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Research Article

Agronomic management and seasonal interaction on vegetative growth, seed yield and oil content of a promising oil crop *Monechma ciliatum*

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Abstract - To assess the impact of agricultural techniques and determine genotype-season interaction on *Monechma ciliatum*, a field experiment was carried out over the course of two growing seasons (autumn and winter). In the Abu Naama environment, four sample seeds were seeded at four different times and with four different plant spacings (10, 20, 30, and 40 cm). The sample seeds were from separate sites. Plant height, leaves, branch count, population density, yield, oil content, and fresh and dry weight were all found to be impacted by the sowing date and plant spacing. Data was captured and subjected to statistical analysis. When compared to plants grown in the winter, autumn-grown plants produced higher plant spacing values. The greatest values were obtained from plants spaced 40 cm apart, then 30 cm, 20 cm, and 10 cm. According to the yield-related sowing date effect, autumn was preferable to winter. Sowing dates were found to have a substantial ($P \leq 0.01$) impact on oil content. Plants cultivated in the autumn had higher oil content values recorded, but plants grown in the winter had lower values. The oil content and fresh weight of the four sample seeds did not differ significantly. Seasons, spacing, and different seeds all displayed extremely significant ($P \leq 0.01$) differences.

Keywords: Autumn, summer, *Monechma ciliatum*, spacing, seed

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1. Introduction

Monechma ciliatum a renowned tropical herb from the Acanthaceae family, known in Sudan as Black Mahlab, has been extensively used in Africa for food and medicine (Sharief, 2002). It is growing wildly in Darfour, Kordofan, and Kassala states of Sudan. In this nomadic area, *M. ciliatum* is one of the useful odor plants. Traditional Sudanese perfumes, lotions, and other cosmetics are produced from the seeds to prepare for weddings and childbirth traditions (Mariod et al., 2009; Abdel Karim et al., 2017). *M. ciliatum* is very effective in the Gabel Mara Area for stomach upset remedies and as a carminative for children (Abdel Moneum, 2008).

Also, *Monechma ciliatum* was found to grow in South Sudan. Sudan is considered a promising country to produce Black Mahalab to cover the increasing demand for medicine. However, more research and cultural practices for this crop are highly needed. This country possesses large areas of land and a good supply of water and labor; there are good prospects for industrial production of plants, such as black mahalab (*M. ciliatum*) species. Recently, some studies were carried out by researchers (Sharief & Elballa, 2015) to determine the best methods of administration required for this crop's cultivation.

A study conducted by Sayar et al. (2013) revealed significant genotype-season interactions in both dry-matter yield and seed yield. This suggests that the physical conditions of the location consistently impact these economic outcomes. Drought-induced stress and delayed sowing date decreased the oil content of the roselle seed (Zand-Silakhoor et al., 2022). The productivity of black mahlab is influenced by temperature and soil conditions. Prior research on anise (*Pimpinella anisum* L.) examined the influence of seed rates on crop production (Tuncturk & Yildirum, 2006). A study conducted by Hossain et al. (2015) examined the impact of cauliflower plant spacing and planting date on seed yield. The objective of the present study is to investigate the impact of different sowing dates and spacing between plants on vegetative development, yield, and oil content, as well as their potential interactions with other parameters.

2. Materials and methods

A field experiment was conducted in two growing seasons, 2018/2019 and 2019/2020, in the demonstration farm of the Faculty of Agriculture, University of Sinnar, Abu Naama, Sudan. The climate of the experimental site is semi-tropical savanna with seasonal annual rainfall of 315 to 750 mm. The mean maximum temperature in summer is as high as 45°C, while during winter the mean minimum temperature is as low as 25°C. The winter and Autumn temperatures and low relative humidity were measured using standards tools.

The soil of the Abu Naama area is commonly known as vertisols with high clay content; it is characterized by cracked heavy clay soil (Dinder series) and the pH ranged from 7.0 to 8.7. The oil is heavy cracking clay with dark grey or dark brown color. Soil sample parameters were analyzed, and result showed that pH (7.3 - 8.0), color (Black, Brown), and alkalinity (14-32. 5 mg/L), EC (0.043 - 0.125x 10.3), chloride (4.00 - 5.184 mg/L), carbonate (15.40 - 32.20 mg/L), calcium (1.39 - 3.63 mg/L), magnesium (1.09 - 1.65 mg/L), organic matter (0.1741 - 0.087%).

The four seed samples of Black Mahalab (*M. ciliatum*) collected from different towns in Sudan (Kazgail, Liery, Damazien and Sinnar) were cultivated in the Abu Naama, Sudan, environment, using randomized complete block design (RCBD) with four replications. These experiments were done both in the autumn and winter seasons as follows: 15/8/2018 (Autumn), 3/1/2019 (Winter), 27/8/2019 (Autumn), and 17/12/2019 (Winter). Land leveled, ridged, and divided into 64 plots. Each one comprised of 4×3 m^2, consisting of 4 ridges each ridge 7 m long and 70 cm apart. The distance between ridges is 20 cm.

Black Mahalab seeds were sown in holes (4 seeds/ hole), on one side of the ridge manually. The spaces between holes were 10, 20, 30, and 40 cm. Irrigation during the autumn season due to rain. Supplementary irrigation was provided as and when required. Two weeks after sowing, thinning was done. 3-6 weeks after planting, hoe weeding was done as weed control. The same agricultural processes were used in all four experiments.

Agricultural practices and growth development of *M. ciliatum* seeds were expressed as the impact of planting dates and distances between plants. Five plants from each plot were selected randomly to calculate number of leaves /plants, plant height, fresh and dry weight, and oil content were determined. Days to 50% emergence, 5 plants were taken as a sample after 50% of plant seedling in the plot had emerged. At maturity stage seed pods were dried and opened from pods apexes, at this stage seeds may shatter. Before seed shattering occurred, harvesting was done.

Oil content was determined according to AOCS (2005). For three months, results were recorded in all these parameters. The gathered data were analyzed using variance, and standard error (SE) and LSD were used to assess the mean differences at 5% significance.

3. Result and discussion

3.1 Days until 50% emergence and 50% flowering of *M. ciliatum* at different seasons.

The results illustrated that the effect of sowing date (seasons) on 50% of seedling emergence was varied in the four sample seeds. Kazgail seeds emerged after 6, 9, 7, and 10 days in the 1st (Autumn) and 2nd (Winter) seasons. Damazien sample seeds reached 50% emergence in a short time, followed by Kazgail seeds, Liery and Sinnar. Generally, all seed samples sown in the autumn season were shown to have early seedling emergence compared to those sown late in the winter, as shown in (Table 1). While plants grown in winter reached 50% flowering in a short time than in autumn (Table 1). This might be due to low temperature and low relative humidity during the winter season (Xu et al., 2010). The period for reaching 50% flowering was shorter in winter than in Autumn at the two seasons which could be due to relatively low temperature (20.3 ^{O}C to 33.7 ^{O}C) and low relative humidity (19 – 29 %) during vegetative growth in winter. This is quite in agreement with Sharif and Elballa (2015).

3.2 Impact of sowing date and plant space on vegetative growth of *M. ciliatum.*

Analysis of variance showed significant effect of sowing date in these parameters (Table 2). However, plants grown in the Autumn season gave higher values for vegetative growth parameters (plant height and branch number) than those grown in winter. As in winter the days begin to shorten and temperatures cool, then plants grow slowly and begin to move the sugars from their leaves down into the roots for storage and nourishment during the winter months. While in autumn as temperature increases, photosynthesis, transpiration and respiration also increase, resulting in higher vegetative growth. .

The effect of spacing on these characters was shown in the opposite direction. Whereas the longest plants were obtained from close space (10 cm), and the shortest ones from wider spaces, the highest value of branch number was recorded in wide space (30 and 40 cm), which differed significantly. The growth habit of Black Mahalab required a wide space, which indicated that branch number increased as spacing between plants increased. Streck et al. (2014) studied the effect of plant spacing

Table 1. Effect of sowing date on number of days to 50% emergence and 50% flowering in Black Mahalab (*M. ciliatum*) at different seasons

Varieties	Days to 50% Emergence		Days to 50% flowering		LS
	Autumn 15/8/2018	Winter 3/1/2019	Autumn 27/8/2019	Winter 17/12/2020	
Kazgail					
1st season	6	9	62	54	**
2nd season	7	10	67	59	**
Liery					
1st season	8	12	68	71	**
2nd season	9	13	59	62	**
Sinnar					
1st season	8	12	68	60	**
2nd season	9	13	71	52	**
Dmazien					
1st season	6	8	61	67	**
2nd season	6	9	54	56	**

on growth, development and yield of cassava, and found that the final leaf size and number of lateral shoots increased as plant density decreased. However, at 10 cm space, the plant density was high; the plants elongated and reduced the growth of branches. These results were quite in agreement with those obtained by Ibrahim (2000), who studied similar growth habits of "Basil's spp." Plants sown in autumn were given high values of leaves and pods per plant, while the lowest values were recorded for those sown in the winter season. As presented in (Table 2), the vegetative growth for different sample seeds showed highly significant ($P \leq 0.001$) differences in plant number/plot. The Damazien seed sample had the highest plant number (103.61) and branch number/ plot (40.64), while Kazgail had the lowest. The height of the plants did not differ significantly between Kazgail and Damazien samples (Sinnar and Liery samples). The results obtained in this study demonstrated that both sowing date and spacing seemed to have some effect on plant height at flowering. However, greater values were associated with plants grown in autumn with a spacing of 40 and 30 cm. These results agree with Kumar et al. (2017), who studied plant growth of tulsi.

Comparison effects between the four sample seeds on leaves and pod number/plot showed highly significant ($P \leq 0.001$) variations. The best values were obtained from Sinnar sample seed (476.484), followed by Kazgail (453.391) and Damazien (451.172). Also, Sinnar seeds showed a higher value in the number of pods/plots followed by Kazgail and Damazien sample seeds, while the Liery sample gave the lowest value (400.75) as shown in (Table 2). However, the season had great effects on these two parameters, which indicated that there was a suitable and same environment for growth and development at Sinnar and Abu Naama.

However, the impact of the season (sowing date) was evident on plant growth, which produced different types of leaves in color, shape, and number. This might be due to genotypic environmental interaction. The mean effects of spacing on leaf number and pod number/plot were significantly different. 40 cm of spacing was the best, followed by 30 cm and 20 cm. Similar findings are reported by Sherif and Elballa

(2015). Nonetheless, plants grown in a small space with a high population density (10 cm) produced fewer leaves and pods than plants grown in a larger space with a low population density (20, 30, and 40 cm). This indicates that the suitable spaces between plants for the vigorous growth of Black Mahalab are at low population density. Interaction between sowing date and spacing on these parameters was clear in autumn in the 2nd season combined with 40 cm spacing.

Table 2. Mean comparison effects of genotypes on plant number, plant height, branch, leaves, and pods number in Black Mahalab (*M. ciliatum*)

Source/ Parameters	Ob	Plant Number/ plot		Plant height		Branch number/ plant		Leaves number/ plant		Pods number/ plant	
		LSM	SE	LSM	SE	LSM	SE	LSM	SE	LSM	SE
Overall mean	256	88.07	1.48	23.03	0.24	37.35	0.27	445.449	2.666	400.738	3.562
location:											
Kasgail	64	84.70[b]	2.97	25.32[a]	0.48	34.41[c]	0.54	453.391[b]	5.332	411.797[ba]	7.123
Liery	64	79.81[b]	2.97	21.44[b]	0.48	37.77[b]	0.54	400.750[c]	5.332	363.359[c]	7.123
Sinnar	64	84.16[b]	2.97	21.04[b]	0.48	36.59[b]	0.54	476.484[a]	5.332	424.812[a]	7.123
Damazien	64	103.61[a]	2.97	24.31[a]	0.48	40.64[a]	0.54	451.172[b]	5.332	402.984[b]	7.123
LS		***		***		***		***		***	3.562

LS = level of significance, * = P ≤ 0.05 ; ** = P ≤ 0.01, *** P = P ≤ 0.001

3.3 Seasonal, sample seeds (genotype), and spacing on seed yield and quality of crude oil content of *M. ciliatum* seed.

Seed yield is a quantitative character controlled by many genes and influenced by the environment. Production (seed yield) of *M. ciliatum* seeds showed highly significant (P ≤ 0.001) differences in the values among different seasons, as illustrated in (Table 3). First Autumn season showed highest production (159.8kg/ha) followed by 2nd Autumn (353 kg/fed), while the lowest (yield) production (183.156 kg/fed) was obtained on Winter at the 2nd sowing date. The effect of season on yield indicated that Autumn season is the best than Winter in seed production. Similar finding was reported by (Ahmad et al., 2004; Mohammed, 2000), studying the effect of season on Herbag yield. Higher yield values were produced from sample seeds obtained from Sinnar, Damazien and Kazgail, while Liery seed was gave the lowest value. Plant spacing was affected seed yield; the highest yield was obtained from wide space (40 cm). Also, the yield of Black Mahalab vary depending on ecological conditions such as temperature, water supply (rain fall) and soil fertility. However, the suitable environmental factors can lead to a higher yield in this crop. Similarly, Tunctrk and Yildirum (2006), discussed seed yield and quality on some Anise crop.

(Table 3) revealed that oil content was affected by seasons in a significant (P ≤ 0.01) way. Results presented in this table showed the higher values of oil content (19.904 and 19.238) were produced from plants grown in Autumn for both sowing dates, while the lower values (16.117 and 15.012) of oil content were obtained from plants grown in both Winter seasons. This finding was quite in agreement with Sharif and Elballa (2015). Although there were no significant effects of spacing or sample variety on oil content, as shown in (Tables 4) and (Table 5). Production of *M. ciliatum* was affected by plant spacing, as presented in (Table 5). The highest (yield) production was obtained when plants were sown at 30 and 40 cm, which are the best for high yield (153.89 kg). However, the lowest yield was obtained at 10 cm. That means wide space produced more branches, more pods/ plant, and a high yield. Whereas yield increased as spacing increased between plants. This result was like that reported by Saddam et al. (2012).

Table 3. Mean comparison effects of season on seed yield and oil content of Black Mahalab (*M. ciliatum*) plant

Source/Parameters	Oil content		Seed yield Kg/ha	
	LSM	SE	LSM	SE
Overall mean	17.568	0.552	121.15	**3.705**
1st Autumn	19.238 a	0.103	159.81 a	**0.409**
1st Winter	15.012 b	0.103	107.71 c	**0.409**
2nd Autumn	19.904 a	0.103	142.94	**0.409**
2nd Winter	16.117 b	0.103	74.121 d	**0.409**
LS	**		***	

** = P ≤ 0.01, *** P = P ≤ 0.001

Table 4. Mean comparison effects of spacing on yield and oil content in Black Mahalab (*M. ciliatum*) plant

Source/Parameters	Observations	Oil content		Yield Kg/Fed	
		LSM	SE	LSM	SE
Overall mean	256	17.568	0.552	125.731	3.705
Spacing:					
10 cm	64	17.215	0.103	92.025 d	0.409
20 cm	64	19.112	0.103	109.954 c	0.409
30 cm	64	16.762	0.103	141.225 b	0.409
40 cm	64	17.181	0.103	153.89 a	0.409
LS		Ns		***	

*** P = P ≤ 0.001, ns = not significant.

Table 5. Mean comparison effects of genotypes on yield and oil content in Black Mahalab (*M. ciliatum*) plants

Source/Parameters	Observations	Oil content		Yield Kg/Fed	
		LSM	SE	LSM	SE
Overall mean	256	17.568	0.552	125.731	0.705
Kazgail	64	16.407	0.103	127.457[a]	0.409
Liery	64	16.508	0.103	113.255[b]	0.409
Sinnar	64	19.093	0.103	134.288[a]	0.409
Damazain	64	18.263	0.103	127.922[a]	0.409
LS		Ns		***	

*** P = P ≤ 0.001, ns = not significant

3.4 The effects of seasons, sample seeds (genotype), and spacing on 1000 seed weight of *M. ciliatum*.

(Table 6) displayed highly significant (P ≤ 0.001) differences in 1000-seed weight values among seasons, genotypes and spacing. However, heavier seeds were produced in the autumn season followed by winter. The highest value of 1000-seed weight was obtained from the Damazien sample seed (77.238), followed by Kazgail (66.224) and Sinnar (68.214) while, Liery was recorded lowest weight value. Also, the widest plant spacing was superior in seed weight. The heaviest seeds were recorded at 40 cm, followed by 30, 20 and 10 cm. That means at high density, seed weight was decreased. This finding is supported by Bakure et al. (2023) and Ozer (2003), who discovered that 1000-seed weight decreased as plant population increased. Fresh weight per plant differed significantly among sowing dates (seasons) (Table 7). While there were no significant differences between the four seed samples in fresh weight among the same seasons. The most vigorous plants were produced when spacing was increased to 40 cm, i.e., plants in the Autumn season obtained more dry matter, while those in the winter season recorded the lowest.

Table 6. Mean comparison effects of season, genotypes, and spacing on weight of 1000 seed in Black Mahalab (*M. ciliatum*) plant

Source/ Parameters	1000 Seed weight (g)	Source/ Parameters	1000 seed weight (g)	Source/ Parameters	1000 seed yield (g)
Overall mean	81.120	Overall mean	65.932	Overall mean	63.266
Season:		Location:		Spacing	
1st Autumn	99.106[a]	Kazgail	66.224[b]	10 cm	49.211[d]
1st Winter	67.132[c]	Liery	50.256[c]	20 cm	56.423[c]
2nd Autumn	88.117[b]	Sinnar	68.214[b]	30 cm	67.152[b]
2nd Winter	70.126[d]	Damazain	77.238[a]	40 cm	80.281[a]
LS	***	LS	**	LS	***
SE	0.411	SE	0.411		0.411

** = P ≤ 0.01, *** P = P ≤ 0.001

Table 7. Effect of season and spacing interaction on fresh weight and dry weight in Black Mahalab (*M. ciliatum*) plant

Source/Parameters	Obs	Fresh weight		Dry weight	
Season × Spacing		LSM	SE	LSM	SE
1st Autumn1 × 10	16	278.213	8.561	149.230	14.818
1st Autumn1 × 20	16	285.820	8.561	149.302	14.818
1st Autumn1 × 30	16	378.406	8.561	211.153	14.818
1st Autumn1 × 40	16	639.496	8.561	219.194	14.818
1st Winter1 × 10	16	278.233	8.561	135.212	14.818
1st Winter1 × 20	16	353.198	8.561	178.402	14.818
1st Winter1 × 30	16	330.518	8.561	135.163	14.818
1st Winter1 × 40	16	344.108	8.561	131.000	14.818
2nd Autumn2 × 10	16	456.361	8.561	208.112	14.818
2nd Autumn2 × 20	16	461.300	8.561	198.218	14.818
2nd Autumn2 × 30	16	528.432	8.561	227.301	14.818
2nd Autumn2 × 40	16	685.290	8.561	230.171	14.818
2nd Winter2 × 10	16	300.273	8.561	140.162	14.818
2nd Winter2 × 20	16	321.440	8.561	147.240	14.818
2nd Winter2 × 30	16	409.231	8.561	152.013	14.818
2nd Winter2 × 40	16	489.123	8.561	123.000	14.818
LS		**		**	

[1]LSM = Least-square mean, SE = standard error; LS = level of significance,
* = $P \leq 0.05$; ** = $P \leq 0.01$, *** P = $P \leq 0.001$

4. Conclusion

Plant sowing date and spacing, as well as genotype-season interaction, influenced vegetative growth, yield, and oil content in Black Mahalab. Autumn season is found to be the best date for sowing this crop in Sudan. The effect of spacing on plant growth had appeared clearly, a wider space (40 cm) is better than a closer one (10 cm), because the growth habit of Black Mahalab requires wide spaces. Three out of four Black Mahalab genotypes collected from Kazgail, Damazien, and Sinnar exhibited good performance in their vegetative growth and yield under the Abu Naama (Sinnar State, Sudan) environment. Nevertheless, the yield of Black Mahalab varies depending on ecological conditions such as temperature, water supply (rainfed) and soil fertility. This shows that they were able to adapt to the environment in Sinnar State and must be raised there as well as where they came from.

The sowing date and spacing of Black Mahalab plants, as well as the interaction between genotype and season, had an impact on vegetative growth, yield, and oil content. The autumn season was found to be the best time for sowing this crop in Sudan. The spacing between plants also had a clear effect on growth, with wider spacing (40 cm) being better than closer spacing (10 cm) due to the growth habit of Black Mahalab requiring more space. Three out of four Black Mahalab genotypes collected from Kazgail, Damazien, and Sinnar showed good performance in vegetative growth and yield under the Abu Naama environment in Sinnar State, Sudan. However, the yield of Black Mahalab varied depending on ecological conditions such as temperature, water supply (rainfed), and soil fertility. This indicates their ability to adapt to the environment in Sinnar State and suggests that they should be cultivated there as well as in their original locations.

Artificial intelligent declaration

The authors utilized no artificial intelligent tool fin the preparation of this work. Subsequently, the author(s) conducted a thorough review and editing process, taking full responsibility for the content of the publication.

Human/animal ethics declaration

No human or animal ethics declaration needed.

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