Effect of Sowing Dates and Compound Fertilizer NPK on Growth and Yield of Flax (*Linum usitatissimum* L.)

Rayan F. A. Al-Obady* & Ayad T. Shaker
Department of Agronomy, College of Agriculture and Forestry, University of Mosul, Iraq

*Corresponding author email: rayanobady79@uomosul.edu.iq, (A.T.S.) ayadalmeran@uomosul.edu.iq

Received 1st April 2021; Accepted 8th April 2022; Available online 13th October 2022

**Abstract:** Two field experiments were conducted during winter growing season 2019-2020 at Ninevah Governorate at two locations: Talkief and Al-Hamdaniya. The main objective was to study the effect of two sowing dates (November 2017 and December 2017), and four levels of N_{15}P_{15}K_{15} fertilizers (0, 100, 150 and 200 kg.ha^{-1}) on growth and yield of flax under rainfed conditions. The factorial experiment was carried out in Randomized Complete Block Design (R.C.B.D.) with triplicate. The results showed that there were significant differences (p<0.05) between sowing dates in all the studied characters in the both locations, the date of sowing (November 17) gave the highest rate of plant height, number of fruiting branches. plant^{-1}, number of capsules. plant^{-1}, number of seeds. capsule^{-1}, 1000 seed weight, seed yield, seed oil percentage and linolenic acid percentage. Adding NPK fertilizer with 200 Kg NPK.ha^{-1} to the soil was superior in some characters i.e. plant height, number of fruiting branches. plant^{-1}, number of capsules. plant^{-1} and number of seeds. capsule^{-1} in Al-Hamdaniya location, Whereas linolenic acid percentage was superior in Talkief location. Also highest seeds oil percentage was obtained in both locations. The interaction between date (November 17) with 200 kg.ha^{-1} of N_{15}P_{15}K_{15} fertilizer was significantly (p<0.05) superior in linolenic acid percentage in Talkief location only.

**Keywords:** Compound fertilizer, Flax, Linolenic acid, Sowing dates.

**Introduction**

Flax (*Linum usitatissimum* L.) is an important industrial crop and is grown either to obtain dry oil from seeds and fibers from stems. It is the third largest fiber crop and one of the five major oil crops in the world; the oil in the seeds of flax ranges between 30 -45% and its oil is non-edible because of higher content of linolenic acid (47-58%) (Mueller et al., 2010). The oil is important in the manufacture of paints, soap and printer's ink and for medical purposes or for obtaining fibers from the stems are used in the manufacture of linen textiles, denomination, rugs, insulating material and tyre of cars (El-Borhamy & Khedr, 2017).

The average productivity of flax per unit area in Iraq is very low, and it is only at the level of research, so it is necessary to expand the sowing of this crop and increase its yield per unit of area through some agricultural operations, including the dates of sowing and the use of fertilizers especially macronutrients including NPK Fertilizer (Berti, et al., 2010). Optimum sowing date is very important management tool in minimizing the negative impact of high temperature and...
moisture stress during the critical flowering and seed filling periods, the appropriate sowing dates is very important since it ensures good seed germination, as well as timely appearance of seedling and optimum development of the root system (Kumari, 2020).

Application of macronutrient i.e. nitrogen, phosphorus and potassium, is essential for enhancing flax growth and productivity. Nitrogen is often the most important plant nutrients which is a structural component of nucleic acids, chlorophyll formed, nucleotides, phosphatides, alkaloides, enzymes, hormones, Vitamins so led to increase plant efficiency in water consumption, resistance to external stress, delayed aging and extend the life of the plant. phosphorous fertilizer plays a major role in regulating photosynthesis reactions, a source of energy and regulate the translocation process (Mengel et al., 2001).

The potassium element contributes to the formation of proteins and carbohydrates, the transfer of sugars from the leaves to the seeds, and a stimulant agent for enzymes that contribute to the process of photosynthesis. It also contributes to the regulation of the osmotic effort of the plant cell and thus maintains its swelling pressure and thus increases the plant's ability to resist conditions of drought, frost, salinity, fungi and diseases. (Abd El-Daiem & El-Borhamy, 2015).

Jana et al. (2018) found when using of three sowing dates (15 November, 22 November and 29 November) indicated the superiority of the first date (15 November) in the characters no. of capsules plant\(^{-1}\), seed yield and seed oil percentage. The results of Kumari (2020) in his experiment in which he used four sowing dates (15 November, 1 December, 15 December and 31 December) showed that the date of the first sowing (15 November) was significantly better in the characters of no. of capsules plant\(^{-1}\), 1000 seeds weight and seed yield. Al-Juheishy (2020) used three sowing dates (1 November, 15 November and 30 November) in their study and showed that the date of the first sowing (1 November) significantly outweigh in the characters plant height, no. of fruiting branches plant\(^{-1}\), no. of capsules. plant\(^{-1}\), no. of seeds. capsule\(^{-1}\), seed yield and seed oil percentage.

Abd El-Daiem & El-Borhamy (2015) observed the level (185 kg N+57 kg P\(_2\)O\(_5\)+59 kg K\(_2\)O.ha\(^{-1}\)) was significantly superior in characters of plant height, no. of capsules plant\(^{-1}\) no. of seeds capsule\(^{-1}\) and seed yield compare with the control treatment (no added the fertilizer). Kumar et al. (2016) found when using of three level of NPK fertilizer (50:30:20, 75: 45: 40 and 100:60:60 Kg NPK. ha\(^{-1}\)), that the level (75:45:40 kg NPK. ha\(^{-1}\)) was better in the characters of plant height, no. of capsules. plant\(^{-1}\), number of seeds. capsule\(^{-1}\), 1000 seed weight and seed yield. Devedee et al. (2017) showed a significant increase in no. of capsules. plant\(^{-1}\), number of seeds. capsule\(^{-1}\),1000 seed weight and seed yield when increase added NPK fertilizer from control to 48:34.5:45 and 64:46:60 kg NPK.ha\(^{-1}\). This study aims to determine the best planting date and the best level of NPK compound fertilizer when growing flax seed under rainfed conditions at Ninawa province.

**Materials & Methods**

One field Experiment was carried out during winter growing season 2019-2020 at Nineveh Governorate at two locations (Talkief and Al-Hamdaniya). In order to know the effect of two sowing dates (17 November and 1 December) and four levels of N\(_{15}\)P\(_{15}\)K\(_{15}\) fertilizers (0, 100, 150 and 200. kg NPK. ha\(^{-1}\))
on growth characters and yield. The factorial experiment was applied used in Randomized Complete Block Design (R.C.B.D.) with triplicate. Added N15P15K15 fertilizer to the soil all at once when planting. Some of the physical and chemical properties of the soil were analyzed (Table 1) at the depth of 0-30cm. The date of temperature requirement and precipitation requirement are presented in table (2).

Table (1): Some physical and chemical properties of experiments soil.

<table>
<thead>
<tr>
<th>Physical characters</th>
<th>Talkaif location</th>
<th>Al-Hamdaniya location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clay (g .kg(^{-1}))</td>
<td>203</td>
<td>558</td>
</tr>
<tr>
<td>Silt (g .kg(^{-1}))</td>
<td>452</td>
<td>364</td>
</tr>
<tr>
<td>Sand (g .kg(^{-1}))</td>
<td>345</td>
<td>78.0</td>
</tr>
<tr>
<td>Texture</td>
<td>Loam</td>
<td>Clay</td>
</tr>
<tr>
<td>Chemical characters</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Available N (mg .kg(^{-1}))</td>
<td>59.12</td>
<td>34.9</td>
</tr>
<tr>
<td>Available P (mg .kg(^{-1}))</td>
<td>48.07</td>
<td>35.5</td>
</tr>
<tr>
<td>Available K (mg .kg(^{-1}))</td>
<td>260.0</td>
<td>325.0</td>
</tr>
<tr>
<td>Organic matter (g .kg(^{-1}))</td>
<td>1.2</td>
<td>1.3</td>
</tr>
<tr>
<td>pH</td>
<td>7.3</td>
<td>7.8</td>
</tr>
<tr>
<td>Ec. (ds.m(^{-1}))</td>
<td>0.262</td>
<td>0.168</td>
</tr>
</tbody>
</table>

Table (2): Maximum and minimum monthly temperature (°C) and precipitation during the planting season 2019-2020 at two experimental site Talkief and Al-Hamdaniya.

<table>
<thead>
<tr>
<th>Month</th>
<th>Temperature (°C)</th>
<th>Precipitation (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Talkief</td>
<td>Al-Hamdaniya</td>
</tr>
<tr>
<td>October 2019</td>
<td>Max. 32.9</td>
<td>Min. 19.8</td>
</tr>
<tr>
<td>November 2019</td>
<td>Max. 23.7</td>
<td>Min. 9.9</td>
</tr>
<tr>
<td>December 2019</td>
<td>Max. 16.2</td>
<td>Min. 8.3</td>
</tr>
<tr>
<td>January 2020</td>
<td>Max. 12.8</td>
<td>Min. 4.8</td>
</tr>
<tr>
<td>February 2020</td>
<td>Max. 14.0</td>
<td>Min. 5.4</td>
</tr>
<tr>
<td>March 2020</td>
<td>Max. 20.7</td>
<td>Min. 10.5</td>
</tr>
<tr>
<td>April 2020</td>
<td>Max. 24.1</td>
<td>Min. 11.9</td>
</tr>
<tr>
<td>May 2020</td>
<td>Max. 35.4</td>
<td>Min. 19.3</td>
</tr>
</tbody>
</table>

The land of the experiment was plowed with a Moldboard plow, then it was set and flattened and then divided into experimental units. Each unit contained five lines and with long three meter for one line and a distance of 30 cm between one line and another. The manual weeding process was carried out several times during the growing season and the experiment was harvested when the plants reached full maturity. Ten plants were randomly selected from the midlines of each experimental unit and the following characters were studied:

**Plant height**

It was measured from the base of the stem to the height peak in the plant at completion of maturity.

**Number of fruiting branches.plant\(^{-1}\)**

It was calculated as an average of ten plants randomly selected.
Number of capsules plant\(^{-1}\)
It was calculated as an average of ten plants randomly selected at maturity.

Number of seeds capsule\(^{-1}\)
By dividing the average number of seeds by the average number of capsules plant\(^{-1}\).

1000 seed weight (g)
After mixing the seeds of the harvested plants, a thousand seeds were randomly taken from each experimental unit and then weighted.

Seed yield (kg ha\(^{-1}\))
This was done by harvesting the middle lines and leaving the guard lines in the experimental unit.

Seed oil percentage
Estimated by Soxhlett. Where samples were used, weighing one gram, and the oil was extracted for three hours by adding Petroleum Ether with a boiling point of 60-80°C, then the samples were dried at a temperature of 90°C (AOAC., 2016)

Linolenic acid percentage
Saponification process of the oil was carried out using a basic solution where 0.1 g of oil was taken in a Soxhlet device and 3 ml of 20% solution of NaOH was added to it and 3 ml of ethanol was added to it, which replaced the heating process in a water bath for a period 90 minutes, after which it was cooled. Then the volume was cooled to 10 ml of ethanol, after which 0.1 ml of saponification solution and lighten with ethanol to 10 ml and then examined samples by (Specter photometer to determine the wavelength by operating condition (hmax) and after used High performance Liquid Chromatography (HPLC) from type Shimedzu Lc- 2010AHT (Takatori et al., 2011) under operating condition (Table 3).

### Table (3): Detaching conditions of HPLC.

<table>
<thead>
<tr>
<th>Detaching conditions</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Device name</td>
<td>High Performance Liquid Chromatography (HPLC)</td>
</tr>
<tr>
<td>Column type</td>
<td>C18 for dimension (4.6mm × 25mm)</td>
</tr>
<tr>
<td>Detector</td>
<td>U.V.</td>
</tr>
<tr>
<td>Wave length</td>
<td>242 nm</td>
</tr>
<tr>
<td>Injecting amount</td>
<td>25 µl</td>
</tr>
<tr>
<td>Carrier phase</td>
<td>70% Water : 30% Acetonitrile</td>
</tr>
<tr>
<td>Speed of flow</td>
<td>1 ml. minute (^{-1})</td>
</tr>
<tr>
<td>Column temperature</td>
<td>40°C</td>
</tr>
</tbody>
</table>

Statistical analysis
data were analyzed statistically according to the Randomized Complete Block Design (R.C.B.D.), and the Duncan multi – range test at the probability level 1 and 5% was used to compare the averages.

Results & Discussion

Plant height (cm)
The results in table (4) indicate that there are significant differences between sowing dates in the plant height trait in both locations of study. The first sowing date (November 2017) was given the highest rate of the trait (44.2 and 46.8 cm), while the second date of sowing December 2017 given less rate for the trait (42.3 and 44.0 cm) for both locations respectively. The reason of superior the sowing date November 2017 compare with the sowing of date (December 17) might be due to long growth period (one month) and its suitability for the rain and temperature during period of vegetative growth. These results are in agreement with results of both of Rahimi
The results of the table (4) show the presence of significant differences between levels of NPK fertilizer in the trait of plant height at Al-Hamdaniya location only, the highest rate of this trait was (48.3 cm) in the level of NPK fertilizer (200 kg NPK.ha⁻¹), while the lowest rate of this trait was 42.8cm when no added the fertilizer (control).

This is attributed to decrease content of soil from nutrients especially nitrogen and phosphor (Table 1); this increased the plant's response to high levels of the compound fertilizer and led to increase elongation the internodes. This is noted by Abd El-Daiem & El-Borhamy (2015) and Kumar et al. (2016).

The results of table (4) shows no significant differences for the interaction between sowing dates and NPK fertilizer in the trait of the plant height in both locations.

### Table (4): Effect of sowing dates and N₁₅P₁₅K₁₅ fertilizer on plant height (cm).

<table>
<thead>
<tr>
<th>Sowing dates</th>
<th>N₁₅P₁₅K₁₅ (kg . ha⁻¹)</th>
<th>Means of Sowing dates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>November 17</td>
<td>43.2a± 2.0</td>
<td>43.4a± 1.8</td>
</tr>
<tr>
<td>December 17</td>
<td>40.2a± 2.8</td>
<td>42.8a± 1.5</td>
</tr>
<tr>
<td>Means of N₁₅P₁₅K₁₅</td>
<td>41.7a± 0.4</td>
<td>43.1 a± 0.4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sowing dates</th>
<th>N₁₅P₁₅K₁₅ (kg . ha⁻¹)</th>
<th>Means of Sowing dates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>November 17</td>
<td>44.0a± 2.4</td>
<td>46.1a± 5.1</td>
</tr>
<tr>
<td>December 17</td>
<td>41.6a± 0.4</td>
<td>43.1a± 0.6</td>
</tr>
<tr>
<td>Means of N₁₅P₁₅K₁₅</td>
<td>42.8c± 1.2</td>
<td>44.6 bc±2.4</td>
</tr>
</tbody>
</table>

The values followed by different letters in the same column differ from each other’s at probability 1 and 5% levels.

**Number of fruiting branches, plant⁻¹**

The results in table (5) showed that there are significant differences between sowing dates in the trait of the number of fruiting branches. plant⁻¹ in both locations of study. The highest rate of the trait was 4.7 and 4.1 branch.plant⁻¹ at the date of sowing (November 17), while the lowest rate was 4.4 and 3.8 branch.plant⁻¹ at the date of sowing December 17 for both locations of study. This might be due to the fact that earlier of sowing date leads to long growth period (one month) and suitable of rain and temperature during vegetative growth period. This result is consistent with Emam (2019) and Al-Juheishy (2020).

The results of table (5) showed that there are significant differences between levels of NPK fertilizer in the trait of number of fruiting branches plant⁻¹ at Al-Hamdaniya location only, the highest rate of this trait was
4.2 branch plant\(^{-1}\) in the level of NPK fertilizer (200 kg NPK ha\(^{-1}\)), while the lowest rate of this trait was 3.7 branch plant\(^{-1}\) when the control treatment. This might be due to the low content of the soil of nitrogen and phosphorous available in Al-Hamdaniya location (Table 1) compared to Talkief location, which led to plant response to high levels of compound fertilizer, which affected the regulation and action the hormones such as auxines and cytokines, which led to an increase in the division of meristematic cells and thus giving an increase in the number of fruiting branches plant\(^{-1}\) (Mengel et al., 2001).

The results of Table (5) that there is no significant effect of interaction between sowing dates and NPK fertilizer in the trait of the number of fruiting branches plant\(^{-1}\) in both locations.

Table (5): Effect of sowing dates and N\(_{15}\)P\(_{15}\)K\(_{15}\) fertilizer on Number of fruiting branches plant\(^{-1}\).

<table>
<thead>
<tr>
<th>Sowing dates</th>
<th>N(<em>{15})P(</em>{15})K(_{15}) (Kg . ha(^{-1}))</th>
<th>Means of sowing dates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>November 17</td>
<td>4.5 a± 0.3</td>
<td>4.4a± 0.5</td>
</tr>
<tr>
<td>December 17</td>
<td>4.2 a± 0.4</td>
<td>4.4a± 0.2</td>
</tr>
<tr>
<td>Means of N(<em>{15})P(</em>{15})K(_{15})</td>
<td>4.4 a± 0.3</td>
<td>4.4 a± 0.3</td>
</tr>
</tbody>
</table>

Al-Hamdaniya location

<table>
<thead>
<tr>
<th>Sowing dates</th>
<th>N(<em>{15})P(</em>{15})K(_{15}) (Kg . ha(^{-1}))</th>
<th>Means of Sowing dates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>November 17</td>
<td>3.9 a± 0.4</td>
<td>3.9a± 0.4</td>
</tr>
<tr>
<td>December 17</td>
<td>3.5a± 0.3</td>
<td>3.6 a± 0.1</td>
</tr>
<tr>
<td>Means of N(<em>{15})P(</em>{15})K(_{15})</td>
<td>3.7 c± 0.3</td>
<td>3.8 b c± 0.2</td>
</tr>
</tbody>
</table>

The values followed by different letters in the same column differ from each other's at probability 1 and 5% levels.

Number of capsules plant\(^{-1}\)

The results in Table (6) shows the presence of significant differences between sowing dates in the number of capsules plant\(^{-1}\) in both locations of study. The first time of sowing November 2017 succeeds the highest rate of the trait (15.7 and 13.4 capsule plant\(^{-1}\)), while the second time of sowing December 17 recorded the lowest rate of the trait (14.3 and 11.6 capsule plant\(^{-1}\)) and for both locations, respectively. The cause may be due to increase number of fruiting branches plant\(^{-1}\) (Table 5) in the first date. This result is in conformity with Jana et al. (2018), Emam (2019) and Kumari (2020).
The results described in table (6) showed the presence of significant differences between levels of NPK fertilizer in the number of capsules plant\(^{-1}\) at Al-Hamdaniya location only a level of NPK fertilizer (200 kg NPK.ha\(^{-1}\)) a produced the highest rate of his trait (14.7 capsule . plant\(^{-1}\)), while the control was least average of his trait (10.2 capsule. plant\(^{-1}\)). This can be attributed to the positive role of NPK fertilizer in formation of chlorophyll and increase efficiency process of photosynthesis and then giving increase dry matter accumulation by cell divisions cell multiplication led to increase number of flowers and fruits in plant because increase efficiency and vitality pollination. This result is consistent with Abd El-Daiem & El-Borhamy (2015), Kumar \textit{et al.} (2016) and Devedee \textit{et al.} (2017).

The results of table (6) show non-significant differences between the date of sowing and NPK fertilizer in the trait of number of capsules plant\(^{-1}\).

### Table (6): Effect of sowing dates and N\(_{15}\)P\(_{15}\)K\(_{15}\) fertilizer on Number of capsules. Plant\(^{-1}\).

<table>
<thead>
<tr>
<th>Sowing dates</th>
<th>N(<em>{15})P(</em>{15})K(_{15}) (Kg . ha(^{-1}))</th>
<th>Means of sowing dates</th>
</tr>
</thead>
<tbody>
<tr>
<td>November 17</td>
<td>15.6a± 2.4</td>
<td>15.7 a± 1.7</td>
</tr>
<tr>
<td>December 17</td>
<td>12.5a± 2.3</td>
<td>14.3 b± 1.5</td>
</tr>
<tr>
<td>Means of N(<em>{15})P(</em>{15})K(_{15})</td>
<td>14.0a ± 2.3</td>
<td>16.2a±2.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sowing dates</th>
<th>N(<em>{15})P(</em>{15})K(_{15}) (Kg . ha(^{-1}))</th>
<th>Means of Sowing dates</th>
</tr>
</thead>
<tbody>
<tr>
<td>November 17</td>
<td>11.1a± 0.7</td>
<td>13.4 a± 0.9</td>
</tr>
<tr>
<td>December 17</td>
<td>9.3 a± 1.8</td>
<td>11.6 b± 0.3</td>
</tr>
<tr>
<td>Means of N(<em>{15})P(</em>{15})K(_{15})</td>
<td>10.2 d± 1.2</td>
<td>14.7a±0.6</td>
</tr>
</tbody>
</table>

The values followed by different letters in the same column differ from each other's at probability 1 and 5% levels.

**Number of seeds. capsule\(^{-1}\)**

The results in table (7) show the presence of significant differences between sowing dates in the trait of number of seeds. capsule\(^{-1}\) for both locations of study. The highest rate of the trait was 9.3 and 9.2 seed. capsule\(^{-1}\) at the date of sowing November 2017, while the date of sowing December 17 gave the lowest rate of this trait (9.1 and 9.0 seed. capsule\(^{-1}\)) for both locations respectively. This can be attributed to the delay of sowing dates that leads to negative effect of sudden rise temperature and increase water stress during the period of flowering and the period of seed fullness addition short of period from flowering until the harvest and result less number of seeds. capsule\(^{-1}\). This result agreement with those Sohair \textit{et al.} (2015) and Al-Juheishy (2020).
The results in table (7) show that there are significant differences between the levels of NPK fertilizer in the trait of number of seeds. capsule\(^{-1}\) at Al-Hamdaniya location only. The highest medium of this trait reached (9.3 seed. capsule\(^{-1}\)) at level of NPK fertilizer (200 kg NPK.ha\(^{-1}\)) whereas the least medium for this trait was (8.8 seed. capsule\(^{-1}\)) at control treatment. The reason increase number of seeds. capsule\(^{-1}\) when increase levels NPK fertilizer due to role of NPK fertilizer in enhanced growth of plant and increase efficiency photosynthesis and increase of fertilization in flowers leads to increase number of seeds capsule\(^{-1}\). This result consistent with results of both Abd El-Daiem & El-Borhamy (2015), Kumar et al. (2016) and Devedee et al. (2017).

The results of table (7) show no significant effect of interference between sowing dates and levels of NPK fertilizer in the trait of number of seeds. capsule\(^{-1}\) for both locations of study.

Table (7): Effect of sowing dates and N\(_{15}\)P\(_{15}\)K\(_{15}\) fertilizer on number of seeds. capsule\(^{-1}\).

<table>
<thead>
<tr>
<th>Sowing dates</th>
<th>Talkief location</th>
<th>Al-Hamdaniya location</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N(<em>{15})P(</em>{15})K(_{15}) (Kg. ha(^{-1}))</td>
<td>Means of Sowing dates</td>
</tr>
<tr>
<td>November 17</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>9.2a± 0.1</td>
<td>8.9 a± 0.1</td>
</tr>
<tr>
<td>100</td>
<td>9.4a± 0.2</td>
<td>9.1a± 0.1</td>
</tr>
<tr>
<td>150</td>
<td>9.3a± 0.1</td>
<td>9.3a± 0.3</td>
</tr>
<tr>
<td>200</td>
<td>9.5a± 0.1</td>
<td>9.5a± 0.1</td>
</tr>
<tr>
<td>Means of N(<em>{15})P(</em>{15})K(_{15})</td>
<td>9.1a± 0.1</td>
<td>9.2 a± 0.1</td>
</tr>
<tr>
<td>December 17</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>9.0a± 0.1</td>
<td>8.9 a± 0.3</td>
</tr>
<tr>
<td>100</td>
<td>9.0 a± 0.3</td>
<td>9.1a± 0.3</td>
</tr>
<tr>
<td>150</td>
<td>9.4a± 0.3</td>
<td>9.2 a± 0.1</td>
</tr>
<tr>
<td>200</td>
<td>9.2 a± 0.1</td>
<td>9.0 b± 0.1</td>
</tr>
<tr>
<td>Means of N(<em>{15})P(</em>{15})K(_{15})</td>
<td>9.1a± 0.1</td>
<td>9.3 a± 0.2</td>
</tr>
</tbody>
</table>

The values followed by different letters in the same column differ from each other's at probability 1 and 5% levels.

### 1000 seed weight (g)

Table (8) shows that the sowing dates significantly affected on the 1000 seed weight in both locations of the study. The date of sowing November 2017 was better in giving the highest average of the trait (7.3 and 7.8 g), while the date of sowing December 17 given less average for the trait (6.9 and 7.4g) for both locations, respectively. The cause increase 1000 seed weight due to increase dry matter. plant\(^{-1}\) where earlier of sowing led to long growth period and this led increase of transfer for the products of photosynthesis from leaves to seeds and increase of accumulation it and this led to increase of seed weight until maturity compare with the delay of sowing date. This result agreement with the results of both of Rahimi (2014), Emam (2019) and Kumari (2020).

The results of table (8) show there is no significant differences between levels of NPK
fertilizer in the trait of rate of 1000 seed weight for both locations. The results of table (8) indicate no significant effect of interaction between sowing dates and levels of NPK fertilizer in the trait of the 1000 seed weight for both locations.

Table (8): Effect of sowing dates and \(N_{15}P_{15}K_{15}\) fertilizer on 1000 seed weight (g).

<table>
<thead>
<tr>
<th>Sowing dates</th>
<th>(N_{15}P_{15}K_{15}) (Kg. ha(^{-1}))</th>
<th>Means of Sowing dates</th>
</tr>
</thead>
<tbody>
<tr>
<td>November 17</td>
<td>7.2a± 0.1 7.3a± 0.1 7.4a± 0.2 7.4a± 0.1</td>
<td>7.3 a± 0.1</td>
</tr>
<tr>
<td>December 17</td>
<td>7.7a± 0.1 6.8a± 0.3 6.9a± 0.4 7.1 a± 0.1</td>
<td>6.9 b± 0.2</td>
</tr>
</tbody>
</table>

Means of \(N_{15}P_{15}K_{15}\)

|                          | 7.0 a± 0.1 | 7.1a± 0.2 | 7.1a± 0.1 | 7.3a ± 0.1 |

**Talkief location**

<table>
<thead>
<tr>
<th>Sowing dates</th>
<th>(N_{15}P_{15}K_{15}) (Kg. ha(^{-1}))</th>
<th>Means of Sowing dates</th>
</tr>
</thead>
<tbody>
<tr>
<td>November 17</td>
<td>7.6 a± 0.6 7.8 a± 0.7 7.9a± 0.3 7.9 a± 0.2</td>
<td>7.8 a± 0.4</td>
</tr>
<tr>
<td>December 17</td>
<td>7.2a± 0.2 7.1 a± 0.4 7.4 a± 0.3 7.7 a± 0.3</td>
<td>7.4b± 0.1</td>
</tr>
</tbody>
</table>

Means of \(N_{15}P_{15}K_{15}\)

|                          | 7.4a± 0.2 | 7.5a ± 0.4 | 7.6a± 0.3 | 7.8a± 0.1 |

**Al-Hamdaniya location**

The values followed by different letters in the same column differ from each other's at probability 1 and 5% levels.

**Seed yield (kg. ha\(^{-1}\))**

The results in table (9) shows the presence of significant differences between sowing dates in the seed yield in both locations of study. The date of sowing November 2017 has been the highest rate of this trait (1507.2 and 1383.6 kg. ha\(^{-1}\)), while the date of sowing December 2017 produced the lowest rate of this trait (1303.3 and 1194.6 kg. ha\(^{-1}\)) for both locations respectively. This is attributed to the increase in the number of capsules, plant\(^{-1}\), number of seeds, capsule\(^{-1}\) and 1000 seed weight (Tables 6, 7 and 8) which increase seed yield in the date of sowing (November 17). This result agreement with those of Rahimi (2014), Jana et al. (2018) and Kumari (2020).

Table (9) shows that there are significantly differences between levels of NPK fertilizer in this trait for both locations. The highest rate of this trait was 1533.7 and 1404.9 kg. ha\(^{-1}\) in the level of NPK fertilizer (200 kg NPK. ha\(^{-1}\)), while the lowest rate of this trait was 1294.4 and 1204.2 kg NPK.ha\(^{-1}\) in the control treatment for both locations, respectively. This is attributed to the increase in the number of capsules,plant\(^{-1}\) and number of seeds,capsule\(^{-1}\) (Tables 6 and 7). This result is consistent with the results of Abd El-Daiem & El-Borhamy (2015), Kumar et al. (2016) and Devedee et al. (2017).

It is clear from table (9) that there are significant effect of interaction between sowing dates and levels of NPK fertilizer in this trait in Talkief location only and the highest rate of this trait was 1707.6 kg. ha\(^{-1}\) in the date of sowing November 2017 and the level of NPK fertilizer (200 kg NPK. ha\(^{-1}\)).
while the lowest rate of this trait was December 17 and control treatment. (1227.6 kg ha\(^{-1}\)) in the date of sowing.

Table (9): Effect of sowing dates and N\(_{15}\)P\(_{15}\)K\(_{15}\) fertilizer on Seed yield (kg ha\(^{-1}\)).

<table>
<thead>
<tr>
<th>Location</th>
<th>Sowing dates</th>
<th>N(<em>{15})P(</em>{15})K(_{15}) (kg ha(^{-1}))</th>
<th>Means of Sowing dates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>100</td>
<td>150</td>
</tr>
<tr>
<td>Talkief location</td>
<td>November 17</td>
<td>1361.3 c ± 516.1</td>
<td>1405.8c ± 368.4</td>
</tr>
<tr>
<td></td>
<td>December 17</td>
<td>1227.6d ± 251.4</td>
<td>1265.9d ± 133.9</td>
</tr>
<tr>
<td></td>
<td>Means of</td>
<td>1294.4 c ± 380.1</td>
<td>1335.8c ± 250.1</td>
</tr>
<tr>
<td></td>
<td>N(<em>{15})P(</em>{15})K(_{15})</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Al-Hamdaniya location</td>
<td>November 17</td>
<td>1319.5a ± 249.0</td>
<td>1310.3a ± 149.6</td>
</tr>
<tr>
<td></td>
<td>December 17</td>
<td>1088.9a ± 158.8</td>
<td>1151.2a ± 172.9</td>
</tr>
<tr>
<td></td>
<td>Means of</td>
<td>1204.2c ± 203.6</td>
<td>1230.8c ± 143.3</td>
</tr>
<tr>
<td></td>
<td>N(<em>{15})P(</em>{15})K(_{15})</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The values followed by different letters in the same column differ from each other's at probability 1 and 5% levels.

**Seed oil percentage**

The results shown in table (10) indicate the presence of significant differences between sowing dates in the trait of seed oil percentage in the study locations. The highest rate of this trait (38.8 and 41.0%) at the date of sowing November 2017, while the date of sowing December 2017 gave the lowest rate (37.9 and 40.3%) for both locations, respectively. The reason of decrease in seed oil percentage when delay the sowing date due to impact of unfavorable weather conditions, especially high temperature and increase water stress during the period of seed fullness that led to decrease trans of nutrient mobility from leaves to seeds and this decrease seed oil percentage. This result is consistent with Sohair *et al.* (2015) and Emam (2019).

The result in table (10) shows the presence significant differences between levels of NPK fertilizer in this trait for both locations. The highest rate of this trait was 40.1 and 41.9% at level of NPK fertilizer (200 kg NPK ha\(^{-1}\)), while the lowest rate of this trait was 37.0 and 39.6% at control treatment for both locations, respectively. The increase of seed oil percentage when increase levels of fertilizer is attributed to the turning a large amount of carbohydrates by the process of photosynthesis to the fats either the rest has been transformed to protein and resulting increase seed oil percentage at the expense of protein percentage.
Table (10) shows the presence of no significant differences for the interaction between sowing dates and levels of NPK fertilizer in this trait for both locations.

**Table (10): Effect of sowing dates and N15P15K15 fertilizer on oil (%).**

<table>
<thead>
<tr>
<th>Sowing dates</th>
<th>Talkiefi location</th>
<th>Al-Hamdaniya location</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N15P15K15 (Kg . ha⁻¹)</td>
<td>Mean of Sowing dates</td>
</tr>
<tr>
<td>November 17</td>
<td>37.4± 0.4</td>
<td>38.8± 0.6</td>
</tr>
<tr>
<td>December 17</td>
<td>36.5± 0.3</td>
<td>37.9± 0.5</td>
</tr>
<tr>
<td>Mean of N15P15K15</td>
<td>37.0± 0.4</td>
<td></td>
</tr>
</tbody>
</table>

The values followed by different letters in the same column differ from each other's at probability 1 and 5% levels.

**Linolenic acid percentage**

The results in table (11) indicate the presence of significant differences between sowing dates in the trait of linolenic acid percentage in the locations of study. The highest rate of this trait was 46.9 and 47.1 % at the date of sowing November 2017, while the lowest rate of this trait was 45.3 and 46.0% at the date of sowing December 17 for both locations, respectively. The reason increase Linolenic acid when planting early is low temperature in flowering period and the length of time necessary for ripening and increase the accumulation of oil especially linolenic acid. Green (1986) indicated that the temperature when is high and water stress during the period of seed fullness reduce linolenic acid percentage in several crops including flax.

The results of the table (11) show the presence of significant differences between levels of NPK fertilizer in the trait of linolenic acid percentage at Talkiefi location only, the highest rate of this trait was 47.8% in the level of NPK fertilizer (200Kg NPK.ha⁻¹), while the lowest rate of this trait was 44.8% when control treatment. The increase of linolenic acid when increase levels of compound fertilizer due to the turning a large amount of carbohydrates to the fats either the rest has been transformed to protein and resulting increase linolenic acid compared with low levels of compound fertilizer.

Table (11) shows the existence of significant differences of interaction between sowing dates and levels of NPK fertilizer in this trait in Talkiefi location only and the highest rate of the mentioned trait reached
(50.0%) in the date of sowing November 2017 and the level of NPK fertilizer (200 kg NPK.ha⁻¹), while the lowest rate was 43.5% in

the date of sowing December 2017 and control treatment.

Table (11): Effect of sowing dates and N₁₅P₁₅K₁₅ fertilizer on Linolenic acid (%).

<table>
<thead>
<tr>
<th>Sowing dates</th>
<th>N₁₅P₁₅K₁₅ (Kg . ha⁻¹)</th>
<th>Means of Sowing dates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>November 17</td>
<td>46.0bc±2.8</td>
<td>45.9 bc±2.2</td>
</tr>
<tr>
<td>December 17</td>
<td>43.5 c ± 0.5</td>
<td>44.4 c ± 1.8</td>
</tr>
<tr>
<td>Means of N₁₅P₁₅K₁₅</td>
<td>44.8 c±1.1</td>
<td>45.1 bc±1.9</td>
</tr>
</tbody>
</table>
| Al-Hamdaniya location
<table>
<thead>
<tr>
<th>Sowing dates</th>
<th>N₁₅P₁₅K₁₅ (Kg . ha⁻¹)</th>
<th>Means of Sowing dates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>November 17</td>
<td>46.8 a±1.1</td>
<td>46.1a± 1.5</td>
</tr>
<tr>
<td>December 17</td>
<td>44.7a± 0.2</td>
<td>46.6a± 1.2</td>
</tr>
<tr>
<td>Means of N₁₅P₁₅K₁₅</td>
<td>45.8a±0.6</td>
<td>46.3a± 0.1</td>
</tr>
</tbody>
</table>

The values followed by different letters in the same column differ from each other's at probability 1 and 5% levels.

Conclusions

The determining factor for the timing of planting flax under the weather conditions is the climatic conditions and it is preferable to plant early to obtain a high yield of seeds. The accumulation of oil in the seeds is determined by temperature, soil readiness, moisture, fertilizer quantity and their interactions. The proportion of linolenic acid in flax oil increases with increasing temperature, the length of time the crop is in the soil, and the increase in NPK levels.

Acknowledgements

We would like to thank the Department of Field Crops, College of Agriculture and Forestry, University of Mosul to provide an opportunity for this project. We also wish to thank the Ministry of Higher Education and Scientific Research of Iraq for the opportunity to implement this project.

Conflict to interest

The authors declare that they have no conflict of interest.

Contributions of authors


A.T.S.: Follow up on laboratory analysis, reading and revised of the manuscript.

ORCID

R.F.A.A.: https://orcid.org/0000-0002-1762-1386
A.T.S.: https://orcid.org/0000-0001-7375-6923
References


تأثير مواعيد الزراعة والسماد المركب NPK في نمو وحاصل الأقانم Linum usitatissimum L.  

ريان فاضل أحمد العبادي1 و ايد طلعت شاكر2

1 قسم المحاصيل الحقلية، كلية الزراعة والغابات، جامعة الموصل، العراق
2 قسم المحاصيل الحقلية، كلية الزراعة والغابات، جامعة الموصل، العراق


الكلمات المفتاحية: السماد المركب، الأقانم، حامض اللينولينيكي، مواعيد الزراعة.