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Genotype and Intra-Row Spacing Effects on Seed Yield of Safflower (*Carthamus tinctorius* L.) Under Winter Conditions of Central Sudan

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Abstract: The introduction of any new crop to an area requires information concerning its performance under the local environmental conditions. The goals of the experiment were to investigate the effects of genotype and intra-row spacing on seed yield, yield components, of ten safflower (*Carthamus tinctorius*) genotypes. This field experiment was conducted at two sites in central Sudan, the field of the experimental farm of the Faculty of Agricultural Sciences in Nisheishiba and the experimental farm of the Faculty of Agriculture and Natural Resources at Abu Hraz, University of Gezira, Wad Medani, Sudan, during the winter seasons of 2007/08 and 2008/09. The factorial treatments were arranged in split plot design with three intra-spacings (30, 40, and 50cm) as main plots and the ten genotypes as sub-plots with four replications. Seed yield (kg/ha), seed yield per plant (g), head diameter, number of heads per plant and 100-seed weight (g), According to the results, the measured traits were affected by genotypes and to some extent by spacing with non-significant effects of genotypes x spacings. The highest number of capitula per plant (95) was shown by genotypes 1 and 5 while the lowest (21) was shown by genotypes 2 and 4. Genotype 4 showed the largest capitulum diameter while genotype 1 showed the smallest. Genotype 1 gave the highest number of capitula/plant, the smallest capitulum diameter. Across locations, the highest 100-seed weight was given by genotype 4 (6.4g) while the lowest was recorded by genotypes 2 and 1 (3.9g). Genotype 4 gave the largest capitulum diameter, indicating that seed weight and capitulum diameter were positively related, while seed weight and number of capitula / plant were inversely associated. The highest yielding genotypes were 10, 6, 1 and 3 respectively, with across seasons and sites. Their seed yields per hectare were 1953, 1777, 1726 and 1725 kg respectively. The highest yielding genotype (genotype 10) was recommended for further improvement under the conditions of hand harvesting while genotype number 6 was suggested to be grown when mechanical harvesting is possible under Sudan dry conditions.

Keywords: safflower, seed yield, winter sowing, Sudan

1. INTRODUCTION

Safflower (*Carthamus tinctorius* L.) is an oilseed crop member of the Asteraceae family. Safflower (*Carthamus tinctorius* L.) is one of the oldest crops, but generally it is grown in small areas for particular use and remains a minor crop. It's a xerophilous species native to Asia and the Mediterranean and grown in dry and semi-arid regions worldwide (Beyyavas *et al.*, 2011; El-Lattief, 2012). It's a minor, underutilized oilseed crop, formerly grown for its color called carthamin, obtained from dried, ground petals and used in fabric colorings (Cho et al 2000; Omidi *et al.*,). safflower is substantially used as cosmetic and for food and medicinal purposes (Fatahi *et al.*, 2008); also, it is used as a fodder crop in Mediterranean cropping systems (Danieli *et al.*, 2011). The growing demand for vegetable fats as food resulted in expansion of oilseed crops cultivation each over the world. safflower ranks last in oil seed crops; its oil has multi-purpose use in medicinal indusry and its carthamin used for human food coloring. Safflower oil has a nutritive value that's analogous to olive oil also, the high oleic type is veritably suitable for hypo-cholesterol diets, for frying and in the industry of frozen food. The high linoleic type may also be used for making varnishes and production of biodiesel. Safflower is also a source of important chemicals like α-tocopherols and carthamin (Ekin, 2005). Currently, scientific interest in this species is substantially due to its high- quality vegetable oil for nutritional and industrial use (Carvalho *et al.*, 2006; Rudolphi *et al.*, 2012). The nutritive value of safflower oil is in fact, analogous to that of olive oil (Ekin, 2005) and, for this reason, the crop has gained significance in recent times as a result of human need for its oil in dry and semi-arid regions. Safflower is a multipurpose crop, has been grown for centuries in India for the orange-red color (carthamin) obtained from its colored flowers and for its quality oil which is rich in polyunsaturated fatty acids such as linoleic acid, 78%. Safflower flowers are known to have numerous medicinal uses for curing several diseases , and they're extensively used in Chinese herbal medications. The tender leaves, shoots, and thinning of safflower are used as pot condiment and salad. They're rich in vitamin A, iron, phosphorus, and calcium. Packets of young plants are generally vended as a green vegetable for human consumption in India and some other countries (Nimbkar, 2002). Safflower (*Carthamus tinctorius*

L.) is used in many countries as animal feed in form of grain, forage, hay and silage. It is used as an alternative fibre and protein source, and as a source of fatty acids and flavonoids and lignans (Peiretti, 2017). The seed cake after oil extraction which contains 22-25% protein and much fiber is used for feeding livestock (Kurt *et al.,* 2011). seed supplementation of safflower for lambs, cattle and broilers improved the meet quality particularly the fatty acid profiles (Bolte *et al.,* 2002; Shafey *et al.,* 2003; Boles *et al.,* 2005; Peng *et al.,* 2010). However, the egg fatty acid profile improved by feeding seeds to egg laying chickens (Shafey *et al.,* 2003; Malakian *et al.,* 2011). Broilers feed including 10% grinded safflower seed result in lower cholesterol values and increased polyunsaturated fatty acid values in meat (Yasin and Yener, 2019). On the other hand, Alizadeh *et al.,* (2012) reported increase in milk production by adding 25 g roasted Safflower seeds +10 g fish oil per kilogram of dietary feed. Safflower (*Carthamus tinctorius* L.) ranks 8th after soybean, groundnut, rapeseed, sunflower, sesame, linseed, and castor crops grown world-wide. India, Mexico, USA, Ethiopia, Argentina, and Australia are leading countries in area and production and together account for 99% and 87% (Damodaram and Hegde, 2002).

Safflower has high adaptability to drought. Therefore, safflower production confined to areas with low rainfall., the area under safflower around the world is limited largely due to lack of information regarding crop management and product development and utilization. The research and development on different aspects of safflower, have not received more attention therefore the crop remained underutilized (Emongor, 210). This probably is the main reason for its status as a minor crop around the world in terms of area and production, compared to the other oilseed crops. However, interest in this crop has been rekindled in the last few years due to three major reasons: A huge shortfall in oilseed production in countries having a sizable area with scanty rainfall, to which safflower is most suited, the preference of consumers for a healthy oil with less percentage of saturated fats, for which safflower is well known and the medicinal uses of flowers in China and extraction of edible dyes from flowers have become more widely known. Safflower is not cultivated in Sudan, any longer, except in the Northern state along the Nile River, It has been mainly grown for seeds and not really for oil production. The seeds have been roasted with wheat to make what is known as "Galleya" and served to people on occasions. Safflower gives farmers some options in a dryland crop rotation in using soil moisture available to its deep taproot. Bassil *et al.,* (2002) reported that, safflower is a deep-rooted crop, it can improve water and N use efficiencies of cropping systems and reduce groundwater pollution by preventing nitrate leaching downwards.in the soil.

The Objectives of this **is t**o evaluate the agronomic performance of different genotypes of safflower under irrigation conditions suitable for Sudan, to determine the optimum intra-row spacing for the evaluated genotypes, to select high performance spineless lines suitable for mechanical harvesting and to encourage safflower cultivation in the country so as to contribute in reducing shortfall in oil production.

2. Materials And Methods

The experiments were carried out for two winter seasons Abu Haraz (2007/08) and Nisheishiba (2008/09) all at the University of Gezira, Wad Medani, Sudan, under irrigation. The two sites (Nisheishiba and Abu Haraz) were very close and opposite to each other but lying on the western and eastern bank of the Blue Nile, respectively. The two sites were within the vicinity of Wad Medani town which lies at latitude 14˚ 24′ N, longitude 33˚ 29′ E and altitude 407m above sea level. The soil of the area was classified as fine montmorillonitic isohyperthermic Entic chromusterts, Suleimi series. It was described as heavy cracking clay with high clay content (40 – 65%), low organic carbon content (0.4%), high cation exchange capacity (CEC), low permeability when wet and with a pH ranging from 7.2 – 9.6. The area is characterized by an arid tropical climate with the lowest temperature in January and the highest in July. The annual average rainfall is about 350mm received mainly between mid-July to mid-October. The winter experiments were sown in mid-November and harvested during the last week of April in each season. Ten safflower genotypes (table 1) were used and fixed three spacings between plants along the ridge (30, 40 and 50 cm). The treatments were arranged in a split plot design with spacing as the main plots and safflower genotypes as the subplots with four replications. The area of the experimental plot was $12m^2$ (3m x 4m) and consisted of five ridges 0.80m apart. The seeds were sown in hills, (2-3 seeds/hole) and then thinned to one plant per hill after full field emergence (about 21 days from sowing). The land was prepared by discing, leveling and ridging. Then, 43kg N/ha (in form of urea) were broadcasted on the ridges three weeks after sowing. The experiments were irrigated according to crop water requirements. Weeding was done manually. Analysis of variance procedure was performed for each of the characters studied to test significance of mean differences among genotypes. Duncan's Multiple Range Test was computed to compare and separate average values of genotypes. MSTATC (1990) package was used for the statistical analysis.

Table.1. The10 safflower genotypes and their place of collection

Genotype no.	Place of collection
1	Dongla, Sudan
2	CHINA
3	ICARDA
4	ICARDA
5	Wad Medani, Sudan
6	ICARDA
7	ICARDA
8	ICARDA
9	ICARDA
10	ICARDA

2.1 Characters measured

1. The number of capitula present in three tagged plants per plot were counted manually on an individual plant basis. The average was worked out and expressed as number of capitula per plant at harvest for each treatment.
2. Capitulum diameter: Three well matured, dried and normal size capitula were taken at random from each of the three plants, then the diameter of each capitulum was measured using the fernier scale. After that, the diameters were averaged and recorded as the capitulum diameter in (cm).
3. 100-Seed weight (g) hundred seeds were randomly selected from each plant and the weight of the selected seeds was recorded in grams.
4. seed yield per plant (g)
5. Seed yield per hectare: Seed yield was determined by harvesting of two square meters from the two central ridges using a pair of scissors, then the harvested capitula were kept in sacks, threshed and cleaned manually, then weighed on an analytical balance and expressed in kilograms. Seed yield per hectare was computed from the two square meter data and recorded as seed yield per hectare in kilograms.

3. Results And Discussion

3.1 Seed yield and its components:

Table 2. Mean squares for different characters in ten safflower(*Carthamus tinctorius* L.) genotypes evaluated at Abu Haraz, Wad Medani, Sudan, in 2007/08 season.

Character	Source of variation		
	Spacing(df =2)	**Genotypes(df=9)**	**Spacing x gen. (df =18)**
Capitulum/plant	815.30*	7498.56**	154.55^{ns}
Capitulum diameter	0.10*	3.93**	0.03^{ns}
100 seed weight	0.16^{ns}	6.45**	0.11^{ns}
Yield/plant	3298.88**	7505.00**	228.89^{ns}
Yield /ha	1433.42^{ns}	1486250.00**	777765.10^{ns}

*,** and ns are the levels of significance at 5%, 1% and non-significant, respectively respectively.

Table 3. Mean squares for different characters in ten safflower (*Carthamus tinctorius* L.) genotypes evaluated at Nisheishiba, Wad Medani, Sudan, in 2008/09 season.

Character	Source of variation		
	pacing (df=2)	**Genotype (df=9)**	**Spacingxgenotype (df=18)**
Capitulum/plant	1379.34**	5492.74**	79.36^{ns}
Capitulum diameter	0.83*	3.39**	0.01^{ns}
100 seed weight	0.24^{ns}	11.86**	0.08^{ns}
Yield/plant	4600.01**	2800.12**	64.41**
Yield /ha	405969.00*	2812820.00**	76901.50^{ns}

*,** and ns are the levels of significance at 5%, 1% and non-significant, respectively.

3.2 Number of capitula per plant

This trait was suggested as one of the most important yield components of safflower and can be used as a selection criterion for seed yield improvement (Dajue and Mundel, 1996). significantly affected by genotypes and spacing but not by their interaction (Tables 2 and 3).

The highest number of capitula per plant was shown by genotype 1 at both Abu Haraz (106) and Nisheishiba (85) and across them (95), while the lowest was shown by genotypes 2 and 4 with the lowest general mean of 21 (Table 4). In general, the grand mean for the 10 studied genotypes was around 40 capitula per plant and that the genotypes with the highest number of capitula were spiny and bushy. Eslam *et al*. (2010) and Soleymani *et al*. (2011) reported significant variation for number of capitula per plant among a large number of safflower genotypes. The number of capitula per plant was decreased by decreasing intra-row spacing along the ridge from 50cm to 30 cm at Abu Haraz from 48 to 39 and Nisheishiba from 44 to 33 (Table 17). The findings of this study were in accordance with those of Oad *et al* (2002), which revealed that increasing row spacing up to 45 cm apart resulted in maximum number of capitula per plant (51.17). Their results also indicated that, plant spaced at 30 cm apart produced greater number of capitula per plant (48.23) and lower number of capitula at the closer plant spacing of 15 cm.

Table 4. Means and ranks for number of capitula per plant of ten safflower genotypes, Abu Haraz (2007/08) and Nisheishiba (2008/09), Wad Medani, Sudan

Genotype	Abu Haraz		Nisheishiba		Combined	
	Mean	Rank	Mean	Rank	Mean	Rank
1	106.0a	1	85.00a	1	95.51a	1
2	20.97i	10	21.19h	9	21.08h	9
3	34.90cdf	6	27.50f	6	31.20e	6
4	24.68eh	9	18.36i	10	21.52h	10
5	41.83cd	4	41.80d	4	41.79d	4
6	44.22c	5	38.53e	5	41.38d	5
7	28.66eg	7	24.31g	7	26.49f	7
8	61.33b	2	58.47b	2	59.90b	2
9	36.81cde	3	52.94c	3	44.88c	3
10	29.50deg	8	20.81h	8	25.15g	8
Mean	42.89		38.88		40.89	
C.V.(%)	32.67		25.34		30.36	

Means within the same column followed by the same letter (s) are not significantly different at the probability level of 5% according to Duncan's Multiple Range test.

3.3 Capitulum diameter

Genotypic and spacing effects on capitulum diameter were significant at both sites (Tables 2 and 3). The largest capitulum diameter was shown by genotype 4 at Abu Haraz (3.72 cm) and at Nisheishiba (3.45 cm) and across the two sites (3.58 cm) table 5. In contrast, the smallest capitulum diameter was depicted by genotype 1 at Abu Haraz (1.99 cm) and at Nisheishiba (1.89 cm) and across the two sites (1.94). Though the effect of spacing on capitulum diameter was significant, the differences in diameters were not large or pronounced, e.g. at Abu Haraz it was almost 2.8 cm at the three spacings while it was 2.6 cm at Nisheishiba at the three spacings, too (Table 5).Those findings were partially in agreement with those of Belle *et al*. (2012) who observed a decrease in capitulum diameter in the fall/winter growing season from 2.23cm at a plant density of 48 plant/m^2 to 2.03cm at 128 plants m^2. However, in the Spring/Summer growth season at the lowest plant density (48 plants m^2) the diameter was 2.4cm and decreased to 2.18 cm at 80 plants/ m^2. Moreover, the results obtained by Qayyum (1988) who stated that the average capitulum diameter was not significantly affected by variety or intra-row spacing. Furthermore, the effect of spacing on the capitulum diameter of the two varieties disagreed with such result. capitulum diameter was not significantly affected by intra-row spacing.

Table 5. Means and ranks for capitulum diameter (cm) of ten safflower genotypes, Abu Haraz (2007/08) and Nisheishiba (2008/09), Wad Medani, Sudan.

Genotype	Abu Haraz		Nisheishiba		Combined	
	Mean	Rank	Mean	Rank	Mean	Rank
1	1.99h	10	1.89f	10	1.94h	10
2	2.31fg	8	2.27e	8	2.29fg	8
3	3.26c	3	2.96c	3	3.11c	3
4	3.72a	1	3.45a	1	3.58a	1
5	2.47ef	7	2.29e	7	2.38ef	7
6	2.84d	5	2.56d	5	2.70d	5
7	2.97d	4	3.13bc	4	3.05c	4
8	2.27g	9	2.23e	9	2.25g	9
9	2.53e	6	2.36e	6	2.44e	6
10	3.51b	2	3.25b	2	3.42b	2
Mean	2.78		2.64		2.72	
C. V.(%)	5.60		6.88		5.94	

Means within the same column followed by the same letter (s) are not significantly different at the probability level of 5% according to Duncan's Multiple Range test.

Table 6. Effect of spacing on number of capitula per plant and capitulum diameter (cm) of safflower genotypes, winter 2007/08 and 2008/09 at Abu Haraz and Nisheishiba, respectively, Wad Medani, Sudan

	No. of capitula/plant			Capitulum diameter (cm)		
Spacing	**Abu Haraz**	**Nisheishiba**	**Mean**	**Abu Haraz**	**Nisheishiba**	**Mean**
30 (cm)	38.46b	32.63c	35.55	2.76b	2.61b	2.69
40 (cm)	42.75ab	39.78b	41.27	2.76b	2.63ab	2.70
50 (cm)	47.48a	44.26a	45.87	2.84a	2.69a	2.77
Mean	42.90	38.89		2.79	2.65	
C.V.(%)	32.67	25.34		5.60	6.08	

Means within the same column followed by the same letter (s) are not significantly different at the probability level of 5% according to Duncan's Multiple Range test.

3.4 Seed yield per plant

The analysis of variance procedure revealed that there were significant differences among genotypes for seed yield per plant at the two sites (Tables 2 and 3). With genotype 10 and genotype 2 giving the highest and lowest seed yield per plant, respectively at Abu Haraz. Whereas at Nisheishiba the genotypes no. 2 and 10, respectively gave the highest and the lowest seed yield per plant varied from 105.1g for genotype 10 to14.69g for genotype 2 and from 15.13g (genotype 2) to 66.63g (genotype 10) (Table 11). The findings of Patel *et al.* 1989; Pascual-Villalobos and Alburquerque,1996, confirmed the wide variation for seed yield in *Carthamus tinctorius* as found in the current study. Intra-row spacing effect on seed yield per plant was high and significant (P< 0.01) at both sites (Table 10). Seed yield per plant was increased with increasing plant spacing from 30cm to 50cm at both sites. The interaction effect of genotype x spacing on seed yield per plant was significant at Nisheishiba but not at Abu Haraz (Table 2 and 3). Generally, the interaction effect of spacing x genotype on most of the studied traits were not significant indicating that the performance of each genotype at the two sites was almost the same.

3.5 100-seed weight

Only the genotypic effect on 100-seed weight was significant (Tables 2 and 3). The highest 100-seed weight was given by genotype 4 6.0, 6.7 and 6.4g for Abu Haraz, Nisheishiba and across them, respectively, whereas the lowest was recorded for genotype 2, 8 and 1 with a general mean of 3.68, 3.75 and 3.88 g, respectively, (Table 7). It is worth mentioning that genotype 4 gave the lowest number of capitulum per plant but the largest capitulum diameter. This indicates that seed weight and capitulum diameter were positively related whereas seed weight and number of capitulum per plant were inversely associated. The genotypic variation in 100-seed weight reported in the present study were higher than those recorded for 1000-seed weight by Mündel *et al.* (1985) of 36.6-43.7g, or by Esendal (1990) of 31.5-36.7 g or by Bayraktar (1991) of 36.4-49.9 g. Such discrepancy may be attributed to the nature of genetic differences of the material used in the different studies. There is a significant increase in seed weight with increasing intra-row spacing from 30 cm to 50 cm but it did reach the significance at P<0.05 (Table 2, 3 and 8). The grand mean for 100-seed weight is around 4.89 g. As seen for most of the characters measured the interaction effect of genotype x spacing on seed weight was not significant indicating that the different genotypes behave similarly at the different intra-row spacing (Table 7 and 8). So narrowing down the spacing should be for the whole crop and not for specific genotype though genotypes have different architecture (e.g. erect or prostrate or bushy). However, Nevzat *et al*. (1998) showed that the effect of cultivar x row spacing interactions on the plant height, head number, seed weight and seed yield were significant.

Table 7. Means and ranks for 100-seed weight (g) of ten safflower genotypes, Abu Haraz (2007/08) and Nisheishiba (2008/09), Wad Medani, Sudan.

Genotype	Abu Haraz		Nisheishiba		Combined	
	Mean	**Rank**	**Mean**	**Rank**	**Mean**	**Rank**
1	4.11 f	8	3.66 f	8	3.88 e	8
2	3.71 g	10	3.66 f	10	3.68 f	10
3	4.73 de	6	5.37 bc	3	5.04 c	6
4	6.02 a	1	6.70 a	1	6.35 a	1
5	5.21 c	3	4.74 d	6	4.97 c	3
6	5.67 b	2	5.43 b	2	5.54 b	2
7	4.67 e	7	4.43 e	7	4.54 d	7
8	3.97 f	9	3.54 f	9	3.75 ef	9
9	4.99 cd	4	5.17 bc	4	5.08 c	4
10	4.94 cd	5	5.13 c	5	5.03 c	5
Mean	4.80		4.78		4.79	
C.V.(%)	6.99		7.71		7.30	

Means within the same column followed by the same letter (s) are not significantly different at the probability level of 5% according to Duncan's Multiple Range test.

Table 8. Effect of spacing on number of seeds/capitulum and 100-seed weight of safflower genotypes, winter 2007/08 and 2008/09 at Abu Haraz and Nisheishiba, respectively, Wad Medani, Sudan

Spacing	**Seeds /capitulum**			**100-seed weight (g)**		
	Abu Haraz	Nisheishiba	Means	Abu Haraz	Nisheishiba	Means
30 (cm)	47.69b	39.5c	43.59	4.73b	4.78ab	4.76
40 (cm)	47.58b	41.39b	44.48	4.86a	4.70b	4.77
50 (cm)	51.93a	44.09a	48.01	4.81ab	4.85a	4.83
Mean	49.07	41.66		4.80	4.78	
C.V.(%)	15.03	17.82		6.99	7.71	

Means within the same column followed by the same letter (s) are not significantly different at the probability level of 5% according to Duncan's Multiple Range test.

3.6 Seed yield per hectare (kg)

Safflower seed yield was highly and significantly (P<0.01) affected by genotype at both sites (Tables 2 and 3). The per hectare range for this trait was 311 kg given by genotype 2 to 1437 kg given by genotype 10 at Abu Haraz and 662 kg to 2469 kg for both genotypes 2 and 10 respectively at Nisheishiba (Table 9). As expected, the per hectare yield depends largely on seed yield per plant Significant genetic effect on safflower seed yield were reported by Putnam *et al*. (1993) in USA, Vollman *et al*. (1996) and Francis and Campbell (2003). The seed yield reported in this study was within the range reported by Dadashi and Khajehpour (2004) and Azari and Khajehpour (2005). However, Salvatore *et al.,* (2019) in agronomic assessment of 16 safflower accessions reported 1.7 t per hectare as higher seed yield in semi-arid area of Sicily in Italy. The superiority of genotype 10 to genotype 2 in seed yield might be due to the lowest number of capitula per plant, number of seeds per capitulum, seed weight and seed yield per plant, for genotype 2 which is erect and spiny whereas, genotype 10 is bushy, non-spiny and late maturely compared to genotype 2 with the highest number of seeds per capitulum and seed yield per plant. The present study showed that the highest yielding genotypes were 10, 6, 1, and 3, with an across seasons and sites seed yield per hectare of 1953, 1977,1726 and 1725 kg, respectively. The highest yielder genotype, (genotype10) which is spineless was suggested for further improvement under the condition of hand harvesting, particularly, under Sudan conditions. in 2000, the spineless was released in India, providing a dual income to farmers, as the florets can easily be collected from non-spiny safflower after the crop matures and is thus sold for food and textile dye (Mundel , 2008). Genotype 6, which is erect and spiny, was suggested to be grown when mechanical harvesting is possible.

On the other hand, seed yield per hectare was not significantly affected by intra-row spacing at Abu Haraz but significantly increased by increasing intra-row spacing from 30cm to 50 cm at Nisheishiba sites. (Table 10). The present findings showed that the lower plant population per hectare gave the highest yield per hectare (Table 10), but the seed yield per plant suggested a different trend. Such discrepancies questioned the fact that the current spacings used did not give the optimum plant per hectare of this crop under Gezira environment. Emami *et al*. (2011) reported that the highest seed yield was recorded by using 12.5cm plant spacing, averaging 1911.1 kg/ha. Many researchers, (Alessi *et al*. (1981), Rao *et al*. (1990), Patel *et al* 1994, Ali Zadeh *et al* 2012), studied plant density effect by changing plants spacing on row in safflower and indicated that low to medium densities (80000 to 175000 plants/ha) produced more yield, but at very high densities yield was reduced due to increasing competition for water, nutrients and light.

Table 9. Means and ranks of seed yield (kg/ha) of ten safflower genotypes grown at Abu Haraz (2007/08), and Nisheishiba (2008/09) and across them

Genotype	**Abu Haraz**		**Nisheishiba**		**Combined**	
	Mean	**Rank**	**Mean**	**Rank**	**Mean**	**Rank**
1	1347.0 c	3	2106.0c	3	1726c	3
2	311.10 i	10	662.30i	10	486.7i	10
3	1381.0 b	2	2069.0d	4	1725c	4
4	1162.0 e	5	2057.0e	6	1610bd	5
5	1068.0 f	6	1996.0f	7	1532ce	6
6	1308.0 d	4	2246.0ab	2	1777b	2
7	1032.0 g	7	1886.0g	8	1459cf	7
8	1028.0 g	8	1817.0h	9	1423g	8
9	666.70 h	9	2064.0de	5	1366h	9
10	1437.0 a	1	2469.0a	1	1953a	1
Mean	1074.09		1937.40		1505.77	
C. V.	22.35		14.49		18.68	

Means within the same column followed by the same letter (s) are not significantly different at the probability level of 5% according to Duncan's Multiple Range test.

Table 10. Effect of spacing on seed yield per plant (gm) and seed yield per hectare (kg) of safflower genotypes, winter 2007/08 and 2008/09 at Abu Haraz and Nisheishiba, respectively, Wad Medani, Sudan

Spacing	Seed yield / plant (g)			Seed yield / hectare (kg)		
	Abu Haraz	Nisheishiba	Mean	Abu Haraz	Nisheishiba	Mean
30 (cm)	58.15b	45.79c	51.97	1071.00a	1766.00c	1418.5
40 (cm)	67.93a	56.76b	62.35	1070.00a	1927.00b	1498.5
50 (cm)	76.30a	67.74a	72.02	1081.00a	2266.00a	1673.5
Mean	67.46	56.76		1074.09	1037.41	
C.V. (%)	28.58	18.64		22.35	15.5	

Means within the same column followed by the same letter (s) are not significantly different at the probability level of 5% according to Duncan's Multiple Range test.

Table 11. Means and ranks for seed yield per plant (g) of ten safflower genotypes, Abu Haraz (2007/08) and Nisheishiba (2008/09), Wad Medani, Sudan

Genotype	Abu Haraz		Nisheishiba		Combined	
	Mean	Rank	Mean	Rank	Mean	Rank
1	76.78d	4	60.89c	5	68.83d	4
2	14.69h	10	15.13f	10	14.91j	10
3	82.26b	2	65.14b	4	73.70b	2
4	77.42d	5	56.97d	7	67.20e	5
5	66.25f	7	61.21c	6	63.73f	6
6	79.59c	3	63.97b	3	71.78c	3
7	69.57e	6	55.38e	9	62.47g	7
8	64.76f	8	55.10e	8	59.93h	8
9	38.16g	9	67.20a	2	52.68i	9
10	105.1a	1	66.63a	1	85.89a	1
Mean	67.46		56.76		62.11	
C.V.(%)	28.58		18.64		25.29	

Means within the same column followed by the same letter (s) are not significantly different at the probability level of 5% according to Duncan's Multiple Range test.

4. CONCLUSIONS AND RECOMMENDATIONS

The results from the present study indicated that seed yield, yield components, of safflower were significantly affected by genotypes and to some extent some of them by intra-row spacing. Safflower showed generally good adaptation to central Sudan conditions, though its seed yields were relatively low compared to other countries like India and Ethiopia. High seed yield, observed in the present study, encourages the introduction and cultivation of this crop in Sudan.

Because of its higher productivity and non-spiny character, genotype 10 was suitable for cultivation as an irrigated oil crop in Sudan. Further studies are required to elucidate the appropriate cultivation requirement of safflower under central Sudan conditions. The intra-row spacings used in this study were not suitable for safflower production. Therefore, research work was needed to detect the suitable intra-row spacing. The ideal planting date and the cultural practices that would do the best job, also, need to be determined. More research work will be needed to find new or expanded uses for safflower products and to select non-spiny genotypes with high yield and higher oil content with higher oleic acid percentage to increase the profitability and to introduce safflower as a commercial crop in the existing farming system of central Sudan.

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