Effects of cultivar, irrigation interval and nitrogen on seed yield, oil content and quality of sunflower (*Helianthus annuus* L.)

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ABSTRACT

Field trials were carried out during summer (2010/11) and winter (2011/12) seasons. The objective of the study was to investigate the effects of two sunflower cultivars: Hysun33 (hybrid) and Damazin-1 (open-pollinated), three irrigation intervals: (7, 14 and 21 days) and three rates of nitrogen in the form of urea: (0, 86 and 129 kg N/ha) on seed yield, oil content and quality of sunflower. Hysun33 significantly out-performed Damazin-1 in seed yield, oil content and quality during the winter season, while Damazin-1 had a higher seed yield, higher oil content and quality compared with Hysun 33 during the summer season. The 7-day irrigation interval gave the highest seed yield compared with 14 and 21-day irrigation intervals during the summer season. However, the 14-day irrigation interval out-yielded the two other irrigation intervals during the winter season. The highest oil content was obtained by both cultivars (Hysun33 and Damazin-1) in both seasons with 7-day irrigation interval. Nitrogen rate of 129 kg/ha gave the highest seed yield (1.56 and 1.17 t/ha) during the summer season. The highest oil content (39.72% and 35.85%) was obtained when 86 kg N/ha was applied during both seasons. Stearic, palmitic, oleic and linoleic acids were the most dominant fatty acids in sunflower seed oil. Hysun33 significantly out-yielded Damazin-1 in oleic and linoleic acids in both seasons. However, Damazin-1 had significantly higher content of stearic and palmitic acids in both seasons. Based on this study, to obtain high seed yield and high oil content and quality of sunflower, it is recommended to grow Damazin-1 in summer and Hysun33 in winter, irrigate every 14 days and apply 86 kg N/ha for both cultivars.

INTRODUCTION

Sunflower (*Helianthus annuus* L.) is currently the world′s fourth largest oil seed crop (De Rodriguez *et al.,* 2002). The world production of sunflower seeds increased from 26 to 30 million metric tons between 2004 and 2006 (FAO, 2007). Sunflower oil is considered to be of good quality for edible purposes.

The development of cultivars with high oleic acid content is, at present, an important improvement (Martinez *et al,* 1993). Ahmed *et al*., (2006), in Sudan obtained an oil content of 36.6% for hybrid (Hysun33) and 34.1% for open-pollinated cultivar (Rodeo) at the same irrigation regime (700 mm) during winter season. Lazim (1985) found that sunflower was most sensitive to water stress at flowering, as it reduced seed yield and oil content. Daffalla *et al*., (2013) reported that for maximum seed and oil yields sunflower should not be subjected to water stress during bud formation or flowering stage. Moreover, seed yield and oil content increased in proportion to the increase in the amount of irrigation given to the crop (Ghazy and Abu Ghaazala, 1999). Sunflower is greatly influenced by irrigation and vigorous growth and high seed yield can be achieved by application of optimum irrigation (Ramamoorthy *et al.,* 2009). Moisture content and light during growth and seed development affect yield, oil content and fatty acid composition of the oil (Khalifa *et al.,* 2000). Daffalla *et al.,* (2013), reported that nitrogen rate of 86.7 kg/ha produced higher seed yield and higher fatty acids content.

Information on sunflower seed production, oil content and quality subjected to different irrigation intervals and nitrogen levels are scanty. The objective of this study was to investigate the effects of irrigation intervals, nitrogen fertilization and cultivar on seed yield, oil content and quality of sunflower**.**

MATERIALS AND METHODS

Field trials were carried out for two consecutive seasons, summer (2010/11) and winter (2011/12), at the Experimental Farm of the Faculty of Agricultural Sciences, University of Gezira, Wad Medani, Sudan. The experimental site has dark- brown, deep cracking clay soil, with very low permeability when moist, low in organic matter (0.5%), nitrogen (0.03%) and available phosphorus (6 mg/kg soil). The soil is alkaline with a pH of 8.3.

Treatments consisted of two cultivars, 3 irrigation intervals and 3 nitrogen levels. Treatments were arranged in a split-split plot design with three replicates. The two cultivars Hysun33 and Damazine-1 were assigned to the main plots, the three irrigation intervals (7, 14 and 21 days) were allotted to the sub- plots and the three levels of nitrogen (0, 86 and 129 kg/ha) in the form of urea were assigned to the sub- sub- plots.

The field was disc ploughed, harrowed, leveled, ridged, and then divided into main, sub and sub-sub-plots. The size of the sub-sub- plots was 4×5 m. Sunflower seeds were sown on the 5th of March (summer sowing) and mid of November (winter sowing). Seed rate was 5-7 seeds per hole, thinned to one plant/ hole three weeks later. Irrigation water was applied immediately after sowing and continued thereafter according to the schedule of the experiment. Nitrogen was applied at sowing at the rate of 0, 86 and 129 kg/ha.

Yield components were determined at maturity stage, and seed yield was obtained from a harvested area of one square meter (m^2). Oil content and quality were determined by soxhlet extraction method (A.O.A.C, 1990) and Gas liquid chromatography (GLC) at the National Oil Processing Research Institute (NOPRI) laboratories, University of Gezira, respectively.

Data were collected for yield (t/ha) and yield components, which consisted of number of seeds/head,1000-seed weight (g), empty seed percentage and oil content and fatty acid composition.

Data were analyzed using the standard analysis of variance procedure and the treatments means were separated using Duncan's Multiple Range Test (DMRT) at 0.05 level of significance.

RESULTS AND DISCUSSION

a. Yield and yield components

1. Cultivar

The yield and yield components of the two cultivars Hysun33 and Damazin-1 were significantly different in the summer and winter seasons (Table 1). Hysun 33 produced significantly higher seed yield (1.39 t/ha), more than 78% increase than Damazin-1, (0.78 t/ha), higher number of seeds/plant, heavier 1000-seed weight and significantly less empty seeds percentage

(9.39%) than Damazin-1 (16.22%) in the winter season. However, Damazin-1
mentioned parameters and had significantly lower empty seeds percentage in the summer season. The high seed yield of Hysun33 and Damazin-1 could be attributed to the high number of seeds and 1000-seed weight obtained at the winter and summer seasons, respectively. These results were in line with the findings of Ali *et al.*, (2003) and Daffalla (2010) who stated that Hysun33 was superior to Damazin-1 in most of the studied characters in winter.

2. Irrigation interval

Table 1 showed that irrigation intervals had no significant effect on seed yield of the two cultivars in both seasons. However, significant differences were detected for 1000- seed weight and empty seeds percentage of the two cultivars with varying irrigation intervals in both seasons. Higher seed yields (1.51 and 1.27 t/ha) were obtained when 7 and 14-day irrigation intervals were practiced in the summer and winter seasons, respectively. The heaviest seeds (33.37 and 39.22 g) and the lowest empty seeds percentage (15.99 and 12.36%) were obtained under 7-day irrigation interval in the summer and winter seasons, respectively. Irrigation interval had no significant effects on number of seeds/ head in both seasons. The higher numbers of seeds/plant (656 and 688) were obtained when 14 and 21-day irrigation intervals were practiced during the summer and winter seasons, respectively. These results disagreed with the results of Ahmed *et al.*, (2006) who reported that irrigation every 7 days led to high number of seeds per head compared to 14 or 21-day irrigation intervals.

3.Nitrogen

Nitrogen significantly ($P \leq 0.05$) increased number of seeds/head, and 1000-seed weight, while nitrogen had inconsistent effects on empty seeds percentage in summer and winter seasons (Table 1). These results were in agreement with the findings of Ali *et al.* (2003) and Daffalla (2010) who found that nitrogen at the rate of 130 kg/ha gave higher seed yield which was mainly due to increased number of seeds/m^2, 1000-seed weight and reduced empty seed percentage. However, these results disagreed with those of Osman (1995), who reported that nitrogen application had no significant effects on the above mentioned parameters of sunflower grown under rain-fed conditions.

Table 1. Effects of cultivar, irrigation intervals and nitrogen on seed yield, and its components of sunflower in summer (2010/11) and winter (2011/12) seasons.

Treatment	Summer				Winter			
Cultivar:	Seed yield (t/ha)	No. of seeds/head	Empty seeds/head (%)	1000-seed wt. (g)	Seed yield(t/ha)	No. of seeds/head	Empty seeds/head (%)	1000-seed wt. (g)
Hysum33	1.31b	589a	18.79a	29.32b	1.39a	689a	9.39b	37.30a
Damazin-1	1.47a	645b	14.00b	35.00a	0.78b	653b	16.22a	37.04a
Sig. level	*	*	*	*	*	*	*	*
C.V%	7.2	10.54	5.64	15.95	22.9	2.89	2.92	21.25
Irr. Intervals (days):								
07	1.51	641	15.99c	33.38a	1.04	666	12.36b	39.22a
14	1.42	656	17.02a	32.78a	1.27	658	12.78b	37.00b
21	1.24	554	16.31b	29.82a	0.95	688	12.27a	35.28c
Sig. Level	NS	NS	*	*	NS	NS	**	*
C.V%	19.1	15.62	15.31	8.91	25.9	6.65	2.21	23.28
Nitrogen rate(Kg/ha):								
Zero	1.26b	588b	16.13c	28.72b	0.98	635b	13.08a	35.89c
86	1.26b	632a	16.78	31.45b	1.13	685a	12.56b	39.11a
129	1.56a	621a	16.41b	3581a	1.17	693a	12.78b	36.50b
Sig. Level	**	**	**	**	NS	**	**	**
C.V%	14.4	4.06	2.85	3.49	20.8	5.37	2.21	11.99

Means in columns with similar letter(s) are not significantly different at 0.05 level of probability according to Duncan's Multiple Range Test.
*, ** and NS indicate significance at P≤0.05, 0.01 and not significant, respectively.

The interaction effects of cultivar× irrigation intervals× nitrogen on seed yield of sunflower were significant in both seasons (Table 2). Interactions of (Cv×W), (Cv×N) and (W×N) generally gave significantly (P≤ 0.05) high of seed yield. The greatest seed yield values (1.7 and 1.8 t/ha) were achieved by Hysun33 and Damazin-1 with 7 and 21-day irrigation intervals, respectively when both received the 129 kg N/ha during summer season. Compared to Hysun33 and Damazin-1, which obtained highest seed yield values (2.05 and 1.02 t/ha), respectively when both received 14-day irrigation interval and 86 kg N/ha during the winter season. These findings were in agreement with those of De Giorgio *et al.*, (2007), who showed that the environmental conditions strongly influenced sunflower performance when different cultivars and different irrigation intervals were used.

b. Seed oil content

1.Cultivar

During summer season, the two cultivars showed no significant difference in seed oil content, while in winter, Damazin-1 had significantly higher seed oil content (35.70%) than Hysun33 (35.30%). However, summer sowing had the highest seed oil content (38.81%) than winter sowing (35.50%) (Table 3). Ahmed *et al*., (2006), in Sudan obtained an oil content of 36.6% for hybrid (Hysun33) and 34.1% for open-pollinated cultivar (Rodeo) at the same irrigation regime during winter season.

2. Irrigation interval

The highest and lowest seed oil content (39.55% and 33.98%) were obtained under 7 and 21-day irrigation intervals in the summer and winter seasons, respectively (Table 3). This result was supported by the results of Hang and Evans (1985), who noticed that oil concentration was increased with increased irrigation water.

3.Nitrogen

In this study, 86 and 129kg N/ha gave the highest and lowest seed oil content (39.72% and 35.02%) in the summer and winter seasons, respectively (Table 3). This finding was in line with those of Daffalla (2010), in Sudan, who stated that the seed oil content was negatively associated with nitrogen application. Contrarily, however, Ayyappan *et al*., (2002), in India, reported that seed oil content increased by increasing nitrogen up to 120 kg/ha.

Table 2. Interaction effects of cultivar, irrigation intervals and nitrogen on seed yield (t/ha) of sunflower in summer (2010/11) and winter (2011/12) seasons.

Nitrogen rate (kg/ha)	Summer						
	Hysum 33			Damazin-1			
	7 day	14 days	21 days	7 days	14 days	21 days	Mean
Zero	1.30d	1.35d	0.78f	1.15de	1.44d	1.53c	1.26C
86	1.59c	1.40d	0.88f	1.41d	1.46d	1.35d	1.35B
129	1.70b	1.29d	1.09c	1.50c	1.57c	`.80a	1.49A
Irrig. Mean	1.53A	1.35A	0.91B	1.35A	1.49A	1.56A	
Cultivar mean		1.26			1.27A		
Season mean				1.39A			
C.V%				14.41			

Table 2. Continued.

Nitrogen rate (kg/ha)	Winter						
	Hysum 33			Damazin-1			
	7 day	14 days	21 days	7 days	14 days	21 days	Mean
Zero	1.05cd	1.22c	1.27c	0.76d	0.89d	0.68de	0.98A
86	1.18c	2.05a	1.11c	0.86d	1.02cd	0.56e	1.13A
129	1.55b	1.62b	1.50b	0.86d	0.79d	0.5c	1.15A
Irrig. Mean	1.26B	1.63A	1.29B	0.83C	0.90C	0.60D	
Cultivar mean		1.39A			0.78B		
Season mean				1.09A			
C.V%				20.77			

Means with similar letter(s) are not significantly different at 0.05 level of probability according to Duncan's Multiple Range Test.

Table 3. Interaction effects of cultivar, irrigation intervals and nitrogen on oil content (%) of sunflower in summer (2010/11) and winter (2011/12) seasons.

Nitrogen rate (kg/ha)	Summer						
	Hysum 33			Damazin-1			
	7 day	14 days	21 days	7 days	14 days	21 days	Mean
Zero	39.0 g	36.1 k	32.0n	41.6c	402c	39.5f	38.07C
86	38.4 h	43.0 a	44.5c	40.8d	35.31	39.3f	39.72A
129	37.2 i	42.1 b	40.6d	40.3e	35.0 m	36.7j	38.65B
Irrig. Mean	38.2C	40.4 B	38/03D	40.9A	36.83 E	38.5C	
Cultivar mean		38.88 A			38.74 A		
Season mean				38.81A			
C.V%				0.36			

Table 3. Continued

Nitrogen rate (kg/ha)	Winter						
	Hysum 33			Damazin-1			
	7 day	14 days	21 days	7 days	14 days	21 days	Mean
Zero	35.1fg	36.3d	35.10fg	35.5 ef	40.0 a	31.8 g	35.63B
86	38.0b	35.2fg	34.10i	35.7e	34.9g	37.2c	35.85A
129	37.4c	35.29f	31/20 k	37.5c	34.2 hi	34.5b	35.02C
Irrig. Mean	36.83A	35.5C	33.4 E	36.23B	36.27B	34.5D	
Cultivar mean		35.30B			35.70D		
Season mean				35.50B			
C.V%				0.56			

Means with similar letter(s) are not significantly different at 0.05 level of probability according to Duncan's Multiple Range Test.

The three way interaction (cultivar× irrigation intervals× nitrogen) had a significant effect on seed oil content. Results in Table 3 show that Hysun33 under 14-day irrigation interval and 86 kg N/ha and Damazin-1 under 7-day irrigation interval and no nitrogen produced the highest seed oil content (43% and 41.6%), respectively, in the summer season, while the lowest seed oil content (31.20% and 31.80%) were recorded for Hysun33 and Damazin-1, when 21-day irrigation interval was practiced coupled with 129 and 0kg N/ha, respectively, in the winter season. These findings disagree with those of Daffalla *et al.* (2013), who found that N rates of 86 kg/ha resulted in seed oil content of 42.9% with respect to Hysun33 when irrigated every 14 days.

c. Fatty acid composition

1. Cultivar

Fatty acid composition of sunflower oil is presented in Table 4. Oleic and linoleic acids were the most dominant unsaturated fatty acids, while stearic and palmitic were the most dominant saturated ones. In this study the two cultivars were significantly different in fatty acids content. Hysun33 had a significantly higher oleic and linoleic acids (35.46%,50.07%) and (37.31%, 50.29%) than Damazin-1 (32.03%, 41.07%) and (36.63%, 47.10%) in the summer and winter seasons respectively. Damzin-1 on the other hand, had significantly higher stearic and palmitic acids (4.66%, 7.51%) and (5.51%,7.59%) than Hysun33 (3.95%, 6.67%) and (4.11%, 7.57%) in the summer and winter seasons, respectively. These variations in fatty acids content are strongly influenced by both genetics and climate. They are in line with those of De Rodrigues *et al.*, (2002) who reported that the values of fatty acids were 5.8 to 6.5% for stearic acid, 5.9 to 7.0% for palmitic acid, 15.8 to 22.2% for oleic acid and 36.0 to 69.5% for linoleic acid. The British Pharmacopoeia (2005) listed stearic, palmitic, oleic and linoleic acids range of 1% to 7%, 4% to 9%, 14% to 40% and 48% to 74%, respectively.

2. Irrigation interval

Table 4 shows that in summer and winter seasons, the fatty acid composition of sunflower oil were significantly affected by irrigation intervals. The 14-day irrigation interval registered the highest mean of stearic acid (5.09% and 5.85%), palmitic acid (7.95% and 8.28%), oleic acid (35.99% and 38.03%) and linoleic acid (48.94% and 50.58%) in the summer and winter seasons, respectively. These findings were confirmed by those of Daffalla (2010), who concluded that frequent irrigation (two weeks interval) gave higher fatty acids composition of sunflower oil.

3.Nitrogen

Nitrogen rate of 86 kg/ha resulted in the highest stearic acid (4.60% and 5.47%), palmitic acid (7.35% and 7.84%), oleic acid (34.45% and 37.24%) and linoleic acid (46.81% and 49.93%), in the summer and winter seasons, respectively (Table 4). These findings were in agreement with those of Daffalla *et al.* (2013), who reported that nitrogen rate of 86.7 kg/ha produced higher fatty acids content. Zheljazkov *et al.*, (2009), demonstrated that agricultural factors such as planting date, hybrid and nitrogen rate may significantly modify fatty acids composition and oil content of sunflower grown in Mississippi. However, these results were not in agreement with those of Elhaj (1999), who reported that significant differences were not observed due to application of different foliar fertilizers on the fatty acids content such as stearic, palmitic, oleic and linoleic.

Table 4. Effects of cultivar, irrigation intervals and nitrogen on fatty acid composition of sunflower in summer (2010/11) and winter (2011/12) seasons.

Treatment	Summer				Winter			
	Fatty acid composition(%)				Fatty acid composition(%)			
	Stearic	Palmitic	Oleic	Linoleic	Stearic	Palmitic	Oleic	Linoleic
Cultivar:								
Hysum 33	3.95b	6.67b	35.46a	50.07a	4.11b	7.57	37.31a	50.29a
Damazin-1	4.66a	7.51a	32.03b	41.07b	5.51a	7.59	36.63b	47.10b
Sig. level	**	**	**	**	*	NS	*	**
C.V%	2.32	2.00	0.51	0.29	6.25	4.76	1.43	0.18
Irrig. Intervals (days):								
07	4.13b	6.95 b	33.12 b	43.79 c	5.08 b	7.26 b	36.46 b	48.97 b
14	5.09 a	7.95 a	35.99 a	48.94a	5.58 a	8.28 a	38.03a	50.59a
21	3.70 c	6.37 c	32.13 c	44.63 b	4.27 c	7.19 b	36.41 b	46.69c
Sig. level	**	**	**	**	**	**	**	**
C.V%	4.65	2.83	0.56	0.61	5.73	4.17	1.38	0.93
Nitrogen rate (kg/ha):								
Zero	4.18b	7.24a	34.20b	45.92b	5.85a	7.65b	37.03b	48.33b
86	4.60a	7.35a	34.45a	46.81a	5.47a	7.84a	37.24a	49.93a
129	4.13b	6.68b	33.19c	44.93b	4.93b	7.22c	36.63c	46.83c
Sig. level	**	**	**	**	**	**	**	**
C.V%	3.28	2.83	0.78	0.54	3.29	3.73	0.54	0.47

Means in columns with similar letter(s) are not significantly different at 0.05 level of probability according to Duncan's Multiple Range Test.
*, ** and NS indicate significance at P≤0.05, 0.01 and not significant, respectively.

CONCLUSIONS AND RECOMMENDATIONS

High seed yield of sunflower was obtained by Damazin-1 in the summer season, while Hysun33 out-yielded Damazin-1 in the winter season. High seed yield is obtained by Damazin-1 and Hysun33 when 7 and 21-day irrigation intervals and 129 kg N/ha were practiced during summer and winter seasons, respectively. Hysun33 irrigated every 14 days and given 86 kg N/ha and Damazin-1 irrigated every 7 days without nitrogen, produced the highest seed oil content (43.00 and 41.60%), respectively, during summer season. Optimum fatty acids composition was obtained by the two cultivars when 14-day irrigation interval coupled with 86 kg N/ha during the winter season. To obtain high seed yield, seed oil content and fatty acids composition, Damazin-1 is recommended to be grown in the summer season and Hysun33 in the winter season and to receive irrigation every 14 days coupled with 86 kg N/ha.

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تأثير الصنف و فترات الري والنيتروجين على إنتاجية وكمية ونوعية بذور وزيت زهرة الشمس (***Helianthus annuus* L.**)

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الخلاصة

أجريت التجارب الحقلية خلال العروة الصيفية موسم(11/2010) والشتوية موسم (12/2011). هدفت الدراسة لمعرفة تأثير صنفي زهرة الشمس: هايصن33 (هجين) ودمازين-1 (مفتوح التلقيح) وثلاث فترات ري: (7، 14 و21 يوم) وثلاث معدلات نيتروجين في صورة يوريا: (صفر، 86 و129 كجم N /هكتار) على إنتاجية وكمية ونوعية زيت زهرة الشمس. تفوق الصنف هايصن33 معنوياً علي الصنف دمازين-1 في الإنتاجية وكمية ونوعية الزيت في العروة الشتوية، بينما أعطي الصنف دمازين-1 أعلى إنتاجية وكمية ونوعية زيت مقارنة بالصنف هايصن33 في العروة الصيفية. أعطت فترة الري كل 7 – يوم أعلى إنتاجية بذور مقارنة بفترتي الري و14-21 يوم في العروة الصيفية. تفوقت فترة الري كل 14- يوم- إنتاجياً-على الفترتين الأخريين في العروة الشتوية. أعلى كمية زيت تحققت لكلا الصنفين (هايصن33 ودمازين-1) في كلا العروتين عند الري كل 7 أيام. حقق معدل النيتروجين (129 كجم N/هكتار) أعلى إنتاجية بذور خلال العروة الصيفية. تحققت أعلى كمية زيت عند إضافة 86 كجم نيتروجين/هكتارخلال العروتين. أحماض السيتاريك، البالماتيك، الأوليك واللينوليك هي الأحماض الدهنية السائدة في بذرة زهرة الشمس. أظهر الصنف هايصن33 تفوقاً معنوياً علي الصنف دمازين-1 في أحماض الأوليك واللينوليك في كلا العروتين. بينما أعطى الصنف دمازين-1 أعلى محتوى من أحماض السيتاريك والبالماتيك خلال العروتين. بناءاً على هذه الدراسة للحصول على أعلى إنتاجية وأعلى كمية ونوعية زيت زهرة الشمس يوصى بزراعة الصنف دمازين-1 في العروة الصيفية والصنف هايصن33 في العروة الشتوية والري كل 14 يوماً وإضافة 86 كجم نيتروجين/هكتار لكلا الصنفين.