Science Discovery Plants
2026, Vol. 1, No. 2, pp. 93–99
https://doi.org/10.11648/j.sdplants.20260102.13

SciencePG
Science Publishing Group

Research Article

Determination of Seed Rate and Row Space of *Sinapis alba* L. of Bee Forage at Highland of Bale Zone Southeast Oromia Regional State, Ethiopia

Temaro Gelgelu*, Wondimu Lelisa, Habtamu Dereje

Oromia Agricultural Research Institute (OARI), Sinana Agricultural Research Center (SARC), Robe, Ethiopia

Abstract

Sinapis alba L is one of the most important bee forage species adapted to the highlands of Bale, which is well known for providing pollen and nectar to honeybees. Seed rate and row space are the most important parameters that play a great role in the growth performance of *Sinapis alba*. This study was conducted at the Sinana Agricultural Research Center, Bale Zone, and southeastern Oromia region, to evaluate the effects of seed rate and row spacing on the growth performance of *Sinapis alba* in the highland of Bale condition during the 2021 to 2023 main season. This study used RCBD with three replications and two treatments arranged in a factorial combination. The spaces between the plot & block were 1 m & 1.5 m, respectively. The plot size of each treatment was 1.2 m x 3 m (3.6 m^2). The collected data was analyzed statistically by using ANOVA methods. Duncan's multiple range test and general linear model (GLM) tested the mean differences between treatments and within treatments. The highest number of secondary branches (13.87) was obtained by 15 cm row spacing. The highest number of pods/plant (94.16) was found when seeds were sown in 25 cm row spacing. Thirty cm row spacing produced the highest number of seeds/pod (3.66), and 15 cm row spacing produced the lowest number of seeds/pod (2.72). The highest seed yield (17.17 qt/ha) was produced when the seeds were sown in 20 cm row spacing. The highest pollen yield (0.85 gm) was produced by 20 cm row spacing, and the lowest (0.59 gm) was produced by 30 cm row spacing. The highest number of the secondary branches (13.07) was obtained by the application of 10 kg/ha. A higher number of pods/plant (101.65) was produced by the application of 8 kg of seeds. A higher number of seeds/pods (4.08) was produced by the application of 10 kg of seeds/ha. 10 kg of seeds/ha produced a higher seed yield (16.75 Qt/ha), and 14 kg of seeds/ha produced a lower seed yield (12.4 Qt/ha). The highest thousand-seed weight (4.06) was obtained by the application of 10 kg/ha. Using an appropriate seed rate (10 kg/ha) and row spacing (20 cm) is of paramount importance to increasing the seed of *Sinapis alba*.

Keywords

Highland, Honeybee Forage, Seed Rate, *Sinapis alba*, Row Spacing

*Correspondence: Temaro Gelgelu (temage581@gmail.com)

Received: 15 January 2026; **Accepted:** 9 May 2026; **Published:** 19 May 2026

1. Introduction

Sinapis alba L. (Brassicaceae) is a cultivated bee forage species adapted by short-tongued bees. *Sinapis alba* traditional cultivars are attractive to insect pollinators and supply significant amounts of nectar and pollen during bees intensive foraging [1]. The performance of bees is dependent on the quality and quantity of bee forage resources in the area, and it will enhance their productivity and survival rate. More flowers as well as colonies with vigorous queens produce large numbers of foraging bees [2].

It is one of the most important bee forage species, which is well known for providing pollen and nectar for honeybees [3]. Besides its importance as bee forage, it is one of the most important nitrogen-fixing crops, and most of the farmers use it as rotation to break monocropping in Bale. The growth performance of *Sinapis alba* is affected by agronomical practices, soil types, seed rate, row space, and other factors. Seed rate is an important agronomical practice affecting the growth performance of any given cultivars of any plants [4]. Many studies have shown that *Sinapis alba* species confront density, scattered affected growth performance, forms of plant density, and related yield of plant species. Seed rate and row space are the most important parameters that play a great role in the growth performance of any kind of plant. Seed rate and row space also have significant effects on the number of primary branches, number of flowers, number of pods per plant, 1000 seed weight, pod length, and length of a given plant [4].

However, cultivars of *Sinapis alba* species had problems with agronomic practices, especially for seed rate and row spacing in our country and the particular highland of Bale, as it is planted by blanket recommendation. The base of the blanket recommended a seed rate, and row spaces were used at 10 kg/ha and 20 cm, respectively. Most of the farmer beekeepers have also reported that *Sinapis alba* has a seed rate problem during planting. In addition, we have also observed that it has a great seed rate and row spacing problem in field conditions; it is shown in scattered and low density (personal observation). This in turn affects the amount of pollen and nectar load and seed yield gained per acre of land allocated for this plant. Moreover, the optimum row spacing and seed rate of *Sinapis alba have not yet been studied* in our country, and particularly in the highlands of Bale. Therefore, to solve this realistic problem, it is very important to see the seeding rate and row spacing of *Sinapis alba* in our condition. So, this study was initiated to see the level of row spacing and seed rate on the growth performance of *Sinapis alba* under highland conditions in Bale, southeast Ethiopia.

2. Materials and Method

2.1. Description of Study Area

The study was conducted at the Sinana Agricultural Research Center with the objective to determine the effect of row spacing and seed rate on the growth performance of *Sinapis alba*. The Sinana Agricultural Research Center is located in the Sinana district of the Bale Zone, southeastern Oromia region, Ethiopia. It is situated approximately 460 km southeast of Addis Ababa, at an altitude of 2,400 meters above sea level. The geographical coordinates of the center range from 07° 06' 12" to 07° 07' 29" N latitude and from 40° 12' 40" to 40° 13' 52" E longitude [5].

Climate

Sinana district area is characterized by a bimodal rainfall pattern, which supports dual cropping cycles each year. This bimodal rainfall pattern enables farmers to produce crops twice a year, optimizing agricultural productivity. The two distinct rainy seasons are: Bona Season: This season extends from July to late December. Ganna Season: This season spans from mid-March to August. Annual Average Temperature: Ranges from 9°C to 25°C. Annual Rainfall: Varies between 452.7 mm and 1129.5 mm.

2.2. Experimental Setup

To evaluate the effect of different row spacing and seed rates on the growth performance of *Sinapis alba*, a field experiment was carried out at Sinana Agricultural Research Center during the main season (rain-fed conditions) from 2021 to 2023. Randomized complete block designs with three replications and two treatments arranged in factorial combination were used. For this study, two factors included seed rates of 8 kg/ha, 10 kg/ha, 12 kg/ha, and 14 kg/ha, and row spacing of 15 cm, 20 cm, 25 cm, and 30 cm were used. The space between the plot & block was 1 m & 1.5 m, respectively. The plot size of each treatment was 1.2 m x 3 m (3.6 m^2).

Data collection and Measurements

The pollen yield of each treatment was determined by collecting 50 matured flower heads of similar age and was kept for certain days to dry. For removal from the flower, pollen was shaken on a paper tray and weighed using a sensitive weighing balance.

Data for the number of branches per plant, number of pods per plant, number of seeds per pod, and plant height were taken from five randomly selected plants from internal rows, and then the average of the sample plants was used. Thousand seed weight was measured from each treatment. For seed yield, middle rows of each plot were harvested and measured by sensitive balance, recorded, and then converted to seed yield quintal per hectare. Data were managed and documented using Microsoft Excel to ensure accuracy and organization.

Statistically Data Analysis

One-way Analysis of Variance (ANOVA) was conducted to compare the mean values of different treatments. This was performed using R software version 4.1.1. The significance of differences between treatment means was assessed using the Least Significant Difference (LSD) test.

3. Results and Discussions

The experiment was conducted to determine the seed rate and row spacing of *Sinapis alba*. A summary of the analysis of the variance of the data with respect to all the parameters studied has been shown in a table. The results obtained in this experiment have been presented and discussed below.

A combined analysis of variance (ANOVA) for various agronomic parameters and yields of *Sinapis alba* is presented in Table 1. The analysis revealed significant effects ($p < 0.05$) of replication, seed rate, and row spacing on the number of secondary branches, plant height, number of pods per plant, number of seeds per plant, and seed yield. Additionally, row spacing significantly influenced pollen yield. Thousand seed weight also showed significant variation ($p < 0.05$) due to replication and seed rate. Furthermore, the interaction between seed rate and row spacing had a significant effect ($p < 0.05$) on plant height, indicating that *Sinapis alba* responded differently across various seed rate and row spacing levels.

Table 1. *Mean square of ANOVA for yield and yield parameters of Sinapis alba.*

Source of variation	Mean Square								
	DF	PY (gm)	NPB	NSB	PH (cm)	NPP	NSPP	TSW (gm)	SY (Qt/ha)
Replication	2	0.02ns	11.96ns	15.78*	6011.4*	196.01ns	4.04*	0.95*	7.24ns
Seed rate	3	0.11ns	11.81ns	59.33*	14853.58*	1431.14*	3.85*	0.37*	0.37*
Row spacing	3	0.22*	0.54ns	32.09*	6397.97*	474.24*	2.08**	0.21ns	42.07*
SR*RS	9	0.04ns	5.67ns	3.88ns	2242.04*	112.45ns	0.42ns	0.04ns	14.6ns
Residual	30	0.06	5.07	2.91	738.17	63.01	0.66	0.10	7.36

DF= degree of freedom; PH= plant height; ns= non-significant; *= significant at (P<0.05), PY= pollen yield, DF= Degree of freedom, NPB= Number of primary branch, NSB= Number of secondary branch, PH= Plant height, NPP= Number of pods per plant, NSPP= Number of seed per pod, TSW= Thousand Seed weight

3.1. Effect of Row Spacing on Growth Performance of *Sinapis alba*

3.1.1. Pollen Yield

Pollen is a fine powder produced by certain plants when they reproduce. According to the current result, the pollen yield was significantly influenced by different row spacing (Table 2). The highest pollen yield (0.85 gm) was produced by 20 cm row spacing, and the lowest pollen yield (0.59 gm) was produced by 30 cm row spacing.

3.1.2. Number of Branches/Plant

The number of primary branches/plants was not significantly influenced by different row spacing, while the number of secondary branches was significantly influenced by different row spacing (Table 2). The highest number of secondary branches was obtained (13.87) by 15 cm row spacing, and the lowest number of secondary branches was obtained by 30 cm row spacing (Table 2). The result was contrary to the findings of [6], who reported that the highest number of branches/plants was produced by the application of wider row spacing in *Sinapis alba.* These contrary findings might be due to sensitivity to environmental factors. The branching is highly plastic: when grown in a dense stand, a plant can produce a single branch with fewer stems, whereas when grown similarly, the same plant can produce numerous branches [7].

3.1.3. Number of Pods/Plant

Different row spacing significantly influenced the number of pods/plants (Table 2). The highest number of pods/plants (94.16) was found when seeds were sown in 25 cm row spacing, and the lowest number of pods/plants (79.93) was found when seeds were sown in 15 cm row spacing. [8], found that with the increase in row spacing, the number of pods/plants increased to 15.

3.1.4. Number of Seeds/Pod

The seed number per plant is closely correlated with the number of pods per plant and is, therefore, an important yield attribute. The number of pods per plant depends upon the number of primary and secondary branches. Thirty cm row spacing produced the highest number of seeds/pods (3.66), and 15 cm row spacing produced the lowest number of seeds/pods (2.72). The results are in line with the observations of [9], who stated that, the number of effective branches and pods per branch decreased with increasing plant density.

Higher branching observed in wide row spacing was a major cause of the increased number of pods per plant. [10], also

reported that seed numbers per plant increased by 31% when row spacing increased from 17 cm to 34 cm in some plants.

3.1.5. Thousand Seed Weight

The weight of the seed expresses the magnitude of seed development, which is an important yield determinant and plays a decisive role in showing off the yield potential of a crop [11]. The analysis of variance indicated row spacing had no significant effect on a thousand seed weight (Table 1). The result of the current study agreed with the result of [12], who reported that row spacing did not significantly influence the thousand seed weights of some plant species.

3.1.6. Seed Yield

The final seed yield of a crop is the expression of the combined effect of various yield components. Seed yield was significantly influenced by row spacing (Table 2).

The highest seed yield (17.17 Qt/ha) was produced when the seeds were sown in 20 cm row spacing, and the lowest seed yield (12.85 Qt/ha) was produced when the seeds were sown in 30 cm row spacing. These results are in analogy with the results of [12], who concluded that the seed yield of Sinapis alba decreased with an increase in row spacing.

Table 2. *The effect of row spacing on growth performance of Sinapis alba yield and yield parameters.*

Level in RS (cm)	PY (gm)	NPB	NSB	NPP	NSPP	TSW (gm)	SY (Qt/ha)
15 cm	0.62^{b}	11.05	13.87^{a}	79.93^{b}	2.72^{b}	3.19	13.69^{b}
20 cm	0.85^{a}	11.54	13.04^{a}	91.3^{a}	3.29^{ab}	3.49	17.17^{a}
25 cm	0.79^{a}	11.41	10.77^{b}	94.16^{a}	3.52^{a}	3.81	14.85^{b}
30 cm	0.59^{b}	11.38	8.97^{c}	91.13^{a}	3.66^{a}	4.01	12.85^{b}
Overall mean	0.71	11.35	11.66	89.13	3.30	3.91	14.64
CV (%)	33.65	19.83	14.62	8.91	24.72	8.24	18.54
LSD (0.05)	0.20	NS	1.42	6.62	0.68	NS	2.26

RS= Row spacing, SR= Seed rate, PH= plant height; NS= non-significant; S= significant t ($P<0.05$), PY= pollen yield, NPB= Number of primary branch, Number of secondary branch, PH= Plant height, NPP= Number of pods per plant, NSPP= Number of seeds per pod, TSW= Thousand Seed weight, CV= Coefficient variance, LSD= Least significant Difference

3.2. Effect of Seed Rate on Growth Performance of *Sinapis alba*

3.2.1. Pollen Yield

According to the current result, there is no significant influence of seed rate on the pollen yield of the plants (Table 3). [13] also reported that seed rate had no significant effect on the pollen yield of some plants species.

3.2.2. Number of Branches/Plant

According to the current result, no significant influence due to seed rate on several primary branches/plants was observed (Table 3), while seed rate had a significant influence on the number of secondary branches. The highest number of secondary branches (13.07) was obtained by the application of 10 kg/ha, while the lowest number of secondary branches (9.41) was obtained by the application of 8 kg/ha. The result was contrary to the findings of [14], who reported that different levels of seed rate did not have any significant effect on the number of branches/plants in *Sinapis alba.*

3.2.3. Number of Pod/Plant

The seed rate has a significant influence on the number of pods/plants (Table 3). A higher number of pods/plants (101.65) was produced by the application of 8 kg of seeds/ha, and a lower number of pods/plants (79.74) was produced by the application of 14 kg of seeds/ha. [15], reported that with the increase in seed rate, the number of pods/plants decreased. [16], reported that seed rate had a negative correlation with the number of pods/plants.

3.2.4. Number of Seeds/ Pod

According to the current results, seed rate had a significant influence on the number of seeds/plants (Table 3). A higher number of seeds/pods (4.08) was produced by the application of 10 kg of seeds/ha, and a lower number of seeds/plants (2.83) was produced by the application of 12 kg of seeds/ha.

3.2.5. Thousand Seed Weight

The analysis of variance indicated that seed rate had a significant effect on a thousand seed weights (Table 3).

The highest thousand seed weight (4.06 gm) was obtained by the application of 10 kg/ha, while the lowest thousand seed weight (3.65) was obtained by the application of 14 kg/ha. The result was contrary to the findings of [17], who reported that seed rates had no significant effects on the 1000-seed weight of *Sinapis alba* plants.

3.2.6. Seed Yield

Table 3. *The effect of Seeding rate on growth performance of Sinapis alba yield and yield parameters.*

Level in SR (kg)	PY (gm)	NPB	NSB	NPP	NSPP	TSW (gm)	SY (Qt/ha)
8 kg	0.78	11.75	9.41^{c}	94.91^{b}	3.36^{b}	3.98^{a}	15.51^{ab}
10 kg	0.71	12.53	13.07^{a}	101.65^{a}	4.08^{a}	4.06^{a}	16.75^{a}
12 kg	0.76	10.30	12.63^{ab}	80.22^{c}	2.83^{b}	3.94^{a}	13.9b^{c}
14kg	0.57	10.81	11.53^{b}	79.74^{c}	2.92^{b}	3.65^{b}	12.4^{c}
Overall mean	0.71	11.35	11.66	89.13	3.30	3.91	14.64
CV (%)	33.65	19.83	14.62	8.91	24.72	8.24	18.54
LSD (0.05)	NS	NS	1.42	6.62	0.68	0.27	2.26

Means with the same letter are not significantly different, RS= Row spacing, SR= Seed rate, PH= plant height; NS= non-significant; S= significant t (P<0.05), PY= pollen yield, NPB= Number of primary branch, Number of secondary branch, PH= Plant height, NPP= Number of pods per plant, NSPP= Number of seeds per pod, TSW= Thousand Seed weight, SY= Seed Yield, CV= Coefficient variance, LSD= Least significant Difference

Seed rate is one of the agronomic factors that decrease seed yield by subjecting plants to lodging and competition. The current result shows that seed rate had a significant influence on seed yield (Table 3). 10 kg of seeds/ha produced a higher seed yield (16.75 Qt/ha), and 14 quintal seeds yield/ha produced a lower seed yield (12.4 Qt/ha). [17], also reported that seed rate has a profound influence on the economic production of crops of all species.

3.3. Effect of Row Spacing and Seed Rate Interaction on Growth Performance of *Sinapis alba*

According to the ANOVA table results, row spacing and seed rate had no interaction effect on the tested parameters except plant height (Table 4).

Table 4. *Effect of row spacing and Seed rate interaction on plant height.*

Level in Seed rate (kg)	level in Row spacing (cm)			
	15 cm	20 cm	25 cm	30 cm
8kg	187.1^{bcde}	250.6^{abc}	257.2^{ab}	249.7^{abc}
10 kg	209.0^{abcde}	288.2^{a}	233.1^{abcd}	260.2^{ab}
12 kg	167.9^{cde}	159.0^{de}	191.6^{bcde}	234.6^{abcd}
14kg	149.3^{de}	140.0^{e}	193.4^{bcde}	206.4^{abcde}
Overall mean	211.1	211.1	211.1	211.1
CV (%)	12.9	12.9	12.9	12.9
LSD (0.05)	45.53	45.53	45.53	45.53

NS=Means with the same letter are not significantly different, RS= Row spacing, SR= Seed rate

4. Conclusion and Recommendation

An experiment was conducted from 2021 to 2023 at the Sinana on-station site to evaluate the effects of seed rate and row spacing on the growth performance of *Sinapis alba* in the highlands of Bale. Variation in seed rate and row spacing significantly affected the number of secondary branches, number of pods per plant, number of seeds per pod, and seed yield. Thousand seed weight was influenced by seed rate but remained unaffected by changes in row spacing, while pollen yield was impacted by row spacing but not by seed rate. Seed rate and row spacing showed no interaction effects on most growth parameters except plant height. A combination of a 10 kg/ha seed rate and 20 cm row spacing is recommended for maximum seed yield of *Sinapis alba.*

Abbreviations

ANOVA	Analysis of Variances
CV	Coefficient of Variation
GLM	General Linear Model
LSD	Least Significant Differences

Author Contributions

Temaro Gelgelu: Conceptualization, Data Curation, Formal Analysis, Investigation, Methodology, Software, Validation, Visualization, Writing – original draft

Wondimu Lelisa: Conceptualization, Data Curation, Fund acquisition, Investigation, Methodology, Project Administration, Resources, Software, Supervision, Validation, Writing – review & editing

Habtamu Dereje: Data Curation, Fund acquisition, Investigation, Methodology, Project Administration, Resources, Supervision, Validation, Writing – review & editing

Acknowledgments

The authors express their gratitude to the Oromia Agricultural Research Institute for its financial support. We also thank the Sinana Agricultural Research Center, for providing the seed sources. Special appreciation goes to the entire Apiculture research team for their dedication, patience, and positive spirit during the data collection process; without their efforts, this study would not have been possible.

Conflicts of Interest

The authors declare no conflicts of interest.

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