Moroccan Journal of Agricultural Sciences
Vol 3 No 4 (2022): (December 2022), 212-217
Crop Production and Environment

Impact of sulphur fertilization on yield and its components of three flax (Linum usitatissimum L.) genotypes

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The objective of this experiment was to investigate yield, yield components and quality of three flax genotypes (Sakha 3, Sakha 5 and Giza 11) under different sulphur fertilization levels (0, 25.0, 37.5, 50.0 and 62.5 kg/ha). Split-plot design was used for the experiment with four replicates. The main-plots were assigned to the five fertilization levels of sulphur and the sub-plots were allocated to the three flax genotypes. Application of 50.0 kg sulphur/ha significantly increased most of the studied characters *i.e*. technical length, straw yield/plant, straw yield/ha, fruiting zone length, number of capsules/plant, seed yield/ha, fiber length and fiber yield/ha in both seasons. Results also showed that Giza11 significantly surpassed other genotypes in technical length, stem diameter, straw yield/plant and per hectare, seed index and fiber length, whilst Sakha 3 was superior in fiber percentage and fiber yield/ha in the first and second seasons, respectively. Sakha 5 genotype recorded the best results for fruiting zone length, number of capsules/plant and seed yield/ha in both seasons. Therefore, this study recommends using fertilization level of 50.0 kg sulphur/ha with Giza11 for the best straw yield/ha, Sakha 3 for the best fiber yield/ha and Sakha 5 for the best seed yield/ha.

Keywords: Flax genotypes, sulphur fertilization, straw yield, seed yield, fiber yield

INTRODUCTION

Flax (Linum usitatissimum L.) is the oldest fiber crop in Egypt. Egyptians used flax since thousands of years and have grown this crop for dual purpose (fibers and seeds). Nowadays, flax is a crop with an industrial importance cultivated on a global scale and cultivated in Egypt as an annual winter crop. Due to its importance and the fact that it is produced locally and exported, flax is regarded as a key crop in our economic strategy (El Harriri et al., 1998). In addition to the oil obtained from seeds, the fibres that are extracted from flax stems by the retting process are a useful material for textiles (El-Shimy et al., 2020). Two to three times stronger than cotton fibres, flax fibres are inherently smooth and straight. Linseed oil has many industrial applications and seed cake is used as animal feed. The entire cultivated area of flax crop in Egypt reached about 9019 hectare in 2020 season, producing 7768 tons of fibers (FAO, 2022).

Sulphur is an essential macronutrient in plant growth and development. It is becoming more often acknowledged as the fourth main nutrient for plants, after phosphorus, nitrogen, and potassium (Raghav et al., 2016). The use of sulphur is one of the most vital factors in increasing yields. Sulphur is crucial for the synthesis of amino acids, proteins, chlorophyll and oil (Singh and Singh, 2007). Oilseeds are more sensitive to sulphur deficiency and are thus more responsive to sulphur fertilization than legumes and cereals due to their higher requirements for this nutrient (Marschner, 1995). Kushwaha et al. (2019) demonstrated that increasing sulphur (S) levels from 0 kg S ha-1 to 60 kg S ha-1 increased significantly all nutrient contents both in seed as well as in straw in comparison to control. According to Solo et al. (2021), sulphur application of 40 kg per hectare resulted in significantly higher plant height, number of branches per plant, capsules per plant, seeds per capsule and seed production (797 kg per hectare), as well as straw yield (1558 kg per hectare).

Flax genotypes' yield potential varied greatly based on a variety of physiological processes that are influenced by both genetics and environment. There is an urgent need to replace the old varieties from the farmers' field with new improved high yielding and disease resistant varieties (Singh, 2013). Leilah et al. (2018) stated that Sakha 3 gave the best results compared with other flax genotypes under study and produced the maximum values of technical length, fiber yield per plant and per feddan (4200 m2), fiber length, total fiber percentage and fiber fineness in both seasons. Also, Giza 11 cultivar significantly surpassed other studied genotypes in stem diameter, straw yield per plant and per feddan, length of fruiting zone, number of capsules/plant, 1000-seed weight, number of seeds/plant, seed yield per plant and per feddan in two seasons. However, Sakha 5 cultivar produced the maximum values of seed oil content. Sakha 3 cultivar was superior in terms of plant height, technical stem length, fibre length, fibre fineness, total fibre percentage and fibre productivity per hectare, according to Rashwan et al., (2021). In contrast, the Giza 11 and Giza 12 cultivars largely outperformed the others in terms of main stem diameter and straw yield/ha. On the other hand, Sakha 5 had the highest values of number of capsules per plant, seed, oil yields per hectare and oil percentage.

Therefore, the main objective of the present research was to study the impact of different levels of sulphur fertilization on straw and seed yields as well as their components for some flax genotypes.

MATERIALS AND METHODS

A field trial was carried out in the Experimental Farm of Sakha Agricultural Research Station, Agricultural Research Center (ARC), Egypt, over the two succeeding winters of 2020/21 and 2021/22. The main purpose for this experiment is to find out the suitable level of sulphur fertilization with the best flax genotype for yield and its components.

The experimental design was a split-plot design with four replicates, where each experimental sub-plot area was 6 m2 (2 x 3 m). The main-plots were assigned to the five levels of sulphur (S) fertilization (0, 25.0, 37.5, 50.0 and 62.5 kg sulphur/ha), where the sub-plots were allocated to the three flax genotypes; Sakha 3 (fiber type), Sakha 5 (oil type) and Giza 11 (dual type). Table 1 shows the pedigree of the different flax genotypes.

The experimental location has a clay soil texture. In both study seasons, the summer crop that came before was maize. Mechanical and chemical analysis for the experimental sites in the first and second seasons is shown in table 2.

The entire quantity of sulphur in the form of gypsum ($CaSO_4.2H_2O$) was incorporated uniformly in accordance with the mentioned treatments into the soil before sowing. During soil preparation, all phosphorus requirement fertilizer as calcium super phosphate (15.5% P_2O_5) was added at the rate of 240 kg/ha. In addition, the nitrogen fertilizer was applied at a rate of 110 kg N/ha as ammonium nitrate (33.5% N) in two doses of equal amounts. The first half of nitrogen before the second irrigation while the second one was applied before the third irrigation.

Flax was sown using broadcast sowing method with the recommended seed rate for every genotype on 31th October for the first season and on 2nd November for the second. The other agricultural practices for flax were kept the same as normally practiced according to the recommendations of the Ministry of Agriculture and Land Reclamation.

The studied characters

Ten plants were selected in random at maturity in each sub-plot to record the following traits:

Straw yield and its components:

Technical length (cm),

Stem diameter (mm),

Straw yield/plant (g),

Straw yield/ha (ton).

Seed yield and its components:

Fruiting zone length (cm),

Number of capsules/plant,

Seed index (g),

Seed yield/ha (kg).

Fiber yield and its components:

Fiber length (cm),

Fiber percentage (%),

Fiber yield/ha (kg).

Fiber percentage was calculated as (weight of total fiber (g)/weight of straw after retting (g)) x 100. Straw yield/ha (ton), fiber yield/ha (ton) and seed yield/ha (kg) were measured from the central area of one square meter of each sub plot.

Statistical analysis

The data was statistically analysed using the method of analysis of variance (ANOVA) for the split-plot design as published by Gomez and Gomez (1984) using the “MSTAT-C” software package. In addition, treatment means were compared by using the least significant difference (LSD) method at 5% level probability as described by Snedecor and Cochran (1980).

RESULTS AND DISCUSSION

Straw yield and its components

Data shown in table 3 showed that sulphur fertilizer levels have a significant effect on technical length, straw yield/plant and straw yield/ha, while stem diameter was not significantly affected by the sulphur fertilization. The obtained results showed that 50.0 kg S/ha significantly exceeded other levels in technical length, straw yield/plant and straw yield/ha in both growing seasons. The application of 62.5 kg S/ha came in the second rank after 50.0 kg S/ha, while the minimum values for the aforementioned studied characters were in the control treatment (0 kg S/ha) in each season. These results could be attributed to the direct role of sulphur in the photosynthetic process in plants, consequently have a positive impact on plant growth through cell division which, causes expanding of leaf and light interception then increase in plant vegetative growth. These results are in accordance with those obtained by Singh and Singh (2007), Patil et al. (2014), Bakry et al. (2015), Minz et al. (2017) and Solo et al. (2021).

We noticed that the flax genotype Giza 11 (dual purpose type) significantly surpassed the other studied genotypes, Sakha 3 (fiber type) and Sakha 5 (oil type), and resulted in the best values of technical length, stem diameter, straw yield/plant and straw yield/ha throughout the two seasons (Table 3). However, Sakha 3 cultivar came as the second best genotype concerning technical length, straw yield per plant and per hectare and Sakha 5 ranked at the second best genotype in stem diameter character in both seasons. The lowest values were for Sakha 5 genotype, except for the characteristic of stem diameter, which was higher for Sakha 3 genotype in the two seasons. These results are mainly due to differences in the genetical factors of the three tested genotypes and potentiality between the fiber, oil and dual-purpose types of flax. These results are in harmony with those reported by Kushwaha et al. (2019), Omar et al. (2020), Omar et al. (2021) and Rashwan et al. (2021).

The interaction between sulphur fertilization levels and flax genotypes exhibited a significant influence on straw yield (ton/ha) in each season (Table 3). Furthermore, data revealed that the maximum values of the aforementioned character belonged to application level of 50.0 kg S/ha with Giza 11 flax genotype, while the lowest one obtained by 0 kg S/ha (control) with Sakha 5 flax genotype in both seasons, respectively.

Seed yield and its components

The studied sulphur fertilization levels had a significant effect on fruiting zone length, number of capsules/plant and seed yield/ha, whilst there was no significant effect on the characteristic of seed index in both agronomic seasons (Table 4). Sulphur application level of 50.0 kg S/ha attained the best results for the aforementioned studied characters in the 1st and 2nd seasons. But with the increase in the level of sulphur fertilization to 62.5 kg/ha, a decrease in these characteristics began to occur, and this could be the result of being in excess of the plants' need, which led to an opposite result. The lowest values obtained from those mentioned traits were in the fertilization level of 0 kg S/ha (control) for both seasons of this study. This increase in seed yield and its components might be attributed to the fact that sulphur is mainly responsible for enhancing the reproductive growth and the proportion of the reproductive tissue (inflorescence and capsules). These results are matching with those reported by McGrath and Zhao (1996), Basumatary (2018), Kushwaha et al. (2019) and Solo et al. (2021).

The studied flax genotypes (Sakha 3, Sakha 5 and Giza 11) differed significantly in fruiting zone length, number of capsules/plant, seed index and seed yield/ha, in each season, as shown in table 4. Sakha 5 genotype produced the greatest values of fruiting zone length, number of capsules/plant and seed yield/ha, followed by Giza 11 genotype, while Giza 11 genotype attained the best values of seed index, in both seasons. At the same time, the lowest values of seed yield and its attributes were from Sakha 3 genotype in each season (Table 4). The variation between the flax genotypes may be mainly because of the genetic factors and genetic makeup of the studied flax cultivars. These results are in line with those reported by Leilah et al. (2018), Kushwaha et al. (2019), Omar et al. (2020), Omar et al. (2021) and Rashwan et al. (2021).

The interaction effect between sulphur fertilization levels and flax genotypes reflected that the interaction exhibited a significant effect on seed yield/ha in both seasons (Table 4). Data indicated that the greatest values of seed yield/ha were achieved by application of 50.0 kg S/ha with Sakha 5 flax genotype, while the lowest seed yield/ha was obtained by applying 0 kg S/ha (control) with Sakha 3 flax genotype, respectively in both seasons (Table 4).

Fiber yield and its components

The data in table 5 showed that sulphur fertilization levels significantly affected fiber length and fiber yield per hectare of flax in the 1st and 2nd seasons of this study. Data showed that the highest fiber length and fiber yield/ha characteristics were recorded with the application of 50.0 kg S/ha, followed by 62.5 kg S/ha, in both seasons. On the other hand, application of 0 kg S/ha (control) gave the lowest values of the aforementioned characters in both seasons. These findings may be due to the positive effect of sulphur, which is the constituent of a number of amino acids that are essential for the growth and development of plant tissues, consequently increasing plant height, technical stem length and straw yields per plant and per hectare, which define fiber biomass and hence fiber yield. These findings are in agreement with those obtained by Singh and Singh (2007), Patil et al. (2014), Bakry et al. (2015), Minz et al. (2017) and Solo et al. (2021).

Statistical analysis showed highly significant differences for fiber length, fiber percentage and fiber yield per hectare between the three flax genotypes. Data presented in table 5 indicated that Giza 11 genotype gave the tallest fiber length values followed by Sakha3, whilst Sakha 3 genotype recorded the greatest values of fiber percentage and fiber yield per hectare in both seasons, followed by Giza 11 which ranked second in these traits. On the other hand, the shortest fiber length, the lowest total fiber percentage and fiber yield per hectare were obtained by Sakha 5 genotype in both seasons. It is worthy to note that the trend of fiber traits was similar to that of technical stem length, and although Giza 11 produced the highest straw yield per plant and per hectare, it ranked the second in fiber traits. These results may be due to the fact that fiber genotypes generally exceeded dual and oil types in fiber length, fiber fineness, fiber percentage and fiber yield per hectare due to their genetic potential. Also, the fiber type cultivars had higher fiber content in later harvests compared with seed type cultivars. These results are in accordance with those obtained by Singh and Singh (2007), Baud and Lepiniec (2010), Patil et al. (2014), Bakry et al. (2015), Minz et al. (2017) and Solo et al. (2021).

With respect to the interaction effect between sulphur fertilization levels and flax genotypes, the data in table 5 displayed a significant effect on fiber yield/ha in both seasons. The maximum fiber yield/ha was obtained from Sulphur fertilization level of 50.0 kg S/ha with Sakha 3 flax genotype and the lowest one was obtained by applying 0 kg S/ha (control) with Sakha 5 flax genotype, respectively in both seasons of the study.

CONCLUSION

This study recommends using a sulphur fertilization rate of 50 kg/ha with Giza 11 genotype for best straw yield/ha, with Sakha 3 genotype for best fiber yield/ha and with Sakha 5 genotype for best seed yield/ha under the environmental conditions of Northern Delta of Egypt.

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