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Yield and Fatty Acid Profile as Affected by Sowing Date and Seed Rate of Linseed *(Linum usitatuissimum* L.) Under River Nile State Environment

Barakat A. Abdelfarag[1] and Abdalla M. Ali[2] and

[1]**Hudeiba Research Station, Agricultural Research Corporation, Sudan**
[2]**Department of Horticulture, Faculty of Agriculture, University of Khartoum**

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Abstract: linseed is rich in oil and fatty acid content, both of which vary greatly with the environment. The objective of this experiment was to determine the optimum planting date and seed rate of linseed as a potential crop for the existing cropping system of River Nile state. Four sowing dates (first of November, mid November, first of December and mid December) and three seed rates (50, 60,and 70 kg/ha) were studied in an experiment carried out in Hudeiba Research station farm for two winter seasons *ie* 2011/2012 and 2013/2014. The experiment was laid out in split plot design with three replications. Seed rates were randomized in the main plots and sowing dates in subplots. Results showed that seed yield was not significantly affected by seed rate but by sowing date.. First of November sowing date with 60kg/ha seed rate resulted in the highest seed yield of 1216 kg/ha; seed yield declined with delaying sowing. The highest oil content (20.8%) was obtained from planting at 50 kg/ha in first of November. A total of twenty fatty acids were identified in different sowing dates . Number of fatty acid varied from one sowing date to another. That is, 15 in First November, 7 in mid November, 8 in First of December and 14 in mid of December sowing. Dominant fatty acids in first of November, mid November, first of December and mid December sowing dates were oleic acid, linolelaidic acid, linolelaidic acid and oleic acid respectively.

Key words: Flaxseed; cultural practices; linseed; oil content; fatty acids; Sudan.

INTRODUCTION

Flax has been cultivated since at least 5000 BC, probably first by the ancient Mesopotamians and later by the Egyptians who wrapped their mummies in linen cloth. The Romans spread flax cultivation to Northern Europe and now the plant is grown all over the world. The flax species is an annual crop, with two different forms used for fibers which are made into linen and other cloths (flax), and the seed for oil extraction (linseed). Now it is the third largest natural fiber crop and one of the five major oil crops in the world.Flax seed is rich in fat, protein and dietary fiber. The seed composition is about 30-40% of fatty oil (linseed oil) with esters of linoleic acid, linolenic acid, stearic acid and oleic acid; also, mucilage, proteins, a cyanogenic glycoside (linamarin) and enzymes. The composition of flax can vary with genetics, growing environment, seed processing and method of analysis (Daun *et al.* 2003). The protein content of the seed decreases as the oil content increases (Daun and De Clercq 1994), and the oil content of flax can be improved through traditional plant cultural practices, breeding methods, and it is affected by geographical location. Abd El-Mohsin *et al*. (2013), in Egypt, found significant linear relationship between planting dates and each of seed and oil yield which provides a clue that these traits are dependent upon planting dates. Also, Sohair *et al*. (2015) indicated that sowing dates, significantly affected seed index, seed yield / plant as well as per unit area and oil yield /ha in the two seasons of the study in Egypt. In Ethiopia, Abebe and Adane (2015) reported significant ($P \leq 0.05$) effects of seed rates on all yield components reflecting the importance of seeding rate for linseed growth, yield and yield components. The cool nights as in northern Canada improved oil content and quality (Anonymous 2001).

In Sudan, information regarding the production of flax is not available. So, it is unfortunate that the flax wealth is never brought out to the forefront of any level of discussion to promote the crop for local consumption or export. Therefore, the present research was conducted to investigate the potentiality of introducing linseed in the cropping system of River Nile State as an oil crop for food, export and other purposes as medicinal use. The

specific objective of this research was to determine the optimum seed rate and sowing date for high seed yield, oil content and fatty acids composition.

MATERIALS AND METHODS

The experiment was conducted at Hudeiba Research Station (HRS) farm, in the River Nile State, 300 km North of Khartoum at lat. 17˚ 34′ N and 23˚ 56′ E with altitude of 351 meter above sea level. Winter season is characterized by short duration (100-110 days) and relatively cool temperature (mean max.32.5ºC and mean min. 15.6ºC). The soil of the experimental farm is classified as Karima series, which is moderately fertile and ranges from clay to loam (Omer 2004).The experimental area was ploughed then harrowed, leveled, ridged and divided into plots of 5x2.5m. Each plot contained three ridges 4.2 m long and 0.6m wide. The experimental design was split plot design with three replicates. Seed rate treatments were randomized in the main plots and sowing dates were in the subplots. Seed rates were 50, 60. 70 kg/ha, and the sowing dates were first of November, mid-November, first of December and mid-December, during 2011-2012 and 2013-2014 seasons. Seeds were drilled along both sides of the ridges, covered and irrigated. Urea fertilizer was added at the rate of 120 kg/ ha after 45 days from planting as recommended (Shareif *et al.* 2005). Plants were harvested after three months from sowing and pods were threshed and seeds were collected. Oil extraction was carried out according to the method described by (Harborne 1984) for seed yield of season 2011/2012. Extracted fixed oil profile was carried by the fatty acid methyl ester method (Ehrisue 1990) using gas chromatography-(GC 2010 Shimadzu, Japan). All data were statistically analyzed by Mstat computer software.

RESULTS AND DISCUSSION

The linseed yield was significantly ($P \leq 0.5\%$), affected by both seed rate and sowing date in both seasons (Table 1). The highest mean seed yield for both seasons (1085.6 kg/ha) was obtained in first of November and decreased progressively by late sowing dates. This result agrees with Wiedenhoeft and Carlson (2006) who reported that flax grain yield decreased linearly with

later planting dates. The linseed oil percent was significantly (P≤ 0.5%) affected by sowing date in the first season but not by seed rate in both seasons. The highest combine mean of the two seasons for oil percent was (18.6 %) in first of November. Rest of the sowing dates reflected inconsistent trend. For instance, the lowest percent oil was recorded in mid- November in the first season and in mid-December in the second season and in the combine analysis means (Table 1). This may be due to the prevailing temperature during grain filling and seed formation. The interaction between sowing date and seed rate was not significant regarding oil percentage. The linseed oil yield was significantly (P≤ 0.5%) affected by sowing date in both seasons and by seed rate in the first season. The highest mean oil yield (200.9 kg/ha) resulted from sowing in the first of November and then deceased with delayed sowing to the first of December when lowest yield (125.9 kg/ha) was obtained and slightly increased with the latest sowing in mid December (Table 1).

Table 1. Effect of seed rate and sowing date on seed yield, oil content and oil yield of linseed at Hudeiba Research Station for seasons 2011/2012 ,2013/2014 and combined analysis.

sowing Date (SD)	Season 2011/2012 Seed Rates (S R)				Season 2013/ 2014 Seed Rates (S R)				
	50kg/ha	60 kg/ ha	70 kg/ha	Mean	50kg/ ha	60 kg/ ha	70 kg/ha	Mean	Combine
					Seed yield (kg/ha)				
1st November	939.9	1187.4	860.2	995.8 a	1228.6	1245.3	1052.0	1175.3a	1085.6a
Mid November	862.3	890.6	958.9	903.8 a	1226.0	1082.2	744.3	1017.5b	960.7 b
1st December	612.1	928.0	619.6	719.9 b	1008.4	796.**6**	870.5	891.8c	805.9 c
Mid December	569.1	701.4	661.9	644.1 b	827.2	864.6	868.6	853.5c	748.8 c
Seed rate means	745.9 a	926.9 a	775.1 a		1072.6 a	997.2a	883.9b		
SR×SD				31.6				23.6 .	15.9
					Oil content (%)				
1st November	20.829	19.761	20.282	20.291 a	18.7	15.5	16.7	17.0a	18.6a
Mid November	14.333	17.301	16.046	15.893 c	16.2	17.1	17.4	16.9a	16.4 a
1st December	18.476	15.004	17.663	17.048 bc	15.1	13.7	14.8	14.5a	15.8 a
Mid December	19.237	16.141	17.219	17.532b	16.8	16.2	15.6	16.2a	16.8 a
Seed rate means	16.208 a	17.653a	19.212a		16.7 a	15.6 a	16.1 a		
SR×SD				N S				N S	N S
					Oil yield (kg/ha)				
1st November	198.627	234.797	169.173	200.886 a	229.8	192.7	176.3	199.6a	200.3 a
Mid November	126.480	162.317	155.397	148.131 b	199.1	185.4	129.7	171.4ab	155.8a
1st December	113.860	123.603	111.220	116.228 b	152.9	109.4	129.5	130.6b	125.9 a
Mid December	110.162	114.290	113.047	137.259 b	137.6	140.5	137.8	138.6b	128.0 a
Seed rate means	123.290 b	144.865ab	165.138 a		179.8a	157.0a	143.3a		
SR×SD				N S				22.9	N S

N S= not significant; Means within columns and rows followed by the same letter(s) are not significantly different at P≤ 0.05, according to Duncan Multiple Range Test.

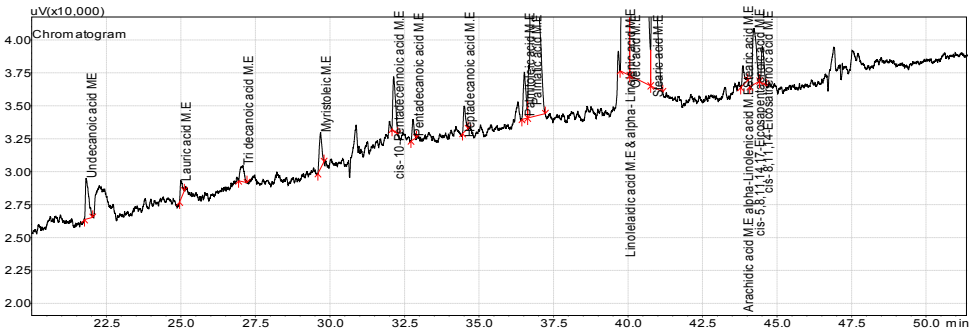
Sowing date significantly affected both oil content and oil yield in the first season only; seed rate , however, did not in both seasons. This might be due to the fact that grain filling was affected by prevailing temperature and day length which differ with different sowing date. Saeidi and Khodarbashi (2007) and Pageau and Lajeunesse (2011), reported that late sowing reduced the oil content and 1000-grain weight of flax. Moreover, cool nights have been reported to improve linseed oil content and quality (Annonymus 2001). Seed development of early planting in November has actually coincided with the cool temperature of January at HRS and consequently resulted in the high oil content and high number of fatty acids (Tables 1 and 2).

Table 2. Effect of sowing date on linseed fatty acids composition and proportion at HRS.

No.	Fatty acids	Fatty acids composition and proportion			
		Sowing dates			
		1st Nov.	Mid of Nov.	1st Dec.	Mid of Dec.
1	Undecanoic Acid ME	0.9929	-	-	0.9342
2	Luraic Acid ME	0.2921	-	1.8779	0.6767
3	Tridecanoic Acid ME	0.4716	-	-	0.4956
4	Myristoleic ME	0.7066	-	-	0.0331
5	Cis-10 pentadecannoic Acid ME	1.0860	-	-	0.5414
6	Pentadecanoic Acid M	0.2893	5.3368	-	0.3265
7	Heptadecanoic Acid ME	0.4291	-	-	-
8	Palmitoleic Acid ME	0.9316	-	0.4074	0.2325
9	Palmatic Acid ME	14.8105	15.3378	12.9702	11.2225
10	Linolelaidic Acid ME-Alpha lino	31.9296	46.7160	60.2338	37.4309
11	Oleic Acid ME	39.6807	14.9798	13.2231	39.0185
12	Stearic Acid ME	5.7819	6.6551	9.7198	7.8361
13	Archidic Acid ME- Alpha linolen	0.3208	-	-	0.2207
14	Cis-5-8-11-14-17-Eicosapentaeloic	1.5561	-	-	-
15	Cis 5-8-11-14-Eicosapentaenoic Acid ME	0.7212	-	-	-
16	Lignoceric Acid ME	-	4.4929	-	-
17	Carpic Acid ME	-	6.4817	-	-
18	Myristic Acid M.E	-	-	0.4327	-
19	Heneicosanoic Acid ME	-	-	1.1350	0.6013
20	Cis 4-7-10-13-16-19-Decosahexaen	-	-	-	0.4299
	Total	15	7	8	14

The fatty acid profiles (number and percentage) of oils from different sowing date showed clear differences (Table 2 and Figs 1, 2, 3 and 4). That is, first of November sowing date resulted in the largest number of fatty acids (Table 2 and Fig 1) followed by oil from mid December sowing (Table 2 and Fig 4), first of December (Table 2 and Fig 3) and mid November (Table 2 and Fig2) . Also some fatty acids appeared in one sowing date but not in others. That is, undecanoic acid, tridecanoic acid, myrestolic, Cis-10 pentadecannoic acid and arachidic acid were not found in the oil from mid November and first of December sowing but were present in first of November (early) and mid of December (late) sowing dates. Heptadecanoic acid, Cis-5-8-11-14-17 eicosapentaenoic and Cis-5-8-11-14 eicosapentaenoic were found only in first of November sowing but not in the other three sowing dates. Lignoceric and capric acids were detected only in mid November sowing. Myristic acid was produced only in first of December sowing. Cis-4-7-10-13-16-19 decosahexaen was detected only in mid- December sowing. Fatty acids produced in relatively high proportions in all sowing dates, were palmatic, linalelaidic-alpha lino, oleic and stearic. The highest fatty acids produced in first of November, mid November first of December and mid – December sowing dates were oleic (39.68%), linolelaidic-alpha lino (46.7 %), linolelaidic (60.2 %) and oleic (39.0 %), respectively. Palmitic acid, linolelaidic acid- alpha lino, oleic acid and stearic acid appeared in all sowing dates (Table2).

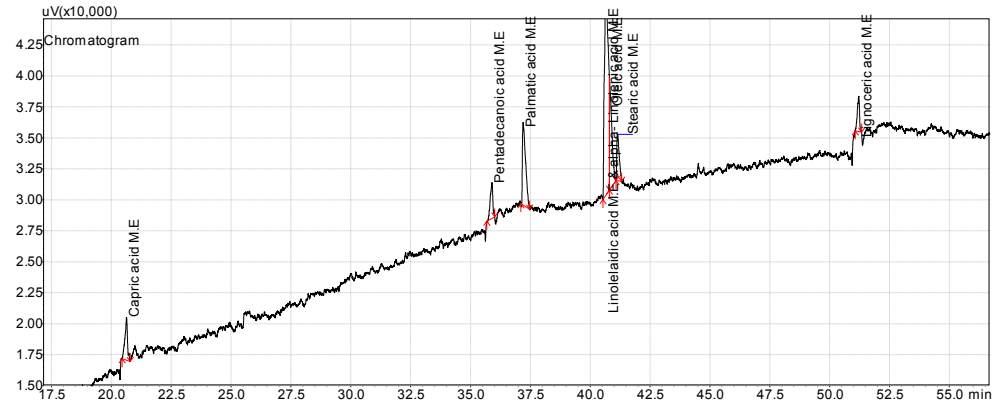
The above results suggest that the prevailing growing environment, primarily temperature, during development of seed cotyledons, had direct effect on the amount and type of fatty acid synthesized and accumulated. In fact Slack and Rough (1978) reported that in linseed and soya bean, molar proportion of oleate increased when the temperature was increased whereas that of linoleate or linolenate, depending on the species, increased when the temperature was lowered. Moreover, Dornbos and Mullen (1992) showed that drought had little effect on the fatty acid composition of soya bean oil, but high air temperature reduced the proportion of polyunsaturated fatty acid components. Linseed oil content and quality were reported to be improved by cool nights (Anonymous 2001).



Peak Table – Channel 1

Peak#	Name	Ret. Time	Area	Height	Area%	Height%	Conc.	Un.
1	Undecanoic acid M.E	21.818	23174	3084	0.9929	2.1017	0.035	Ppm
2	Luraic acid M.E.	24.997	6817	1390	0.2921	0.9474	0.029	Ppm
3	Tri decanoic acid M.E	27.079	11008	1228	0.4716	0.8366	0.020	Ppm
4	Myristoleic M.E	29.686	16490	2726	0.7066	1.8573	0.085	Ppm
5	Cis-10-Pentadecennoic acid M.E.	32.141	25345	4080	1.0860	2.7801	0.044	Ppm
6	Pentadecanoic acid M.E	32.787	6752	1526	0.2893	1.0396	2.868	Ppm
7	Heptadecanoic acid M.E	34.509	10015	1961	0.4291	1.3366	0.000	Ppm
8	Palmitoleic acid M.E	36.522	21743	3509	0.9316	2.3910	0.280	Ppm
9	Palmatic acid M.E	36.753	345660	21061	14.8105	14.3514	3.823	Ppm
10	Linolelaidic acid M.E-alpha-Lino	39.886	745199	46501	31.9296	31.6868	1224.092	Ppm
11	Oleic acid M.E	40.059	926102	39741	39.6807	27.0806	168.792	Ppm
12	Stearic acid M.E	40.824	134943	11489	5.7819	7.8292	0.428	Ppm
13	Arachidic acid M.E alpha-Linolen	43.858	7486	1442	0.3208	0.9828	0.026	Ppm
14	Cis-5,8,11,14,17-Eicosapentaenoic	44.228	36319	4240	1.5561	2.8891	12.582	Ppm
15	Cis-5,8,11,14-Eicosapentaenoicacid M.E	44.506	16831	2773	0.7212	1.8898	31.755	Ppm
Total			2333884	146751	100.0000	100.0000		

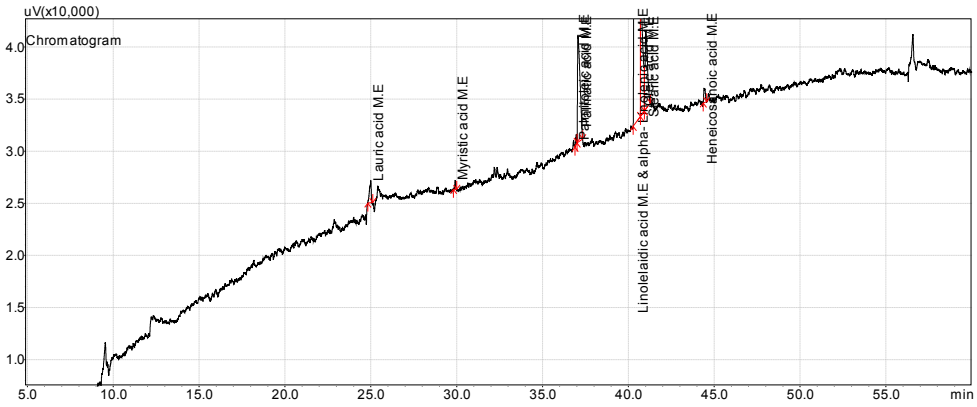
Fig 1. Chromatogram and peak table showing number and percentage of fatty acids in linseed grown on first of November.



Peak Table – Channel 1

Peak#	Name	Ret. Time	Area	Height	Area%	Height%	Conc.	Un.
1	Capric acid M.E	20.634	25856	3448	6.4817	7.5994	0.188	ppm
2	Pentadecanoic acid M.E	35.892	21289	2879	5.3368	6.3460	9.044	ppm
3	Palmatic acid M.E	37.198	61185	6640	15.3378	14.6352	0.677	ppm
4	Linolelaidic acid M.E-alpha-Lino	40.649	186357	16978	46.7160	37.4246	306.116	ppm
5	Oleic acid M.E	40.806	59756	8827	14.9798	19.4559	10.891	ppm
6	Stearic acid M.E	41.140	26548	3753	6.6551	8.2726	0.084	ppm
7	Lignoceric acid M.E	51.214	17923	2843	4.4929	6.2662	4.355	ppm
Total			398914	43568	100.0000	100.0000		

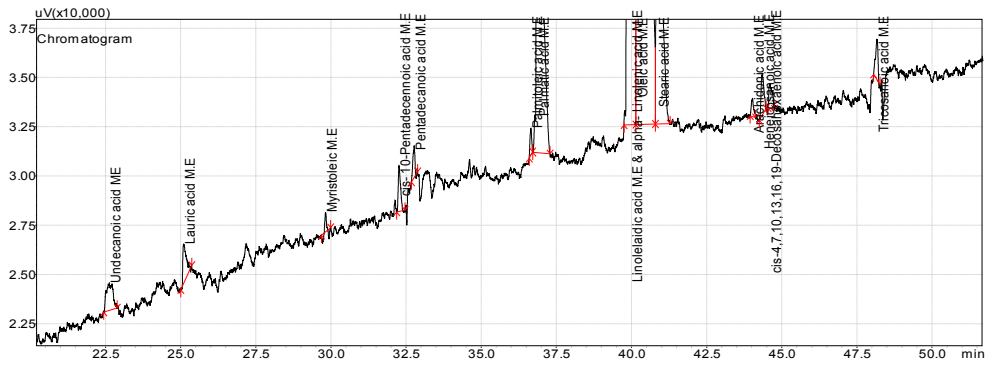
Fig 2. Chromatogram and peak table showing number and percentage of fatty acids in linseed grown in mid November



Peak Table – Channel 1

Peak#	Name	Ret. Time	Area	Height	Area%	Height%	Conc.	Un.
1	Luraic acid M.E.	24.995	14782	2102	1.8779	3.5583	0.063	ppm
2	Myristic M.E	29.917	3407	823	0.4327	1.3932	0.047	ppm
3	Palmitoleic acid M.E	36.967	3207	922	0.4074	1.5612	0.041	ppm
4	Palmatic acid M.E	37.105	102100	9146	12.9702	15.4823	1.129	ppm
5	Linolelaidic acid M.E-alpha-Lino	40.400	474155	25445	60.2338	43.0728	778.865	ppm
6	Oleic acid M.E	40.729	104091	11755	13.2231	19.8987	18.972	ppm
7	Stearic acid M.E	41.023	76513	7516	9.7198	12.7232	0.243	ppm
8	Heneicosanoic acid M.E	44.417	8935	1365	1.1350	2.3103	0.028	ppm
Total			787190	59074	100.0000	100.0000		

Fig 3. Chromatogram and peak table showing number and percentage of fatty acids in linseed grown in first of December.



Peak Table – Channel 1

Peak#	Name	Ret. Time	Area	Height	Area%	Height%	Conc.	Un.
1	Undecanoic acid M.E	22.629	21043	1368	0.9342	1.0242	0.032	ppm
2	Luraic acid M.E.	25.095	15242	2018	0.6767	1.5108	0.065	ppm
3	Myristoleic M.E	29.821	746	979	0.0331	0.7328	0.004	ppm
4	Cis-10-Pentadecennoic acid M.E.	32.266	12196	2325	0.5414	1.7408	0.021	ppm
5	Pentadecanoic acid M.E	32.770	7355	1602	0.3265	1.1993	3.124	ppm
6	Palmitoleic acid M.E	36.650	5238	1367	0.2325	1.0233	0.067	ppm
7	Palmatic acid M.E	36.875	252789	17530	11.2225	13.1236	2.796	ppm
8	Linolelaidic acid M.E-alpha-Lino	39.978	843139	47982	37.4309	35.9216	1384.971	ppm
9	Oleic acid M.E	40.153	878899	39282	39.0185	29.4084	160.189	ppm
10	Stearic acid M.E	40.862	176510	13070	7.8361	9.7844	0.560	ppm
11	Arachidonic acid M.E	44.028	4971	922	0.2207	0.6901	0.710	ppm
12	Heneicosanoic acid M.E	44.367	13546	1822	0.6013	1.3643	0.042	ppm
13	Cis-4,7,10,13,16,19-Decosahexaen	44.610	9684	1253	0.4299	0.9381	5.501	ppm
14	Tri decanoic acid M.E	48.171	11163	2055	0.4956	1.5383	0.063	ppm
Total			2252521	133575	100.0000	100.0000		

Fig 4. Chromatogram and peak table showing number and percentage of fatty acids in linseed grown in mid December.

CONCLUSIONS

- Sowing date, but not seed rate, significantly affected seed yield.
- The highest seed yield results from first of November sowing date at 60 kg/ha seed rate and declines with delay in sowing date.
- The highest oil content results from planting in first of November.
- Number and proportion of fatty acids vary from one sowing date to anther.
- Four fatty acids were detected at different concentrations at the four sowing dates. These were palmitic acid, linolelaidic acid, oleic acid and stearic acid.
- Dominant fatty acid were oleic acid, linolelaidic acid, linoleaidic acid and oleic acids respectively in first of s November, mid-November, first of November and mid- December sowing dates.

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مجلة جامعة الخرطوم للعلوم الزراعية: المجلد الخامس والعشرون – العدد الثاني، 2017.

تأثير ميعاد الزراعة ومعدل البذر على إنتاجية الكتان ومحتوى ومكونات الزيت

عبد الله محمد علي[1]، بركات عبد الفراج[2]

[1]قسم البساتين، كلية الزراعة، جامعة الخرطوم

[2]هيئة البحوث الزراعية– محطة بحوث الحديبة، – السودان

المستخلص : أجريت هذه التجربة خلال موسمي 2012/2011 و 2014/2013 بمحطة بحوث الحديبة، ولاية نهر النيل لدراسة تأثير تاريخ الزراعة ومعدل البذر على إنتاجية ونسبة الزيت ومكوناته في محصول الكتان، شملت معاملات التجربة أربعة تواريخ زراعة (أول نوفمبر، منتصف نوفمبر، أول ديسمبر ومنتصف ديسمبر) وثلاثة معدلات بذر (50، 60 و 70 كجم / هكتار) ثم تنظيمها في تصميم القطاعات المنشطرة ، حيث وضع معدل البذر في القطع الرئيسة وتواريخ الزراعة في القطع المنشطرة. أظهرت نتائج التحليل الإحصائي أن الإنتاجية تأثرت معنوياً بتاريخ الزراعة وليس بمعدل البذر.

أعطى تاريخ الزراعة في الأول من نوفمبر مع معدل بذر 60 كيلوغرام/للهكتار أعلى إنتاجية (1216.4 كيلوغرام/هكتار) ، وتناقصت الإنتاجية مع تأخير الزراعة حتى منتصف ديسمبر. أعلى نسبة للزيت(20.8 %) نتجت من الزراعة في اول نوفمبر بمعدل بذر 50 كجم للهكتار. أظهر تحليل زيت البذرة وجود عشرين نوع من الأحماض الدهنية بكميات مقدرة ونسب مختلفة حسب تاريخ الزراعة. فقد كان عدد الأحماض الدهنية 15 في تاريخ زراعة الأول من نوفمبر، 7 في تاريخ زراعة منتصف نوفمبر، 8 في الاول من ديسمبر و 14 في منتصف ديسمبر. الأحماض الدهنية السائدة في تواريخ الزراعة اول نوفمبر، منتصف نوفمبر، اول ديسمبر ومنتصف ديسمبر كانت حامض الأوليك وحامض اللينولايدك وحامض اللينولايدك وحامض الاوليك على التوالي.