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EFFECT OF ROW SPACING ON GROWTH AND YIELD TRAITS OF SAFFLOWER (*CARTHAMUS TINCTORIUS* L.)

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SUMMARY

In two different locations — the Badush Dam area and the College of Agriculture and Forestry-University of Mosul, Iraq — a field experiment commenced in the winter of 2021–2022 to investigate how planting distances between lines at 30, 45, and 60 cm affect the growth and productivity characteristics of safflower cultivars (Gilla, Almais, and Urdine). The experiment with a randomized complete block design used two parameters. The outcomes showed significant differences between planting distances in most read-up attributes for both regions. A planting distance of 30 cm gave the most essential impetus for the height of a plant in the Badush Dam region. Moreover, both regions recorded the highest rate for seeds/capitula from a planting distance of 45 cm and the maximum rate for branches/plant, leaf area, 1000-seed weight, seed yield, oil content (%), and oil yield, and capitula/plant only in the college region. In both experimental sites, the varieties substantially impacted every trait under study. The highest values emerged for the Gilla variety for the 1000-seed weight at both sites. The utmost rates showed for the plant height, branches/plant, leaf area, capitula/plant, seeds/capitula, seed yield, and percentage of oil for the Almais variety. Moreover, the oil yield regarding branches/plants in the kidney site, leaf area in the dam site, and seed yield in both sites revealed a significant interaction between the Almais variety and the planting distance of 60 cm.

Keywords: Safflower, planting distances, cultivars

Key findings: Broad distances fared better for the qualities under study due to the influence of planting distances. The study determined that safflower should have a planting distance of 60 cm due to its increased yield productivity, and the Almais variety also showed superiority over the other two kinds.

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INTRODUCTION

The safflower crop is one of the most significant oilseeds that contributes substantially to vegetable oil production worldwide (Li and Mundel, 1996). Its high proportion of essential unsaturated fats and low proportion of superfluous unsaturated fats reflect its development as a means of extracting oil from its seeds (Gecgel *et al.*, 2007). In addition to its various industrial, oil, and fodder uses, this crop offers numerous health benefits, such as lowering blood pressure and treating blood disorders (Munoz-Valenzuela *et al.*, 2007). Compared with other oil crops, safflower growing still exists in moderately small areas, according to data from the International Food and Agricultural Organization.

The total cultivated area for safflower was 850,000 ha. India, the US, Ethiopia, and Mexico are the top four safflower-growing nations (FAOSTAT, 2004). Crop administration activities and hereditary elements are critical in safflower crops' development and efficiency, and the most crucial of these are the differences between varieties and row spacing. Depending on how differently each variety grows and has other productive qualities, assorted sunflower varieties can be more or less successful in their growth and producing crops in various environments (Parmeshwarappa *et al*., 1984; Nikabadi *et al.,* 2008).

During their examination of the three-row line spacing, Eryiğit *et al.* (2015) discovered that the characteristics of plant height, branches per plant, capitula per plant, yield of seeds, and oil percentage varied significantly depending on the row spacing (20, 30, and 40 cm). Köse and Bilir (2017) observed massive contrasts in branches number/plant, number of seeds/capitula, 1000-seed weight, yield of seeds, and oil yield concurring on the column dividing, i.e., 15, 30, and 45 cm. Results from an experiment by Mirza *et al.* (2018) showed substantial changes in plant height, branches per plant, leaf area, and yield of seeds depending on the row spacing (30, 45, 60, 75, and 90 cm).

Findings by Caliskan and Caliskan (2018) from their investigation of four-row spacings (15, 30, 45, and 60 cm) demonstrated that the distance was noticeably wider than 60 cm for branches per plant, capitula/plant, and seeds/capitula. Furthermore, the distance was considerably better at 45 cm for the 1000-seed weight, seed yield, and oil content (%). Madab *et al.* (2012), while concentrating on five safflower cultivars (Almais, Urdine, 400, 540, and 2081), tracked down huge contrasts between cultivars in plant height, number of capitula/plant, number of seeds/capitula, 1000-seed weight, and yield of seeds. In their preliminary study, Omidi *et al.* (2012), using three combinations of safflower (Goldasht, Padideh, and K.w2), observed that the plant height, capitula/plant, seeds/capitula, 1000-seed weight, seed yield, oil content, and oil yield varied significantly among the cultivars. In their 2016 study, Killi *et al.* found notable variations among the safflower cultivars (Dincer, Balc1, Remzibey, Rio, Nebraska, Oleicleef, Qairieq088, San Jose, Sina, and Gilla) for plant height, branches/plant, capitula/plant, weight of 1000 seeds, seed yield, percentage of oil, and oil yield. Al-Doori (2017), while examining three safflower cultivars (Hartinan, Syrian, Gilla), demonstrated that the Syrian cultivar was essentially successful based on plant height, branches per plant, capitula per plant, seeds per capitula, 1000-seed weight, seed yield, and oil yield, while Gilla cultivar was also superior for oil rate. This study's goal seeks to determine the influences of distance between rows on the growth and yield characteristics of three safflower cultivars.

MATERIALS AND METHODS

In two different locations—the Badush Dam area and the College of Agriculture and Forestry-University of Mosul—a field experiment commenced in the winter of 2021–2022 to investigate how planting distances between lines (30, 45, and 60 cm) and cultivars (Gilla, Almais, and Urdine) affect safflower characteristics growth and productivity. The experiment, laid out in a randomized complete block design, used two parameters with three blocks. The number of experimental units was 3×3×3=27 trial units, with an exploratory unit of four lines measuring 2.5 m in length and 20 cm between plants. Obtained readings came from two middle-line plants, leaving two extreme lines as guard lines within each replicate. With treatments assigned randomly to experimental units, the experimental units are a meter apart. The field's surface plowing used moldboard furrows that faced each other, afterward, at a point, performing smoothing to even out the division tasks. Relying on the airport with the addition of three supplementary irrigation systems, sowing the seeds occurred on November 15, 2021. Fourteen days later, after the seedlings had finished emerging, thinning of the plants ensued by keeping just one plant in the hole. Crop maintenance activities, such as weeding and hoeing, followed.

Data recording and analysis

From randomly selected 10 plants, data recording transpired on the traits, i.e., plant height (cm), branches/plant, leaf area (cm^2), capitula/plant, seeds/capitula, 1000-seed weight, seed yield (kg/ha), oil content (%), and oil yield (kg/ha). Using the Statistical Analysis System (SAS), data examination used the analysis of variance method (Antar and Al-Wakaa, 207). At the 1% and 5% probability levels, Duncan’s multiple range test helped compare the arithmetic means (Al-Rawi and Khalaf-Allah, 2000).

RESULTS AND DISCUSSION

Plant height (cm)

No discernible variations showed in the row spacing between the outcomes displayed in Table 1 in the height of the plant at the College area. For the Badush Dam area, considerable contrasts were visible, as the row spacing of Quality's highest recorded mean was 30 cm, which added up to 81.20 cm. Likewise, it did not vary essentially from the line separating of 45 cm, which recorded a normal of 79.83 cm; however, row spacing of 60 cm was the least mean for the characteristic at 78.13 cm. It might be because of the way that the absence of line dividing prompts an increase for immature microorganisms to acquire maximum light, prompting an expansion in plant level. Findings from Blackshaw (1993), Eryiğit *et al.* (2015) and Mirza *et al.* (2018) support these results.

Assortments fundamentally affected plant height for both trial areas, as shown in Table 2. Plants of the Almais cultivar gave a significant mean of the attribute (80.46 and 82.71cm), which differed non-significantly from the Gilla cultivar, producing the standard 78.64cm. However, the Urdine cultivar gave the lowest rate at 75.60 and 76.11 cm in each area. It might be due to the hereditary variety between the assortments utilized in the examination. The result aligns with the findings of Meddeb *et al.* (2012) and Killi *et al.* (2016).

Branches per plant

Table 1 demonstrated an existing significance between row spacing in branches per plant in the exploratory area, as a planting distance of 60 cm gave the most elevated normal for this characteristic (6.24 and 6.23 branches/plant). However, the planting distance of 30 cm provided the least typical of this attribute. It reached 5.55 and 5.48 branches/plants) for both areas separately. The reason might be the absence of a contest for development factors affecting water, light, and supplements increased the plant branches. These results are consistent with Eryiğit *et al.* (2015), Kőse and Bilir (2017), and Mirza *et al.* (2018).

Significant variations appeared between cultivars in two areas for plant branches (Table 2). The Almais cultivar gave the most elevated at 6.72 and 6.65 branches/plant, while the Urdine cultivar plants provided the minimum for this trait (4.96 and 5.12 branches/plant) for two areas separately. It might refer to the idea of the genetic background and their communication with the

Table 1. Effect of planting distances on safflower traits.

Planting distances (cm)	Plant height (cm)	Branches / plant	Leaf area (cm^2)	Capitula/ plant	Seeds/ capitula	1000-seed weight	Seed yield (kg/ha)	Oil content in seeds (%)	Oil yield (kg/ha)
College area									
30	80.44a	5.55b	1719.56c	26.52a	25.75b	41.23b	1041.41c	28.27c	295.01c
45	78.01a	5.26b	1851.11b	27.48a	29.48a	42.01ab	1061.93b	29.74b	316.41b
60	76.25a	6.24a	1910.11a	28.53a	27.18ab	43.07a	1088.28a	31.61a	344.58a
Badush Dam area									
30	81.20a	5.48c	1775.33c	28.20b	26.67b	41.61b	1049.40c	28.71b	101.73c
45	79.83ab	5.84b	1898.67b	29.15ab	30.27a	42.32b	1069.66b	29.93b	320.70b
60	78.31b	6.23a	1971.00a	30.96a	27.61b	43.74a	1093.73a	31.72a	347.56a

A Duncan's multiple range test indicates that values within a single column that are followed by different letters differ significantly from one another.

Table 2. Effect of cultivar on safflower traits.

Cultivars	Plant height (cm)	Branches / plant	Leaf area (cm^2)	Capitula/ plant	Seeds/ capitula	1000-seed weight	Seed yield (kg/ha)	Oil content in seeds (%)	Oil yield (kg/ha)
College area									
Gilla	78.64ab	5.63b	1816.78b	27.03b	27.68a	43.42a	1051.77a	29.04b	305.75b
Almais	80.46a	6.82a	1975.33a	30.44a	29.90a	42.01b	1115.55a	32.08a	358.16a
Urdine	75.60b	4.96c	1688.67c	25.06c	24.84b	40.88b	1024.30c	28.50b	292.08c
Badush Dam area									
Gilla	80.34b	5.78b	1853.11b	29.81b	27.72b	43.95a	1058.85b	29.23b	309.75b
Almais	82.71a	6.65a	2060.67a	32.01a	31.50a	42.24b	1122.00a	32.28a	362.50a
Urdine	76.11c	5.12c	1731.22c	26.50c	25.34b	41.21b	1031.94c	28.84b	297.74b

A Duncan's multiple range test indicates that values within a single column that are followed by different letters differ significantly from one another.

Table 3. Effect of interaction between planting distances and cultivars on safflower traits.

Planting distances (cm)	Cultivars	Plant height (cm)	Branches / plant	Leaf area (cm^2)	Capitula/ plant	Seeds/ capitula	1000-seed weight	Seed yield (kg/ha)	Oil content in seeds (%)	Oil yield (kg/ha)
College area										
	Gilla	80.16a	5.10de	1709.00a	26.33a	25.93a	42.30a	1027.53f	27.00a	277.33a
30	Almais	84.50a	6.90b	1820.67a	29.53a	28.60a	41.33a	1095.40c	30.53a	334.40a
	Urdine	78.66a	4.66e	1629.00a	23.70a	22.73a	40.06a	1001.30g	27.30a	273.30a
	Gilla	79.40a	5.50d	1837.00a	27.83a	29.56a	43.13a	1049.63e	29.13a	305.73a
45	Almais	80.40a	6.20c	2035.33a	30.03a	31.40a	41.80a	1110.56b	31.90a	355.00a
	Urdine	74.03a	5.16d	1681.00a	24.06a	27.50a	41.10a	1025.60f	28.13a	288.50a
	Gilla	76.36a	6.30c	1904.33a	26.93a	27.56a	44.83a	1078.16d	31.00a	334.20a
60	Almais	78.50a	7.36a	2070.00a	31.76a	29.70a	42.90a	1140.70a	33.76a	385.10a
	Urdine	73.90a	5.06de	1756.00a	26.60a	24.30a	41.50a	1046.00e	30.06a	314.46a
Badush Dam area										
	Gilla	81.96a	5.40a	1743.00f	28.50a	26.30a	42.80a	1032.73g	27.43a	284.27a
30	Almais	84.46a	6.31a	1917.33c	30.93a	30.70a	41.30a	1136.00c	30.70a	337.27a
	Urdine	77.16a	4.93a	1665.67g	25.16a	40.03a	40.73a	1015.10h	27.90a	283.17a
	Gilla	80.66a	5.76a	1863.00d	29.76a	29.80a	43.53a	1058.36e	29.46a	311.80a
45	Almais	82.76a	6.60a	2110.33b	31.40a	32.73a	42.30a	1120.03b	32.03a	358.73a
	Urdine	76.06a	5.16a	1722.67f	26.30a	28.30a	41.13a	1030.60g	28.30a	291.57a
	Gilla	78.40a	6.20a	1953.33c	31.26a	27.06a	45.53a	1085.46d	30.70a	333.20a
60	Almais	80.90a	7.23a	2145.33a	33.70a	31.06a	43.13a	1145.60a	34.13a	391.00a
	Urdine	75.10a	5.26a	1805.33e	28.03a	24.70a	41.76a	1050.31f	30.33a	318.50a

A Duncan's multiple range test indicates that values within a single column that are followed by different letters differ significantly from one another.

ecological states of the locale (Nasrallah *et al.,* 2012). This result makes sense in light of the information presented by Al-Doori (2017) and Killi *et al.* (2016).

The results indicate notable differences in planting distances and cultivars in branches/plants in the College area (Table 3), where a planting distance was 60 cm, and the affected cultivar showed this attribute's maximum reaching 7.36 branches/plant. Meanwhile, at a planting distance of 30 cm, the Urdine cultivar had the minimum mean rate for this quality (4.66 branches/plant). The interaction was not statistically significant about the location of the Badush Dam.

Leaf area (cm^2)

A noteworthy planting distance of 60 cm provided the most significant sum of the leaf area (cm^2) reaching 1910.11 and 1971.00 cm^2. On the other hand, planting distance of 30 cm gave the lowest sum of this characteristic at 1719.56 and 1775.33 cm^2 for both areas, separately. It might be because of an expansion in branches at a similar line dividing (60 cm^2) (Table 1), causing a boost in the leaf area. Results are in line with the findings of Mirza *et al.* (2018).

The leaf area of the various cultivars in the two trial areas varied significantly, as indicated by the results shown in Table 2. The Almais cultivar gave a most notable mean for this quality, measuring 1975.33 and 2060.67 cm^2. However, the cultivar displayed the lowest mean (1688.67 and 1731.22 cm2) for each area separately. Justification for this could refer to the Almais cultivar's dominance in branch count, clearly reflecting the plant's increased leaf area.

No notable differences occurred between cultivars in leaf area and row spacing at the College area, as demonstrated by the data in Table 3. The Badush Dam region exhibits striking differences in row spacing. The Almais cultivar has the highest notable normal for this characteristic, measuring 2145.33 cm^2, while the Urdine cultivar has the lowest measuring 1665.67 cm^2 at a row spacing of 30 cm.

Capitula per plant

The statistical analysis's findings in Table 1 showed no massive contrasts between planting distances in capitula per plant at the College area; however, in the Badush Dam area, a planting distance of 60 cm gave the most elevated incentive for the capitula per plant (30.96 capitula/plant). However, the planting distance of 30 cm resulted in the lowest incentive of capitula per plant (28.20 capitula/plant). Results are in context with for this might be because of the absence of competition between plants at large separations, increasing their absorption of more supplements and light. It caused increased plant development and improved photosynthesis cycle efficiency, strongly reflecting enhanced capitula/plant. This result was valid, drawing from the research conducted by Eryiğit *et al.* (2015) and Caliskan and Caliskan (2018).

In both experimental areas, meaningful differences arose between the assortments in capitula per plant (Table 2). Almais cultivar plants recorded the most noteworthy incentive for the quality, adding to 30.44 and 32.01 capitula/plant. In contrast, Urdine plants recorded the minimum incentive for the characteristic (25.06 and 26.50 capitula/plant) for two areas separately. A reason is due to the distinction in genotype between assortments utilized in the review. The outcomes of Meddeb *et al.* (2012), Killi *et al.* (2016), and Al-Doori (2017) all agree with this result.

Table 3 presents the findings, showing no significant statistical differences between the two exploratory regions' planting distances and cultivars concerning capitula per plant.

Seeds per capitula

Significant differences emerged in planting distance and seeds per capitula for both exploratory regions, as indicated by the results in Table 1. The row spacing of 45 cm indicated the highest sum for this attribute (29.48 and 30.27 seeds/capitula), showing no discernible variation from the 45-cm row spacing on the

College area, which gave a measure of 7.18 seeds/capitula. The row spacing of 30 cm provided the lowest sum of this quality (25.75 and 26.67 seeds/capitula) for both areas, consecutively. One possible explanation for this could be a low capitula per plant at 45 cm row spacing. It resulted in a lack of rivalry between them to obtain the cycle's products through photosynthesis, which was evident in the seeds or capitula. The finding made by Caliskan and Caliskan (2018) supports this conclusion.

The experimental sites and cultivars significantly impacted seeds per capitula (Table 2). The cultivar Almais showed the most elevated measure of this quality, reaching 29.90 and 31.50 seeds/capitula. Inversely, Urdine plants gave the lowest measure of this attribute, adding to 24.84 and 25.34 seeds/capitula for the two destinations separately. The clarification can give credit to the cultivars' ability to produce genetic beauty care products. Results from Omidi *et al.* (2012) and Al-Doori (2017) implied an unexpected outcome of this study. Table 3 presents no significant differences in cultivars' numbers of seeds or capitula or planting distance in each area.

1000-seed weight

Notable variations were visible in planting distances for 1000-seed weight in both exploratory regions (Table 1). The planting distance of 60 cm gave the most significant average of this attribute (43.07 and 43.74 g), producing a normal of 42.01 and 42.32 g at a distance of 45 cm. It did not differ from the minimum mean of this quality (41.23 and 41.61 g) for each area when the planting distance was 30 cm. A rise in the 1000-seed weight may have resulted from a lack of competition for the growth elements (water, light, and supplements) over such large distances. Caliskan and Caliskan (2018) and Kőse and Bilir (2017) found results that are consistent with this outcome.

The results displayed notable distinctions between cultivars in two areas regarding the 1000-seed weight (Table 2). The Gilla cultivar plants had the highest remarkable standard age for this attribute, adding to 43.42 and 43.95 g; however, the Urdine cultivar gave the lowest mean at 40.88 and 41.21 g of each area separately. The nature of genetic differences and how they interact with climatic conditions could be the cause (Nasrallah *et al.*, 2012). This result is consistent with the accounting from Meddeb *et al.* (2012), Killi *et al.* (2016), and Al-Doori (2017). Table 3 presents data indicating no statistically significant variation in 1000-seed weight between cultivars and planting distances in either region.

Seed yield

The seed yield varies greatly depending on the distance at which seeds are planted in both areas (Table 1), where a 60-cm row spacing produced the highest seed yield, totaling 1088.28 and 1093.73 kg/ha. Meanwhile, a row spacing of 30 cm provided the minimal measure for yield of seeds (1041.41 and 1049.40 kg/ha) in the areas. A reason might be due to an expansion in branches/plant, capitula/plant, and 1000-seed weight at a similar line dispersing (60 cm) (Table 1), which prompted an increase in seed yield. This result aligns with the findings of Eryiğit *et al.* (2015) and Mirza *et al.* (2018).

Prominent differences existed in seed yield between the cultivars in both areas, as indicated by the data presented in Table 2. Almais cultivar plants yield the most notable amounts of seeds (1115.55 and 1122.00 kg/ha), whereas the Urdine cultivar produced the lowest measure of seed yield (1024.30 and 1031.94 kg/ha) in both areas separately. It can be due to the corrupt cultivar's dominance of branches/plant, the capitula/plant, and seeds/capitula (Table 2), showing up as an increase in seed production. The results of Omidi *et al.* (2012) and Al-Doori (2017) agree with this finding.

The results also revealed that the yield of seeds in both zones immensely varies depending on planting distance and cultivar (Table 3). The Almais cultivar recorded the remarkable usual yield of seed (1140.70 and 1145.60 kg/ha)with a planting distance of 60 cm. However, with a planting distance of 30 cm for two areas, the Urdine cultivar produced the minimum amount of seeds on average (1001.30 and 1015.10 kg/ha) simultaneously.

Seed oil content (%)

The percentage of oil for each of the two experimental sites varied remarkably, depending on the planting distance, according to the statistical analysis results shown in Table 2. The highest value for the trait emerged at a planting distance of 60 cm (31.61% and 31.72%), and the lowest value was at a planting distance of 30 cm. The trait reached 28.27% and 28.71% for both sites, respectively. It could be because plants are less likely to compete with one another across large distances, allowing them to have greater access to nutrients and light. This result was dependable based on findings by Eryiğit *et al.* (2015) and Caliskan and Caliskan (2018).

The results further revealed that the oil contents in each cultivar vary considerably in the two trial areas (Table 2). The Almais cultivar recorded the most noteworthy incentive for the attribute, reaching 32.08% and 32.28%. However, Urdine assortment plants documented the minimum incentive for the characteristic, adding to 28.50% and 28.84% in the areas separately. It might be because of the distinction in hereditary construction between the assortments. Killi *et al.* (2016) and Al-Doori (2017) have shown that this conclusion is consistent with their findings. According to the findings (Table 3), no significant differences surfaced in cultivars' oil content across both regions for planting distance.

Oil yield

The analysis signified massive contrasts between planting distances in oil yield in both regions (Table 1). Concerning this characteristic, the planting distance of 60 cm yielded the highest rate (344.58 and 347.56 kg/ha), whereas a planting distance of 30 cm yielded the lowest (295.01 and 101.73 kg/ha) for both sites. The reason could be its dominance in seed yield and oil content (%) (Table 1), making the study findings consistent with the disclosures provided by Caliskan and Caliskan (2018).

Significant variations exist in the oil yield between cultivars in exploratory areas, as Table 2 illustrates. On quality, the Almais cultivar recorded the highest incentive (358.16 and 362.50 kg/ha), and the Urdine cultivar produced the lowest incentive (292.08 and 297.74 kg/ha) for each area separately. A cultivar's success in seed yield and oil content (%) may be the explanation (Table 2). Results from Al-Doori (2017) and Killi *et al.* (2016) concur with this study outcomes. It demonstrates that for both trial areas, no notable differences in oil yield arose between cultivars and row spacing (Table 3).

CONCLUSIONS

This experiment's findings indicate that given the circumstances of the College area and the Badush Dam, planting Almais cultivar plants at a distance of 60 cm provided the highest safflower productivity.

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