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Research Article

Impact of the Seeding Method on Physiological, Agronomic, and Biochemical Performance of Sesame (*Sesamum indicum* L.) Varieties Grown in Burkina Faso

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In Burkina Faso, the sesame sector is still relatively unorganized, with poor quality seeds that are unsuitable or outdated farming practices and noncompliant with recommended technical itineraries. This situation is very worrying and needs to be rectified. For this reason, we undertook this study to highlight the impact of the seeding method on the physiological, morphological, and agronomic performances of sesame (*Sesamum indicum* L.) varieties grown in Burkina Faso. The experiment was conducted at the Gampèla agropedagogical station located at 12°25′N, 12°22′W from Ouagadougou. Varieties S-42, 32-15, Wollega, and Humera were grown in strips (broadcast seeding) and in randomized complete blocks (row sowing). Row seeding favored plant growth and development for all varieties. Seed yield per plant for row seeding was significantly ($P < 0.001$) higher than for broadcast seeding. In terms of 1000 seed weight, there was a decrease in the Wollega variety (2.42 g) in the broadcast seeding group compared with the row seeding group (3.13 g). The seeding method had no effect on the other varieties. The seeding method also had no significant influence on the lipid and protein contents of the seeds. When sown in rows, varieties S-42 (25.7 g/kg), 32-15 (20.64 g/kg), and Wollega (17.33 g/kg) accumulated more K than the broadcast seeding groups. For the Humera variety, the seeding method had no effect on K. Na accumulation in leaves was statistically equal for all varieties in both broadcast and row seeding. Variety 32-15 accumulated more Mg when sown broadcast (5.95 g/kg) than when sown in rows (3.85 g/kg). On the other hand, the varieties S-42 (3.13 g/kg), Wollega (4.21 g/kg), and Humera (3.12 g/kg) accumulated less Mg when broadcast than when sown in rows (S-42 (4.37 g/kg), Wollega (5.68 g/kg), and Humera (5.73 g/kg)). Thus, seeding in rows is recommended to obtain better vegetative development and higher capsule and seed yields for all varieties. Both of the seeding methods deliver the same lipid, protein, and Na contents for all varieties. Broadcast seeding is recommended for better Mg content for variety 32-15, and row seeding is recommended for better K content for varieties S-42, Wollega, and 32-15.

1. Introduction

The agricultural sector is an important component of Burkina Faso's economy. It contributes by 35% to the country's gross domestic product (GDP) and employs 82% of the working population. Agricultural production is dominated by cereals (sorghum, millet, maize, and rice), the main food crops, and by cotton, sesame, groundnuts, and cowpeas considered as the main cash crops [1]. For several years now, the emphasis has been on developing cash crops, including sesame (*Sesamum indicum* L.) which is an annual oleaginous plant whose seeds contain high levels of lipids, dry matter, protein, carbohydrates, potassium, phosphorus, calcium, iron, and vitamin C, as well as phytochemicals such as polyphenols, tannins, and flavonoids [2, 3]. This plant is of great importance for many uses of its products (seeds, oil, and cake) in human and animal nutrition, as well as for its therapeutic and industrial properties [2]. Today, sesame is

Burkina Faso's second most important export crop after cotton. This second place for sesame is linked not only to growing and unmet world demand but also to its relatively easy and low-input production. With regard to exports, the country's production over the last five years has evolved as follows: 253,936 tons in 2019, 374,703 tons in 2020, and 384,614 tons in 2021; production then fell considerably in 2022, with only 186,449 tons, a drop by 51.52% compared to 2021. This drop in production is due to a number of factors comprising pockets of drought, poor soils, and insecurity combined with armed attacks and above all the relatively unorganized sesame sector [4]. The poor quality seeds, unsuitable or outdated farming practices, and non-compliance with the technical itinerary recommended by the Institute of the Environment and Agricultural Research (INERA) easily explain the fact that the yield per hectare of sesame remains low at around 1.000 t/ha on station and 0.450 t/ha on the farm, compared with an average potential yield of 1.500 t/ha [5]. This constitutes a serious concern and that is why the present study focuses on the impact of seeding methods on the agromorphophysiological and biochemical performance of four sesame varieties (S-42, 32-15, Humera, and Wollega) grown under field conditions. The overall aim is to assess the physiological, agronomic, and biochemical performance of these sesame varieties under row and broadcast seeding methods. Specifically, it is to

(i) evaluate the agrophysiological and biochemical parameters of these sesame varieties using the row seeding method

(ii) evaluate the agrophysiological and biochemical parameters of these sesame varieties in the broadcast seeding method

2. Materials and Methods

2.1. Plant Material. Seeds of the four sesame varieties were used as the plant material: Jalgoan 128 (originated from India and introduced to Burkina Faso under code S42); 32-15 (originated from Argentina and resulting from the cross, S4); S30 (originated from Brazil) and popularized in Burkina Faso; and two varieties of Ethiopian origin introduced into Burkina Faso under the names Humera and Wollega [6]. The seeds used were obtained from the Institute of the Environment and Agricultural Research (INERA) at Kamboinsé, in Burkina Faso, and were of very high quality. The characteristics of the varieties are presented in Table 1.

2.2. Experimental Site. The experiment was conducted at Gampèla research station (Figure 1) located at 12°25′N, 12°22′W, approximately 20 km in the eastward of Ouagadougou (capital city of Burkina Faso). The climate of this area is Sudano-Sahelian.

A sample of the upper soil horizon (0–20 cm) was taken from the field and analyzed at the National Soil Bureau Laboratory (BUNASOLS), Burkina Faso.

2.3. Edaphic Description and Rainfall of the Study Site. The results of soil particle size and mineral analysis are shown in Table 2.

2.4. Experimental Setup and Sowing. The experimental setup used was a randomized complete block (RCB) design with three replicates. Each block was made up of two sub-blocks, and each sub-block was made up of elementary plots. The factors studied were variety and sowing method. Natural conditions were used as treatments.

The soil was plowed, and the clods of the earth were flattened with a harrow. Two seeding methods were used: row seeding and broadcasting. Row seeding was carried out over a total area of 168 m^2 (16.8 m × 10 m). The individual plots were measured 0.8 × 1.20 m (0.96 m^2) and were spaced 1.5 m apart, each with three rows of 10 plants.

The seeds were mixed with sand (40 g sand to 10 g sesame) to reduce the number of seeds per pocket. The spacing between the feet was 60 cm between the row and 20 cm between pits. The sowing depth was approximately 2 cm, and the soil was lightly packed to ensure good contact between moisture and the seed.

Broadcasting was performed by balancing a handful of seeds from back to front on the plot in a homogeneous way, and then the soil was slightly stirred to cover the seeds. The seedlings were sown in strips over a total area of 168 m^2.

N-P-K fertilizer (6%N-20%P-10%K) was applied at a rate of 12 g/m^2 on day 21 after seeding (DAS).

Rainfall data were recorded after each rainfall using a rain gauge.

2.5. Evaluation of Parameters. The impact of the two seeding methods was evaluated based on phenological, morphological, nutritional, and plant yield parameters in the four sesame varieties. Phenological observations were made during emergence time, flowering start and end times, capsules' maturation time, and cycle length. For morphology, measurements were made on the diameter at the collar (DC) using an electronic caliper. The height of the plants (HP) with a graduated ruler, the number of leaves (NL) and branches (NB) per plant, and the dry weights of the aerial part (DWA) and roots (DWR) use an electronic balance with a precision of 0.001 g (Denver AC-1200D). The harvest index (HI) per plant was calculated according to the following formula: the ratio of total dry seed weight from a plant to the total dry weight of the plant. The number of capsules per plant (NCP) and the number of seeds per capsule (NSC) were determined by manual counting. The 1000 seed weight (WTS) was determined using the same scale mentioned above. Seed yield per plant (SYP) was calculated according to the formula of Garfius [7]: $W = XYZ$ (X: number of capsules per plant; Y: average number of seeds per capsule; Z: average seed weight). The nutritional quality of the seeds was evaluated by determining their contents in proteins (PCS) using the Bradford method [8], in lipids (LCS) using the

Table 1: Characteristics of the four varieties.

Parameters	Varieties			
	S-42	32-15	Wollega	Humera
Density of stem hair	Very dense	Very dense	Sparse	Sparse
Color of the flowers	White + slight purplish tint	White + slight purplish tint	White + purple stripes	White
Color of the seeds	White	White	White	White
Leaf necrosis	Very few	Very few	Very few	Very few
Resistance to lodging	Good	Good	Good	Good
Exercise date (DAS)	3			
Date of beginning of flowering (DAS)	35		42	
Date of end of flowering (DAS)	65	67	83	
Date of capsules' maturity (DAS)	84	85	100	
Cycle time (DAS)	90		105	

Source: Ily [6]; DAS: days after seeding.

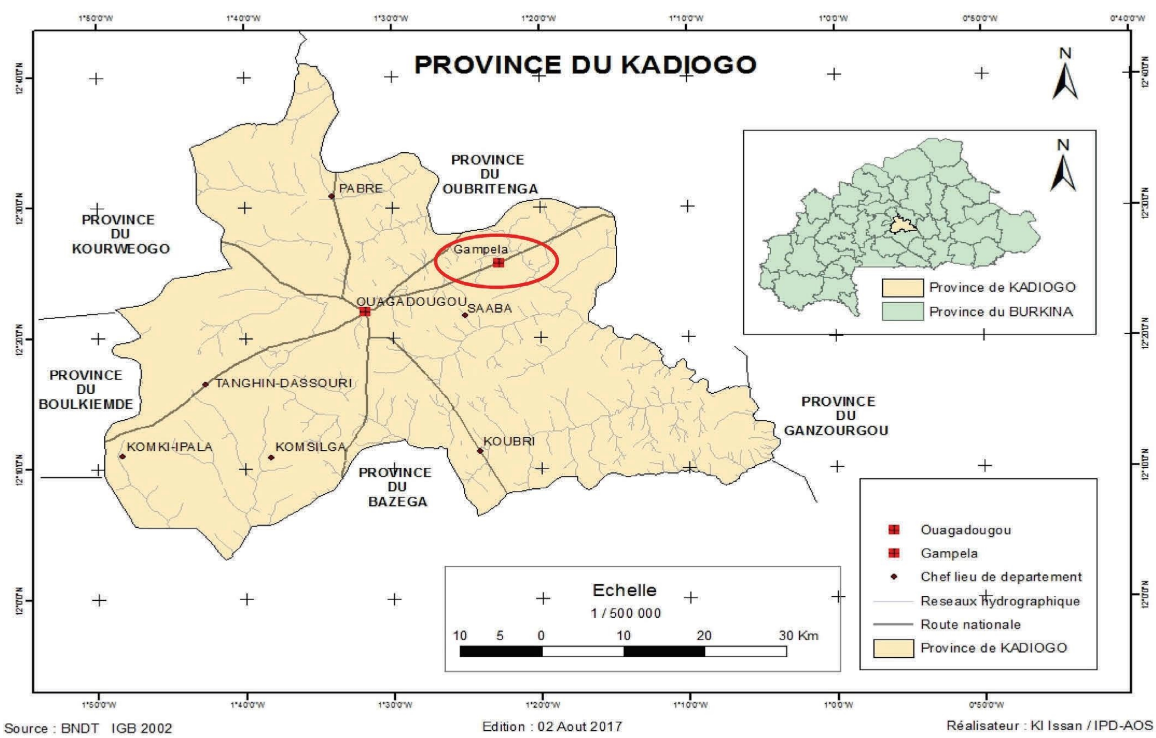

Figure 1: Location of the experimental site.

Table 2: Analytical characteristics of the soil sample.

Granulometric composition		
Clay (%)	Silt (%)	Sand (%)
17.67	21.57	60.78

Mineral elements									
pH KCl	C %	OM %	N %	C/N	P ppm	K ppm	Fe ppm	Ca ppm	Mg ppm
4.92	0.475	0.819	0.040	12	7.41	31.97	82	613	114

Soxhlet method, and in minerals. The foliar contents of sodium (NaCF) and potassium (KCF) were determined using the flame photometer method. Finally, the Mg content (MgCF) was determined by atomic absorption spectroscopy.

2.6. Statistical Analyses. The data collected in this study were subjected to a two-criteria analysis of variance classification (ANOVA) considering the seeding method and the sesame varieties. In the case of a significant difference, tests of comparison of means were carried out using XLSTAT 2016 software and the Student Newman–Keuls method with a threshold of 5%.

3. Results

3.1. Evolution of Sesame Plant Parameters according to the Type of Seeding during Cultivation

3.1.1. Evolution of the Diameter at the Neck of the Plants. In the four sesame varieties (S-42, 32-15, Wollega, and Humera), sowing in rows favored radial growth of the stems through the diameter at the collar which was larger (approximately 5 mm more) than that of the seedlings resulting from broadcast sowing (Figure 2). However, the evolutionary kinetics of radial growth was not influenced by the seeding method in any variety. Indeed, in both cases of seeding, the largest diameter at the collar reached at the same time: on the 63rd day of seeding in varieties S-42 (a) and 32-15 (b) and then on the 70th day of seeding in varieties Wollega (c) and Humera (dD), independent of the seeding method.

3.1.2. Evolution of the Height of Sesame Plants. The evolution of plant height for the four sesame varieties (S-42, 32-15, Wollega, and Humera) under different seeding methods (row and broadcast) indicates that the growth in plant height is favored by the row seeding. However, it was observed that during the first two months after emergence, HP was more under broadcast seeding plants than in the row seeding plants (Figure 3). In fact, growth rates are reversed at 56 DAS for varieties S-42 (a) and 32-15 (b) and then at 63 DAS for varieties Wollega (c) and Humera (d). This vertical growth then gradually decreases over time.

3.1.3. Evolution of the Number of Leaves. The number of leaves (NL) per plant of the S-42, 32-15, Wollega, and Humera varieties of sesame was greater in plants grown in rows (at least 50 more leaves) than in plants grown by broadcasting. Under both the seeding methods, the maximum NL was reached on the 63rd day of seeding for the varieties S-42 (a) and 32-15 (b) and on the 70th day of seeding for the varieties Wollega (c) and Humera (d). This was followed by progressive leaf drop over time (Figure 4).

3.2. Statistical Analysis of Morphological Parameters

3.2.1. Number of Branches according to the Seeding Method. In all four varieties (S-42, 32-15, Humera, and Wollega), row seeding promoted more branching than broadcast sowing. For the plants grown in rows, there was one more branch in varieties S-42 and 32-15, two more in variety Humera, and more than four more branches in variety Wollega (Figure 5). However, the analysis of the morphological parameters of the seedlings of the four sesame varieties showed no significant difference in the number of branches under sowing in rows and broadcasting in Humera ($P = 0.203$), S-42 ($P = 0.708$), and 32-15 (0.250). There was a significant difference in the variety Wollega ($P = 0.071$) (Table 3).

3.2.2. Impact of Seeding Method on Root and Aerial Dry Weights. Figures 6 and 7 show that, in all four varieties (S-42, 32-15, Humera, and Wollega), the aboveground and root dry weights of the row-farmed plants were twice as high as those of the broadcast plants. There was a significant difference in root dry weight among all varieties for the seeding method with 32-15 ($P = 0.006$), Humera ($P = 0.017$), Wollega ($P = 0.011$), and S-42 ($P = 0.032$). For air dry weight, there was a highly significant difference depending on the seeding method for all varieties (Humera ($P < 0.001$), S-42 ($P < 0.001$), 32-15 ($P < 0.001$), and Wollega ($P < 0.001$)) (Table 3).

3.3. Statistical Analysis of Agronomic Parameters

3.3.1. Effect on Yield-Attributing Traits as a Function of Seeding Method. In all four varieties, plants from row seeding had more capsules per plant than those from broadcast sowing (Figure 8 and Table 4). In S-42 and Humera, row seeding tripled capsules' production per plant compared to broadcast seeding. However, for varieties 32-15 and Wollega, row seeding doubled this number. There was a significant difference between row and broadcast seeding for all varieties (Humera ($P < 0.001$), S-42 ($P < 0.001$), 32-15 ($P < 0.001$), and Wollega ($P < 0.001$)). There was no difference in the number of seeds per capsule (Figure 9 and Table 4) between seeding methods in S-42 ($P = 0.16$), Wollega ($P = 0.12$), and 32-15 ($P = 0.052$). On the other hand, there were some differences in the Humera variety ($P = 0.03$). The sowing method slightly influenced the weight of seeds among sesame varieties (Figure 10 and Table 4). There was no significant difference in 1000 seed weight in Humera ($P = 0.62$), S-42 ($P = 0.801$), and 32-15 ($P = 0.288$), but there was a significant difference in Wollega ($P = 0.016$) due to the methods of seeding. Results showed higher seed yields per plant in row seeding in all varieties (Humera ($P < 0.001$), S-42 ($P < 0.001$), 32-15 ($P < 0.001$), and Wollega ($P < 0.005$)) (Figure 11 and Table 4). Row seeding resulted in a higher harvest index for the S-42 ($P = 0.003$) and Humera ($P = 0.027$) varieties but no significant influence observed in varieties 32-15 ($P = 0.166$) and Wollega ($P = 0.802$) due to seeding method (Figure 12 and Table 4).

3.4. Statistical Analysis of Biochemical Parameters. Table 5 presents the analysis centered on the variance of the biochemical parameters concerning seedlings of the four sesame varieties. For leaf potassium content, there was a highly significant difference between seeding in rows and broadcasting in varieties S-42 ($P < 0.001$), Wollega ($P < 0.001$), and 32-15 ($P < 0.001$), but no difference was observed in Humera ($P = 1.000$). There was no difference in foliar sodium contents between sowing in rows and broadcasting in the varieties Humera ($P = 0.69$), Wollega ($P = 0.554$), and 32-15 ($P = 0.366$), but there was a significant difference in the variety S-42 ($P = 0.03$). For leaf Mg content, a significant difference existed between row and broadcast seeding in all varieties (Humera ($P < 0.001$), S-42

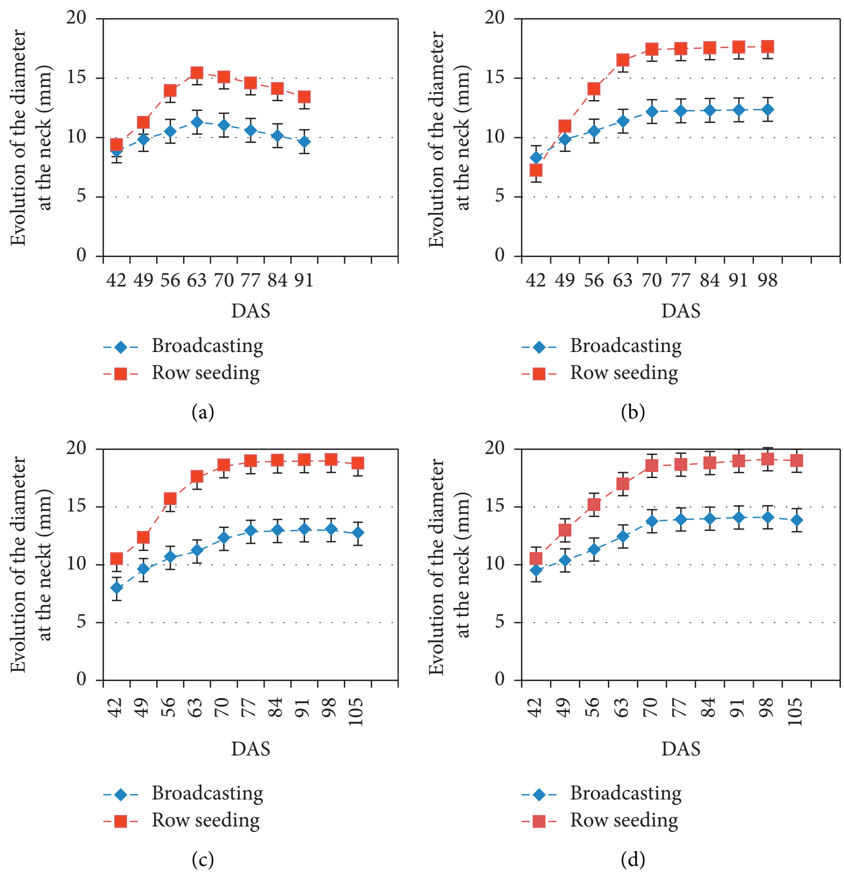

Figure 2: Evolution of the diameter at the collar of plants of the sesame varieties such as S-42 (a), 32-15 (b), Humera (d), and Wollega (c) under different seeding methods.

($P = 0.005$), 32-15 ($P < 0.001$), and Wollega ($P = 0.012$)). There was no difference in seed lipid contents between sowing in rows and broadcasting in Humera ($P = 0.096$), Wollega ($P = 0.176$), and 32-15 ($P = 0.219$) varieties, but there was a significant difference in S-42 ($P = 0.011$) varieties. For seed protein content, there was no difference between row and broadcast seeding in S-42 ($P = 0.908$), Wollega ($P = 0.446$), and 32-15 ($P = 0.148$); however, there was a significant difference in Humera ($P = 0.042$).

3.4.1. Impact of Seeding Method on the Lipid Content of Sesame Seeds. All varieties produced statistically the same lipid content, regardless of the seeding method (Figure 13).

3.4.2. Protein Content of Seeds according to Seeding Method. All varieties statistically produced the same protein content, regardless of the seeding method used (Figure 14).

3.4.3. Variation in Leaf Potassium Content by Seeding Method. Row seeding favored a higher accumulation of potassium in the varieties S-42, Wollega, and 32-15 compared to broadcasting. There was no difference ($P = 1.000$) in the Humera variety depending on the seeding method (Figure 15).

3.4.4. Variation in Leaf Sodium Content according to Seeding Method. Figure 16 shows that all varieties statistically produced the same sodium content, regardless of the seeding method.

3.4.5. Magnesium Content of Leaves according to Seeding Method. For variety 32-15, the magnesium content of the leaves of the broadcast seedlings was higher than that of the row seedlings. In contrast, in the varieties S-42, Wollega, and Humera, the leaves of the sown plants had the highest Mg content (Figure 17).

3.5. Phenology of the Plants according to the Seeding Mode and the Sesame Variety. The phenological parameters of sesame plants according to the seeding method and variety are presented in Table 6. There was no significant difference ($P \leq 1.000$) between the varieties according to the seeding method for emergence which was observed in all varieties from the 3rd day of seeding and extended until the 4th day when 100% emergence was noted. There was no significant difference ($P \leq 1.000$) between the varieties at the beginning of flowering which occurred on the 35th day of the season or for the maturity of the seeds which ended approximately 5 days after the maturity of the capsules. Similarly, there was

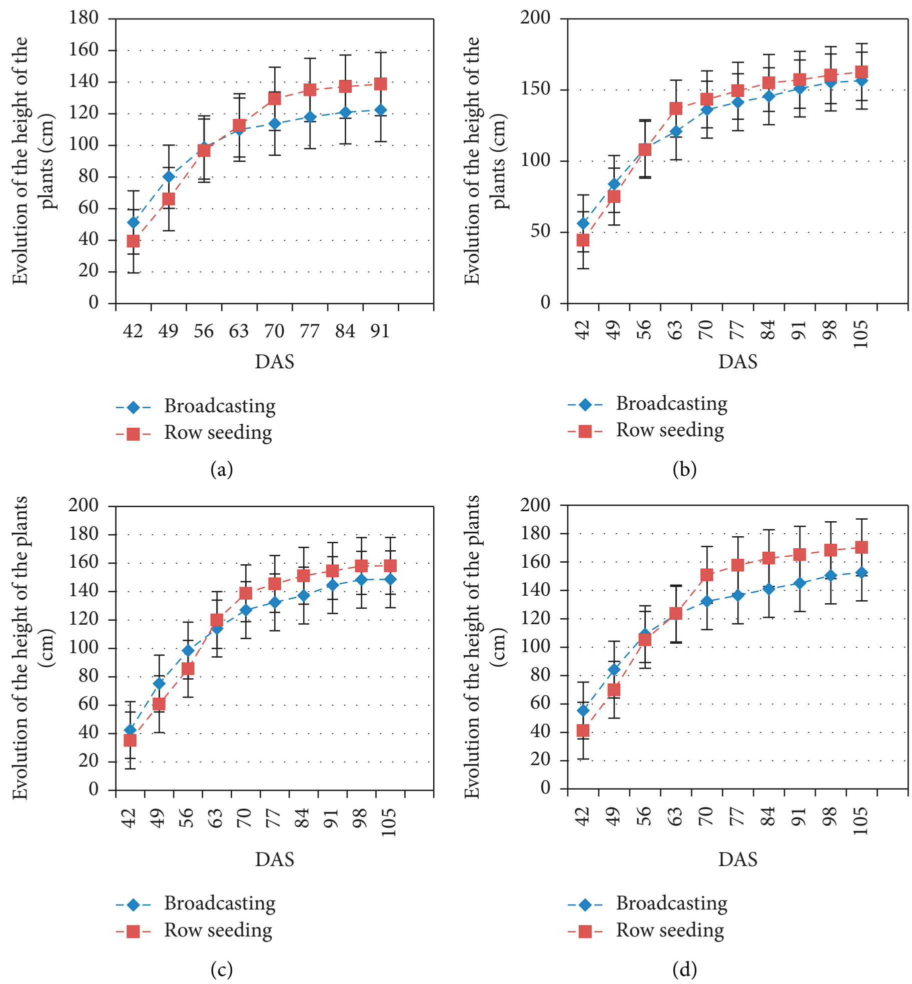

FIGURE 3: Plant height evolution of S-42 (a), 32-15 (b), Wollega (c), and Humera (d) varieties grown in rows and in the field.

no significant difference ($P = 1.000$) between varieties in relation to the seeding method for the maturity of the capsules which was reached on the 85th day after seeding for the varieties S-42 and 32-15 and the 100th day for the varieties Wollega and Humera.

3.6. Some Illustrative Pictures Taken during the Experiment. Figures 18(a) and 18(b) show the young seeding at the vegetative stage of the Wollega and S-42 varieties, respectively. Figures 18(c) and 18(d) give a partial view of the field with row seeding and broadcast seeding, respectively. Figures 18(e) and 18(f) show a seeding of the variety Humera at the flowering stage and then young capsules of the variety 32-15.

4. Discussion

The seeding method significantly affected the morphological responses of the four sesame varieties studied. The performance of seedlings sown in rows (with adequate spacing between plants) was generally better than that of seedlings sown in broadcast (high density) in terms of morphology. In fact, for each of the four sesame varieties, the row seeding favored a larger diameter of the crown at maturity with greater final stem height. It also has a greater number of branches and leaves as well as higher root and aerial dry biomass. Other authors (Goalbaye et al. [10], Moukala et al. [9], and Kouamé et al. [11]) have reported similar results for species in the same family, namely, groundnuts and cowpeas. These authors agree that two hypotheses are generally accepted to explain the poor morphological performance of plants at high seeding density compared with those with adequate spacing: the availability of resources for the plants and strong intraspecific competition. In fact, plants at high densities struggle to fully photosynthesize as light does not reach many leaves, so their development is difficult. Added to this is the strong competition between plants for essential resources such as light, moisture, and nutrients which influence the formation of vegetative parameters.

Capsule production per plant was affected by the seeding method in all four sesame varieties studied. Row seeding doubled capsule production per plant for varieties 32-15 and Wollega and tripled it for varieties S-42 and Humera. This visible difference in the number of capsules between row seeding and broadcast seeding (high density) is a direct

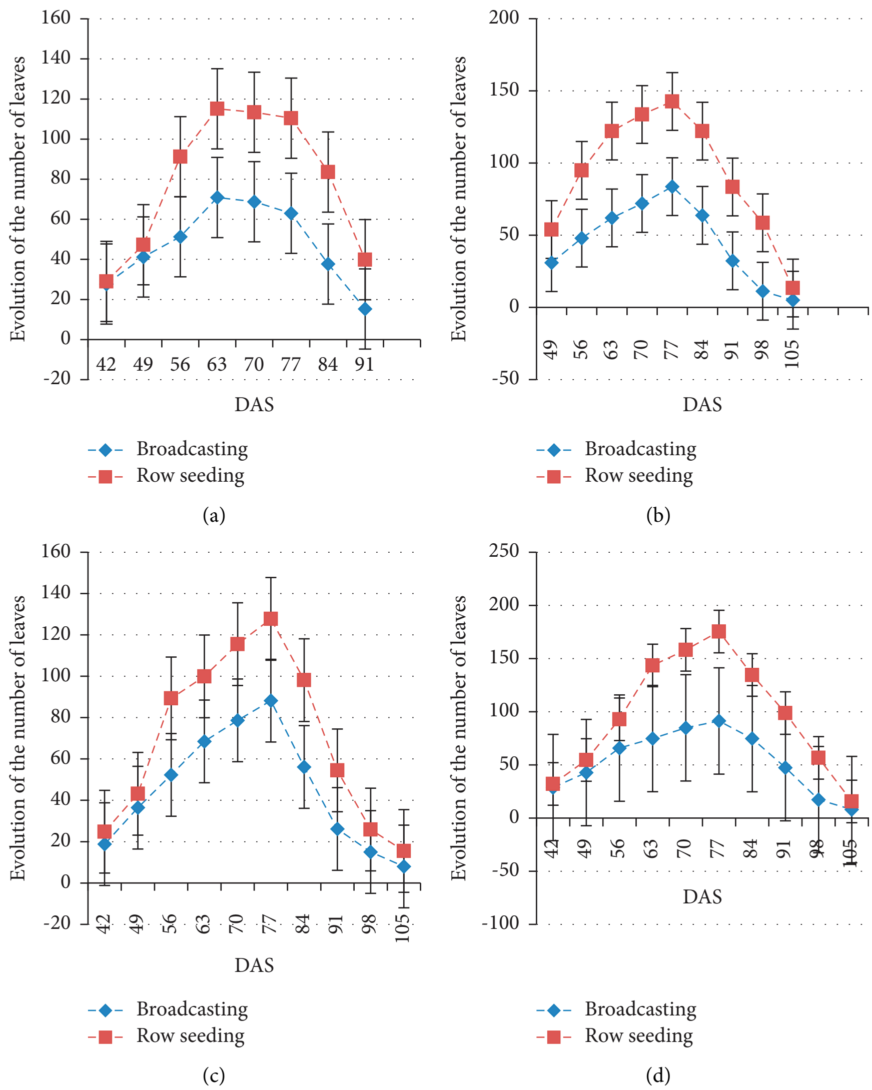

FIGURE 4: Evolution of the NL per plant in S-42 (a), 32-15 (b), Wollega (c), and Humera (d) soybean varieties grown in rows and in the field.

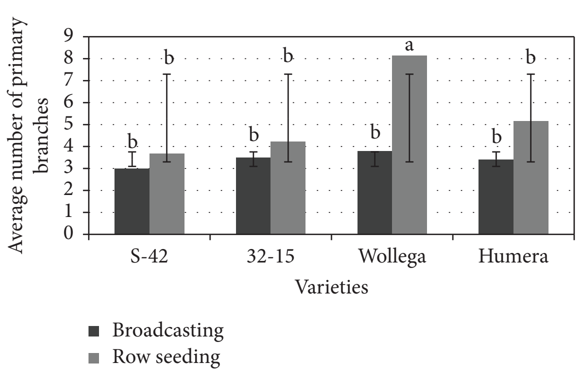

FIGURE 5: Average number of branches per plant according to the seeding method.

consequence of the competition between broadcast seedlings with light, water, nutrients, and space, the lack of which leads to a reduction in the amount of synthetic organic matter and therefore a reduction in growth, development, and capsule production. However, alternatively, an accumulation of auxins in these growing plants would have directed development towards plant production. Moukala et al. [11], Useni et al. [12], N'dri et al. [13], and Kouamé et al. [11] reported similar results on cowpea cultivars. In fact, these authors reported that high seeding density not only reduced the

Table 3: Means (±standard deviation) and statistical group of morphological variables of varieties according to seeding method.

Varieties	Seeding	NB	DWR	DWA
32-15	Row	4.22 ± 0.78^{b}	21.12 ± 2.88^{a}	45 ± 1.5^{d}
	Broadcasting	3.5 ± 0.5^{b}	9.82 ± 2.18^{b}	20.35 ± 0.45^{f}
Humera	Row	5.15 ± 1.85^{b}	18.74 ± 3.76^{a}	70 ± 5^{b}
	Broadcasting	$3.47 \pm 0{,}5^{b}$	8.35 ± 2.65^{b}	30.2 ± 2.8^{e}
S-42	Row	3.67 ± 1.33^{b}	10.64 ± 2.36^{b}	57.4 ± 2.6^{c}
	Broadcasting	3.33 ± 0.58^{b}	5.7 ± 1.23^{c}	21 ± 2^{f}
Wollega	Row	8.15 ± 2.85^{a}	18.52 ± 3.82^{a}	83 ± 6^{a}
	Broadcasting	3.8 ± 1.2^{b}	8.18 ± 1.32^{b}	33 ± 3.5^{e}

*Values with the same letter are statistically equal for each characteristic. NB: number of branches; DWR: root dry weight; DWA: dry weight of aerial parts.

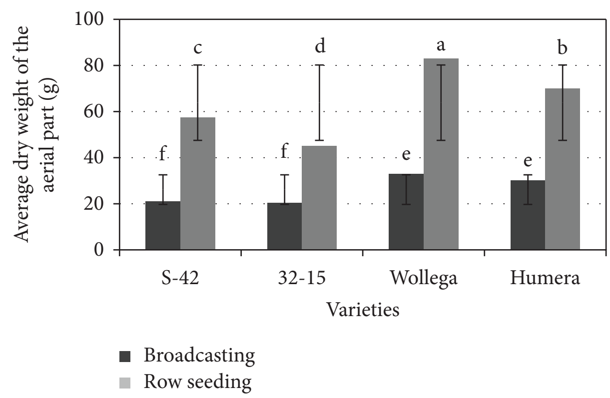

Figure 6: Average dry weight of the aerial part by seeding method.

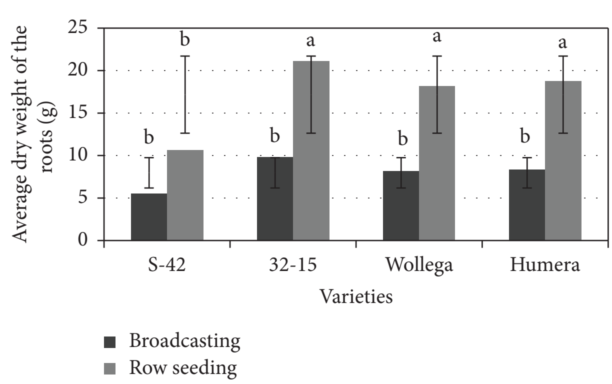

Figure 7: Average dry weight of the roots by seeding method.

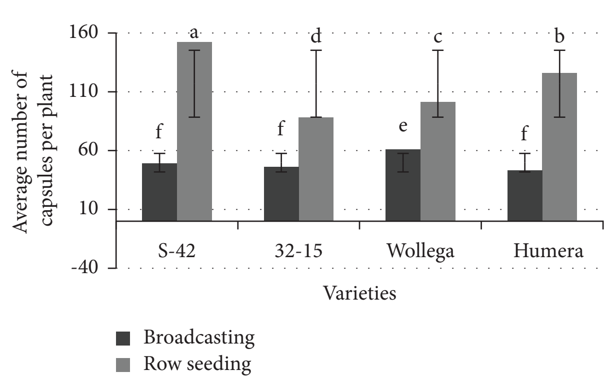

Figure 8: Average number of capsules per plant according to seeding method.

Table 4: Means (±standard deviation and statistical group) of agronomic variables of varieties according to sowing method.

Varieties	Seeding	NCP	NSC	WTS (g)	SYP (g/plant)	HI
32-15	Row	88 ± 50^{d}	63.5 ± 4.5^{b}	3.6 ± 0.3^{a}	20.13 ± 1.47^{c}	0.31 ± 0.01^{bc}
	Broadcasting	46 ± 40^{f}	54.2 ± 3.8^{c}	3.3 ± 0.3^{ab}	8.19 ± 0.61^{d}	0.27 ± 0.03^{c}
Humera	Row	126 ± 11^{b}	79.8 ± 5.2^{a}	3.4 ± 0.7^{ab}	34.43 ± 3.2^{a}	0.42 ± 0.06^{a}
	Broadcasting	43 ± 70^{f}	69.6 ± 1.18^{ab}	3.18 ± 0.12^{ab}	9.51 ± 1.5^{d}	0.25 ± 0.06^{c}
S-42	Row	152.4 ± 7.60^{a}	72.26 ± 6.74^{ab}	2.83 ± 0.77^{ab}	30.68 ± 3.11^{a}	0.45 ± 0.01^{a}
	Broadcasting	49 ± 3.61^{f}	65.3 ± 1.87^{b}	2.95 ± 0.05^{ab}	9.44 ± 0.75^{d}	0.36 ± 0.02^{b}
Wollega	Row	101.1 ± 7.90^{c}	80.5 ± 8.5^{a}	3.13 ± 0.13^{ab}	$25{,}23 \pm 3.98^{b}$	$0.25 \pm 0{,}02^{c}$
	Broadcasting	61 ± 5.29^{e}	70.4 ± 2.6^{ab}	2.42 ± 0.28^{b}	$10{,}46 \pm 2.12^{d}$	$0.25 \pm 0{,}04^{c}$

*Values with the same letter are statistically equal for each characteristic. NCP: number of capsules per plant; NSC: number of seeds per capsule; WTS: weight of 1000 seeds; SYP: seed yield per plant; HI: harvest index per plant.

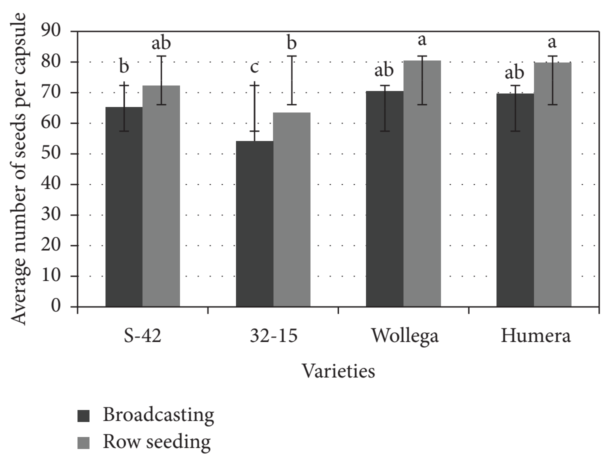

Figure 9: Average NSC as a function of seeding method.

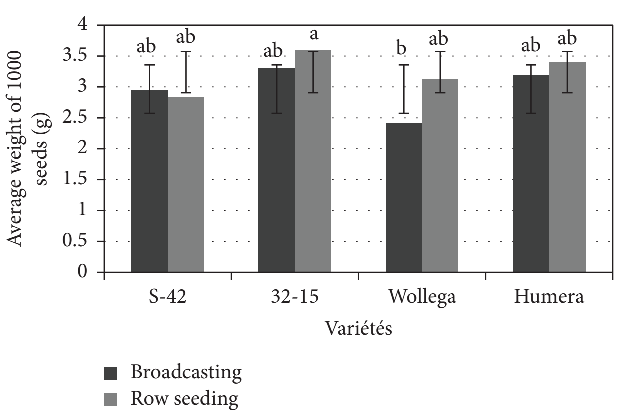

Figure 10: Average seed weight of the four varieties according to seeding method in the field.

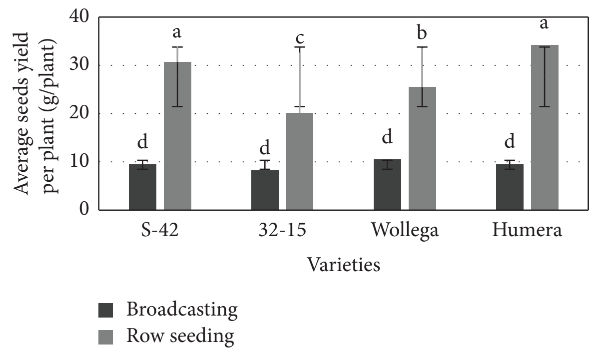

Figure 11: Average yield of seeds per plant according to seeding method.

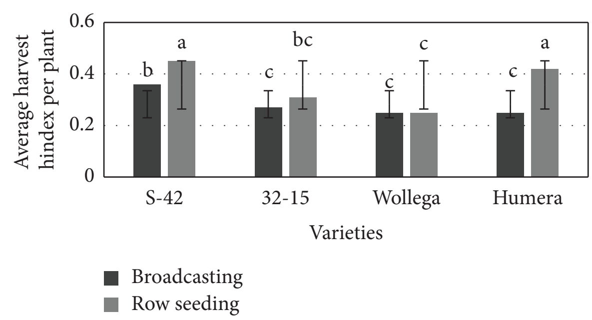

Figure 12: Average harvest index per plant according to seeding method.

number of pods but could also reduce flowering and therefore pod production in certain cultivars.

The seeding method had no significant effect on the seed number or weight. This could be explained by the compensatory effect due to the considerable reduction in the number of capsules in sesame seedlings at high density (broadcast sowing) compared with the number of capsules in seedlings sown at adequate spacing. In fact, competition between broadcast seedlings for light, water, nutrients, and space, the lack of which leads to a reduction in the quantity of synthetic organic matter, has a direct consequence of reducing growth, development, and the number of bolls. Reducing the number of capsules enables sesame plants to ensure good seed filling, while maintaining the number of bolls per plant around the average for each variety. These results are in line with those reported by Badiel [14]. This author reported that reducing the number of capsules in certain sesame varieties, such as S-42, even favored better seed filling and thus an increase in seed weight.

The seeding method did not influence the lipid content of the seeds of the four sesame varieties. In fact, essential oil content is not influenced by the farming method but is

Table 5: Means (±standard deviation) and statistical grouping of biochemical variables of varieties according to seeding method.

Varieties	Seeding	KCF (g/kg)	NaCF (g/kg)	MgCF (g/kg)	LCS (%)	PCS (%)
32-15	Row	20.64 ± 0.26^{b}	0.31 ± 0.07^{ab}	3.85 ± 0.05^{b}	49.29 ± 6.4^{ab}	20.8 ± 1.5^{ab}
	Broadcasting	18.43 ± 00^{c}	0.34 ± 0.04^{a}	5.95 ± 0.05^{a}	51.87 ± 2.93^{ab}	18.61 ± 1.5^{ab}
Humera	Row	18.83 ± 0.75^{c}	0.27 ± 0.07^{ab}	5.73 ± 0.03^{a}	47.96 ± 3.02^{b}	20.14 ± 0.14^{ab}
	Broadcasting	18.43 ± 00^{c}	0.29 ± 0.04^{ab}	3.12 ± 0.12^{c}	52.86 ± 2.5^{ab}	18.61 ± 0.89^{ab}
S-42	Row	25.7 ± 0.66^{a}	0.38 ± 0.04^{a}	4.37 ± 0.37^{b}	54.95 ± 2.02^{a}	16.64 ± 2.36^{b}
	Broadcasting	20.61 ± 0.54^{b}	0.3 ± 0.02^{ab}	$3,13 \pm 0,12^{c}$	48.47 ± 1.53^{ab}	16.86 ± 20^{b}
Wollega	Row	17.33 ± 0.63^{d}	0.2 ± 0.01^{bc}	5.68 ± 0.52^{a}	46.57 ± 1.43^{b}	21.89 ± 0.99^{a}
	Broadcasting	12.16 ± 0^{e}	0.17 ± 0.05^{c}	4.21 ± 0.27^{b}	44.93 ± 0.97^{b}	20.8 ± 20^{ab}

*Values with the same letter are statistically equal for each characteristic. KCF: foliar potassium content; NaCF: foliar sodium content; MgCF: foliar magnesium content; LCS: seed lipid content; PCS: seed protein content.

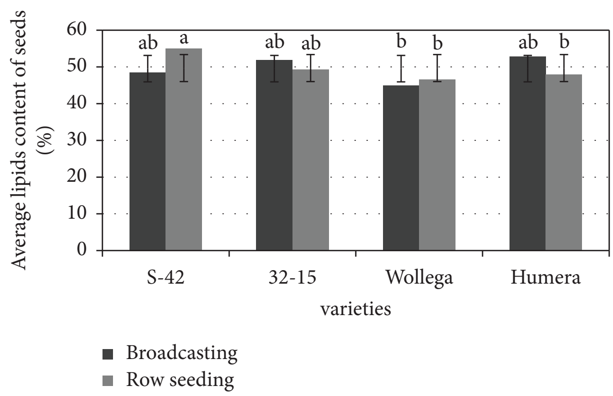

Figure 13: Average lipid content of seeds of the four sesame varieties according to the method of seeding in the field.

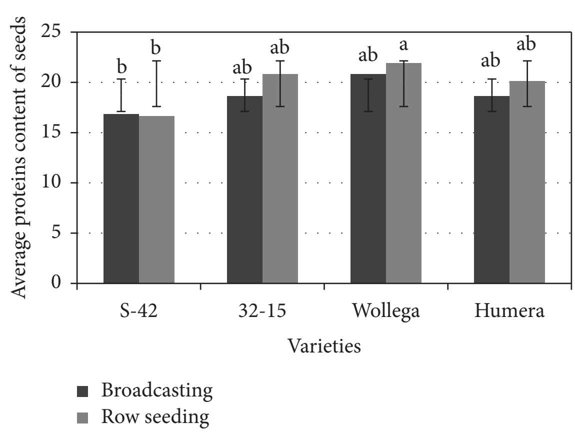

Figure 14: Average protein content of seeds of the four varieties according to the seeding method in the field.

subject to significant seasonal variations, environmental conditions, cultural practices, and genetic factors [15]. Similarly, the seeding method had no effect on seed protein contents in the four sesame varieties. Seed protein content is linked to the ability of the leaves to utilize essential amino acids which are strongly linked to nitrogen. According to Atayi and Odah [16], the increase in the nitrogen content can be explained by proteolysis occurring in the leaves during the water-free period leading to the formation of nitrogen compounds. In addition, sowing methods did not have the same effect on the four sesame varieties in terms of leaf content of mineral elements such as potassium, sodium, and magnesium.

In terms of leaf potassium content, for the varieties S-42, 32-15, and Wollega, the potassium content of broadcast seedlings was significantly higher than that of row seedlings. For Humera, on the other hand, the differences were minimal. K is the main ion present in cytoplasmic solutions. It plays a fundamental role in the passive and active transmembrane exchange processes in cells. It improves chlorophyll assimilation efficiency and restores osmotic potential [17]. Thus, it can be demonstrated that the varieties

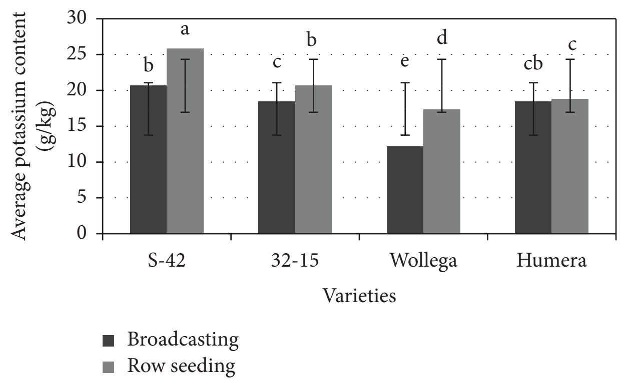

Figure 15: Average potassium content of leaves of the four sesame varieties according to field seeding method.

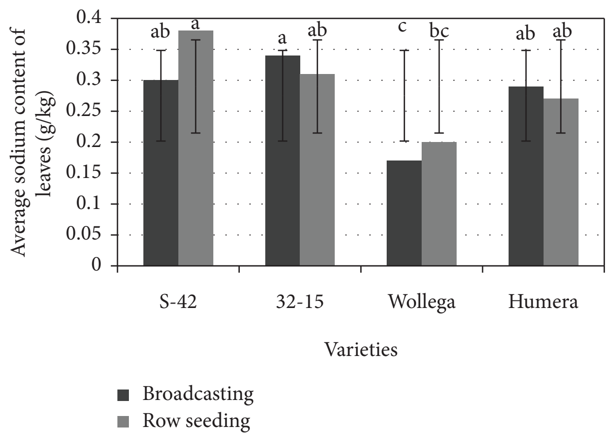

Figure 16: Average leaves sodium content as a function of field seeding method in four sesame varieties.

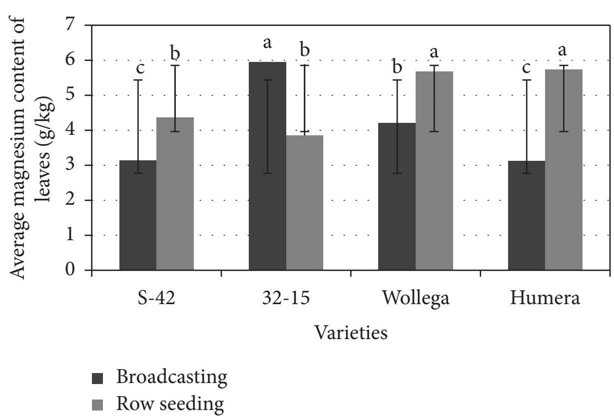

Figure 17: Average leaf magnesium content as a function of plant seeding method in four sesame varieties.

S-42, 32-15, and Wollega have developed a better strategy for withstanding high-density sowing conditions than the variety Humera.

As far as sodium is concerned, all varieties produced the same Na content, whatever the sowing method is. The presence of Na in the soil has always been a concern for agrobiologists because of its negative effect on crop yields. In particular, in non-salt-tolerant plants, sodium decreases soil water content, increases viscosity, and reduces enzyme activity [18]. In a situation of high seeding density with competition, the varieties S-42 and Wollega developed the best adaptation strategy by accumulating less Na.

With regard to Mg content, in variety 32-15, the leaves of the transplanted seedlings had a higher value than those of the row seedlings. On the other hand, in varieties S-42, Wollega, and Humera, the leaves of the plants sown in rows

Table 6: Number of DAS and analysis of variance of phenological traits of the four varieties (field).

Varieties	Seeding method	Phenological parameters (days after sowing)				
		Lift time	Beginning of flowering	End of flowering	Curing time capsules	Cycle time
S-42	Row	3^a	35^c	65^d	84^d	90^b
	Broadcasting	3^a	35^c	65^d	84^d	90^b
32-15	Row	3^a	36^b	67^c	85^c	90^b
	Broadcasting	3^a	36^b	67^c	85^c	90^b
Wollega	Row	3^a	42^a	83^a	100^a	105^a
	Broadcasting	3^a	42^a	83^a	100^a	105^a
Humera	Row	3^a	42^a	83^a	100^a	105^a
	Broadcasting	3^a	42^a	83^a	100^a	105^a
Statistics	Fisher's F	0.000	480.481	2846.771	2387.272	748.871
	P to 5%	=1.000^{ns}	<0.0001**	<0.0001**	<0.0001**	<0.0001**

**highly significant difference; *significant difference; ns: nonsignificant difference at the 5% level; F = fisher variable; P = associated probability. One letter for one parameter: nonsignificant difference; two letters for one parameter: significant difference.

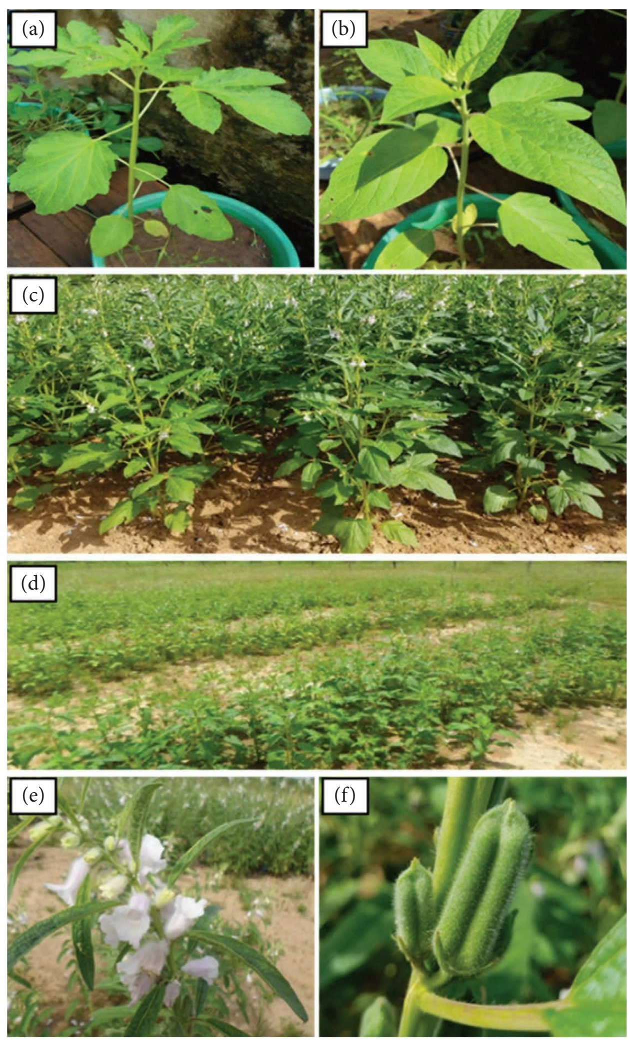

Figure 18: Illustrative photographs by Badiel et al. [9].

contained the highest content. Magnesium is a constituent of chlorophyll. It promotes the synthesis of chlorophyll, xanthophyll, and carotene. It is also a component of essential organic compounds such as phytin and pectin [17]. They activate enzymes, notably those involved in protein synthesis. As a result, variety 32-15 can be considered as most adaptable to high seeding densities by increasing Mg content to maintain high photosynthesis.

5. Conclusion

A study related to the morphophysiological and agronomic evaluation of sesame revealed that in all four varieties (S-42, 32-15, Humera, and Wollega), the seeding method did not influence the emergence or duration of the cycle. The number of capsules produced from row seeding was at least twofold than that produced from broadcast seeding for all varieties. At S-42, the seedlings from row seeders produced significantly more seeds than those from broadcasters. The seeding method did not significantly influence the seed weight, lipid content, protein content, or leaf sodium content. Varieties S-42, 32-15, and Wollega accumulated more K under row seeding than under broadcast seeding. In Humera, the seeding method had no effect on K accumulation. Variety 32-15 adapted better to high seeding rates than did the varieties S-42, Wollega, and Humera by accumulating more Mg. Thus, seeding in rows is recommended to obtain better vegetative development and better capsule and seed yields for all varieties. Both seeding methods are equally recommended for lipids, proteins, and Na for all varieties. Broadcast seeding is recommended for better Mg content for 32–15, and row seeding is recommended for better K content for varieties S-42, Wollega, and 32-15.

Data Availability

The data and analyses are available in an Excel file and they can be verified if needed.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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