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Effectiveness of Sowing Dates and N Rates on Productivity of Two Flax (*Linum usitatissimum* L.) Cultivars

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AT DAR-RAMAD Experimental Farm, Faculty of Agriculture, Fayoum University, Egypt, two field experiments were done during 2016/2017 and 2017/2018 seasons to investigate the effect of date of sowing and N rates on straw and seed yields of two *Linum usitatissimum* L. cultivars. The arrangement was done in split split-plot in RCBD with three replications. Date of sowing (i.e. November 10th, November 25th and December 10th) were allocated in the main plots. Flax cultivars (Sakha-1 and Sakha-2) occupied in the sub-plots, whereas, N rates (i.e., 35, 70, 105 and 140kg N ha^{-1}) were distributed in the sub sub-plots. The obtained results showed that earlier sowing date in November 10th significantly overtop middle and late sowing dates for straw and seed yield and related traits. Sakha-1 significantly surpassed Sakha-2 in studied straw yield traits, while, Sakha-2 exceeded Sakha-1 in seed yield traits. Nitrogen rate at 140kg ha^{-1} gave significantly higher straw and seed yields than other N rates which significantly vary from each other and this is true in both seasons. The regression analysis of seed yield specified that there are three traits, i.e. seed index, number of capsules plant^{-1} and seed yield plant^{-1} in 1st season and two ones, i.e. seed index and number of capsules plant^{-1} in 2nd season were significantly participated ($P \leq 0.001$) in variation of seed yield ha^{-1}.

Keywords: Flax, Cultivars, Sowing Dates, N rates.

Introduction

Flax (*Linum usitatissimum* L.) is an oldest agronomic crop. Worldwide, Flax plant is planting for its oil and fiber as well as for several purposes in medicine and nutrition. In Egypt, since pharaoh age, flax is grown as a dual purpose crop for fibers and oil. The cultivated area was 9201ha in 2017 (FAOSTAT, 2019). Sowing time plays great role in crops yield. Flax yields (straw, seed and oil) were influenced by weather founded with early or later sowing time. Temperature, among weather factors, has a main role in deciding sowing time and consequently flax productivity. Sowing dates has a leading role in crop production. Where, delaying date leads to a change in the environmental agents like temperature throughout reproductive period of crop resulting in change in seed yield and quality. Generally, in many countries, researchers observed that the lateness in sowing date consequently followed by decrease in flax straw, seed and oil yields as well as seed quality among them Rahimi & Bahrani (2011), Rahimi et al. (2011), Al-Doori (2012), Gallardo et al. (2014), Rahimi (2014), Elayan et al. (2015), Raundal et al. (2015), Maurya et al. (2017), Jana et al. (2018) and Ganvit et al. (2019). The flax genotypes react differently under weather factors to achieve straw and seed yields. In addition, many researchers stated that the differences among flax genotypes concerning straw, seed and oil yields as well as seed chemical composition were significant like Gallardo et al. (2014), Kariuki et al. (2014), Andruszczak et al. (2015), Bakry et al. (2015), Elayan et. al. (2015), Raundal et al. (2015), El-Borhamy (2016), El-Shafey & Hassan (2016) Rashwan et al. (2016), Sadi et al. (2017), Jana et al. (2018), Sarkees & Mahmood (2018) and Emam (2019). Nitrogen is the most imperative element for perfect the plant outgrowth and development. Nitrogen statistically increased crop yield and quality through its vital role in the biochemical

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and physiological functions of plant. The plant needs a large quantity of nitrogen about 1000µg/kg dry matter and consequently, it is obligatory supplied to the plants (Leghari et al., 2016). Thus nitrogen is a major element for plants since it is an important component of many structures of plant and for both their internal and external processes of metabolism. Many researchers applied nitrogen fertilization at different levels like Rahimi & Bahrani (2011) up to 150kg ha^{-1}, Khajani et al. (2012) up to 90kg ha^{-1}, Soethe et al. (2013) up to 200kg ha^{-1}, Kariuki et al. (2014) up to 150kg ha^{-1}, Rahimi (2014) up to 150kg ha^{-1}, Andruszczak et al. (2015) up to 80kg ha^{-1}, Chopra & Badiyala (2016) up to 30kg ha^{-1}, El-Borhamy (2016) up to 142.86kg ha^{-1}, Patel et al. (2017) up to 90kg ha^{-1}, Taddese & Tenaye (2018) up to 138kg ha^{-1}, Yan et al. (2018) up to 150kg N and 75kg P ha^{-1}. They found that any increase in N levels followed by an augmentation in straw and seed yields of flax as well as their related characters.

The study endeavored to check the impact of date of sowing and rate of nitrogen on two (*Linum usitatissimum* L.) cultivars straw and seed yields.

Materials and Methods

The field experiment was carried out during the two consecutive seasons 2016/17 and 2017/18 at Dar-Ramad Experimental Farm of the Faculty of Agriculture, Fayoum University (29º 19'31.1''N; 30.0º 51'42.9''E), Egypt to study the effect of date of sowing and rate of nitrogen on two flax cultivars. Each experiment includes 24 treatments which were the combinations of three sowing dates, two flax cultivars and four N rates. With three replications, the arrangement was applied in split split-plot in RCBD. The main plots were captured by the date of sowing (November 10th, November 25th and December 10th) and two flax cultivars (Sakha-1 and Sakha-2) assigned in the sub-plots whereas, the N rates (35, 70, 105 and 140kg ha^{-1}) were distributed in the sub-sub plots. The sub-sub plot comprised 6m^2 with 3m long and 2m wide. *Linum usitatissimum* L. seeds were broadcasting according to sowing dates in both seasons. Flax cultivar seeds were gained from the Field Crop Research Institute, Agricultural Research Centre, Giza, Egypt. Cultivars were sown at the rate of 167kg ha^{-1} to achieve the recommended plant density. The pedigree of flax cultivars are shown in Table 1. The preceding crop was *Sesamum indicum* L. in both seasons.

In the tow growing seasons, meterological data illustraed in Table 2. Conventional tillage was applied in the experimental site. The P_2O_5 (Calcium supper-phosphate) at the rate of 238kg ha^{-1} was added during tillage and before ridging. N was added in 2 doses as form of ammonium nitrate 33.5% at the 2nd and 3rd irrigation. All other agricultural practices for flax production in a clay soil were adopted throughout the growing seasons according to the bulletin of Egyptian Ministry of Agriculture (1086/2007).

Soil idiosyncrasies of the experimental site were given in Table 3. Analytical procedures were those recommended by Wilde et al. (1985).

Measurements

At maturity, randomly 10 plants were transferred from each sub sub-plot to register the following traits:

- Straw yield and its component, i.e., plant height (cm), length of technical stem (cm), stem diameter (cm), number of branches $plant^{-1}$ and straw yield $plant^{-1}$ (g).
- Seed yield and its component, i.e., number of fruiting branches $plant^{-1}$, fruiting zone length (cm) and number of capsules $plant^{-1}$ as well as seed yield $plant^{-1}$ (g).

From the middle of each sub sub-plot, the plants were used to determine:

- 1000-seed weight (g), straw yield (ton ha^{-1}) and seed yield (kg ha^{-1}).
- Oil yield (kg ha^{-1}) was calculated by multiplying seed yield by seed oil %.
- Seed oil percentage (%) was determined by using Soxhelt extraction device with petroleum ether as a solvent. Seed oil % was calculated according to A.O.A.C. (2000).

TABLE 1. The pedigree and purpose of flax cultivars.

Cultivar	Performance	Pedigree or origin	Purpose
Sakha-1	Local cultivar	L. Bombay (U.S.A.) x L. 1485 (U.S.A.)	Egyptian dual purpose type
Sakha-2	Local cultivar	L.2348 (Hungary) x Hera (India)	Egyptian dual purpose type

TABLE 2.Meteorological data for Fayoum Governorate in 2016/2017 and 2017/2018 seasons (Monthly averages).

Month	Season	Temperature C°		Relative humidity (%)	Wind speed (m sec^{-1})	Rain fall (mm day^{-1})
		Min	Max			
Nov.	2016/2017	13.26	25.41	57.62	2.74	4.01
	2017/2018	11.58	24.09	60.64	2.47	2.42
Dec.	2016/2017	6.47	18.01	70.67	2.49	0.75
	2017/2018	9.79	20.96	64.48	2.11	0.03
Jan.	2016/2017	5.25	17.34	65.91	2.22	0.01
	2017/2018	6.23	18.89	64.87	2.59	0.34
Feb.	2016/2017	5.94	19.88	59.75	2.34	0.08
	2017/2018	10.07	22.91	50.98	2.08	0.15
Mar.	2016/2017	9.98	24.39	47.09	2.85	0.00
	2017/2018	11.76	28.29	38.78	2.51	0.02
Apr.	2016/2017	13.19	29.68	37.32	3.36	0.21
	2017/2018	14.33	30.63	36.47	3.02	0.33
May	2016/2017	17.89	34.41	33.00	3.59	0.00
	2017/2018	19.81	35.78	32.61	3.58	0.00

Source: https://power.larc.nasa.gov/data-access-viewer/

TABLE 3. Soil physical and chemical characteristics of the experimental site (two seasons average).

Particle size distribution				Organic Matter (%)	$CaCO_3$(%)
Sand (%)	Silt (%)	Clay (%)	Textural class		
19.1	33.6	47.30	Clay	1.92	5.22

pH (soil paste)	EC (dSm^{-1})	Soluble cations (meq L^{-1})				Soluble anions (meq L^{-1})				CEC (meq/ 100gm soil)	Exchangeable cations (meq/ 100gm soil)			
		Ca^{++}	Mg^{+}	Na^{+}	K^{+}	CO_3^{--}	HCO_3^{-}	Cl^{-}	SO_4^{--}		Ca^{++}	Mg^{++}	Na+	K^{+}
7.81	2.16	6.35	5.32	9.83	0.17	-	2.23	7.73	11.74	38.32	20.79	11.68	4.54	1.68

Statistical analysis

The ANOVA technique for the split split-plot arrangement was used to statistically analyzed all data as published by Gomez & Gomez (1984), using the GenStat 12th edition software. LSD test was applied to test the treatment means differences at 5 and 1% probability level.

Results and Discussion

Straw yield and its components

Effect of sowing date

Significant effect on straw yield and related traits was detected by applying sowing dates (Table 4). Earlier sowing date in November 10th (D_1) significantly transcend middle sowing date in November 25th (D_2) by (4.66 and 8.36%), (7.92 and 9.16%), (21.29 and 17.68%), (10.24 and 15.98%) and (18.25 and 18.85%) for plant height, technical stem length, number of branches $plant^{-1}$, straw yield $plant^{-1}$ and straw yield ha^{-1} in the first and second season, respectively. The same trend was found with D_2 which significantly overrun late sowing date December 10th (D_3) for previous traits by (8.08 and 12.34%), (8.22 and 15.65%), (32.89 and 31.13%), (17.59 and 13.49%) and (24.45

and 23.22%) in the first and second season, respectively. The decreasing in straw yield components may be due to reduction in growth period which required achieving maximum vegetative growth and then giving short plants and few branches. Otherwise, precocious date of sowing give plants appropriate time for harness all growth factors, i.e., water, light and nutrients. In addition, good conditions for growth and reproductive stages were available in early sowing in November, while low soil and air temperatures in December may be played great role in this respect (Table 2). This result was in line with that obtained by Raundal et al. (2015), Maurya et al. (2017), Jana et al. (2018) and Ganvit et al. (2019) from India, Rahimi et al. (2011), Rahimi & Bahrani (2011), Rahimi (2014) from Iran, Al-Doori (2012) from Iraq, and Gallardo et al. (2014) from Argentina, who recorded clear earliness for genotypes sown on early sowing date have great straw yield and related traits compared to delayed sowing date. The same trend was observed in Egypt by Elayan et al. (2015) who announced that delaying date of sowing from October to late November or early December caused a remarkable reduction in straw yield and its components, i.e. height of plant, technical length, branches number plant^{-1}, straw yield plant^{-1}.

Effect of cultivars

Concerning the cultivar effects, Table 4 show that the straw yield and related traits were significantly differed according to different cultivars. Sakha-1 (S_1) gave significantly the highest mean values of plant height (118.50 and 107.05cm), technical stem length (90.33 and 78.48cm), straw yield plant^{-1} (2.69 and 2.66g) and straw yield (3.05 and 2.78ton ha^{-1}) in the 1st and 2nd season, respectively. Furthermore, the lowest straw yield and related traits were statistically observed by Sakha-2 (S_2). These differences perhaps due to the differences in the genetic structure of the flax genotypes. The superiority of Sakha-1 in straw yield ha^{-1} may be due to the increase in plant height, technical length, number of branches plant^{-1} and straw yield plant^{-1}. These results are in agreement with those obtained by Gallardo et al. (2014), Kariuki et al. (2014), Andruszczak et al. (2015), Bakry et al. (2015), Elayan et. al. (2015), Raundal et al. (2015), El-Borhamy (2016), El-Shafey & Hassan, (2016) Rashwan et al. (2016), Sadi, et al., (2017), Jana et al. (2018), Sarkees & Mahmood (2018) and Emam (2019).

Effect of nitrogen levels

Nitrogen rates had highly significant impact in straw yield traits in both seasons. Generally, any excess in nitrogen application was followed by an increment in the plant height, technical stem length, branches number plant^{-1} and straw yields. Comparison among nitrogen level means by LSD test revealed that applied nitrogen fertilizer 140kg ha^{-1} was significantly higher in straw yield traits than other rates which significantly differ from each other and this is true in both seasons. The increase in straw yield due to the application of nitrogen fertilizer can be explained to the nitrogen stimulation effect on growth attributes by maximizing usage of photosynthesis and consequently the metabolites quantity as well as building up new cells in stem. This tendency of an augmentation in straw yield traits with applied nitrogen fertilizer was also observed by Rahimi & Bahrani (2011), Khajani et al. (2012), Soethe et al. (2013), Kariuki et al. (2014), Andruszczak et al. (2015), Chopra & Badiyala (2016), El-Borhamy (2016) and Patel et al. (2017).

Effect of the interactions

The interaction between date of sowing (A) and nitrogen fertilizer (C) was significant only on straw yield plant^{-1} in 2016/2017 season (Table 4 and Fig. 1). Earlier sowing date in November 10th and using 140kg N ha^{-1} recorded the highest straw yield plant^{-1}. It is apparent that the interactions of (AxC) and (BxC) was high significant on technical stem length, number of branches plant^{-1} and straw yield (ton ha^{-1}). Applied nitrogen at 140kg ha^{-1} significantly interact earlier sowing date and Sakha-2 cultivar in the 2017/2018 season. This means that these factors work together to affect these characters. The results are in conformity with those obtained by Rahimi & Bahrani (2011) and Rahimi (2014) who found that the interaction between sowing date and N levels (AxC) was significant on plant height and number of branches plant^{-1} and Andruszczak et al. (2015) who found significant interaction (BxC) between cultivars and agro-technical level (80kg N ha^{-1}, Linurex 50 WP) was found for number of branches plant^{-1}. Meanwhile, the highest values for interaction (BxC) on straw yield and its components obtained by 107kg N ha^{-1} x Giza 12 cultivar (El-Borhamy, 2016).

TABLE 4. Mean values of straw yield and its components of flax cultivars as affected by sowing dates and N levels in 2016/17 and 2017/18 seasons.

Treatments	Plant height (cm)	Technical stem length (cm)	No. of branches plant^{-1}	Straw yield plant^{-1} (g)	Straw yield (ton ha^{-1})
2016/2017 season					
Sowing Dates (A)	*	*	**	*	*
10th Nov. (D_1)	121.68	93.30	2.45	2.80	8.02
25th Nov. (D_2)	116.26	86.45	2.02	2.54	6.79
10th Dec. (D_3)	107.57	79.88	1.52	2.16	5.45
LSD 0.05	9.37	7.16	0.38	0.41	1.45
Cultivars (B)	**	**	NS	**	**
Sakha-1 (S_1)	118.50	90.33	1.88	2.69	7.26
Sakha-2 (S_2)	111.84	82.75	2.11	2.31	6.26
LSD 0.05	3.11	4.08	-	0.24	0.64
N – Rates (C)	**	**	**	**	**
35kg ha^{-1} (N_1)	94.34	70.97	0.99	1.65	4.88
70kg ha^{-1} (N_2)	112.28	83.56	1.61	2.27	6.00
105kg ha^{-1} (N_3)	122.38	91.62	2.50	2.86	7.74
140kg ha^{-1} (N_4)	131.67	100.03	2.88	3.22	8.38
LSD 0.05	2.93	2.90	1.93	0.21	0.57
Interaction					
A*B	NS	NS	NS	NS	NS
A*C	NS	NS	NS	*	NS
B*C	NS	NS	NS	NS	NS
A*B*C	NS	NS	NS	NS	NS
2017/2018 season					
Sowing Dates (A)	**	**	**	**	*
10th Nov. (D_1)	115.80	84.38	2.33	2.83	7.36
25th Nov. (D_2)	106.87	77.30	1.98	2.44	6.19
10th Dec. (D_3)	95.13	66.84	1.51	2.15	5.02
LSD 0.05	8.14	5.85	0.32	0.25	1.57
Cultivars (B)	NS	**	**	**	**
Sakha-1 (S_1)	107.05	78.48	1.83	2.66	6.62
Sakha-2 (S_2)	104.82	73.86	2.05	2.29	5.79
LSD 0.05	-	2.13	0.16	0.19	0.48
N – Rates (C)	**	**	**	**	**
35kg ha^{-1} (N_1)	93.30	66.01	1.22	1.36	4.45
70kg ha^{-1} (N_2)	104.18	74.46	1.67	2.26	5.79
105kg ha^{-1} (N_3)	111.28	80.67	2.27	3.00	6.83
140kg ha^{-1} (N_4)	114.98	83.56	2.60	3.28	7.71
LSD 0.05	2.41	2.05	0.18	0.23	0.52
Interaction					
A*B	NS	NS	*	NS	NS
A*C	NS	**	**	NS	NS
B*C	NS	NS	**	NS	**
A*B*C	NS	NS	NS	NS	NS

*: P≤ 0.05, **: P≤ 0.01, NS: Not significant.

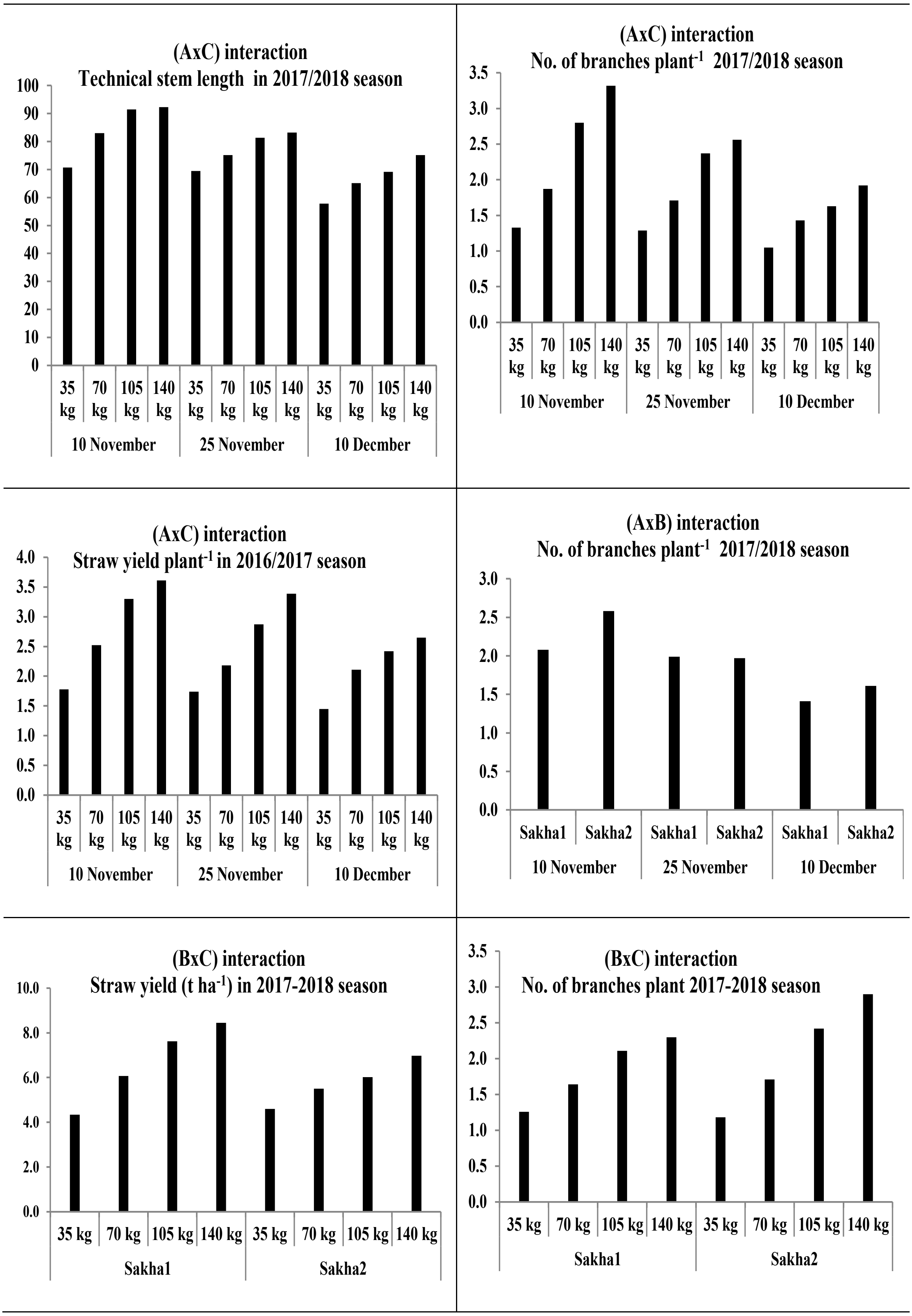

Fig. 1. Effect of the interaction between sowing dates and nitrogen levels on straw yield and its components of two flax cultivars.

Seed yield and its components

Effect of sowing dates

Data in Table 5 cleared that the seed yield and related traits, in both seasons, were significantly affected by sowing dates except fruiting zone length which did not statistically affect by sowing dates. The earlier sowing date in November 10th (D_1) was significantly superior November 25th (D_2) and the late sowing date in December 10th (D_3) which gave significantly decrease mean values of seed yield traits. The crop sown in November 10th (D_1) got enough time than December 10th (D_3) for proper vegetative growth period and development throughout both growing seasons. These results are in congruence with those mentioned by Rahimi et al. (2011), Al-Doori (2012), Gallardo et al. (2014), Rahimi (2014), Elayan et. al. (2015), Raundal et al. (2015), Maurya et al. (2017), Jana et al. (2018) and Ganvit et al. (2019).

Effect of cultivar

Tables 5 showed the cultivars performance on seed and oil yields. According to LSD test in both seasons, Sakha-2 cultivar produces significantly the highest seed and oil yields value. While, Sakha-1 recorded the lowest seed and oil yields value. The increase in seed and oil yields obtained herein is to be expected since this trend was observed with all yield traits such as number of fruiting branches (5.80 and 5.60), fruiting zone length 29.09 and 30.96cm), number of capsules plant^{-1} (19.78 and 18.10), 1000-seed weight (8.26 and 8.08g) and seed yield plant^{-1} (1.82 and 1.72g) over both seasons respectively. The results are agreed with those described by Gallardo et al. (2014), Kariuki et al. (2014), Andruszczak et al. (2015), Bakry et al. (2015), Elayan et. al. (2015), Raundal et al. (2015), El-Borhamy (2016), El-Shafey & Hassan (2016) Rashwan et al. (2016) and Sadi et al. (2017), Jana et al. (2018) and Sarkees & Mahmood (2018).

Effect of nitrogen levels

The differences in yields of seed and oil per hectare encouraged by N rates were highly significant in both seasons of experimentation. It is evident from Table 5 that increasing nitrogen levels caused a remarkable augmentation in seed and oil yields in both seasons. Comparison among N rates by LSD test in both seasons indicated that the 140kg ha^{-1} (which in par with the 105kg ha^{-1}) was significantly outyielded the other rates, i.e., 35 and 70kg N ha^{-1} which significantly not equal each other. Furthermore, 35kg N ha^{-1} had significantly lowest yields of seed and oil overall seasons. The supremacy of 140kg N ha^{-1} is to be expected since this rate produced larger number of branches plant^{-1} (6.64 and 6.19), highest values for fruiting zone length (31.64 and 31.43cm), number of capsules plant^{-1} (22.21 and 20.72), 1000-seed weight (9.28 and 9.19g) as well as seed yield plant^{-1} (2.38 and 2.24g) in the two seasons, respectively. The significant effect and the marked seed yield increases by nitrogen levels were observed previously by many researchers among them Khajani et al. (2012), Soethe et al. (2013), Kariuki et al. (2014), Andruszczak, et al. (2015), Chopra & Badiyala (2016), El-Borhamy (2016), Patel et al. (2017), Taddese & Tenaye (2018) and Yan et al. (2018).

Effect of the interactions:

The interaction among three factors of sowing dates and N levels on flax cultivars was significant on seed yield and related traits over two seasons (Table 5 and Fig. 2). Early sowing dates x cultivars interaction (AxB) was significant for length of fruiting zone (cm) seed and oil yields in the first year and seed index and oil % in both years. In addition, the interaction between sowing dates and N levels (AxC) was significant for number of fruiting branches plant^{-1} and seed index in both seasons, early sowing in November 10th and fertilized by 140 kg nitrogen ha^{-1} gave the highest values. The interaction between (BxC) was significant for number of fruiting branches plant^{-1}, number of capsules plant^{-1} and seed index in two years. The AxBxC interaction gave significantly the highest mean values of fruiting branches plant^{-1}, 1000-seed weight and seed yield plant^{-1}. Sowing Sakha-2 in November 10th and received 105 or 140 kg N ha^{-1} gave the best values. These results are in agreement with Elayan et al. (2015), Raundal et al. (2015) and Jana et al. (2018) found significant interaction (AxB) seed yield and related traits. Also, Rahimi & Bahrani (2011) and Rahimi (2014) who found that the interaction (AxC) was significant on number of capsules plant^{-1}, seed index and seed yield. In addition, Andruszczak et al. (2015) on number of capsules plant^{-1}, seed yield plant^{-1}. The significant interaction between (BxC) was mentioned by El-Borhamy (2016) for fruiting zone length, number of capsules plant^{-1}, 1000-seed weight and seed yield, in two seasons, and seed yield plant^{-1} only in the first one.

TABLE 5. Seed yield traits of two flax cultivars as affected by sowing dates and N rates in 2016/2017 and 2017/2018 seasons.

Treatments	No. of fruiting branches plant^{-1}	Fruiting zone length (cm)	No. of capsules plant^{-1}	Seed index (g)	Seed yield plant^{-1} (g)	Oil %	Seed yield (kg ha^{-1})	Oil yield (kg ha^{-1})
2016/2017 season								
Sowing Dates (A)	**	NS	**	**	**	**	*	*
10th Nov. (D_1)	6.88	28.38	21.95	9.07	1.96	39.51	1694.00	668.55
25th Nov. (D_2)	5.52	29.81	17.97	8.03	1.71	39.23	1395.07	544.62
10th Dec. (D_3)	3.32	27.69	14.87	6.97	1.56	38.44	1284.81	492.71
LSD 0.05	0.71	-	2.56	0.13	0.14	0.28	265.52	101.10
Cultivars (B)	**	NS	**	**	NS	**	**	**
Sakha-1 (S_1)	4.68	28.17	16.74	7.79	1.67	38.48	1396.69	535.95
Sakha-2 (S_2)	5.80	29.09	19.78	8.26	1.82	39.63	1519.24	601.31
LSD 0.05	0.30	-	1.41	0.12	-	0.29	74.40	27.38
N – Rates (C)	**	**	**	**	**	**	**	**
35kg ha^{-1} (N_1)	4.07	23.38	14.18	6.68	1.09	40.26	1045.24	421.74
70kg ha^{-1} (N_2)	4.81	28.72	17.17	7.76	1.51	39.42	1504.64	594.48
105kg ha^{-1} (N_3)	5.46	30.77	19.49	8.38	2.00	38.58	1611.74	623.17
140kg ha^{-1} (N_4)	6.64	31.64	22.21	9.28	2.38	37.98	1670.26	635.12
LSD 0.05	0.26	2.29	1.25	0.16	0.13	0.34	72.17	28.86
Interaction								
A*B	NS	**	NS	**	NS	**	*	*
A*C	**	NS	NS	**	NS	NS	*	*
B*C	*	NS	*	**	*	NS	*	*
A*B*C	**	NS	NS	**	*	NS	NS	NS
2017/2018 season								
Sowing Dates (A)	*	NS	**	**	NS	**	*	*
10th Nov. (D_1)	6.02	31.42	19.76	9.02	1.75	39.28	1679.67	658.36
25th Nov. (D_2)	5.31	29.58	17.35	7.86	1.59	39.03	1374.33	535.29
10th Dec. (D_3)	3.39	28.29	14.79	6.63	1.47	38.20	1276.43	486.33
LSD 0.05	1.47	-	1.16	0.24	-	0.18	244.24	94.24
Cultivars (B)	**	NS	**	**	*	**	*	**
Sakha-1 (S_1)	4.21	28.57	16.50	7.59	1.49	38.33	1358.05	519.57
Sakha-2 (S_2)	5.60	30.96	18.10	8.08	1.72	39.34	1528.88	600.40
LSD 0.05	0.61	-	0.24	0.27	0.21	0.35	120.62	43.79
N – Rates (C)	**	**	**	**	**	**	**	**
35kg ha^{-1} (N_1)	3.74	27.29	13.96	6.27	0.98	40.19	1140.00	459.00
70kg ha^{-1} (N_2)	4.45	29.72	16.51	7.40	1.35	39.15	1438.38	564.48
105kg ha^{-1} (N_3)	5.24	30.61	18.02	8.49	1.84	38.39	1584.14	609.21
140 kg ha^{-1} (N_4)	6.19	31.43	20.72	9.19	2.24	37.62	1611.38	607.26
LSD 0.05	0.30	1.11	0.55	0.26	0.14	0.37	118.45	46.55
Interaction								
A*B	NS	NS	*	**	NS	*	NS	NS
A*C	**	**	**	**	NS	NS	NS	NS
B*C	NS	NS	*	**	NS	NS	NS	NS
A*B*C	NS	NS	NS	*	NS	NS	NS	NS

*: P≤ 0.05, **: P≤ 0.01, NS: Not significant.

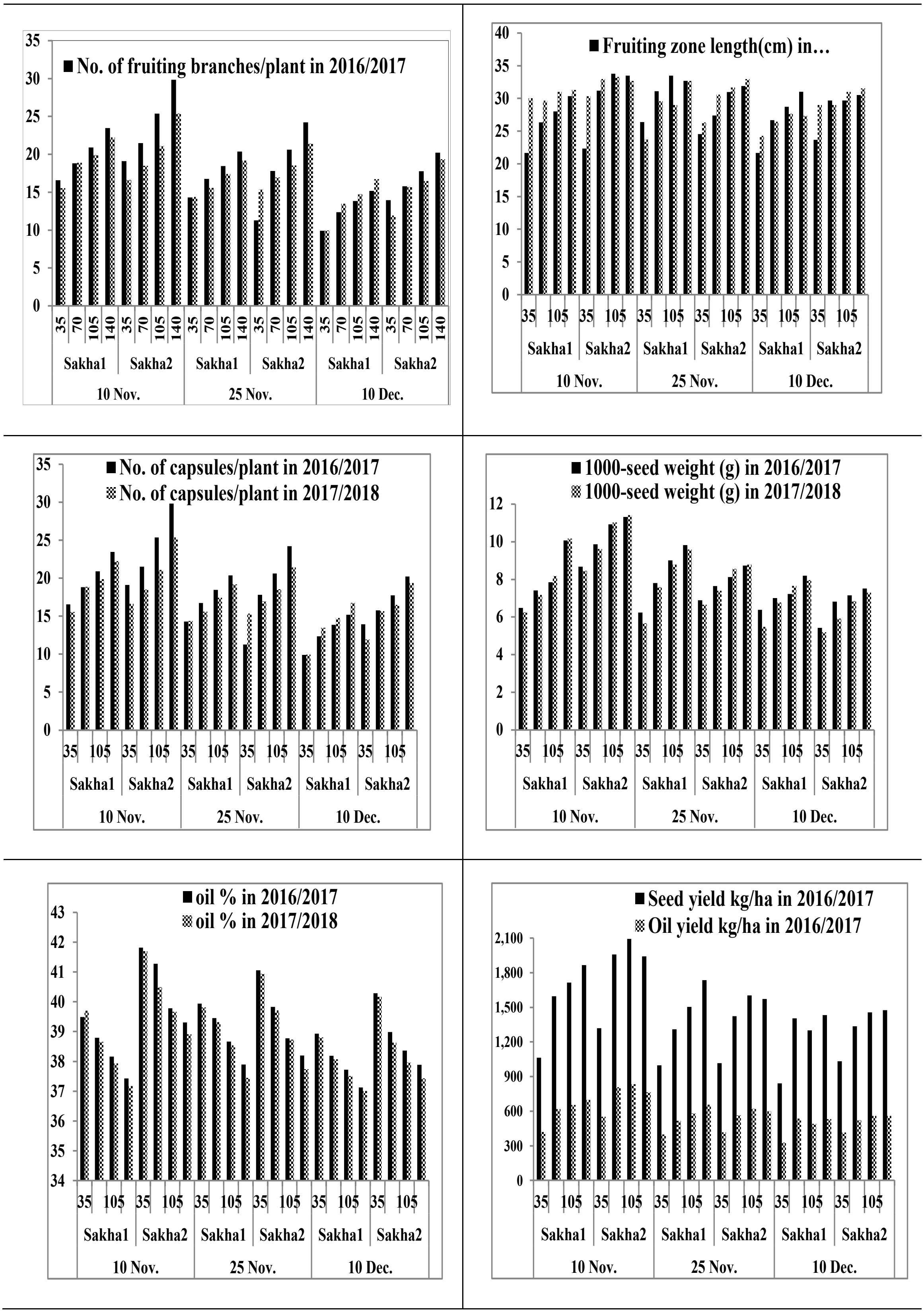

Fig. 2. Effect of interaction between sowing dates and nitrogen rates on two flax varieties seed yield and its components.

Yield analysis

Correlation analysis among flax straw yield traits

Correlation coefficients among straw yield traits in the two seasons are illustrated in Table 6. Straw yield (ton ha^{-1}) correlated positively with plant height, technical stem length, number of branches and straw yield $plant^{-1}$ in both seasons. This is in general agreement with the work done by Tadesse et al. (2009), Kumar & Paul (2016) and Kumar et al. (2018). Table 7 clarified that, there are two traits, i.e., technical length, straw yield $plant^{-1}$ and branches $plant^{-1}$ in 2016/2017 and plant height and straw yield $plant^{-1}$ in 2017/2018 season, were significantly ($P\leq 0.001$) participated to variation in straw yield ha^{-1}. It also noticed that 75.70% of the total straw yield ha^{-1} variations could be linearly related technical stem length, straw yield $plant^{-1}$ and number of branches $plant^{-1}$ in 2016/2017 season and 65.10% of plant height and straw yield $plant^{-1}$ in 2017/2018 season.

Correlation analysis among flax seed yield traits:

The simple coefficients of correlation among seed yield traits in 2016/2017 and 2017/2018 seasons are given in Table 8. In both seasons, it is clearly evident that seed yield positively correlated with number of fruiting branches $plant^{-1}$, fruiting zone length, number of capsules $plant^{-1}$, 1000 seed weight, seed yield $plant^{-1}$ and oil yield kg ha^{-1}. These observations are in concordance with those reported by Tadesse et al. (2009), Kumar & Paul (2016) and Kumar et al. (2018). Data illustrated in Table 9 clarified that, there are three traits, i.e., seed index, capsules number $plant^{-1}$ and plant seed yield in the 1st season and two ones, i.e., seed index and number of capsules $plant^{-1}$ in the second one, were significantly ($P\leq 0.001$) contributed to variation in seed yield. Data revealed that 72.50% of the total seed yield ha^{-1} variations could be linearly related 1000-seed weight, capsules $plant^{-1}$ and seed yield $plant^{-1}$ in 1st season and 59.90 % of seed index and number of capsules $plant^{-1}$ in 2nd season.

TABLE 6. Estimates of simple correlation coefficients in 2016/2017 season (above diagonal line) and in 2017/2018 season (below diagonal line) of straw yield (ton ha^{-1}) and related traits.

Characters		Plant height	Technical stem length	No of branches $plant^{-1}$	Straw yield $plant^{-1}$	Straw yield (ton ha^{-1})
		2016/2017				
Plant height	2017/2018	1	0.949**	0.840**	0.802**	0.793**
Technical stem length		0.970**	1	0.780**	0.795**	0.819**
No of branches $plant^{-1}$		0.773**	0.741**	1	0.671**	0.743**
Straw yield g $plant^{-1}$		0.766**	0.784**	0.728**	1	0.811**
Straw yield (t ha^{-1})		0.759**	0.756**	0.665**	0.758**	1

** Correlation coefficient is significant at $P\leq 0.01$.

TABLE 7. Correlation coefficient (r), determination coefficient (R^2) and standard error of the estimates (SEE) for predicting straw yield (ton ha^{-1}) in 2016/2017 and 2017/2018 seasons.

Season	R	R^2	SEE	Sig.	Fitted equation
2016/2017	0.870	0.757	0.435	**	Straw yield (ton ha^{-1})= - 0.527 + 0.021 technical stem length +0.451 straw yield $plant^{-1}$ + 0.202 number of branches $plant^{-1}$.
2017/2018	0.807	0.651	0.476	**	Straw yield (ton ha^{-1})= -1.195 + 0.027 plant height + 0.381 straw yield $plant^{-1}$

TABLE 8. Coefficients of simple correlation estimates in 2016/2017 season (above diagonal line) and in 2017/2018 season (below diagonal line) of seed yield (kg ha^{-1}) and related traits.

Character		No of fruiting branches plant^{-1}	Fruiting zone length	No of Capsules plant^{-1}	1000 seed weight	Seed yield plant^{-1}	Oil yield (kg ha^{-1})	Seed yield (kg ha^{-1})
		2016/2017						
No of fruiting ranches plant^{-1}	2017/2018	1	0.361**	0.843**	0.833**	0.686**	0.777**	0.757**
Fruiting zone length		0.571**	1	0.466**	0.485**	0.509**	0.455**	0.477**
No of capsules plant^{-1}		0.832**	0.602**	1	0.772**	0.744**	0.754**	0.755**
1000 seed weight (g)		0.766**	0.533**	0.816**	1	0.800**	0.825**	0.818**
Seed yield plant^{-1}		0.561**	0.595**	0.778**	0.706**	1	0.727**	0.768**
Oil yield (kg ha^{-1})		0.666**	0.501**	0.681**	0.746**	0.510**	1	0.990**
Seed yield (kg ha^{-1})		0.660**	0.498**	0.713**	0.756**	0.581**	0.989**	1

*: Correlation coefficient (r) is significant at P≤ 0.05.
**: Correlation coefficient (r) is significant at P≤ 0.01.

TABLE 9. Correlation coefficient (r), coefficient of determination (R^2) and standard error of the estimates (SEE) for predicting seed yield (kg ha^{-1}) in 2016/2017 and 2017/2018 seasons.

Season	R	R^2	SEE	Sig.	Fitted equation
2016/2017	0.851	0.725	77.17	**	Seed yield (kg ha^{-1})= 43.975+ 42.951 seed index + 6.714 number of capsules plant^{-1} + 57.935 seed yield plant^{-1}.
2017/2018	0.774	0.599	88.143	**	Seed yield (kg ha^{-1})= 76.599 + 42.152 seed index + 11.504 number of capsules plant^{-1}

Conclusion

This study was achieved to investigate the effect of sowing dates and nitrogen levels on flax cultivars straw and seed yields. The gained results described that precocious sowing date in November 10th was harmonious to get the best flax straw and seed yields. Sakha-1 gave the elevated mean values of straw yield traits. While, the cultivar Sakha-2 was exceeded Sakha-1 cultivar in seed yield traits. Applied nitrogen fertilizer at 105 or 140kg ha^{-1} gave the highest straw and seed yield and its related traits when compared with 35 or 70kg ha^{-1}. Thus, the recommendations of this study are cultivating Sakha-2 cultivar in early November and fertilized by 140 kg N ha^{-1}. The seed yield regression analysis showed that, there are three traits i.e. seed index, capsules number plant^{-1} and plant seed yield in the first season and two ones i.e. 1000-seed weight and capsules plant^{-1} in the second one, were contributed significantly (P≤ 0.001) to variation in seed yield ha^{-1}.

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فاعلية مواعيد الزراعة ومعدلات النيتروجين على انتاجية صنفين من الكتان (*Linum usitatissimum* L.)

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تم إجراء تجربتين حقليتين خلال موسمي 2017/2016 و2018/2017 في مزرعة كلية الزراعة، جامعة الفيوم، مصر، لدراسة تأثير مواعيد الزراعة ومستويات النيتروجين على محصول القش والبذور لصنفين من الكتان (*Linum usitatissimum* L.). وقد تم استخدام القطع المنشقة مرتين فى تصميم قطاعات كاملة العشوائية باستخدام ثلاث مكررات. وتم تخصيص مواعيد الزراعة وهى (10 نوفمبر، 25 نوفمبر و 10 ديسمبر) في القطع الرئيسية وأصناف الكتان (سخا-1 و سخا-2) في القطع الشقية الأولى وتم توزيع مستويات النتروجين وهى (35، 70، 105 و140 كجم/هكتار) في القطع الشقية الثانية.

و أظهرت النتائج التي تم الحصول عليها ما يلى :

- تخطى موعد الزراعة في 10 نوفمبر بشكل معنوى مواعيد الزراعة الآخرى فى محصول القش ومكوناته (مثل ارتفاع النبات، الطول الفعال، عدد فروع/نبات، محصول القش/نبات) وكذلك محصول البذور ومكوناته (مثل عدد الفروع الثمرية/نبات، عدد الكبسولات/نبات، وزن 1000 بذرة، محصول البذور/نبات، النسبة المئوية للزيت في البذور، محصول الزيت/هكتار.
- تفوق معنوياً الصنف سخا-1 على الصنف سخا-2 في محصول القش ومكوناته، بينما تجاوز الصنف سخا-2 الصنف سخا-1 في محصول البذور ومكوناته.
- كان معدل السماد 140 كجم نيتروجين/هكتار أعلى معنوياً في محصول القش والبذور ومكوناتهما من غيره من مستويات النيتروجين والتي تختلف معنوياً عن بعضها البعض في كلا الموسمين.
- أظهر تحليل الأنحدار لمحصول البذور إلى أن هناك ثلاث صفات وهي: دليل البذور، وعدد كبسولات النبات ومحصول البذور/نبات في الموسم الأول وصفتين اثنين هما دليل البذور وعدد كبسولات النبات في الموسم الثاني قد ساهمت بشكل كبير ($P\leq 0.001$) في الإختلاف في محصول البذور/هكتار.