sci. September, 171-177.

Kandil, A. 1984. Sunflower head development as affected by irrigation intervals. Ann. Agric. Sci. 22:3-13.

Kramer, P.J. 1983. Water relations of plants. (ed.) Academic Press Inc. New York.

Robinson, R.G. 1978. Production and culture. In J.F. Cater (ed.). Sunflower science and technology. Am. Soc. of Agron. crop. Sci. of Am., Soil Sci. Soc. of Am., Inc. Wisconsin.

Slatyer R.O. 1969 Physiological significance of internal water relation to crop yield. In J.D. Eastin, F.A. Haskins, C.Y. Sullivan, and C.H.M. Vabarjel. (ed). Physiological Aspects of crop yield. Am. Soc. of Agron., Crop Sci. Soc. of Am., Wisconsin. crop yield. Am. Soc. of Agron., Crop Sci. Soc. of Am., Wisconsin.

Sobrado, W.A. and Rawson. 1984. Leaf expansion as related to plant water availability in a wild and cultivated sunflower. Physiol. Plants. 60:561-566.

Stegman, E.C. 1983. Corn and sunflower yield vs management of leaf xylem pressures. Transaction of Agric. 26:1362-1368.

Stegman, E.C. and G.W. Lemert. 1981. Sunflower yield vs water deficit in major growth periods. Transactions of Agric. 24:1533-1538.