GROWTH AND YIELD RESPONSE OF SESAME TO THE SQUARE SPACING SYSTEM

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*This is to certify that the thesis entitled "**GROWTH AND YIELD RESPONSE OF SESAME TO THE SQUARE SPACING SYSTEM**" submitted to the DEPARTMENT OF AGRONOMY, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka-1207, in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE (M.S.) in AGRONOMY**, embodies the results of a piece of bona fide research work carried out by **SALMA SUBAH SEMONTI**, Registration. No. **10-03817** under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma.*

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

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The author

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ABSTRACT

A field work was carried out at Agronomy field of Sher-e-Bangla Agricultural University, Dhaka-1207, to study the influence of square spacing system on the growth and yield of sesame during March, 2015 to June, 2015. The experiment was laid out in a split plot design with three replications. Two factors were used those were variety (V_1= Binatil-2, V_2= BARI Til-3 and V_3= BARI Til-4) which allocated to main plot and square spacing (S_1 (control) = 30 cm × 5 cm, S_2 = 20 cm × 20 cm, S_3 = 30 cm × 30 cm, S_4 = 40 cm × 40 cm and S_5 = 50 cm × 50 cm) which assigned to sub-plot. Among the cultivars Binatil-2 well-matched with square spacing and gave the maximum leaf area index (4.44) at 55 DAE, above ground dry matter weight plant^{-1} (60.23 g) at harvest, capsules plant^{-1} (124.03), seed weight plant^{-1} (18.64 g), seed yield (1.03 t ha^{-1}) and harvest index (30.63 %) etc. In the case of different square spacing, the widest (50 cm × 50 cm) was given the highest above ground dry matter weight plant^{-1} (67.24 g) at harvest, capsules plant^{-1} (141.22) and seed weight plant^{-1} (19.79 g) whereas control spacing (30 cm × 5 cm) showed the highest crop growth rate (36.69 g m^{-2} d^{-1}), seed yield (1.79 t ha^{-1}) and harvest index (31.33 %). In combination treatment the highest seed weight plant^{-1} (23.39 g) was taken from Binatil-2 along with the widest spacing (50 cm × 50 cm) while Binatil-2 with control spacing (30 cm × 5 cm) ranked top in seed yield (1.88 t ha^{-1}). It is clear from the experiment that wider spacing influenced individual plant with vigorous growth and yield but failed to produce yield per unit area due to lack of optimum plant population.

LIST OF CONTENTS

LIST OF CONTENTS (contd.)

LIST OF CONTENTS (contd.)

LIST OF CONTENTS (contd.)

LIST OF CONTENTS (contd.)

LIST OF CONTENTS (contd.)

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (contd.)

LIST OF APPENDICES

LIST OF PLATES

LIST OF ACRONYMS

AEZ	=	Agro-Ecological Zone
BARI	=	Bangladesh Agricultural Research Institute
BINA	=	Bangladesh Institute of Nuclear Agriculture
cm	=	Centimeter
CV	=	Coefficient of Variation
DAS	=	Days after sowing
DAE	=	Days after emergence
et al.	=	and others
g	=	Gram
ha^{-1}	=	Per hectare
HI	=	Harvest index
i.e.	=	In other words
LSD	=	Least Significant Difference
mm	=	millimeter
MoP	=	Muriate of Potash
NGO	=	Non Government Organization
no.	=	Number
NS	=	Non significant
SAU	=	Sher-e-Bangla Agricultural University
SCI	=	System of crop intensification
SRI	=	System of rice intensification
t	=	Ton
TSP	=	Triple super phosphate
%	=	Percent
ºC	=	Degree Celsius

CHAPTER 1

INTRODUCTION

Sesame (*Sesamum indicum* L.), a short day C4 energetic oilseed crop, is generally recognized as a crop of warm regions of tropics and subtropics. It is one of the most ancient oil crop of the subcontinent, belongs to the order Tubiflera and family Pedaliaceae. It shows geographical elasticity, that is why it can be cultivated in all continents of the world. The agro-eco zone of sesame cultivation is laid between latitudes 6º and 10º N (Agboola, 1979) and the highest producers belong to Asia because of its diverse uses in these areas such as Myanmar, India, China etc. (FAOSTAT, 2013).

Sesame has great health value. The seeds contain high quality edible oil (43-55 %) and protein (14-20%) (Alpaslan *et al*., 2001). It's seed contains about 47% oleic acid and 39% linoleic acid (poly unsaturated fatty acids) are known for their great health claim (Oplinger *et al*., 1990). A large amount of fat soluble antioxidants, like sesamin, sesamolin, sesamol and tocopherol (Rangkadilok *et al*., 2010) of sesame provide exceptional shelf life of the oil, which ensures the oil cannot be rancid quickly (Alpaslan *et al*., 2001) and they have some medicinal properties such as reduction of the free oxygen radicals in tissues, blocking of bad cholesterol production, healing of fungal skin diseases etc. (Hansen, 2011). It works as an agent of anti-inflammatory (Monteiro *et al*., 2014). For its high nutritional and medicinal value it is well known as "the queen of oils" and the presence of effective antioxidants and medicinal value the seeds are termed as "the seeds of immortality".

Sesame has some other beneficial properties. The oil is used as an ingredient in the production of paint, soap, cosmetics, perfumes, pharmaceutical and ethno botanical uses (FAO, 2002; RMRDC, 2004). The whole seed is used in bakery purposes and in making soup. The higher content of vitamins and minerals like calcium (1500 mg / 100 g) (Arriel *et al*., 2006) & phosphorus, crude fibers (10.8 g / 100 g), methionine & arginine etc. made this semi defatted sesame cake (SDSC) a nutritious feed (Malik *et al*., 2003) and the hull also used as a good fodder (Mahmoud *et al*., 2015; Abdullah *et al*., 2011). Its deep root system made it drought tolerant (Langham *et al*., 2008) hence it is sustainable in low input cropping systems (Sheahan, 2014). This plant can remove residual portion of organochlorine pesticide lindane, a neurotoxin, from the soil and save our environment (Abhilash and Singh, 2010).

Sesame is the second largest source of edible oilseed crop in Bangladesh after mustard. It is cultivated almost everywhere in the country. Bangladesh ranked 26^{th} in area coverage (1.03 lakh ha), 20^{th} in production (0.99 lakh metric ton) and 15^{th} in yield (0.93 metric ton ha^{-1}) in 2013 (FAOSTAT, 2015; AIS, 2015). Compare to other countries this production is not satisfactory. The country is mainly grower of mustard, which is actually banned for edible purpose in the EU, USA & Canada for its several health risks and thus importing oil drains a lot of money of the country for its rapid growing population to fulfill the ever rising demand.

Bangladesh has a great prospect of cultivating sesame to reduce its ever increasing demand of oil and to get enter into world market to earn foreign currency as its climatic and edaphic conditions are quite suitable for this crop production. Alleviation of some factors such as low yielding potentiality, disease susceptibility, poor crop management practices etc. may improve the condition of sesame production in Bangladesh. Releasing high yielding variety

(HYV) of sesame is a great option along with optimum crop management like plant spacing for above task.

Favourable production spacing is one of the most important crop management practices. Due to proper space, plant can achieve greater root growth, higher branching, superior harvesting of sunlight, better nutrition use efficiency and lower competition of the crop that is essential for remarkable yield of a plant. Asghar *et al.* (2009) found that seed yield increased with the increased row spacing from 30 to 45 cm. Avila and Graterol (2005) studied that the number of capsule per plant increased when the spacing is increased in sesame. Rahnama and Bakhshandeh (2006) found that, increased row spacing increased the capsules plant^{-1}, seeds capsules^{-1} and 1000 seeds weight.

Fr. Henri de Laulanié, S. J. in Madagaskar adopted system of rice intensification (SRI) on rice cultivation which was started in 1980 (Latham, 2012). It follows some rules; wider spacing is one of them, which implies row to row and plant to plant distances are equally maintained hence it can be said as square spacing. This square spacing shows advanced yield from the crop rather than rectangular planting (Daisy *et al*., 2013). This principle acted on increased yield up to 50% over conventional irrigated rice cultivation (WWF-ICRISAT, 2008).

After understanding the principle of SRI, now this method is testing on some other crops, therefore, it is called system of crop intensification (SCI), like-wheat, maize, sugarcane, mungbean, lentil, mustard etc. to increase yield with lowering seed rate. In India, applying SRI methods to mustard, increased yield up to 4 tons per hectare was documented (PRADAN, 2012). Considering the findings stated, a research proposal was designed to study if sesame is responsive to the system and the following objectives were fixed.

- To find out the varietal difference being imposed under square spacing system;
- To evaluate the effect of square spacing on the growth and yield of sesame and
- To determine the combined effect of variety and square spacing on the growth and yield of sesame.

CHAPTER 2

REVIEW OF LITERATURE

After a major breakthrough of increased rice production, implementing system of rice intensification (SRI), the principles were executed on other agronomic and horticultural crops to justify their adaptability. Massive successful results were found in India, Ethiopia, Mali, Cuba, Nepal etc. on a number of crops. However, sesame plant is not examined under this principle. So, in this chapter it is tried to realize how sesame responses to this system.

2.1 System of rice intensification (SRI)

2.1.1 Growth parameters

Duttarganvi *et al*. (2014) performed system of rice intensification (SRI) (25 cm × 25 cm) & normal traditional planting (NTP) (20 cm × 10 cm) and irrigation regimes on rice and observed higher plant height (71.9 cm) from SRI while short (67.2 cm) from NTP.

Mohanty *et al*. (2014) employed SRI (25 cm × 25 cm) and traditional random planting (TRP) in zigzag pattern on rice and obtained the tallest plant (141 cm) from SRI and the smallest (134 cm) from traditional form.

Duttarganvi *et al*. (2014) found the largest leaf area (318.9 cm^2) from SRI and the lowest (147.9 cm^2) from NTP.

2.1.2 Yield attributives

Omwenga *et al*. (2014) applied SRI (20 cm × 20 cm) and conventional rice cultivation method (10 cm × 10 cm) on rice and found higher tillers hill^{-1} (55) from SRI and lower (25) from conventional.

Mohanty *et al*. (2014) identified the superior number of tillers hill^{-1} (13) from SRI and inferior (9) from TRP (traditional random planting).

Duttarganvi *et al*. (2014) got the highest panicles hill^{-1} (25.8) from SRI and the lowest (12.5) from NTP (normal traditional planting).

Omwenga *et al*. (2014) attained higher panicles hill^{-1} (51) from SRI and lower (21) from conventional practice.

Mohanty *et al*. (2014) achieved the highest grains panicle^{-1} (115) from SRI and the lowest (109) from TRP (traditional random planting).

Singh *et al*. (2013) observed influence of SRI (25 cm × 25 cm) and conventional spacing (20 cm × 10 cm) on a scented rice variety Pusa sugandh 5 and got the highest grains panicle^{-1} (94.9) from SRI and the lowest (85.1) from conventional.

Duttarganvi *et al*. (2014) found the highest 1000 seed weight (21.6 g) from SRI and the lowest (19.4) from NTP .

2.1.3 Yields

Singh *et al*. (2014) acquired that SRI showed the highest seed yield (3.3 t ha^{-1}) with SRI over conventional spacing (2.3 t ha^{-1}).

Duttarganvi *et al*. (2014) observed 46.23 % higher yield from SRI than NTP.

Chapagain *et al*. (2011) disagreed with SRI (30 cm × 30 cm) under organic and inorganic condition on rice when comparing with conventional (30 cm × 18 cm) obtaining higher yield (6.7 t ha^{-1}) over SRI (6.3 t ha^{-1}).

Singh *et al*. (2013) detected SRI given the highest straw yield (4.4 t ha^{-1}) while conventional spacing showed the lowest (3.9 t ha^{-1}).

Chapagain *et al*. (2011) marked conventional system for top yield of straw (6.5 t ha^{-1}) and SRI, the poor (4.9 t ha^{-1}).

Singh *et al*. (2013) observed the highest harvest index (43 %) from SRI and the lowest (36.8 %) from conventional.

Chapagain *et al*. (2011) discovered SRI as for highest HI (54 %) and conventional the lowest (52.6 %).

2.2 System of crop intensification (SCI)

2.2.1 Cereal crop

The principles of system of crop intensification applied on several cereal crops in different countries. In India, 60-80% increased yield was found in wheat under unirrigated rainfed condition against their conventional practice (Chopra and Sen, 2013) and a NGO PRADAN got average yield of 5.1 t ha^{-1} with SCI (Behera *et al*., 2013). In Nepal, small farmers got 91% more yield (6.5 t ha^{-1}) where the local was 3.4 t ha^{-1}, 75 grains $panicle^{-1}$ (local was 44 grains $panicle^{-1}$) (Khadaka and Raut, 2012). In Mali highest yield was (5.4 t ha^{-1}) obtained from square spacing 15 cm × 15 cm (Styger, 2010).

Finger millet showed higher yield 3.75 – 5 t ha^{-1} with 45 cm × 45 cm (The green foundation, 2006), while an elderly lady of Ethiopia produced 7.8 t ha^{-1}, from the usual broadcasting of 1.4 t ha^{-1} (Araya *et al*., 2013).

In India significant result was found from maize over control. 40 cm × 40 cm gave 6.5 t ha^{-1} than traditional 2.3 t ha^{-1}, 192 cm plant height versus 155 cm and 356 grains cob^{-1} vs. 191 grains cob^{-1} (Abraham *et al*., 2014).

2.2.2 Pulse crop

Under the investigation of a NGO with SCI, 65% increased yield was found in lentil and 42% in peas. In case of blackgram they found the yield 1.4 t ha^{-1}, where the conventional was 850 kg ha^{-1} (Abraham *et al*., 2014).

Mungbean showed 1.875 t ha^{-1} yield against the local practise yield 625 kg ha^{-1} (AKRSP-I, 2013).

Pigeonpea gave 70% increased yield with 1.5 t ha^{-1} from the usual 875 kg ha^{-1} (AMEF, 2011) and 200 pods $plant^{-1}$ whereas the local showed 50-100 pods $plant^{-1}$ (Anon., 2013).

Soybean when utilized as pulse crop, gave 83% higher yield, 4.2 times more branches $plant^{-1}$, 3.7 times more pods $plant^{-1}$ and 4.3 times more seeds $plant^{-1}$ (AKRSP-I, 2013).

2.2.3 Oilseed crop

Mustard crop showed encouraging results with SCI. Under SCI, 30 cm × 30 cm up to 75 cm × 75 cm spacing reduced 95% seed rate against traditional when 8 to 20 branches $plant^{-1}$, 150- 300 g seed weight $plant^{-1}$ and 2.9 – 4.9 t ha^{-1} yield with SCI were obtained and these were significantly greater than traditional method (PRADAN, 2012).

2.3 Effect of spacing on sesame

2.3.1 Growth parameters

2.3.1.1 Plant height (cm)

Nadeem *et al*. (2015) had undertaken an experiment for estimating the response of sesame to planting geometry and water regimes. The highest plant height (99.89 cm) was recorded from higher spacing (30 cm × 20 cm) and the shortest plant (92.44cm) from closer plants in a row (60 cm × 10 cm).

Agele *et al*. (2015) applied sowing date and population density on sesame in Savana of Nigeria. They found the tallest plant (172.00 cm) from the shorter area plant^{-1} (90 cm × 30 cm) and the shortest (161.16 cm) from the larger area plant^{-1} (60 cm × 60 cm).

Ngala *et al*. (2013) studied inter-row spacing and plant spacing on sesame and reported that the tallest plant was (136.2 cm) obtained from wider spacing (75 cm × 25 cm) and the shortest (115.2 cm) from narrower spacing (25 cm × 25 cm).

Hossain (2009) used nitrogen and plant population on sesame and found increased plant height with increased population. The highest plant height (115.17 cm) was obtained from closer spacing (30 cm × 5 cm) and the shortest (100.50 cm) from wider spacing (30 cm × 20 cm).

2.3.1.2 Leaves plant^{-1} (no.)

Agele *et al*. (2015) investigated that higher leaves plant^{-1} (363.83) found from shorter area plant^{-1} (60 cm × 30 cm) and lower (338.50) from wider area plant^{-1} (60 cm × 60 cm).

Jakusko *et al*. (2013) examined effect of row spacing on sesame and reported that wider area plant^{-1} (60 cm × 15 cm) gave higher leaves plant^{-1} (17.00) and narrower area plant^{-1} (75 cm × 10 cm) showed higher leaves plant^{-1} (14.33).

Ahmmad (2010) studied weeding frequency and population density on sesame and found higher distance from plant to plant (20 cm) produced highest leaves plant^{-1} (30.48) and closer distance (5 cm) showed the lowest (25.82) at 60 days after sowing.

2.3.1.3 Leaf area plant^{-1} (cm^2)

Umar *et al*. (2012) examined the effect of nitrogen and intra row spacing on sesame and found that higher leaf area plant^{-1} was (1129 cm^2) practical with broader intra row spacing of 15 cm and the lowest was (1004 cm^2) from narrower of 5 cm at 12 weeks after sowing.

2.3.1.4 Leaf area index

Umar *et al*. (2012) reported higher leaf area index (5.32) from narrow intra row spacing (5 cm) and the lowest was (2.00) from wider spacing (15 cm) at 12 weeks after sowing.

Sivagamy and Rammohan (2013) investigated sowing date and crop spacing on sesame and identified that the narrowest spacing (15 cm × 10 cm) gave the highest LAI (2.21).

Alim (2009) studied population density and source-sink manipulation on sesame and observed higher population density (50 plants m^{-2}) resulted in superior LAI (1.78) and lower density (30 plants m^{-2}) gave inferior LAI (1.475) at 60 days after sowing.

Haruna (2011) studied row spacing and nitrogen doses on sesame and observed that higher LAI was (0.62) given by broader row spacing (30 cm), whereas the lower (0.39) from constricted spacing (7.5 cm).

2.3.1.5 Above ground dry matter weight plant^{-1} (g)

Haruna (2011) found that higher dry matter plant^{-1} of sesame (32.48 g) from wider row spacing (35 cm) and lower (19.44 g) from narrower (5 cm).

Ahmmad (2010) obtained the highest dry matter weight plant^{-1} (22.30 g) of sesame from broader plant to plant distance (20 cm) and the lowest (18.00 g) from narrower distance (5 cm) at harvest.

Agele *et al*. (2015) expressed from their experiment that higher biomass of sesame was (32.36 g) recorded from narrower area plant^{-1} (60 cm × 30 cm) and lower (30.45 g) from wider area (90 cm × 30 cm).

2.3.1.6 Crop growth rate (g m^{-2} d^{-1})

Umar *et al*. (2012) reported that the highest crop growth rate (78.6 g m^{-2} d^{-1}) was obtained from narrower row spacing of 5 cm and the lowest (47.4 g m^{-2} d^{-1}) was from wider spacing (15 cm) at 10 weeks after sowing.

Alim (2009) with 40 plant m^{-2} found highest CGR (4.81 g m^{-2} d^{-1}), whereas 30 plant m^{-2} showed the lowest (4.29 g m^{-2} d^{-1}) at 40-50 days after sowing.

2.3.2 Yield attributes

2.3.2.1 Branches plant^{-1} (no.)

Nadeem *et al*. (2015) inspected that wider spacing (45 cm × 15 cm) provided higher branches plant^{-1} (15.67) and narrower (30 cm × 20 cm) showed lower number (12.22).

Sivagamy and Rammohan (2013) recognized that primary and secondary branches plant^{-1} were (157% and 148%, respectively) increased with 45 cm × 15 cm over narrower spacing 15 cm × 10 cm at harvest stage.

Karim (2008) studied sowing date and population density on sesame and found wider spacing (30 cm × 20 cm) gave the highest branches plant^{-1} (4.93) and closer spacing (30 cm × 5 cm) harvested the lowest number (3.67).

2.3.2.2 Capsules plant^{-1} (no.)

Jan *et al*. (2014) conducted an experiment of phosphorus level and row spacing on sesame and found that 60 cm row spacing showed higher capsules plant^{-1} (81) and with 30 cm lower (45).

Shekh *et al*. (2012) reported that 45 cm × 10 cm produced higher capsules plant^{-1} (47.4) over broadcasting system (37.2).

Hossain (2009) observed wider spacing (30 cm × 20 cm) obtained higher capsules plant^{-1} (79.38) and closer spacing (30 cm × 5 cm) gave lower number (42.54).

Ali *et al*. (2005) investigated the effect of row spacing and sowing date on sesame and described that row spacing of 45 cm showed higher capsules plant^{-1} (40.23) from the 60 cm of 33.87.

2.3.2.3 Seeds capsule^{-1} (no.)

Nadeem *et al*. (2015) stated that wider spacing (45 cm × 15 cm) confirmed the highest seeds capsule^{-1} and narrower spacing (30 cm × 20 cm) gave the lowest (47).

Jan *et al*. (2014) inspected that higher row spacing (60 cm) provided the highest seeds capsule^{-1} (56) and lowest (45) from narrower spacing (30 cm).

Sivagamy and Rammohan (2013) reported that 45 cm × 15 cm treatment resulted 11% more seeds capsule^{-1} over 15 cm × 10 cm spacing.

Hossain (2009) obtained the highest capsules plant^{-1} (79.38) from wider spacing (30 cm × 20 cm) and the lowest value (42.54) from closer spacing (30 cm × 5 cm).

2.3.2.4 1000 seed weight (g)

Jan *et al*. (2014) informed that 1000 seed weight was found heavier (3.42 g) with 60 cm row spacing and lighter (3.03 g) from 30 cm.

Jakusko *et al*. (2013) found that wider spacing (60 cm × 15 cm) had higher 1000 seed weight (2.64 g) and narrower spacing (75 cm × 10 cm) showed lower weight (2.60 g).

Tanjila (2008) employed nitrogen and spacing on sesame and identified that 30 cm × 10 cm (wider) gave bold seed (3.58 g) and 40 cm × 5 cm (narrower) gave light weight (3.23 g).

Ali *et al*. (2005) found that there was no significant difference of 1000 seed weight with different row spacing.

2.3.2.5 Seed weight plant^{-1} (g)

Nadeem *et al*. (2015) found higher seed weight plant^{-1} (31.49 g) from spacious plant (45 cm × 15 cm) when narrower (30 cm × 20 cm) registered 27.11 g.

Ngala *et al*. (2013) reported that wider spacing (50 cm × 25 cm) confirmed higher seed weight plant^{-1} (13.42 g) and narrower spacing (25 cm × 25 cm) showed lower value (12.91 g).

Agele *et al*. (2015) observed the highest seed weight plant^{-1} (25.60 g) from 60 cm × 30 cm (narrower) and lower weight (23.71 g) from 90 cm × 30 cm (wider).

2.3.2.6 Stover weight plant^{-1} (g)

Ngala *et al*. (2013) found that broader spacing (75 cm × 25 cm) gave highest stover weight plant^{-1} (29.45 g) and the narrower spacing (25 cm × 25 cm) showed lowest weight (11.16 g).

2.3.3 Yields

2.3.3.1 Seed yield (kg ha^{-1} or t ha^{-1})

Nadeem *et al*. (2015) concluded that spaced plant (45 cm × 15 cm) had opportunity to use resources comfortably thus registered greater seed yield (742.33 kg ha^{-1}) over dense populated plant (30 cm × 20 cm).

Jan *et al*. (2014) observed higher seed yield (681 kg ha^{-1}) with broader row spacing (60 cm) and narrower spacing (30 cm) gave the lowest (484 kg ha^{-1}).

Jakusko *et al*. (2013) recorded the highest seed yield (561.13 kg ha^{-1}) from larger spacing of 60 cm × 15 cm and lower from closer (60 cm × 10 cm) one.

Ngala *et al*. (2013) explored the top (459 kg ha^{-1}) yielder was 50 cm × 25 cm (narrow spaced) whereas the low (436 kg ha^{-1}) yielder was 75 cm × 25 cm (wider spaced).

Ahmmad (2010) found closer plant to plant distance (5 cm) gave the highest yield (0.94 t ha^{-1}) and broader plant to plant distance (20 cm) showed the lowest yield (0.713 t ha^{-1}).

Alim (2009) obtained highest yield (1445.65 kg ha^{-1}) from 40 plants m^{-2} and 50 plant m^{-2} showed the lowest (1205.29 kg ha^{-1}) result.

Karim (2008) observed that crowded population (30 cm × 5 cm) gave higher yield (1.54 t ha^{-1}) and spaced plant (30 cm × 20 cm) showed lower yield (0.94 t ha^{-1}).

2.3.3.2 Biological yield (kg ha^{-1} or t ha^{-1})

Nadeem *et al*. (2015) estimated higher biological yield (2301.23 kg ha^{-1}) from broader spacing (45 cm × 15 cm) and the lowest (2208.58 kg ha^{-1}) from closer spacing (30 cm × 20 cm).

Ali *et al*. (2005) reported that wider row spacing (45 cm) gave the highest biological yield (3.88 t ha^{-1}) and lowest value (3.72 t ha^{-1}) with narrower (30 cm).

Tanjila (2008) obtained that closer spacing (30 cm × 10 cm) gave highest biological yield (1961 kg ha^{-1}) and wider spacing (40 cm × 10 cm) had lowest yield (1669 kg ha^{-1}).

2.3.3.3 Harvest index (%)

Jan *et al*. (2014) observed highest harvest index (16.23 %) from 60 cm row spacing and the lowest (15.44 %) from 30 cm.

Ali *et al*. (2005) found row spacing 45 cm had highest harvest index value (26.78 %) when 30 cm showed the lowest (20.80 %) which was statistically at par with 60 cm (21.21 %).

Alim (2009) recorded highest HI (37.98 %) from 30 plants m^{-2} and the lowest (32.87 %) from 50 plants m^{-2}.

Karim (2008) observed highest harvest index (24.66 %) from 30 × 5 cm and the lowest (23.25 %) from 30 cm × 20 cm.

Tanjilla (2008) recorded highest HI (52.76 %) with 40 cm × 10 cm and lowest (46.08 %) from 30 cm × 5 cm.

Caliskan *et al*. (2004) obtained highest harvest index (20.5 %) with higher population (510,000) and lowest value (17.3 %) with lower population (102,000).

CHAPTER 3

MATERIALS AND METHODS

The field trial of sesame varieties under different square spacings was carried out in *kharif-1* season at the Agronomy field of Sher-e-Bangla Agricultural University, Dhaka-1207 from March, 2015 to June, 2015.

3.1 Site of experiment

3.1.1 Geographical location

The experimental site was located at 23º41' N latitude and 90º 22' E longitude at a height of 8.6 m above the mean sea level.

3.1.2 Agro-ecological location and soil

The experimental site belongs to “Modhupur Tract”, the agro-ecological zone referred as AEZ 28. It showed deep brown terrace soil developed from the Modhupur clay. The soil of the experimental site possesses red brown terrace belongs to Tejgaon series.

3.1.3 Climate

The subtropical nature of the experimental site induced heavy rainfall during *kharif-I* season (April-June). The average monthly air temperature (ºC), precipitation (mm) and relative humidity (%) were taken from March, 2015 to June, 2015 and presented in Appendix-I. The maximum temperatures were 32, 34, 33 and 32 ºC from March, 2015 to June, 2015, respectively and the minimum were 20, 23, 34 and 26 ºC from March, 2015 to June, 2015, respectively. Total rainfall from March, 2015 to June, 2015 were 610 mm, 1370 mm, 2450 mm and 3150 mm, respectively. Relative humidity from March, 2015 to June, 2015 were 65 %, 74 %, 75 % and 82 %, respectively.

3.2 Materials of experiment

3.2.1 Plant materials

Three sesame varieties, Binatil-2 collected from Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh and BARI Til-3 and BARI Til-4 from Bangladesh Agricultural Research Institute (BARI), Joydebpur.

3.2.2 Fertilizers

Urea, TSP, MoP, Gypsum, Zinc sulphate and Boric acid were collected from the Farm of SAU, Dhaka-1207.

3.3 Varietal description of experiment

3.3.1 Binatil-2

Binatil-2 is tolerant to temporary water-logged and resistant to caterpillar infestation which is released in 2011. This variety is branched, less hairy stem-leaf-capsules with light black seed coat color. Each node contains 3-5 large capsules. It can be grown in *kharif-1* (mid February to mid March) season. Maturity period ranges from 86-92 days. It can be grown in high land and sandy loam type soil. It produces maximum seed yield of 1.8 t/ha. The seed contains 44.0% oil. This variety can be cultivated all over the country.

3.3.2 BARI Til-3

This variety is released in 2002, can be cultivated in *kharif-1* season. The plant is 100-110 cm long, seed is reddish brown, leaves dark green and rough, flowers pale white, branch number varied from 3-5, capsules plant^{-1}

ranged from 60-65 with 4 chambers. It can give maximum seed yield of 1.2-1.4 t ha^{-1} with 43-44 % oil content.

3.3.3 BARI Til-4

This variety is released in 2009, can be cultivated in *kharif-1* season. The plant is 90-100 cm long; seed is reddish brown, leaves green and rough, flowers whitish pink, branch number varied from 3-5, capsules $plant^{-1}$ ranged from 85-90 with 8 chambers. This plant is tolerant to stem rot disease. It can give maximum seed yield of 1.4-1.5 t ha^{-1} with 43-44 % oil content.

3.4 Design and layout of the experiment

The experiment was laid in split-plot design with three replications, where varieties were assigned to main plots and square spacing to sub-plots. 15 treatment combinations were used; hence there were 45 plots of 2.5 m × 1.5 m each plot. Row to row and plant to plant distance were maintained according to treatment. The gaps between plot to plot and replication to replication were 0.5 m and 1.5 m, respectively.

3.5 Treatments of experiment

The experiment was consisted of two factors which were mentioned below:

Factors:

A. **Variety:**

V_1 = Binatil – 2
V_2 = BARI Til – 3
V_3 = BARI Til – 4

B. Square spacing system:

S_1= 30 cm × 5 cm (control)

S_2= 20 cm × 20 cm

S_3= 30 cm × 30 cm

S_4= 40 cm × 40 cm

S_5= 50 cm × 50 cm

3.6 Treatment combination of experiment

15 treatment combinations were:

V_1S_1	V_2S_1	V_3S_1
V_1S_2	V_2S_2	V_3S_2
V_1S_3	V_2S_3	V_3S_3
V_1S_4	V_2S_4	V_3S_4
V_1S_5	V_2S_5	V_3S_5

3.7 Preparations of experiment

3.7.1 Land preparation

The experimental plot was opened on March 20, 2015 using a power tiller to plough and cross-plough the land several times to get a desirable tilth. The land was then prepared by removing the weeds, stubbles and crop residues. The layout of the experiment was done according to the design.

3.7.2 Fertilization

Half of urea and total of other fertilizers were applied during final land preparation. Rest half of urea was applied at 36 DAS.

3.7.3 Sowing of seed

Seeds were sown on March 25, 2016 in 3 cm deep furrows made by hand iron tine. After placement of seed in the furrow, seeds were covered with soil by hand.

3.8 Intercultural operations of experiment

3.8.1 Irrigation and drainage

After sowing of seeds irrigation was given to ensure maximum germination. Considering the soil composition of the plot several irrigations were given to ensure the best growth of the plants. Well drainage was ensured for no water stagnation in the field.

3.8.2 Weeding, thinning and mulching

Two weeding were done at 15 DAS and 29 DAS. Thinning was done 23 DAS to maintain the plant to plant distance according to the square planting treatment. Several mulching were done to break down crust of soil after rainfall.

3.8.3 Pest management

To mitigate the insect attack on the crop, Ripcord 10EC @ 1 ml $litre^{-1}$ was applied to the crop at 40 DAS by knapsack sprayer.

3.8.4 Harvest and post harvest operations

After observing 80 % matured capsules on the plant, the harvesting was done. Due to the early growth, V_2 and V_3 were harvested earlier at 76 DAS and then V_1 at 79 DAS. Harvested plants were tied together according to the treatment and brought to the threshing floor and sundried capsules were separated. Seeds were then separated from the dried capsules and then collected according to the treatment.

3.9 Sample collection of experiment

10 plants were selected from each plot to get various types of data from 25 days after emergence (DAE) to harvest at an interval of 15 days. 5 plants $plot^{-1}$ were taken as destructive sample to record their sample dry weight. Data were recorded on the following parameters:

Crop growth parameters

i. Plant height (cm)

ii. Leaves $plant^{-1}$ (no.)

iii. Leaf area $plant^{-1}$ (cm^2)

iv. Leaf area index (LAI)

v. Above ground dry matter weight $plant^{-1}$ (g)

vi. Crop growth rate ($g\ m^{-2}\ d^{-1}$)

vii. Relative growth rate ($g\ g^{-1}\ d^{-1}$)

viii. Net assimilation rate ($g\ cm^{-2}\ d^{-1}$)

Yield attributes

i. Branches $plant^{-1}$ (no.)

ii. Capsules $plant^{-1}$ (no.)

iii. Seeds $capsule^{-1}$ (no.)

iv. 1000 seed weight (g)

v. Seed weight $plant^{-1}$ (g)

vi. Stover weight $plant^{-1}$ (g)

Yields

i. Seed yield (t ha^{-1})

ii. Biological yield (t ha^{-1})

iii. Harvest index (%)

3.10 Data recording of experiment

3.10.1 Crop growth parameters

3.10.1.1 Plant height (cm)

Ten plants were randomly selected from each plot. The height of those plants measured from the base level to the tip of the plant by measuring scale at 25, 40, 55 and 70 (DAE). The average of heights was determined.

3.10.1.2 Leaves $plant^{-1}$ (no.)

The number of leaves of ten plants was counted at 25, 40, 55 and 70 (DAE). The average number was calculated.

3.10.1.3 Leaf area (cm^2)

Leaf area was measured from the five destructive samples at 25, 40, 55 and 70 DAE by placing the separated leaves on the Leaf area meter. The mean was calculated.

3.10.1.4 Leaf area index (LAI)

Leaf area index was calculated at 25, 40, 55 and 70 DAE according to the following formula (Hunt, 1981).

$$\text{Leaf area index} = \frac{\text{Leaf area plant}^{-1}\ (\text{cm}^2)}{\text{Ground coverage plant}^{-1}\ (\text{cm}^2)}$$

3.10.1.5 Above ground dry matter weight plant^{-1} (g)

Randomly selected five destructive plants were collected from each plot at 25, 40, 55 and 70 DAE to determine their dry matter weight by placing them in separate packets in oven maintaining 70ºC for 72 hours. Separate weights were taken from leaf, stem and capsules and the mean was expressed in gram.

3.10.1.6 Crop growth rate (CGR)

Crop growth rates were calculated at different growth stages according to the following formula (Radford, 1967).

$$CGR = \frac{1}{GA} \times \frac{W_2 - W_1}{T_2 - T_1} \text{ g m}^{-2}\text{ d}^{-1}$$

Where, W_1= Total dry matter production at previous sampling date

W_2= Total dry matter production at current sampling date

T_1= Date of previous sampling

T_2= Date of current sampling

GA= Ground area (m^2)

3.10.1.7 Relative growth rate (RGR)

Relative growth rates were calculated at different growth stages according to the following formula (Brown, 1984).

$$RGR = \frac{\text{Log}_e W_2 - \text{Log}_e W_1}{T_2 - T_1} \text{ g g}^{-1}\text{ d}^{-1}$$

Where, W_1= Total dry matter production at previous sampling date

W_2= Total dry matter production at current sampling date

T_1= Date of previous sampling

T_2= Date of current sampling

Log_e= Natural logarithm

3.10.1.8 Net assimilation rate (NAR)

Net assimilation rates were calculated at different growth stages according to the following formula (Williams, 1946).

$$NAR = \frac{LN\ LA_2 - LN\ LA_1}{LA_2 - LA_1} \times \frac{W_2 - W_1}{T_2 - T_1} \quad g\ cm^{-2}\ d^{-1}$$

Where, LA_1 = Leaf area at previous sampling date

LA_2 = Leaf area at current sampling date

W_1= Total dry matter production at previous sampling date

W_2= Total dry matter production at current sampling date

T_1= Date of previous sampling

T_2= Date of current sampling

LN= Natural logarithm

3.10.2 Yield attributivs

3.10.2.1 Branches plant^{-1} (no.)

Branches plant^{-1} was recorded from the ten randomly selected sample plants at 40, 55 and 70 DAE.

3.10.2.2 Capsules plant^{-1} (no.)

Capsules plant^{-1} was recorded from the ten randomly selected sample plants at 40, 55 and 70 DAE and at harvest.

3.10.2.3 Seeds capsule^{-1} (no.)

Seeds capsule^{-1} was recorded from twenty randomly selected sun-dried capsules of each treatment after harvest.

3.10.2.4 1000 seed weight (g)

1000 seeds were counted from the seed stock of each plot at harvest and then the weight was measured by an electrical balance. It was recorded in gram (g).

3.10.2.5 Seed weight plant^{-1} (g)

Seed weight was measured by an electrical balance from the harvested capsules. Then the average was recorded in gram (g).

3.10.2.6 Stover weight plant^{-1} (g)

Stover weight was measured by an electrical balance from the harvested crop. It was then averaged and recorded in gram (g).

3.10.3 Yields

3.10.3.1 Seed yield (t ha^{-1})

Seed weight was recorded from 2 m^2 preselected area of each plot and converted into t ha^{-1}.

3.10.3.2 Biological yield (t ha^{-1})

Biological yield was determined by adding economic yield and stover yield.

Biological yield = Economic yield + Stover yield

3.10.3.3 Harvest index (%)

Harvest index is the ratio between economic yield and biological yield and expressed in percentage (%).

$$\text{Harvest index (\%)} = \frac{\text{Economic yield (t ha}^{-1}\text{)}}{\text{Biological yield (t ha}^{-1}\text{)}} \times 100$$

3.11 Statistical analysis of data of experiment

The data obtained from different parameters were statistically analyzed using the analysis of variance (ANOVA) following computer based software Statistix 10 and the least significance difference (LSD) was tested at 5% probability level to compare the treatments means differences. Correlation and regression analysis was done and tested with 5% and 1% level of significance.

CHAPTER 4

RESULTS AND DISCUSSION

The results of different data on crop growth parameters, yield attributes and yields of sesame under square spacing method are discussed in this chapter. To ease the understanding the results have been presented through graphs, tables and discussed.

4.1 Crop growth parameters

4.1.1 Plant height (cm)

4.1.1.1 Effect of variety

Effect of different variety on plant height showed significant difference at earlier days. At 25 and 40 DAE, the highest plant heights (30.48 cm and 88.83 cm, respectively) were recorded from BARI Til – 3 (V_2), which were statistically similar (28.67 cm, 86.98 cm, respectively) with BARI Til – 4 (V_3) and the shortest were (22.08 cm and 78.14 cm, respectively) from Binatil – 2 (V_1). But at 55 and 70 DAEs plant heights among three varieties were not significantly different. Effect of different variety on plant height is presented in Figure 1.

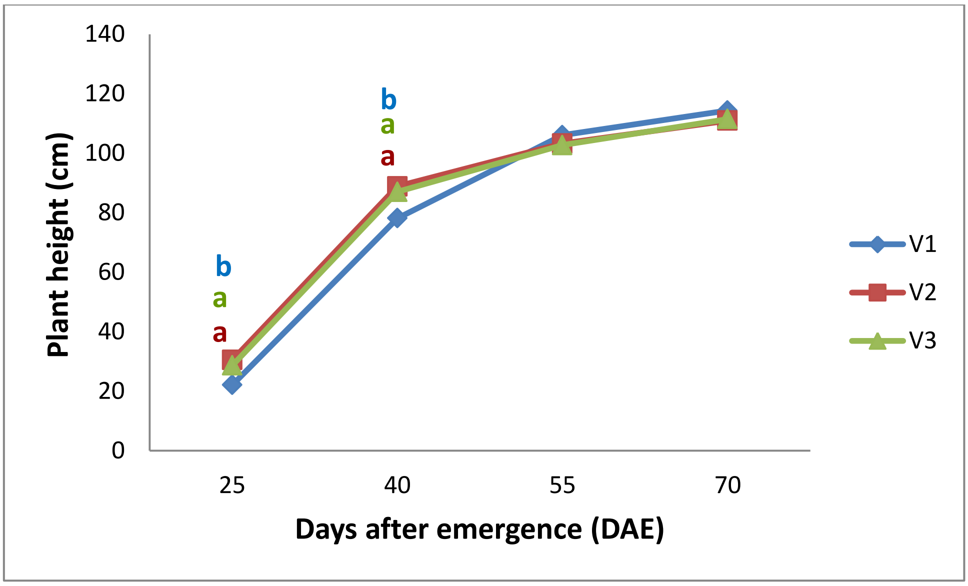

Figure 1. Effect of variety on plant height of sesame at different DAE ($LSD_{0.05}$ = 3.14, 7.83, NS and NS at 25, 40, 55 and 70 DAE, respectively)

V_1= Binatil-2, V_2= BARI Til-3 and V_3= BARI Til-4

4.1.1.2 Effect of square spacing system

Various plant heights were observed with various square spacing systems. The longest plant heights (30.11 cm, 90.08 cm, 113.49 cm and 119.66 cm) were recorded from 50 cm × 50 cm (S_5) at 25, 40, 55 and 70 DAE, respectively, which showed statistical similarity at 40 DAE (88.13 cm and 84.51 cm) with 40 cm × 40 cm (S_4) and 30 cm × 30 cm (S_3), respectively; at 55 DAE (111.51 cm) with 40 cm × 40 cm (S_4) and at 70 DAE (118.84 cm and 114.46 cm) with 40 cm × 40 cm (S_4) and 30 cm × 30 cm (S_3), respectively. The shortest plant height at 25 DAE was (25.32 cm) taken from 30 cm × 30 cm (S_3), which was statistically similar (26.55cm, 26.66 cm and 26.67 cm) with

20 cm × 20 cm (S_2), 30 cm × 5 cm (S_1) and 40 cm × 40 cm (S_4), respectively. At 40 DAE the minimum plant height (79.93 cm) was seen from 20 cm × 20 cm (S_2) which was statistically similar (80.60 cm and 84.51 cm) with 30 cm × 5 cm (S_1) and 30 cm × 30 cm (S_3), respectively. At 55 and 70 DAE the shorter plants (94.64 cm and 102.02 cm, respectively) were acquired from 30 cm × 5 cm (S_1), which were statistically comparable (94.66 cm and 102.86 cm, respectively) with 20 cm × 20 cm (S_2).

Generally it is found that crowded population adjusted themselves to the tendency for sunlight harvesting resulted longest height, but in this research the tallest plant was obtained from wider square planting, it may be due to the lower plant competition for resources of this lesser population ensured their vigorous growth (Caliskan *et al*. 2004). Similar observations also found by Ngala *et al*. (2013) and Sivagamy & Rammohan (2013). Contrast also found with Agele *et al*. (2015), because of the tendency of the plants of massive population to intercept higher light. Again Avila *et al*. (1994) found that plant height depends on genetic makeup and fertility of soil, so row spacing had no significance on plant height. Effect of different square spacing system on plant height is presented in Figure 2.

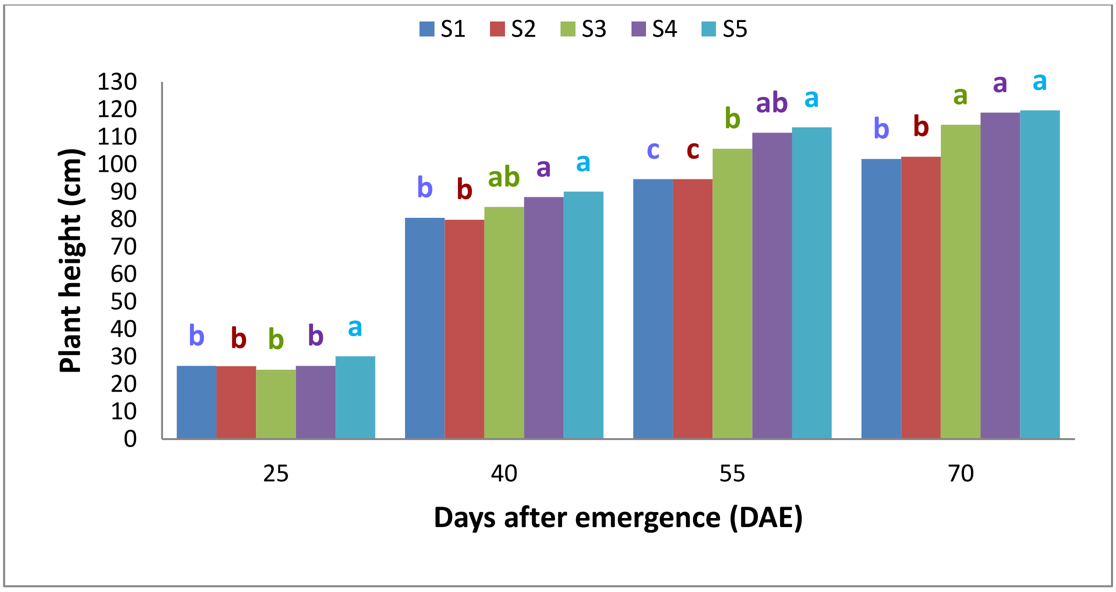

Figure 2. Effect of square spacing system on plant height of sesame at different age ($LSD_{0.05}$ = 1.84, 6.65, 7.07 and 6.93 at 25, 40, 55 and 70 DAE, respectively)

S_1= 30cm × 5cm (Control), S_2= 20cm × 20cm, S_3= 30cm × 30cm, S_4= 40cm × 40cm, S_5= 50cm × 50cm

4.1.1.3 Combined effect of variety and square spacing system

Combined effect of variety and square planting showed variant remark through different DAE. At 25 and 40 DAE the tallest plant (32.33 cm and 98.60 cm, respectively) were found from V_2S_5 combination, which was statistically similar at 25 DAE (31.67 cm, 30.66 cm, 29.60 cm, 29.00 cm and 29.00 cm) with V_2S_1, V_3S_5, V_2S_2, V_3S_1 and V_3S_2, respectively; at 40 DAE (90.07 cm, 89.77 cm, 88.23 cm, 88.03 cm, 87.53 cm and 86.10 cm) with V_2S_4, V_3S_5, V_3S_4, V_3S_3, V_2S_1 and V_1S_4, respectively. The shortest heights (19.32 cm and 69.50 cm) were obtained from V_1S_1 at 25 and 40 DAE, respectively, which showed statistical similarity at 25 DAE (20.65 cm, 21.00 cm and 22.00 cm) with V_1S_3, V_1S_2 and V_1S_4, respectively; at 40 DAE (70.60 cm) with V_1S_2; it may be due to the initial lower growth of Binatil – 2 (V_1). Then at 55 DAE V_1S_5 given the tallest plant (119.63 cm) which was statistically at par (116.73 cm, 114.13 cm, 112.57 cm, 109.7 cm, 108.13 cm and 106.70 cm) with V_1S_4, V_2S_5, V_1S_3, V_2S_4, V_3S_4 and V_3S_5, respectively and V_1S_2 showed the shortest height (90.50 cm) which was statistically similar (90.83 cm, 94.90 cm, 96.27 cm, 96.83 cm, 98.57 cm, 101.23 cm and 103.33 cm) with V_1S_1, V_2S_2, V_2S_1, V_3S_1, V_3S_2, V_2S_3 and V_3S_3, respectively; it may happen due to the vital growth of the wider spaced plant and poorer from the closer spaced at later phases of growth. At 70 DAE the largest plant height (126.20 cm) was recorded from V_1S_4 which was statistically similar (124.73 cm, 121.70 cm, 121.47 cm, 116.17 cm, 114.16 cm, 113.07 cm and 112.77 cm) with V_1S_5, V_1S_3, V_2S_5, V_3S_4, V_2S_4, V_3S_3 and V_3S_5, respectively and the lowest (94.17 cm) was from V_1S_1 which was statistically similar (94.70 cm, 104.97 cm, 105.57 cm and 106.33 cm) with V_1S_2, V_2S_2, V_2S_1 and V_3S_1, respectively. Combined effect of variety and square spacing system on plant height is presented in Table 1.

Table 1. Combined effect of variety and square spacing system on plant height of sesame at different days

Treatment	Plant height (cm)			
	25 DAE	40 DAE	55 DAE	70 DAE
V_1S_1	19.32 c	69.50 d	90.83 f	94.17 e
V_1S_2	21.00 c	70.60 cd	90.50 f	94.70 de
V_1S_3	20.65 c	82.63 bc	112.57 a-c	121.70 ab
V_1S_4	22.00 c	86.10 ab	116.73 ab	126.20 a
V_1S_5	27.33 b	81.87 bc	119.63 a	124.73 ab
V_2S_1	31.67 ab	87.53 ab	96.27 ef	105.57 c-e
V_2S_2	29.60 ab	85.10 b	94.90 ef	104.97 c-e
V_2S_3	28.00 b	82.87 bc	101.23 c-f	108.60 b-d
V_2S_4	30.67 ab	90.07 ab	109.67 a-d	114.16 a-c
V_2S_5	32.33 a	98.60 a	114.13 ab	121.47 ab
V_3S_1	29.00 ab	84.77 b	96.83 d-f	106.33 c-e
V_3S_2	29.00 ab	84.10 b	98.57 c-f	108.90 bc
V_3S_3	27.32 b	88.03 ab	103.33 b-f	113.07 a-c
V_3S_4	27.30 b	88.23 ab	108.13 a-e	116.17 a-c
V_3S_5	30.66 ab	89.77 ab	106.70 a-e	112.77 a-c
$LSD_{0.05}$	4.2	12.82	14.69	14.09
CV%	6.99	8.07	6.99	6.39

**In each column, figures having similar letters or without letters do not differ significantly, where as figures bearing dissimilar letter differ significantly at 5% level of probability.

Variety:
V_1 = Binatil - 2
V_2 = BARI Til - 3
V_3 = BARI Til - 4

Square spacing system:
S_1= 30 cm × 5 cm (Control)
S_2= 20 cm × 20 cm
S_3= 30 cm × 30 cm
S_4= 40 cm × 40 cm
S_5= 50 cm × 50 cm

4.1.2 Leaves plant^{-1} (No.)

4.1.2.1 Effect of variety

At 25 and 40 DAE three varieties showed non-significant effect on leaves plant^{-1}. Then at 55 and 70 DAE V_1 showed the highest numbers of leaves plant^{-1} (92.71 and 47.94, respectively), here at 70 DAE the statistical similarity was (46.56) observed with V_2; whereas the lowest values (81.50 and 42.91, respectively) were from V_3, which were statistically at par (82.47 and 46.56, respectively) with V_2. The number of leaves plant^{-1} was reduced at 70 DAE due to natural leaf senescence. Effect of variety on leaves plant^{-1} is presented in Figure 3.

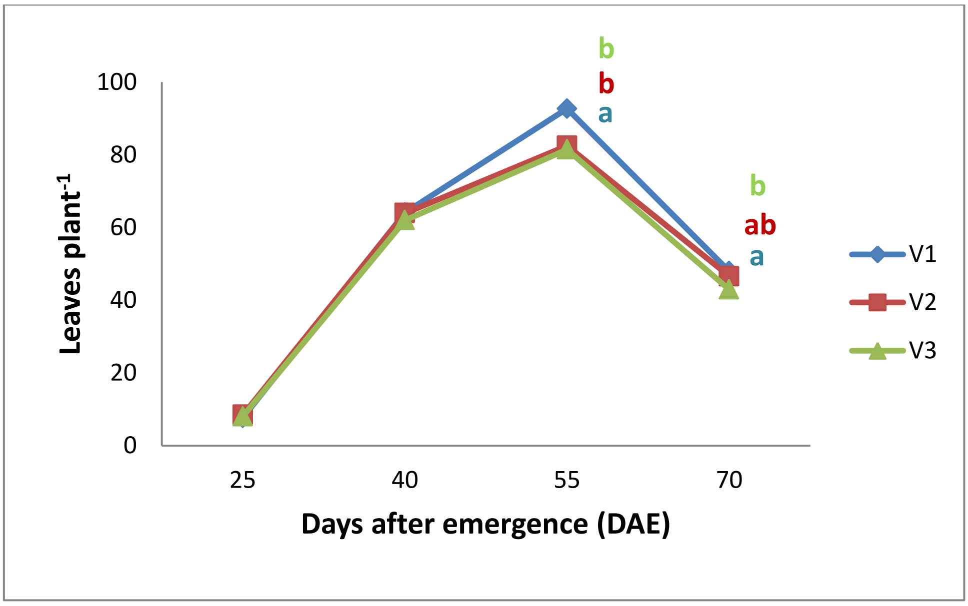

Figure 3. Effect of variety on leaves plant^{-1} of sesame at different age ($LSD_{0.05}$ = NS, NS, 8.44 and 4.84 at 25, 40, 55 and 70 DAE, respectively)

V_1= Binatil-2, V_2= BARI Til-3 and V_3= BARI Til-4

4.1.2.2 Effect of square spacing system

At 25 DAE S_4 showed the highest leaves plant^{-1} (8.48) which showed statistical indifference (7.99, 7.98 and 7.92) with S_5, S_2 and S_3, respectively and the lowest (7.73) from S_1 which was also statistically similar with S_3, S_2 and S_5, respectively. S_5 subsequently given the highest results (73.72, 109.31 and 55.49) at 40, 55 and 70 DAE, respectively, whereas the lowest result was found at 40 DAE (55.13) from S_2 which was statistically similar (55.21) with S_1; at 55 and 70 DAEs (69.26 and 38.04, respectively) from S_1 which was statistically similar (72.94 and 40.50, respectively) with S_2.

Here it was observed that the number of leaves plant^{-1} increased with the increase area of square spacing system. Similar justification was found from Jakusko *et al*. (2013) and Tanjila (2008) whereas different evidence was also found (Agele *et al*., 2015). Effect of square spacing system on number of leaves plant^{-1} is presented in Figure 4.

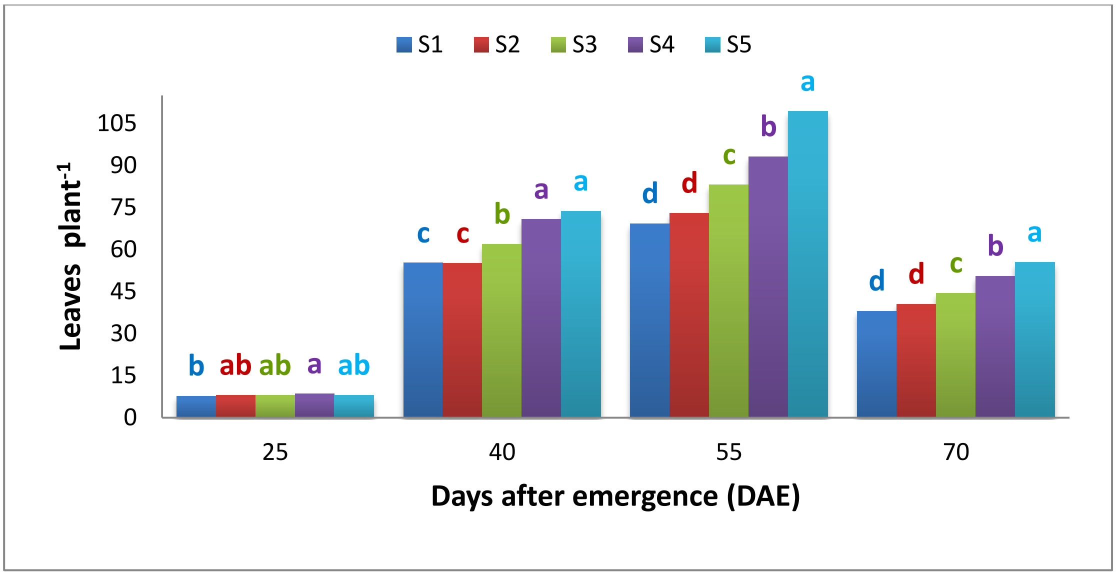

Figure 4. Effect of square spacing system on leaves plant^{-1} of sesame at different age ($LSD_{0.05}$ = 0.68, 4.94, 5.88 and 3.38 at 25, 40, 55 and 70 DAE, respectively)

S_1= 30cm × 5cm (Control), S_2= 20cm × 20cm, S_3= 30cm × 30cm, S_4= 40cm × 40cm, S_5= 50cm × 50cm

4.1.2.3 Combined effect of variety and square spacing system

There are significant differences in leaves number plant^{-1} with different treatments at different DAE. At 25 DAE V_1S_4 given the highest number of leaves plant^{-1} (8.67) which was statistically similar (8.66, 8.47, 8.43, 8.33, 8.30, 8.20, 8.10, 8.03, 7.90 and 7.87) with V_2S_4, V_2S_2, V_2S_3, V_2S_5, V_2S_1, V_3S_5, V_3S_4, V_3S_2, V_3S_3 and V_3S_1, respectively. Whereas the lowest number of leaves plant^{-1} was found (7.03) from V_1S_1 which was statistically at par (7.42, 7.43, 7.43, 7.87, 7.90, 8.03, 8.10, 8.20, 8.30, 8.33, 8.43 and 8.47) with V_1S_1, V_1S_5 V_1S_3, V_1S_2, V_3S_1, V_3S_3, V_3S_2, V_3S_4, V_3S_5, V_2S_1, V_2S_5, V_2S_3 and V_2S_2, respectively. V_2S_4 given the highest leaves plant^{-1} (77.20) which was statistically similar (76.40, 72.53, 72.23 and 69.73) with V_3S_5, V_1S_5, V_1S_5 and V_1S_4, respectively and the lowest was (51.37) from V_3S_2 which showed statistically similar result (51.50, 55.07, 56.97, 57.16 and 58.97) with V_2S_1, V_2S_2, V_3S_1, V_1S_1 and V_1S_2, respectively at 40 DAE. During 55 and 70 DAEs V_1S_5 showed the highest results (126.10 and 61.83, respectively) while the lowests were at 55 DAE (67.43) from V_2S_1 which was statistically similar (68.37, 70.10, 70.60, 71.97, 75.70 and 78.13) with V_1S_1, V_2S_2, V_3S_2, V_3S_1, V_3S_3 and V_1S_2, respectively and at 70 DAE (37.13) from V_1S_1 which showed statistical at par (38.20, 38.80, 38.93, 39.00, 39.93 and 42.57) with V_3S_1, V_2S_1, V_3S_3, V_3S_2, V_1S_2 and V_2S_2, respectively. Combined effect of variety and square spacing system on leaves plant^{-1} is presented in Table 2.

Table 2. Combined effect of variety and square spacing system on leaves plant^{-1} of sesame at different days after emergence

Treatment	Leaves plant^{-1} (no.)			
	25 DAE	40 DAE	55 DAE	70 DAE
V_1S_1	7.03 c	57.16 e-h	68.37 g	37.13 f
V_1S_2	7.43 bc	58.97 e-h	78.13 fg	39.93 ef
V_1S_3	7.43 bc	62.30 d-f	87.27 d-f	46.47 c-e
V_1S_4	8.67 a	69.73 a-d	103.70 bc	54.33 b
V_1S_5	7.42 bc	72.23 a-c	126.10 a	61.83 a
V_2S_1	8.30 a-c	51.50 gh	67.43 g	38.80 f
V_2S_2	8.47 a-c	55.07 f-h	70.10 g	42.57 d-f
V_2S_3	8.43 a-c	63.43 c-f	86.50 d-f	48.03 b-d
V_2S_4	8.66 ab	77.20 a	93.27 c-e	50.23 bc
V_2S_5	8.33 a-c	72.53 ab	95.03 b-d	53.13 bc
V_3S_1	7.87 a-c	56.97 f-h	71.97 g	38.20 f
V_3S_2	8.03 a-c	51.37 h	70.60 g	39.00 f
V_3S_3	7.90 a-c	59.93 e-g	75.70 fg	38.93 f
V_3S_4	8.10 a-c	65.57 b-e	82.43 ef	46.93 c-e
V_3S_5	8.20 a-c	76.40 a	106.80 b	51.50 bc
$LSD_{0.05}$	1.53	8.87	12.29	7.06
CV %	8.81	8.02	12.25	7.60

**In each column, figures having similar letters or without letters do not differ significantly, where as figures bearing dissimilar letter differ significantly at 5% level of probability.

Variety:
V_1 = Binatil - 2
V_2 = BARI Til - 3
V_3 = BARI Til - 4

Square spacing system:
S_1= 30 cm × 5 cm (Control)
S_2= 20 cm × 20 cm
S_3= 30 cm × 30 cm
S_4= 40 cm × 40 cm
S_5= 50 cm × 50 cm

4.1.3 Leaf area plant^{-1} (cm^2)

4.1.3.1 Effect of variety

At 25 DAE, V_2 gave the highest leaf area plant^{-1} (98.34 cm^2) and the lowest was (91.75 cm^2) from V_1. Then V_1 had given the highest results (1253.5 cm^2, 2294.5 cm^2 and 1451.3 cm^2) at 40, 55 and 70 DAE, respectively. Whereas V_3 showed the lowest leaf area (1076.9 cm^2, 1983.9 cm^2 and 1180.8 cm^2) at 40, 55 and 70 DAE, respectively, which were statistically at par (1100.9 cm^2, 2111.2 cm^2 and 1217.5 cm^2 respectively) with V_2. LA was reduced at 70 DAE due to the leaf shedding nature at later stage of plant. Effect of variety on leaf area plant^{-1} is showed in Figure 5.

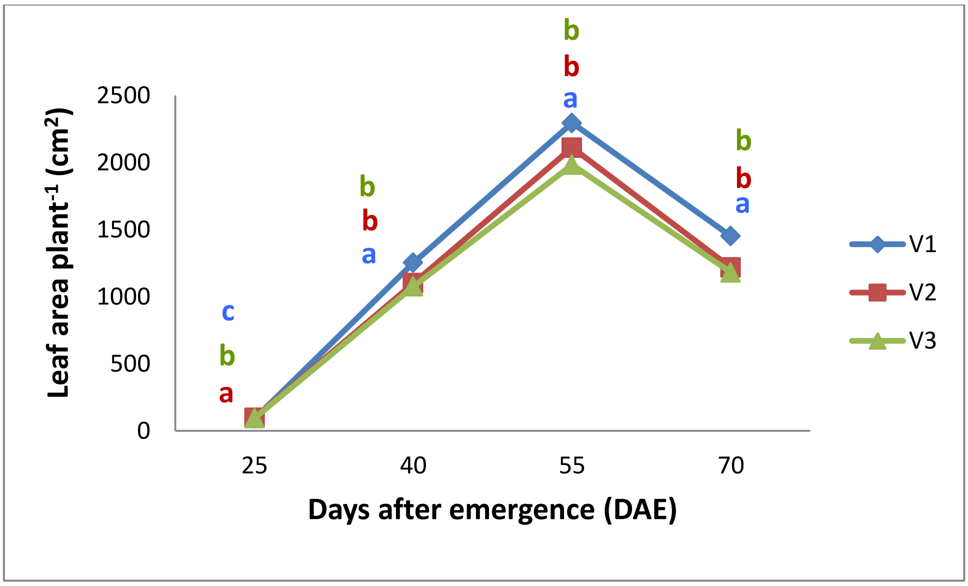

Figure 5. Effect of variety on leaf area plant^{-1} of sesame at different age ($LSD_{0.05}$ = 2.71, 61.74 159.39 and 128.77 at 25, 40, 55 and 70 DAE, respectively)

V_1= Binatil-2, V_2= BARI Til-3 and V_3= BARI Til-4

4.1.3.2 Effect of square spacing system

The largest leaf areas plant^{-1} were (98.79 cm^2, 1346.5 cm^2, 2615.9 cm^2 and 1544.6 cm^2) recorded from S_5 at 25, 40, 55 and 70 DAE, respectively due to its vigorous growth under wider spacing resulted in wider leaves. Similarity was shown by Umar *et al*. (2012). The lowest results were 93.06 cm^2 and 1065.0 cm^2 recorded from S_1 and S_2, respectively at 25 and 70 DAE, respectively; here S_1 showed statistical similarity (1068.7 cm^2) at 70 DAE. At 40 and 55 DAE S_1 scored the lowest leaf area plant^{-1} (953.9 cm^2 and 1788.7 cm^2, respectively) which were showed statistically at par (970.9 cm^2 and 1827.9 cm^2) with S_2 at 40 and 55 DAE, respectively. Effect of square spacing system on leaf area plant^{-1} is showed in Figure 6.

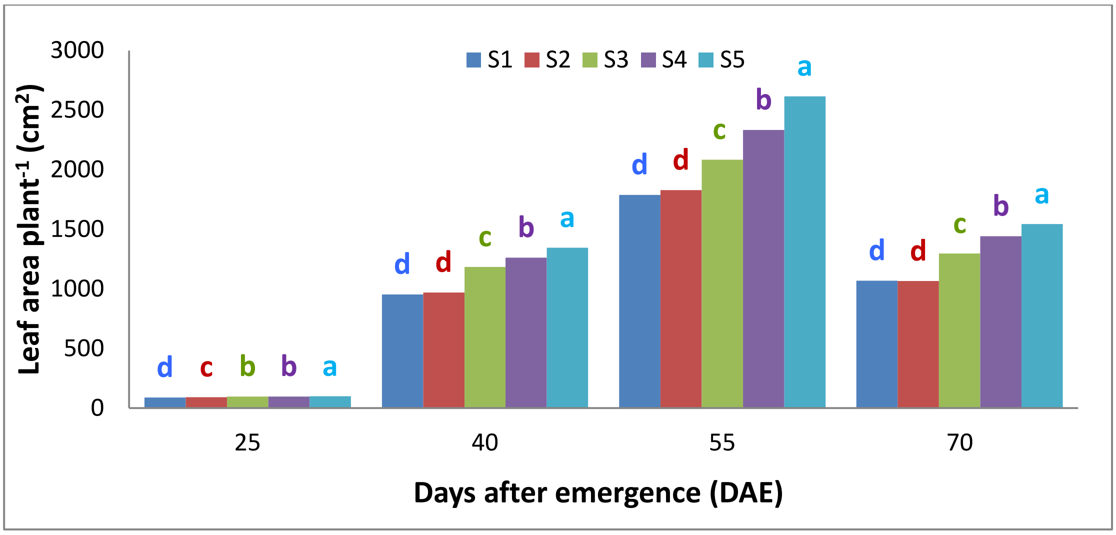

Figure 6. Effect of square spacing system on leaf area plant^{-1} of sesame at different age (LSD$_{0.05}$ = 1.58, 60.22, 88.49 and 85.21 at 25, 40, 55 and 70 DAE, respectively)

S_1= 30cm × 5cm (Control), S_2= 20cm × 20cm, S_3= 30cm × 30cm, S_4= 40cm × 40cm, S_5= 50cm × 50cm

4.1.3.3 Combined effect of variety and square spacing system

At 25 DAE V_2S_5 showed the largest leaf area plant^{-1} (103.12 cm^2) which was statistically similar (101.22 cm^2) with V_2S_4 and the lowest was (88.19 cm^2) recorded from V_1S_1 which was statistically at par (89.83 cm^2, 90.04 cm^2 and 90.29 cm^2) with V_2S_1, V_1S_2 and V_3S_1, respectively. Then at 40, 55 and 70 DAE V_1S_5 showed the highest values (1471.1 cm^2, 3018.3 cm^2 and 1844.5 cm^2, respectively) where V_1S_4 showed statistical similarity (1388.1 cm^2) at 40 DAE. The smallest results were at 40 DAE (850.5 cm^2) from V_2S_1 which was statistically similar (885.8 cm^2 and 938.3 cm^2) with V_3S_2 and V_2S_2, respectively; at 55 DAE (1754.9 cm^2) from V_3S_1 which was statistically at par (1770.0 cm^2, 1800.3 cm^2, 1804.8 cm^2, 1841.2 cm^2, 1878.7 cm^2 and 1892.3 cm^2) with V_2S_1, V_2S_2, V_3S_2, V_1S_1, V_1S_2 and V_3S_3, respectively; at 70 DAE (1007.0 cm^2) from V_2S_2 which showed statistical similarity (1011.3 cm^2, 1018.7 cm^2, 1024.5 cm^2, 1145.1 cm^2, 1163.6 cm^2 and 1176. cm^2) with V_3S_1, V_2S_1, V_3S_2, V_3S_3, V_1S_2 and V_1S_1, respectively. Combined effect of variety and square spacing system is presented in Table 3.

Table 3. Combined effect of variety and square spacing system on leaf area plant^{-1} of sesame at different days after emergence

Treatment	Leaf area plant^{-1} (cm^2)							
	25 DAE		40 DAE		55 DAE		70 DAE	
V_1S_1	88.19	j	1049.4	ef	1841.2	e	1176.1	d-f
V_1S_2	90.04	ij	1088.6	de	1878.7	e	1163.6	d-f
V_1S_3	93.77	f-h	1270.4	c	2204.4	cd	1446.1	c
V_1S_4	92.40	g-i	1388.1	ab	2529.9	b	1626.4	b
V_1S_5	94.35	e-g	1471.1	a	3018.3	a	1844.5	a
V_2S_1	89.83	ij	850.5	h	1770.0	e	1018.7	f
V_2S_2	97.20	d-f	938.3	gh	1800.3	e	1007.0	f
V_2S_3	100.32	bc	1209.5	c	2157.0	cd	1297.3	c-e
V_2S_4	101.22	ab	1201.4	c	2357.8	bc	1367.4	c
V_2S_5	103.12	a	1304.5	bc	2470.9	b	1397.4	c
V_3S_1	90.29	h-j	961.7	fg	1754.9	e	1011.3	f
V_3S_2	91.93	g-i	885.8	gh	1804.8	e	1024.5	f
V_3S_3	97.39	c-e	1075.8	e	1892.3	e	1145.1	ef
V_3S_4	97.81	b-e	1197.3	cd	2109.2	d	1331.2	cd
V_3S_5	98.90	b-d	1264.0	c	2358.3	bc	1392.1	c
$LSD_{0.05}$	3.61		110.97		207.92		182.45	
CV %	1.71		5.41		4.27		6.82	

**In each column, figures having similar letters or without letters do not differ significantly, where as figures bearing dissimilar letter differ significantly at 5% level of probability.

Variety:
V_1 = Binatil - 2
V_2 = BARI Til - 3
V_3 = BARI Til - 4

Square spacing system:
S_1= 30 cm × 5 cm (Control)
S_2= 20 cm × 20 cm
S_3= 30 cm × 30 cm
S_4= 40 cm × 40 cm
S_5= 50 cm × 50 cm

4.1.4 Leaf area index (LAI)

4.1.4.1 Effect of variety

The highest leaf area index at 25 DAE (0.212) was obtained from V_2 which was statistically similar (0.208) with V_3 and the smallest was (0.203) from V_1 which was statistically similar also with V_3. Then V_1 showed the highest values (2.52, 4.44 and 2.42) at 40, 55 and 70 DAE, respectively, where V_2 given statistical similarity (4.23) at 55 DAE. At 40 DAE V_2 showed the lowest value (2.13) which showed statistical similarity (2.22) with V_3. At 55 and 70 DAE the lowest LAI were (4.12 and 2.06, respectively) obtained from V_3, where V_2 given statistical similarity (4.23 and 2.10) at 55 and 70 DAE, respectively. Effect of variety on leaf area index is presented in Figure 7.

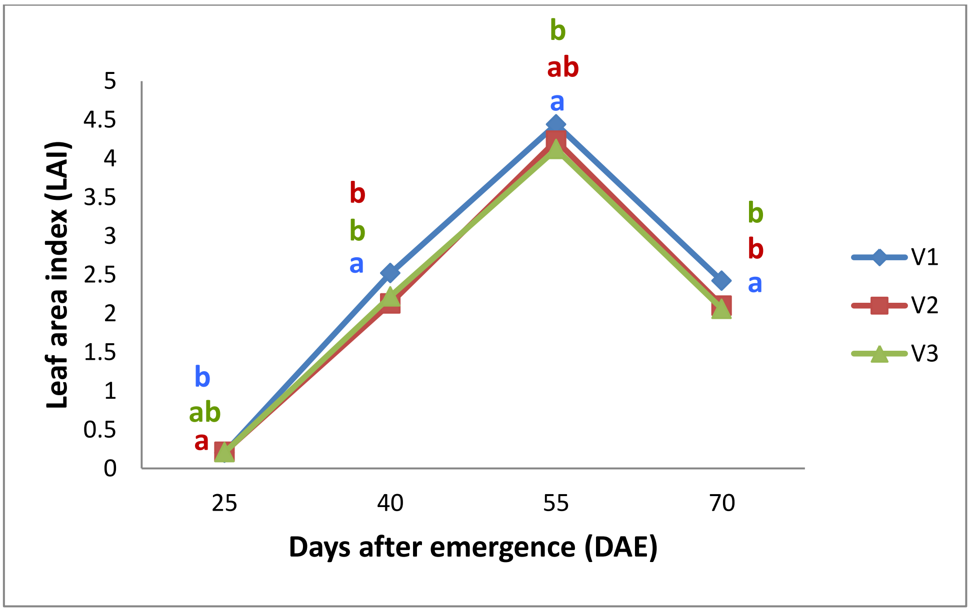

Figure 7. Effect of variety on leaf area index of sesame at different age ($LSD_{0.05}$ = 0.075, 0.16, 0.24 and 0.15 at 25, 40, 55, and 70 DAE, respectively)

V_1= Binatil-2, V_2= BARI Til-3 and V_3= BARI Til-4

4.1.4.2 Effect of square spacing system

The highest leaf area indexes were (0.596, 6.36, 11.92 and 5.34) recorded from S_1, the control treatment at 25, 40, 55 and 70 DAE, respectively due to its lower area coverage on the land. The lowest leaf area indexes were (0.04, 0.54, 1.05 and 0.62) at 25, 40, 55 and 70 DAE, respectively from S_5, though it possessed largest leaf area plant^{-1}. LAI found higher with lower square spacing due to maximum number of plants per unit area ensured higher number of leaf per unit area (Jakusko *et al*., 2013). Similarity was shown by Umar *et* al. (2012) and Alim (2009), but Haruna (2011) found opposite result as minimum space given poor growth. Effect of square spacing system on leaf area index is presented in Figure 8.

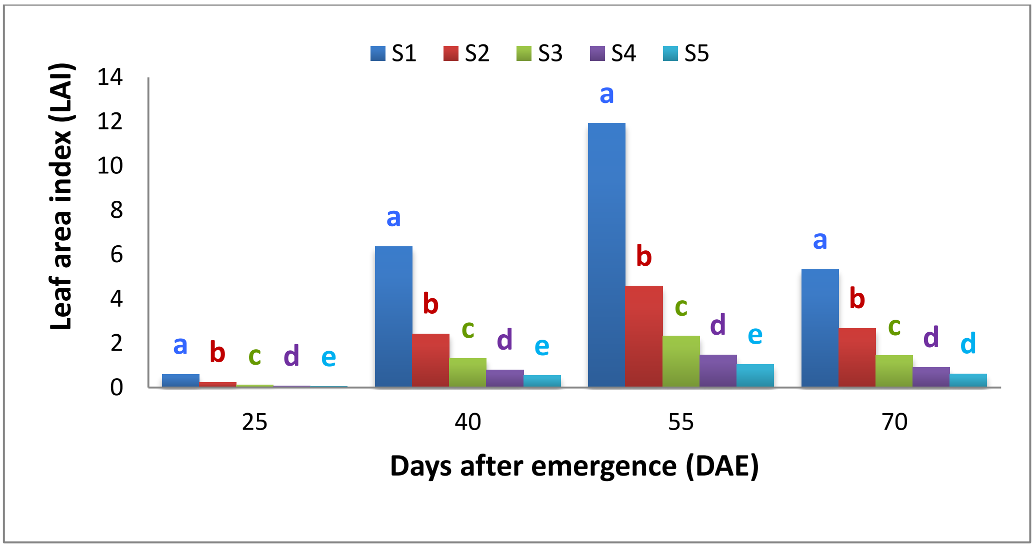

Figure 8. Effect of square spacing system on leaf area index plant^{-1} of sesame at different age ($LSD_{0.05}$ = 0.024, 0.14, 0.31 and 0.33 at 25, 40, 55, and 70 DAE, respectively)

S_1= 30cm × 5cm (Control), S_2= 20cm × 20cm, S_3= 30cm × 30cm, S_4= 40cm × 40cm, S_5= 50cm × 50cm

4.1.4.3 Combined effect of variety and square spacing system

At 25 DAE the highest leaf area index was (0.602) obtained from V_3S_1 which was statistically similar (0.599) with V_2S_1 and the lowest was (0.038) from V_1S_5 which was statistically at par (0.039 and 0.041) with V_3S_5 and V_2S_5, respectively. V_1S_1 treatment then ranked above (6.99, 12.28 and 5.84) at 40, 55 and 70 DAE, respectively; whereas V_3S_5 has shown the lowest LAI (0.50, 0.94 and 0.55) at 40, 55 and 70 DAE, respectively which were showed statistical similarity at 40 DAE (0.52, 0.59, 0.74 and 0.75) and at 55 DAE (0.99, 1.21, 1.32 and 1.47) with V_2S_5, V_1S_5, V_3S_4 and V_2S_4, respectively and at 70 DAE (0.56, 0.74, 0.83, 0.84 and 1.02) with V_2S_5, V_1S_5, V_3S_4, V_2S_4 and V_1S_4, respectively. Combined effect of variety and square spacing system is displayed in Table 4.

Table 4. Combined effect of variety and square spacing system on leaf area indexes of sesame at different days after emergence

Treatment	Leaf area index (LAI)			
	25 DAE	40 DAE	55 DAE	70 DAE
V_1S_1	0.588 b	6.99 a	12.28 a	5.84 a
V_1S_2	0.225 d	2.72 d	4.69 c	2.91 c
V_1S_3	0.104 e	1.41 f	2.45 d	1.61 d
V_1S_4	0.058 f	0.87 g	1.58 ef	1.02 e-g
V_1S_5	0.038 g	0.59 h	1.21 fg	0.74 g
V_2S_1	0.599 ab	5.67 c	11.80 ab	5.12 b
V_2S_2	0.243 c	2.35 e	4.50 c	2.52 c
V_2S_3	0.112 e	1.34 f	2.40 cd	1.44 de
V_2S_4	0.063 f	0.75 gh	1.47 fg	0.85 fg
V_2S_5	0.041 g	0.52 h	0.99 g	0.56 g
V_3S_1	0.602 a	6.41 b	11.69 b	5.07 b
V_3S_2	0.230 d	2.21 e	4.51 c	2.56 c
V_3S_3	0.108 e	1.20 f	2.10 de	1.27 d-f
V_3S_4	0.061 f	0.74 gh	1.32 fg	0.83 fg
V_3S_5	0.039 g	0.50 h	0.94 g	0.55 g
$LSD_{0.05}$	0.011	0.27	0.53	0.53
CV %	2.58	6.52	7.39	15.29

**In each column, figures having similar letters or without letters do not differ significantly, where as figures bearing dissimilar letter differ significantly at 5% level of probability.

Variety:
V_1 = Binatil - 2
V_2 = BARI Til - 3
V_3 = BARI Til - 4

Square spacing system:
S_1= 30 cm × 5 cm (Control)
S_2= 20 cm × 20 cm
S_3= 30 cm × 30 cm
S_4= 40 cm × 40 cm
S_5= 50 cm × 50 cm

4.1.5 Above ground dry matter weight plant^{-1} (g)

4.1.5.1 Effect of variety

At 25 DAE V_2 showed the highest weight (1.09 g) and V_3 showed the lowest (0.93 g) which was statistically similar (0.94 g) with V_1. V_1 then resulted the heaviest weight (13.64 g, 35.72 g, 55.07 g and 60.23 g) through the growing ages, that is at 40, 55, 70 DAE and at harvest, respectively; here V_2 (13.41 g) showed statistical similarity at 40 DAE; whereas the lowest was given at 40 DAE by V_3 (12.72 g) which was statistically similar (13.41 g) with V_2 and then at 55, 70 DAE and at harvest by V_2 (28.35 g, 45.74 g and 48.42 g, respectively) which was statistically at par (28.82 g, 45.91 g and 49.56 g, respectively) with V_3. Effect of variety on above ground dry matter weight plant^{-1} is presented in Figure 9.

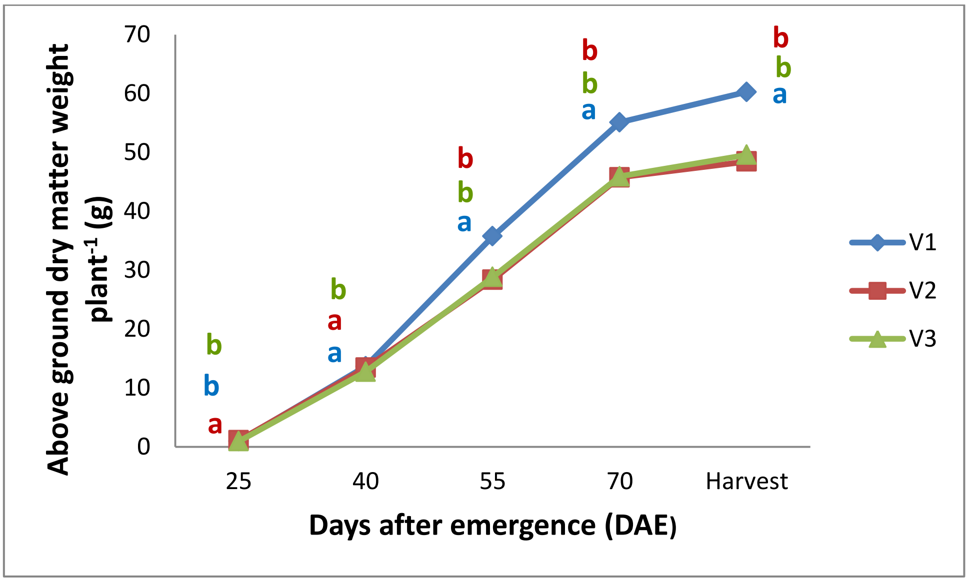

Figure 9. Effect of variety on above ground dry matter weight plant^{-1} of sesame at different age ($LSD_{0.05}$ = 0.14, 0.4, 4.69, 5.44 and 8.47 at 25, 40, 55, 70 DAE and at harvest, respectively)

V_1= Binatil-2, V_2= BARI Til-3 and V_3= BARI Til-4

4.1.5.2 Effect of square spacing system

At 25 DAE the highest dry weight plant^{-1} (1.16 g) was observed from S_4, which was statistically similar (1.15 g) with S_5 and the lowest (0.72 g) from S_1. S_5 treatment then showed the superior values (15.01 g, 38.75 g, 63.54 g and 67.24 g) during its next whole phases i.e. 40, 55, 70 DAE and at harvest, respectively; whereas S_4 showed a statistically significant result (14.89 g) at 40 DAE. At 40, 55 and 70 DAEs and at harvest the lowest weights plant^{-1} (11.30 g, 23.88 g, 36.54 g and 40.01g, respectively) were gained from S_2 which showed statistical similarity (11.81 g, 25.72 g, 38.76 g and 41.31 g, respectively) with S_1.

Here above ground dry matter weight plant^{-1} increased with the increase of square planting. Olowe and Busari (1994) mentioned total dry matter of a plant increased with the increase of row spacing from 30 to 90 cm. In closer square planting inadequate growth resources were allocated among higher number of plants per unit area (Katung, 2003) resulted lower weight. Similar Haruna (2011) and Ahmmad (2010) had similar obsevations but difference also found from Agele *et al*. (2015) where they observed increased competition among the closer spaced plants ensured higher biomass accumulation. Effect of different square spacing system on above ground dry matter weight plant^{-1} is presented in Figure 10.

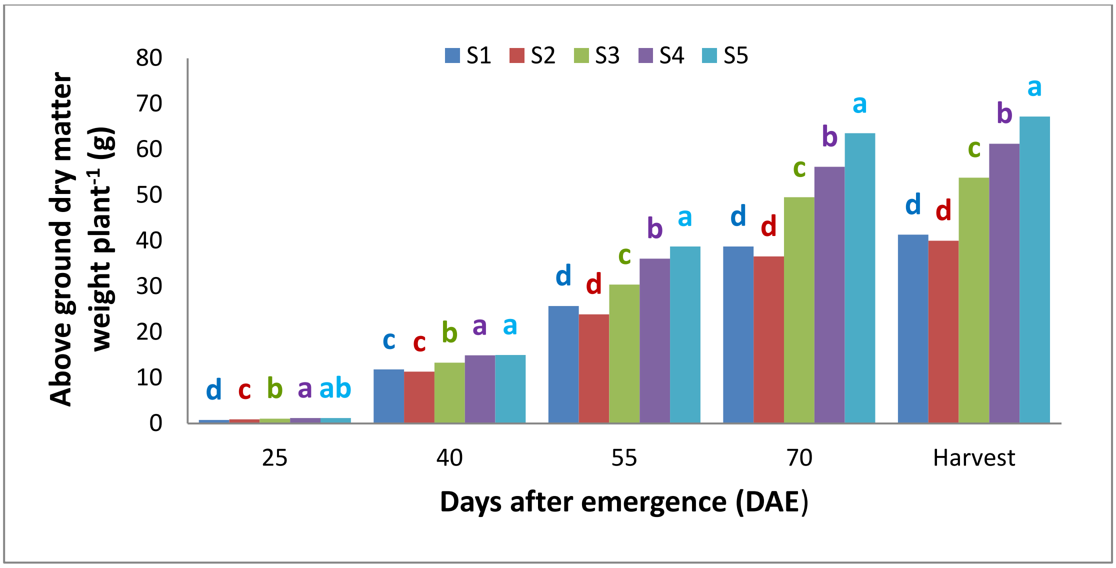

Figure 10. Effect of square spacing system on above ground dry matter weight plant^{-1} of sesame at different age ($LSD_{0.05}$ = 0.12, 0.55, 2.08, 4.01 and 3.28 at 25, 40, 55, 70 DAE and at harvest, respectively)

S_1= 30cm × 5cm (control), S_2= 20cm × 20cm, S_3= 30cm × 30cm, S_4= 40cm × 40cm, S_5= 50cm × 50cm

4.1.5.3 Combined effect of variety and square spacing system

At 25 DAE the highest above ground dry matter weight plant^{-1} (1.30 g) was obtained from V_3S_5 which was statistically at par (1.29 g, 1.28 g, 1.27 g and 1.20 g) with V_2S_3, V_2S_5, V_2S_4 and V_1S_4, respectively, and the lowest was (0.65 g) from V_3S_1 which was statistically similar (0.66 g, 0.76 g and 0.85 g) with V_1S_1, V_2S_2 and V_2S_1, respectively. At 40 DAE V_1S_4 showed the highest value (16.34 g), which was statistically similar (15.97 g) with V_1S_5 and the lowest (10.95 g) from V_1S_2, which showed statistical similarity (11.15 g, 11.38 g, 11.78 g and 11.80 g) with V_3S_2, V_3S_1, V_1S_1 and V_2S_2, respectively. V_1S_5 then showed the highest results (49.02 g, 71.91 g and 79.68 g) at 55, 70 DAE and harvest, respectively. Whereas the lowest were at 55, 70 DAE and at harvest (22.03 g, 34.17 g and 35.65 g, respectively) from V_2S_2 which were statistically related at 55 DAE (23.55 g, 23.71 g, 25.71 g and 26.07 g) to V_3S_2, V_2S_1, V_3S_1 and V_1S_2, respectively; at 70 DAE (34.18 g, 34.94 g, 38.06 g and 40.52 g) to V_2S_1, V_3S_2, V_3S_1 and V_1S_2, respectively; and at harvest (36.86 g, 38.50 g and 40.19 g) with V_2S_1, V_3S_2 and V_3S_1, respectively. Combined effect of variety and square spacing system on above ground dry matter weight plant^{-1} is presented in Table 5.

Table 5. Combined effect of variety and square spacing system on above ground dry matter weight plant^{-1} of sesame at different days after emergence

Treatment	Above ground dry matter weight plant^{-1} (g)				
	25 DAE	40 DAE	55 DAE	70 DAE	At Harvest
V_1S_1	0.66 ef	11.78 gh	27.74 e-h	44.06 fg	46.89 d-f
V_1S_2	0.97 cd	10.95 h	26.07 f-i	40.52 gh	45.89 e-g
V_1S_3	0.96 cd	13.13 d-f	32.58 c-e	54.02 c-e	59.22 c
V_1S_4	1.20 ab	16.34 a	43.18 b	64.85 b	69.45 b
V_1S_5	0.88 cd	15.97 a	49.02 a	71.91 a	79.68 a
V_2S_1	0.85 c-f	12.28 fg	23.71 g-i	34.18 h	36.86 gh
V_2S_2	0.76 d-f	11.80 gh	22.03 i	34.17 h	35.65 h
V_2S_3	1.29 a	13.77 c-e	29.91 c-f	50.41 ef	54.44 c-e
V_2S_4	1.27 a	14.18 bc	32.70 c-e	51.19 ef	55.76 cd
V_2S_5	1.28 a	15.00 b	33.43 cd	58.71 b-d	59.37 c
V_3S_1	0.65 f	11.38 gh	25.71 f-i	38.06 gh	40.19 f-h
V_3S_2	0.85 c-e	11.15 h	23.55 hi	34.94 h	38.50 f-h
V_3S_3	0.87 c-e	12.88 ef	28.73 d-g	44.10 fg	47.83 de
V_3S_4	1.00 bc	14.13 bc	32.31 c-e	52.46 de	58.59 c
V_3S_5	1.30 a	14.06 cd	33.79 c	59.99 bc	62.66 bc
$LSD_{0.05}$	0.23	0.94	5.63	8.17	9.78
CV %	12.17	4.28	6.91	8.42	6.38

**In each column, figures having similar letters or without letters do not differ significantly, where as figures bearing dissimilar letter differ significantly at 5% level of probability.

Variety:
V_1 = Binatil - 2
V_2 = BARI Til - 3
V_3 = BARI Til - 4

Square spacing system:
S_1= 30 cm × 5 cm (Control)
S_2= 20 cm × 20 cm
S_3= 30 cm × 30 cm
S_4= 40 cm × 40 cm
S_5= 50 cm × 50 cm

4.1.6 Crop growth rate (CGR)

4.1.6.1 Effect of variety

At 25-40 DAE varieties showed no significance with the crop growth rate (CGR). At 40-55 DAE V_1 showed the highest (25.11 g m^{-2} d^{-1}) CGR, whereas V_2 given the lowest (17.10 g m^{-2} d^{-1}) CGR which was statistically at par (18.69 g m^{-2} d^{-1}) with V_3. At 55-70 DAE V_1 again gave the highest CGR (28.06 g m^{-2} d^{-1}) and the lowest was (22.85 g m^{-2} d^{-1}) from V_3, which was statistically similar (24.10 g m^{-2} d^{-1}) with V_2. At 70 DAE to harvest V_3 showed the highest CGR (16.42 g m^{-2} d^{-1}) which was statistically at par (15.05 g m^{-2} d^{-1}) with V_2 and the lowest was (12.28 g m^{-2} d^{-1}) from V_1. Effect of variety on crop growth rate is presented in Figure 11.

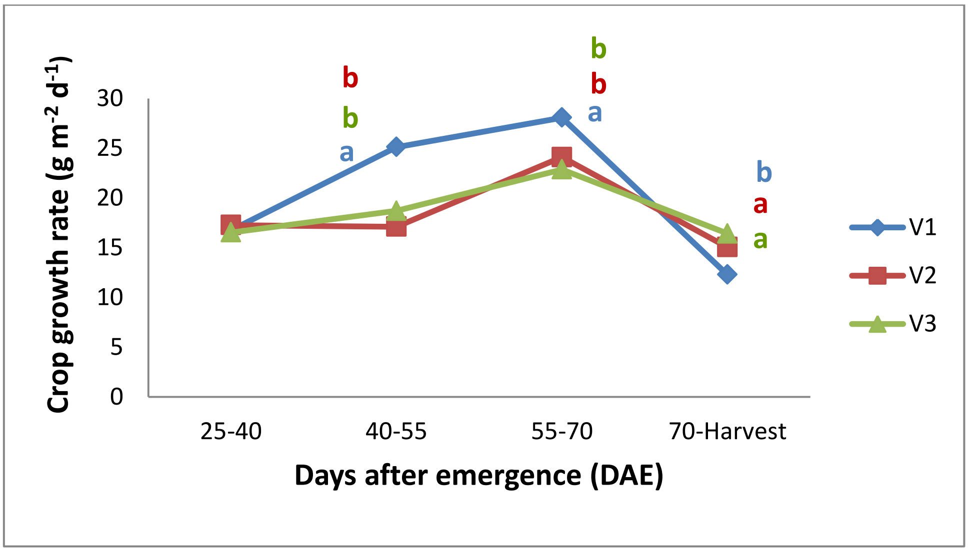

Figure 11. Effect of variety on crop growth rate of sesame at different age ($LSD_{0.05}$ = NS, 2.65, 2.13 and 1.7 at 25-40, 40-55, 55-70 and 70-harvest DAE, respectively)

V_1= Binatil-2, V_2= BARI Til-3 and V_3= BARI Til-4

4.1.6.2 Effect of square spacing system

S_1 means the control treatment showed the highest CGR values (48.54 g m^{-2} d^{-1}, 54.04 g m^{-2} d^{-1}, 71.44 g m^{-2} d^{-1} and 36.69 g m^{-2} d^{-1}) at 25-40 DAE, 40-55 DAE, 55-70 DAE and 70-harvest DAE, respectively. Whereas S_5 given the lowest values (3.65 g m^{-2} d^{-1}, 6.17 g m^{-2} d^{-1}, 6.59 g m^{-2} d^{-1} and 3.35 g m^{-2} d^{-1}) at same DAE, respectively owing to its larger space covering. Here S_4 showed statistical similarity (5.72 g m^{-2} d^{-1} and 8.19 g m^{-2} d^{-1}) with S_5 in its initial phases (at 25-40 DAE and 40-55 DAE, respectively).

Closer spacing ensured early coverage of the land results higher interception of light, hence the crop biomass increased per unit area (Caliskan *et al.*, 2004). Similarites also showed by Umar *et al*. (2012) and Alim (2009). Effect of square spacing system on crop growth rate is presented in Figure 12.

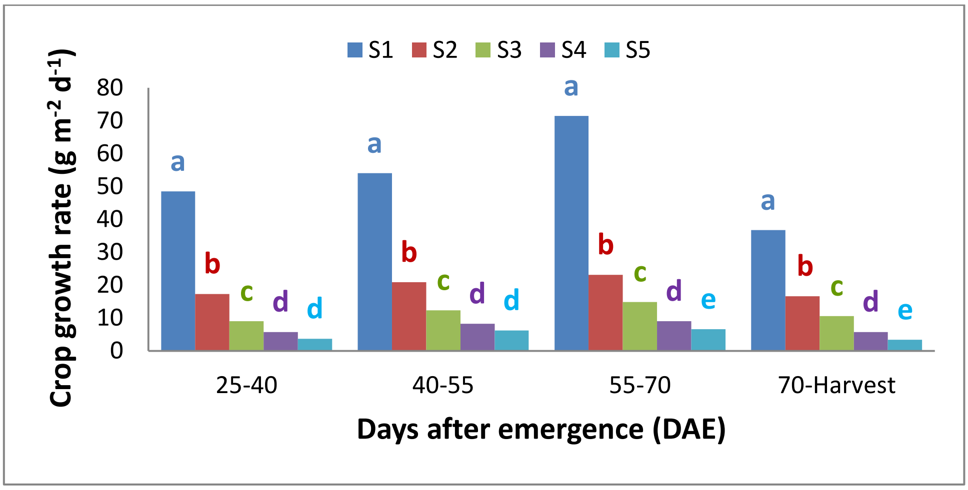

Figure 12. Effect of square spacing system on crop growth rate of sesame at different age ($LSD_{0.05}$ = 2.34, 2.89, 1.35 and 1.13 at 25-40, 40-55, 55-70 and 70-harvest DAE, respectively)

S_1= 30cm × 5cm (Control), S_2= 20cm × 20cm, S_3= 30cm × 30cm, S_4= 40cm × 40cm, S_5= 50cm × 50cm

4.1.6.3 Combined effect of variety and square spacing system

At 25-40 DAE the highest CGR (49.96 g m^{-2} d^{-1}) was recorded from V_2S_1, which was statistically similar (47.94 g m^{-2} d^{-1} and 47.69 g m^{-2} d^{-1}) with V_1S_1 and V_3S_1, respectively; where the lowest was (3.40 g m^{-2} d^{-1}) obtained from V_3S_5, which was statistically similar (3.63 g m^{-2} d^{-1}, 3.93 g m^{-2} d^{-1}, 5.38 g m^{-2} d^{-1}, 5.48 g m^{-2} d^{-1} and 6.31 g m^{-2} d^{-1}) with V_2S_5, V_1S_5, V_2S_4, V_3S_4 and V_1S_4, respectively. At 40-55 DAE, V_1S_1 resulted the highest CGR (65.57 g m^{-2} d^{-1}) and the lowest was (4.23 g m^{-2} d^{-1}) from V_2S_5 which was statistically similar (5.08 g m^{-2} d^{-1}, 6.61 g m^{-2} d^{-1},7.23 g m^{-2} d^{-1}, 9.21 g m^{-2} d^{-1} and 9.32 g m^{-2} d^{-1}) with V_3S_5, V_2S_4, V_3S_4, V_1S_5 and V_3S_3, respectively. At 55-70 DAE the highest CGR was (82.87 g m^{-2} d^{-1}) from V_1S_1 and the lowest was (6.10 g m^{-2} d^{-1}) V_1S_5 which was statistically at par (6.69 g m^{-2} d^{-1}, 6.98 g m^{-2} d^{-1} and 8.65 g m^{-2} d^{-1}) with V_3S_5, V_2S_5 and V_3S_4, respectively. At 70 DAE - harvest the highest CGR (41.28 g m^{-2} d^{-1}) showed by V_2S_1, and the lowest was (2.84 g m^{-2} d^{-1}) from V_1S_5 which was statistically at par (3.08 g m^{-2} d^{-1}, 3.50 g m^{-2} d^{-1} and 4.14 g m^{-2} d^{-1}) with V_2S_5, V_1S_4 and V_3S_5, respectively. Combined effect of variety and square spacing system is presented in Table 6.

Table 6. Combined effect of variety and square spacing system on crop growth rate of sesame at different days after emergence

Treatment	Crop growth rate (g m^{-2} d^{-1})			
	25 – 40 DAE	40 – 55 DAE	55 – 70 DAE	70 – harvest
V_1S_1	47.97 a	65.57 a	82.87 a	35.44 b
V_1S_2	16.63 b	24.33 d	27.02 c	12.01 d
V_1S_3	8.83 c	15.71 ef	15.26 e	7.59 e
V_1S_4	6.31 cd	10.73 f-h	9.06 f	3.50 f
V_1S_5	3.93 d	9.21 g-i	6.10 g	2.84 f
V_2S_1	49.96 a	44.09 c	66.29 b	41.28 a
V_2S_2	18.20 b	18.77 e	22.61 d	12.31 d
V_2S_3	9.14 c	11.81 fg	15.39 e	11.36 d
V_2S_4	5.38 cd	6.61 hi	9.22 f	7.19 e
V_2S_5	3.63 d	4.23 i	6.98 fg	3.08 f
V_3S_1	47.69 a	52.47 b	65.16 b	33.34 b
V_3S_2	17.14 b	19.38 de	19.73 d	25.50 c
V_3S_3	8.90 c	9.32 g-i	13.99 e	12.69 d
V_3S_4	5.48 cd	7.23 g-i	8.65 fg	6.44 e
V_3S_5	3.40 d	5.08 i	6.69 fg	4.14 f
$LSD_{0.05}$	3.79	5.17	2.95	2.46
CV %	14.29	14.66	5.55	8.00

**In each column, figures having similar letters or without letters do not differ significantly, where as figures bearing dissimilar letter differ significantly at 5% level of probability.

Variety:
V_1 = Binatil - 2
V_2 = BARI Til - 3
V_3 = BARI Til - 4

Square spacing system:
S_1= 30 cm × 5 cm (Control)
S_2= 20 cm × 20 cm
S_3= 30 cm × 30 cm
S_4= 40 cm × 40 cm
S_5= 50 cm × 50 cm

4.1.7 Relative growth rate (RGR)

4.1.7.1 Effect of variety

During the early growth phase of the varieties relative growth rates were non significant. But later, different varieties showed superiority over others in different DAE. V_1 revealed the highest value (0.064 g g^{-1} d^{-1}) of RGR at 40-55 DAE, here the lowest was (0.05 g g^{-1} d^{-1}) obtained from V_2 which was statistically at par (0.052 g g^{-1} d^{-1}) with V_3. At 55-70 DAE V_2 showed the great value (0.036 g g^{-1} d^{-1}) which has statistical similarity (0.035 g g^{-1} d^{-1}) with V_3 and the lowest value (0.031 g g^{-1} d^{-1}) from V_1. At 70 to harvest DAE V_3 given the highest RGR (0.023 g g^{-1} d^{-1}) and the lowest was (0.011 g g^{-1} d^{-1}) from V_1. Effect of variety on relative growth rate of sesame is presented in Figure 13.

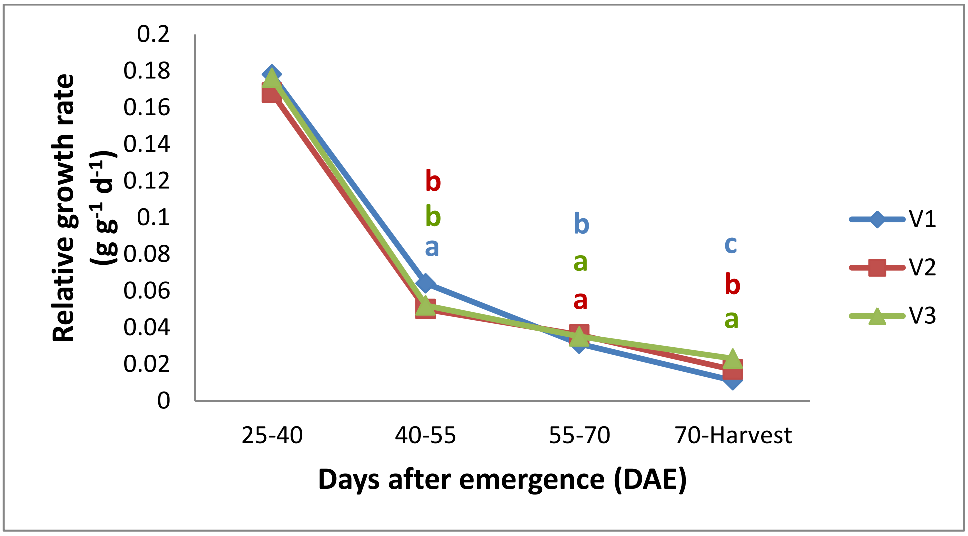

Figure 13. Effect of variety on relative growth rate of sesame at different age ($LSD_{0.05}$ = NS, 0.0029, 0.0031 and 0.0055 at 25-40, 40-55, 55-70 and 70-harvest DAE, respectively)

V_1= Binatil-2, V_2= BARI Til-3 and V_3= BARI Til-4

4.1.7.2 Effect of square spacing system

There were significant results found of relative growth rate on sesame from different square planting at different days after emergence. At 25-40 DAE S_1 showed the highest value (0.186 g $g^{-1}d^{-1}$) and the lowest was (0.170 g $g^{-1}d^{-1}$) which was statistically similar (0.171 g $g^{-1}d^{-1}$, 0.171 g $g^{-1}d^{-1}$ and 0.172 g $g^{-1}d^{-1}$) with S_2, S_4 and S_5, respectively. At 40-55 DAE it was revealed that S_5 has the highest RGR (0.065 g $g^{-1}d^{-1}$) because of its higher number of leaves, branches and capsule production in between these two DAE, and the lowest value (0.047 g $g^{-1}d^{-1}$) was recorded from S_1. S_1 then showed the highest value (0.036 g $g^{-1}d^{-1}$) which was statistically at par (0.035 g $g^{-1}d^{-1}$ and 0.035 g $g^{-1}d^{-1}$) with S_3 and S_5, respectively and the lowest was recorded (0.032 g $g^{-1}d^{-1}$) from S_2 which was statistically similar (0.033 g $g^{-1}d^{-1}$ and 0.034 g $g^{-1}d^{-1}$) with S_4 and S_5, respectively. At 70-harvest DAE S_3 revealed the superiority (0.02 g $g^{-1}d^{-1}$) which was statistically similar (0.018 g $g^{-1}d^{-1}$ and 0.017 g $g^{-1}d^{-1}$) with S_2 and S_4, respectively; the lowest value was (0.013 g $g^{-1}d^{-1}$) from S_5 which was statistically similar (0.015 g $g^{-1}d^{-1}$ and 0.017 g $g^{-1}d^{-1}$) with S_1 and S_4, respectively. Effect of square spacing system on relative growth rate is shown in Figure 14.

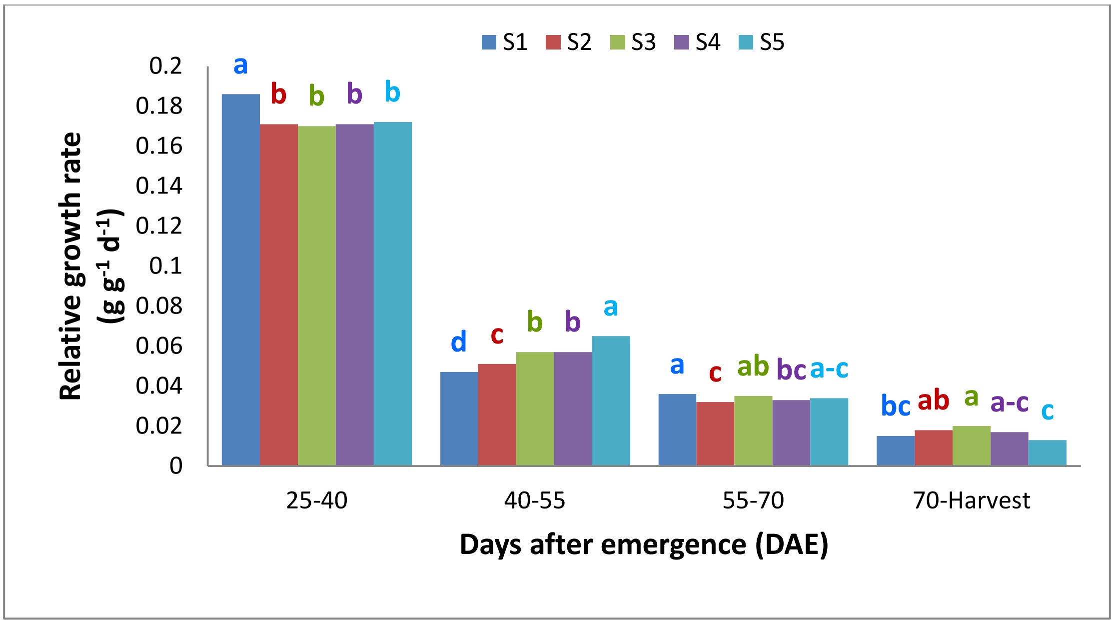

Figure 14. Effect of square spacing system on relative growth rate of sesame at different age ($LSD_{0.05}$ = 0.0082, 0.0024, 0.0029 and 0.0035 at 25-40, 40-55, 55-70 and 70-harvest DAE, respectively)

S_1= 30cm × 5cm (Control), S_2= 20cm × 20cm, S_3= 30cm × 30cm, S_4= 40cm × 40cm, S_5= 50cm × 50cm

4.1.7.3 Combined effect of variety and square spacing system

Statistically significant results were found at different DAE in different treatments. V_1S_5 showed superiority (0.192 g g^{-1} d^{-1} and 0.080 g g^{-1} d^{-1}) at 25-40 and 40-55 DAE, respectively; where at 25-40 DAE statistical similarity was found (0.191 g g^{-1} d^{-1}, 0.190 g g^{-1} d^{-1}, 0.182 g g^{-1} d^{-1}, 0.180 g g^{-1} d^{-1}, 0.177 g g^{-1} d^{-1} and 0.176 g g^{-1} d^{-1}) from V_3S_1, V_1S_1, V_2S_2, V_3S_3, V_2S_1 and V_3S_4, respectively, whereas the lowest values were at 25-40 DAE (0.157 g g^{-1} d^{-1}) from V_2S_3 which was statistically similar (0.159 g g^{-1} d^{-1}, 0.160 g g^{-1} d^{-1}, 0.161

g g^{-1} d^{-1}, 0.163 g g^{-1} d^{-1}, 0.171 g g^{-1} d^{-1}, 0.173 g g^{-1} d^{-1} and 0.174 g g^{-1} d^{-1}) with V_3S_5, V_2S_4, V_1S_2, V_2S_5, V_3S_2, V_1S_3 and V_1S_4, respectively and at 40-55 DAE (0.039 g g^{-1} d^{-1}) from V_2S_1. At 55-70 DAE it was revealed that the highest RGR (0.041 g g^{-1} d^{-1}) was obtained from V_2S_5, which showed statistical similarity (0.038 g g^{-1} d^{-1}, 0.037 g g^{-1} d^{-1}, 0.036 g g^{-1} d^{-1}, 0.036 g g^{-1} d^{-1} and 0.036 g g^{-1} d^{-1}) with V_3S_5, V_2S_4, V_1S_1, V_3S_2 and V_3S_3, respectively. Here the lowest value was recorded (0.025 g g^{-1} d^{-1}) from V_1S_5 which was statistically at par (0.028 g g^{-1} d^{-1} and 0.029 g g^{-1} d^{-1}) with V_1S_4 and V_3S_2, respectively. V_3S_2 showed superiority (0.031 g g^{-1} d^{-1}) at 70-harvest DAE which was statistically similar (0.027 g g^{-1} d^{-1}) with V_3S_3 and the lowest RGR was (0.009 g g^{-1} d^{-1}) from V_1S_4 which was statistically similar (0.010 g g^{-1} d^{-1}, 0.011 g g^{-1} d^{-1}, 0.012 g g^{-1} d^{-1}, 0.012 g g^{-1} d^{-1}, 0.012 g g^{-1} d^{-1} and 0.013 g g^{-1} d^{-1}) with V_1S_5, V_1S_2, V_1S_1, V_1S_3, V_2S_2 and V_2S_5, respectively. Combined effect of variety and square spacing system on relative growth rate of sesame is showed in Table 7.

Table 7. Combined effect of variety and square spacing system on relative growth rate of sesame at different days after emergence

Treatment	Relative growth rate (g g^{-1} d^{-1})			
	25 - 40 DAE	40 - 55 DAE	55 - 70 DAE	70 – Harvest
V_1S_1	0.190 ab	0.054 ef	0.036 a-d	0.012 fg
V_1S_2	0.161 e-g	0.058 de	0.034 b-e	0.011 fg
V_1S_3	0.173 c-g	0.066 b	0.032 c-f	0.012 e-g
V_1S_4	0.174 b-g	0.064 bc	0.028 fg	0.009 g
V_1S_5	0.192 a	0.080 a	0.025 g	0.010 g
V_2S_1	0.177 a-e	0.039 h	0.034 b-e	0.017 c-f
V_2S_2	0.182 a-c	0.047 g	0.031 d-f	0.012 fg
V_2S_3	0.157 g	0.055 d-f	0.035 b-d	0.019 c-e
V_2S_4	0.160 fg	0.051 fg	0.037 a-c	0.021 bc
V_2S_5	0.163 d-g	0.057 de	0.041 a	0.013 d-g
V_3S_1	0.191 ab	0.048 g	0.036 a-d	0.017 c-f
V_3S_2	0.171 c-g	0.047 g	0.029 e-g	0.031 a
V_3S_3	0.180 a-d	0.050 fg	0.036 a-d	0.027 ab
V_3S_4	0.176 a-f	0.056 de	0.033 b-e	0.020 cd
V_3S_5	0.159 g	0.059 cd	0.038 ab	0.017 c-f
$LSD_{0.05}$	0.0017	0.0047	0.0054	0.0076
CV %	4.87	4.48	8.90	21.74

**In each column, figures having similar letters or without letters do not differ significantly, where as figures bearing dissimilar letter differ significantly at 5% level of probability.

Variety:
V_1 = Binatil - 2
V_2 = BARI Til - 3
V_3 = BARI Til - 4

Square spacing system:
S_1= 30 cm × 5 cm (Control)
S_2= 20 cm × 20 cm
S_3= 30 cm × 30 cm
S_4= 40 cm × 40 cm
S_5= 50 cm × 50 cm

4.1.8 Net assimilation rate (NAR)

4.1.8.1 Effect of variety

The net assimilation rate of the varieties showed their higher values during their early growth phase (25-40 DAE) but reduced drastically at their later stages, it may be because of their rapid growth occurrence under high temperature. At 25-40 DAE the great value of NAR (0.00197 g cm^{-2} d^{-1}) was observed from V_2 which was statistically similar (0.00195 g cm^{-2} d^{-1}) with V_3 and V_1 given the lowest value (0.00187 g cm^{-2} d^{-1}). At 40-55 DAE the highest NAR was (0.000836 g cm^{-2} d^{-1}) recorded from V_1 and the lower value (0.000588 g cm^{-2} d^{-1}) from V_2, which showed statistical similarity (0.000644 g cm^{-2} d^{-1}) with V_3. At 55-70 DAE three varieties showed non-significant relationship. Effect of variety on net assimilation rate is presented in Figure 15.

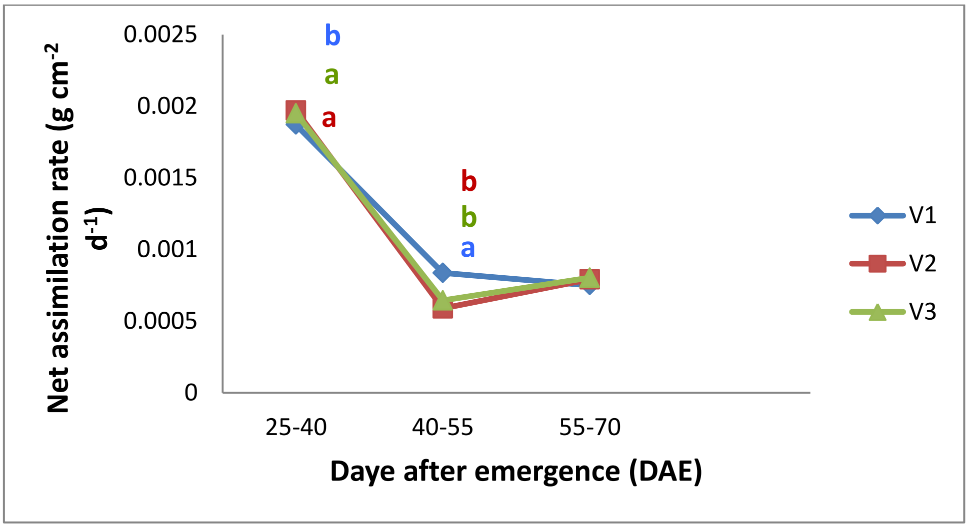

Figure 15. Effect of variety on net assimilation rate of sesame at different age ($LSD_{0.05}$ = 0.000067, 0.000078 and NS at 25-40, 40-55 and 55-70 DAE, respectively)

V_1= Binatil-2, V_2= BARI Til-3 and V_3= BARI Til-4

4.1.8.2 Effect of square spacing system

Net assimilation rate was showed diverse results with different square planting. At 25-40 DAE the highest NAR was (0.00201 g cm^{-2} d^{-1}) obtained from S_4 which showed statistical similarity (0.002 g cm^{-2} d^{-1}) with S_1 and the lowest (0.00185 g cm^{-2} d^{-1}) from S_3 which was statistically similar (0.00186 g cm^{-2} d^{-1} and 0.00191 g cm^{-2} d^{-1}) with S_2 and S_5, respectively. Then S_5 confirmed the highest NARs (0.000791 g cm^{-2} d^{-1} and 0.000826 g cm^{-2} d^{-1}) at 40-55 and 55-70 DAEs, respectively, which showed statistical similarity at 40-55 DAE (0.000747 g cm^{-2} d^{-1}) with S_4; at 55-70 DAE (0.00081 g cm^{-2} d^{-1}, 0.000808 g cm^{-2} d^{-1} and 0.000779 g cm^{-2} d^{-1}) with S_3, S_1 and S_4, respectively. The lowest at 40-55 DAE was (0.000606 g cm^{-2} d^{-1}) witnessed from S_1, which was statistically at par (0.000613 g cm^{-2} d^{-1}) with S_2. At 55-70 DAE the lowest NAR (0.00068 g cm^{-2} d^{-1}) was got from S_2 and here the bars moved upward from previous due to increased weight of seed. Effect of square spacing system on net assimilation rate is showed in figure 16.

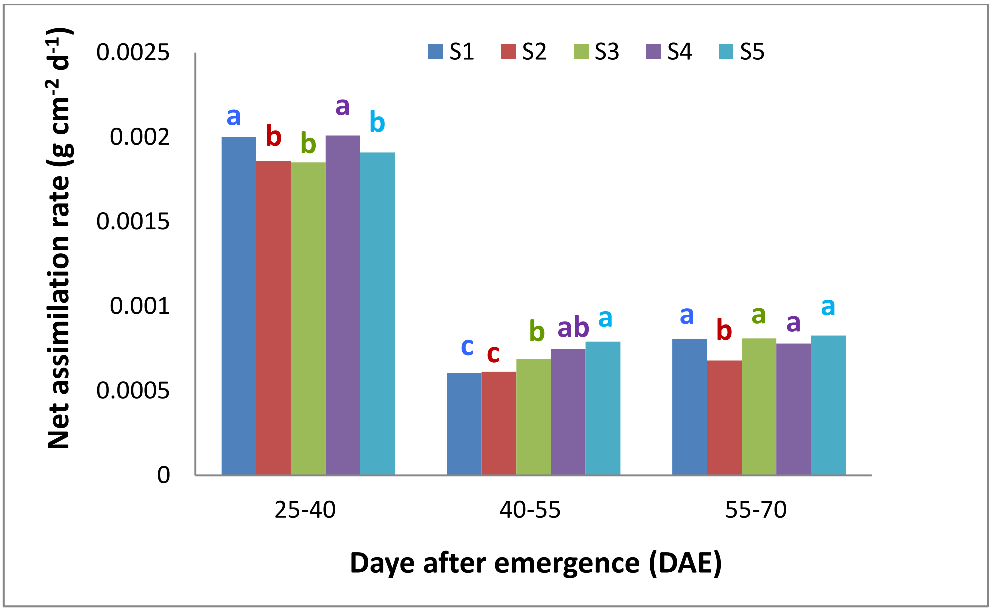

Figure 16. Effect of square spacing system on net assimilation rate of sesame at different age ($LSD_{0.05}$ = 0.000119, 0.0000621 and 0.0000801 at 25-40, 40-55 and 55-70 DAE, respectively)

S_1= 30cm × 5cm (Control), S_2= 20cm × 20cm, S_3= 30cm × 30cm, S_4= 40cm × 40cm, S_5= 50cm × 50cm

4.1.8.3 Combined effect of variety and square spacing system

Significant differences were found from the treatments in different days after emergence. V_2S_1 ranked above (0.00221 g cm^{-2} d^{-1}) at 25-40 DAE which was statistically similar (0.00211 g cm^{-2} d^{-1}) with V_1S_4 and the lowest value (0.00166 g cm^{-2} d^{-1}) given by V_1S_2 which showed statistical similarity (0.00176 g cm^{-2} d^{-1}, 0.00184 g cm^{-2} d^{-1} and 0.00186 g cm^{-2} d^{-1}) with V_1S_3, V_2S_3, and V_1S_1, respectively. Then at 40-55 DAE V_1S_5 resulted the highest value (0.00107 g cm^{-2} d^{-1}) and the lowest (0.00053 g cm^{-2} d^{-1}) with V_2S_1 which was statistically similar (0.00057 g cm^{-2} d^{-1}, 0.00058 g cm^{-2} d^{-1}, 0.00058 g cm^{-2} d^{-1}, 0.00059 g cm^{-2} d^{-1},0.00060 g cm^{-2} d^{-1} and 0.00063 g cm^{-2} d^{-1}) with V_2S_2, V_2S_5, V_3S_3, V_3S_1, V_3S_2 and V_2S_4, respectively. At 55-70 DAE NAR was increased from the previous DAE, because of the increased number and weight of the capsules of the plants. The highest NAR (0.00093 g cm^{-2} d^{-1}) was obtained from V_2S_5 which showed statistical indifference (0.00091 g cm^{-2} d^{-1}, 0.00086 g cm^{-2} d^{-1}, 0.00084 g cm^{-2} d^{-1}, 0.00083 g cm^{-2} d^{-1}, 0.00082 g cm^{-2} d^{-1}, 0.00081 g cm^{-2} d^{-1}, 0.00081 g cm^{-2} d^{-1} and 0.00078 g cm^{-2} d^{-1}) with V_3S_5, V_1S_1, V_3S_3, V_3S_1, V_2S_3, V_3S_4, V_2S_4 and V_1S_3, respectively. With the same DAE the shortest mark was (0.00062 g cm^{-2} d^{-1}) obtained by V_3S_2, which showed statistical at par (0.00064 g cm^{-2} d^{-1}, 0.00067 g cm^{-2} d^{-1}, 0.00071 g cm^{-2} d^{-1}, 0.00073 g cm^{-2} d^{-1} and 0.00076 g cm^{-2} d^{-1}) with V_1S_5, V_2S_2, V_1S_4, V_2S_1 and V_1S_2, respectively. Combined effect of variety and square spacing system on net assimilation rate of sesame is given to the Table 8.

Table 8. Combined effect of variety and square spacing system on net assimilation rate of sesame at different days after emergence

Treatment	Net assimilation rate (g cm^{-2} d^{-1})		
	25-40 DAE	40-55 DAE	55-70 DAE
V_1S_1	0.00186 c-e	0.00069 de	0.00086 a-c
V_1S_2	0.00166 e	0.00067 d-f	0.00076 b-f
V_1S_3	0.00176 de	0.00084 bc	0.00078 a-e
V_1S_4	0.00211 ab	0.00090 b	0.00071 d-f
V_1S_5	0.00195 b-d	0.00107 a	0.00064 f
V_2S_1	0.00221 a	0.00053 g	0.00073 c-f
V_2S_2	0.00196 bc	0.00057 fg	0.00067 ef
V_2S_3	0.00184 c-e	0.00065 d-f	0.00082 a-d
V_2S_4	0.00193 b-d	0.00062 d-g	0.00081 a-e
V_2S_5	0.00191 cd	0.00058 e-g	0.00093 a
V_3S_1	0.00194 b-d	0.00059 e-g	0.00083 a-d
V_3S_2	0.00196 bc	0.00060 e-g	0.00062 f
V_3S_3	0.00196 bc	0.00058 e-g	0.00084 a-d
V_3S_4	0.00199 bc	0.00072 cd	0.00081 a-e
V_3S_5	0.00187 cd	0.00072 cd	0.00091 ab
$LSD_{0.05}$	0.000195	0.000122	0.00015
CV %	6.33	9.27	10.54

**In each column, figures having similar letters or without letters do not differ significantly, where as figures bearing dissimilar letter differ significantly at 5% level of probability.

Variety:
V_1 = Binatil - 2
V_2 = BARI Til - 3
V_3 = BARI Til - 4

Square spacing system:
S_1= 30 cm × 5 cm (Control)
S_2= 20 cm × 20 cm
S_3= 30 cm × 30 cm
S_4= 40 cm × 40 cm
S_5= 50 cm × 50 cm

4.2 Yield attributive parameters

4.2.1 Branches plant^{-1} (No.)

4.2.1.1 Effect of variety

At 40 DAE, three varieties showed non- significant result, i.e. variety has no significance on the initial branch number plant^{-1}. At 55 DAE the highest number was (7.35) showed from V_1, which was statistically similar (7.01) with V_3 and the lowest was (6.42) from V_2, which was statistically similar (7.01) with V_3. At 70 DAE V_1 again given the highest result (10.14) and the lowest was (7.59) from V_2, which was statistically at par (7.75) with V_3. Effect of variety no branches plant^{-1} is showed in Figure 17.

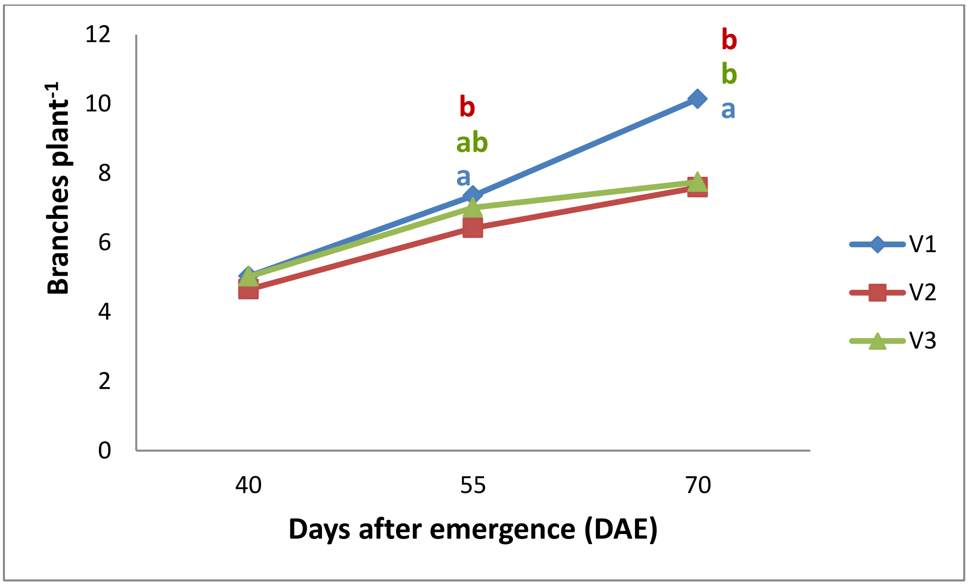

Figure 17. Effect of variety on branches plant^{-1} of sesame at different age ($LSD_{0.05}$ = 0.45, 0.61 and 0.47 at 40, 55 and 70 DAE, respectively)

V_1= Binatil-2, V_2= BARI Til-3 and V_3= BARI Til-4

4.2.1.2 Effect of square spacing system

Different square planting showed significantly variant result at different DAE. Branches plant^{-1} increased with the increasing of square planting. At 40 DAE the highest result was occupied (5.77) by S_4, and the lowest was (4.36) from S_2, which was statistically similar (4.38 and 4.64) with S_1 and S_3, respectively. At 55 and 70 DAE the highest results were (8.78 and 10.88, respectively) obtained from S_5 and the lowest were at 55 DAE (5.56) from S_2 which was statistically similar (5.78) with S_1 and at 70 DAE (6.6) from S_1, which was statistically similar (6.69) with S_2. Wider spacing influenced the growth of higher number of lateral branches of a plant. Resemblance was found with Nadeem *et al*. (2015) and Karim (2008). Effect of square spacing system on branches plant^{-1} is presented in Figure 18.

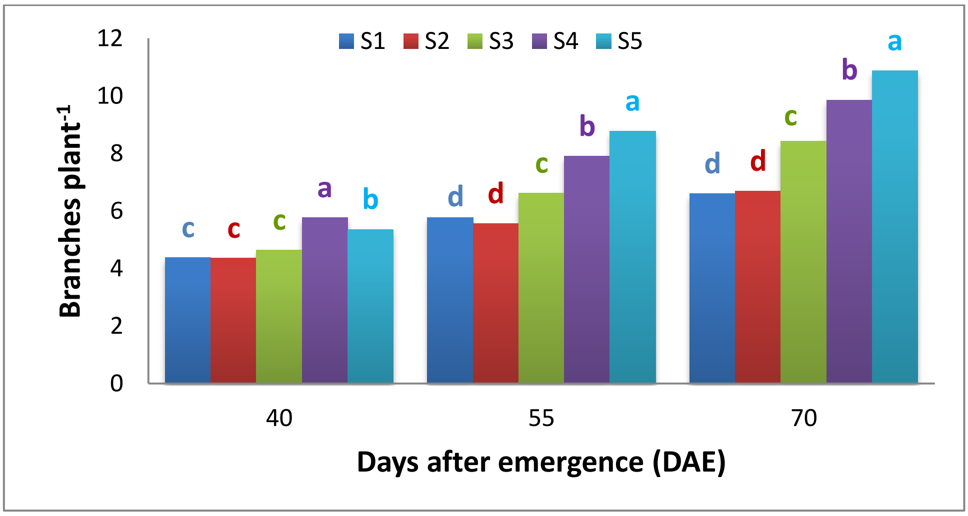

Figure 18. Effect of square spacing system on branches plant^{-1} of sesame at different age ($LSD_{0.05}$ = 0.29, 0.48 and 0.33 at 40, 55 and 70 DAE, respectively)

S_1= 30cm × 5cm (Control), S_2= 20cm × 20cm, S_3= 30cm × 30cm, S_4= 40cm × 40cm, S_5= 50cm × 50cm

4.2.1.3 Combined effect of variety and square spacing system

At 40 DAE V_1S_4 given the highest number of branches plant^{-1} (6.62) and the lowest was (3.90) given by V_1S_2, which was statistically similar (4.00, 4.30, 4.47, 4.50 and 4.60) with V_1S_1, V_2S_2, V_2S_1, V_3S_3 and V_2S_3, respectively. At 55 and 70 DAE V_1S_5 was showed the highest results (10.70 and 14.67, respectively). The lowest branches plant^{-1} at 55 DAE (4.93) was found in V_1S_2, which was statistically at par (5.10, 5.70 and 5.83) with V_1S_1, V_2S_1 and V_3S_2, respectively; at 70 DAE the lowest was (6.16) observed from V_3S_1, which was statistically at par (6.43, 6.70, 6.80, 6.81 and 6.83) with V_3S_2, V_1S_1, V_1S_2, V_2S_1 and V_2S_2, respectively. Combined effect of variety and square spacing system on branches plant^{-1} of sesame is given to the Table 9.

Table 9. Combined effect of variety and square spacing system on branches plant^{-1} of sesame at different days after emergence

Treatment	Branches plant^{-1} (no.)		
	40 DAE	55 DAE	70 DAE
V_1S_1	4.00 f	5.10 gh	6.70 hi
V_1S_2	3.90 f	4.93 h	6.80 hi
V_1S_3	4.83 c-e	7.10 de	10.60 c
V_1S_4	6.62 a	8.93 b	11.83 b
V_1S_5	5.70 b	10.70 a	14.67 a
V_2S_1	4.47 d-f	5.70 f-h	6.81 g-i
V_2S_2	4.30 ef	5.90 fg	6.83 g-i
V_2S_3	4.60 d-f	6.43 ef	7.20 gh
V_2S_4	4.93 cd	6.90 e	8.83 e
V_2S_5	4.97 cd	7.16 de	8.24 f
V_3S_1	4.66 de	6.13 ef	6.16 i
V_3S_2	4.80 de	5.83 f-h	6.43 i
V_3S_3	4.50 d-f	6.32 ef	7.53 g
V_3S_4	5.73 b	7.86 cd	8.93 e
V_3S_5	5.40 bc	8.46 bc	9.73 d
$LSD_{0.05}$	0.63	0.94	0.68
CV %	6.15	7.06	3.94

**In each column, figures having similar letters or without letters do not differ significantly, where as figures bearing dissimilar letter differ significantly at 5% level of probability.

Variety:
V_1 = Binatil - 2
V_2 = BARI Til - 3
V_3 = BARI Til - 4

Square spacing system:
S_1= 30 cm × 5 cm (Control)
S_2= 20 cm × 20 cm
S_3= 30 cm × 30 cm
S_4= 40 cm × 40 cm
S_5= 50 cm × 50 cm

4.2.2 Capsules plant^{-1} (No.)

4.2.2.1 Effect of variety

Binatil – 2 (V_1) showed the highest capsules plant^{-1} (25.8, 89.48, 116.23 and 124.03) at 40, 55, 70 DAE and at harvest, respectively. Whereas at 40 DAE the lowest number (22.64) was obtained from V_3, which was statistically similar (23.05) with V_2 and at 55, 70 DAE and at harvest V_2 given the lowest capsules plant^{-1} (58.61, 86.26 and 93.26, respectively) which were statistically similar (62.26, 87.27 and 95.27, respectively) with V_3. Effect of variety on capsules plant^{-1} is showed in Figure 19.

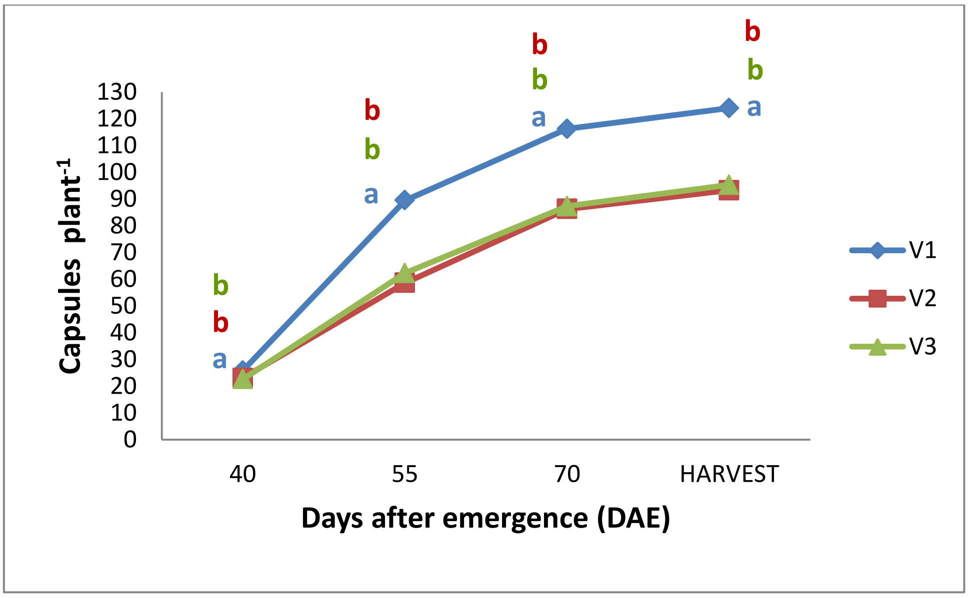

Figure 19. Effect of variety on capsules plant^{-1} of sesame at different age ($LSD_{0.05}$ = 0.84, 8.29, 9.29 and 8.09 at 40, 55, 70 DAE and harvest, respectively)

V_1= Binatil-2, V_2= BARI Til-3 and V_3= BARI Til-4

4.2.2.2 Effect of square spacing system

It was observed that, the larger the square planting (S_5) the higher the capsules plant^{-1} (32.73, 100.07, 132.59 and 141.22), those were obtained at 40, 55, 70 DAE and at harvest, respectively. Wider square planting ensured more healthy plants (Gorachand and Modal, 1990) through proper utilization of the resources under low competition, resulted higher number of lateral branches therefore higher number of capsules plant^{-1}. The lowest numbers were (17.13, 45.08, 66.4 and 72.52) recorded from S_2 at 40, 55, 70 DAE and at harvest, respectively. At 70 DAE, S_1 showed statistical similarity (72.31) with S_2. Related result was identified by Jan *et al*. (2014) and Karim (2008). Dissimilar result was found by Ali *et al*. (2005). Effect of square spacing system on capsules plant^{-1} is presented in Figure 20.

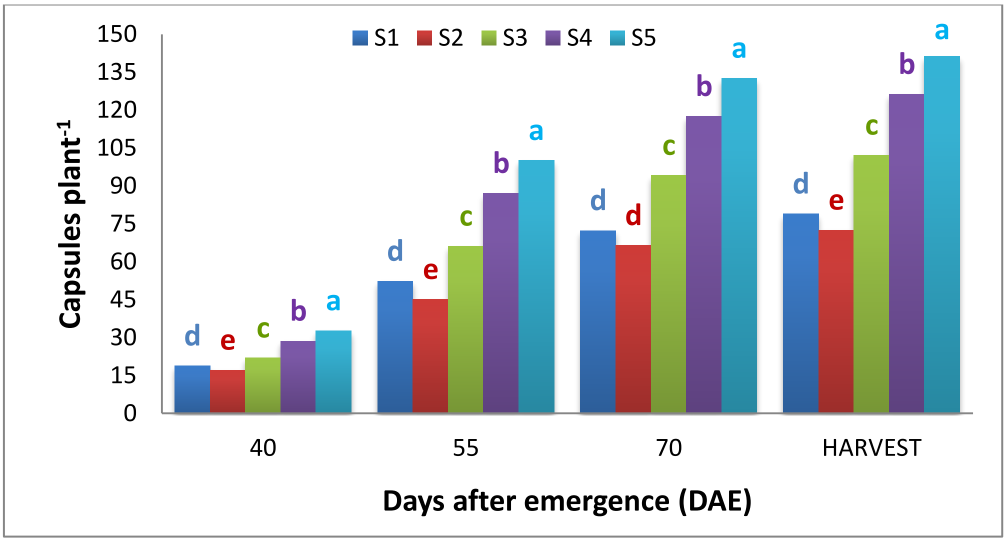

Figure 20. Effect of square spacing system on capsules plant^{-1} of sesame at different age ($LSD_{0.05}$ = 1.29, 5.09, 6.25 and 5.12 at 40, 55, 70 DAE and at harvest, respectively)

S_1= 30cm × 5cm (Control), S_2= 20cm × 20cm, S_3= 30cm × 30cm, S_4= 40cm × 40cm, S_5= 50cm × 50cm

4.2.2.3 Combined effect of variety and square spacing system

V_1S_5 treatment showed the highest capsules plant^{-1} (36.83, 154.87, 176.46 and 184.43) at 40, 55, 70 DAE and at harvest, respectively. V_1S_4 showed statistical similarity (35.83) at 40 DAE. The lowest number (16.87) at 40 DAE was recorded from V_1S_2 which was statistically similar (17.10, 17.43, 18.00 and 18.30) with V_2S_2, V_3S_2, V_1S_1 and V_3S_1, respectively. Then V_2S_2 given the lowest numbers (41.57, 61.70 and 64.93) at 55, 70 DAE and at harvest, respectively; which were statistically similar (46.50, 47.17, 48.87 and 50.77) with V_1S_2, V_3S_2, V_2S_1 and V_3S_3, respectively at 55 DAE; (63.37, 68.40, 69.27 and 74.13) with V_3S_2, V_3S_1, V_2S_1 and V_1S_2, respectively at 70 DAE and (72.07) V_3S_2 at harvest. Combined effect of variety and square spacing system on capsules plant^{-1} is given in Table 10.

Table 10. Combined effect of variety and square spacing system on capsules plant^{-1} of sesame at different days after emergence

Treatment	Capsules plant^{-1} (no.)			
	40 DAE	55 DAE	70 DAE	At Harvest
V_1S_1	18.00 gh	53.70 e	79.27 fg	85.63 ef
V_1S_2	16.87 h	46.50 ef	74.13 f-h	80.57 e-g
V_1S_3	21.47 e	80.23 c	106.13 c-e	113.80 cd
V_1S_4	35.83 a	112.10 b	145.12 b	155.70 b
V_1S_5	36.83 a	154.87 a	176.46 a	184.43 a
V_2S_1	19.97 e-g	48.87 ef	69.27 f-h	74.77 fg
V_2S_2	17.10 h	41.57 f	61.70 h	64.93 h
V_2S_3	20.33 ef	67.47 d	96.53 e	104.67 d
V_2S_4	26.00 d	69.13 cd	97.33 de	105.50 d
V_2S_5	31.87 b	66.00 d	106.47 c-e	116.50 c
V_3S_1	18.30 f-h	54.20 e	68.40 gh	76.17 fg
V_3S_2	17.43 h	47.17 ef	63.37 h	72.07 gh
V_3S_3	24.03 d	50.77 ef	79.83 f	88.00 e
V_3S_4	23.92 d	79.83 c	109.90 cd	117.37 c
V_3S_5	29.50 c	79.33 c	114.83 c	122.73 c
$LSD_{0.05}$	2.15	11.32	13.28	11.21
CV %	5.55	7.46	6.66	5.05

**In each column, figures having similar letters or without letters do not differ significantly, where as figures bearing dissimilar letter differ significantly at 5% level of probability.

Variety:
V_1 = Binatil - 2
V_2 = BARI Til - 3
V_3 = BARI Til - 4

Square spacing system:
S_1= 30 cm × 5 cm (Control)
S_2= 20 cm × 20 cm
S_3= 30 cm × 30 cm
S_4= 40 cm × 40 cm
S_5= 50 cm × 50 cm

4.2.3 Seeds capsule^{-1} (No.)

4.2.3.1 Effect of variety

The highest seeds capsule^{-1} (81.39) was attained from V_2, which was statistically at par (80.19) with V_3 and the lowest number was recorded (72.52) from V_1. Effect of variety on seeds capsules^{-1} is given in Table 11.

4.2.3.2 Effect of square spacing system

S_5 showed the highest number of seeds capsule^{-1} (83.59) whereas S_1 showed the lowest (73.56) which was statistically similar (74.19) with S_2. Due to the lower competition among plants under wider square planting, it then supplied enough nutrients to the plant which then helped to produce higher number of seeds from higher number of capsules plant^{-1}. Similar findings were observed from Jakusko *et al*. (2013), Hossain (2009) and Tanjila (2008). Though Thomas (1984) investigated that decrease seeds capsule^{-1} were resulted from increase of row spacing in canola. Effect of square spacing system on seeds capsules^{-1} is given in Table 11.

4.2.3.3 Combined effect of variety and square spacing system

The top scorer in seed number capsule^{-1} (88.93) was V_3S_5 and the lowest (68.63) was V_1S_3. Combined effect of variety and square spacing system on seeds capsules^{-1} is given in Table 11.

4.2.4 1000 seed weight (g)

4.2.4.1 Effect of variety

The three varieties showed non- significant result, i.e. variety had no significance on 1000 seed weight. Effect of variety on 1000 seed weight is given in Table 11.

4.2.4.2 Effect of square spacing system

The highest 1000 seed weight (3.03 g) was obtained from S_5, which showed statistical similarity (3.00 g and 2.95 g) with S_4 and S_3, respectively. The lowest result was (2.66 g) recorded from S_1, which was statistically similar (2.78 g) with S_2. As the result of increased intra-specific competition of the closer square planted plants, the seed weight and size were reduced (Jan *et al*., 2014). Similar comments also found from Nadeem *et al*. (2015) and Ahmmad (2010) but El-Naim *et al*. (2010) observed there was no significant effect of plant population on thousand seed weight as it is a genetic character. Effect of square spacing system on 1000 seed weight is given in Table 11.

4.2.4.3 Combined effect of variety and square spacing system

V_1S_4 given the highest 1000 seed weight (3.16 g), which was statistically similar (3.08 g, 3.03 g, 3.02 g, 2.99 g, 2.93 g, 2.92 g, 2.91 g and 2.90 g) with V_3S_5, V_2S_5, V_1S_3, V_1S_5, V_2S_4, V_3S_3, V_3S_4 and V_2S_3, respectively. The lowest weight was (2.46 g) recorded from V_3S_1, which was statistically similar (2.71 g) with V_2S_1. Combined effect of variety and square spacing system on 1000 seed weight is given in Table 11.

4.2.5 Seed weight plant^{-1} (g)

4.2.5.1 Effect of variety

The highest seed weight plant^{-1} was (18.64 g) recorded from V_1 and the lowest (13.88 g) from V_2, which showed statistical similarity (14.73 g) with V_3. Effect of variety on seed weight plant^{-1} is given in Table 11.

4.2.5.2 Effect of square spacing system

The wider square planting S_5 given the highest seed weight plant^{-1} (19.79 g) and the lowest was (12.44 g) from one of the narrower square plantings S_2. The higher capsules plant^{-1}, seeds capsule^{-1} and 1000 seed weight of wider square planting were ensured higher seed weight plant^{-1}. Alike result shown by Nadeem *et al*. (2015) and Ngala *et al*. (2013), whereas it is differed from Agele *et al*. (2015). Effect of square spacing system on seed weight plant^{-1} is given in Table 11.

4.2.5.3 Combined effect of variety and square spacing system

The highest seed weight plant^{-1} was taken (23.39 g) from V_1S_5 and the lowest was (11.22 g) from V_2S_2 which was statistically similar (12.55 g) with V_3S_2. Combined effect of variety and square spacing system on seed weight plant^{-1} is given in Table 11.

4.2.6 Stover weight plant^{-1} (g)

4.2.6.1 Effect of variety

The highest stover weight plant^{-1} was (42.12 g) obtained from V_1 and the lowest (35.49 g) from V_3, which was statistically similar (35.93 g) with V_2. Effect of variety on stover weight plant^{-1} is given in Table 11.

4.2.6.2 Effect of square spacing system

S_5 ranked higher (47.28 g) in stover weight plant^{-1} whereas the lower value (29.46 g) from S_2, which was statistically similar (30.16 g) with S_1. Wider square planting ensured maximum utilization of resources for its thin population consequence higher stover weight plant^{-1}. Ngala *et al*. (2013)

showed similar finding. Effect of square spacing system on stover weight plant^{-1} is given in Table 11.

4.2.6.3 Combined effect of variety and square spacing system

Significant results were shown by the treatments in stover weight plant^{-1}. V_1S_5 has shown higher value (55.13 g) and the lower was (26.75 g) from V_2S_1 which was statistically at par (27.09 g, 27.96 g and 29.53 g) with V_2S_2, V_3S_2 and V_3S_1, respectively. Combined effect of variety and square spacing system on stover weight plant^{-1} is given in Table 11.

Table 11. Effect of variety, square spacing system and combined effect of variety and square spacing system on seeds capsule^{-1}, 1000 seed weight, seed weight plant^{-1} and stover weight plant^{-1} of sesame

Treatment	Seeds capsule^{-1} (no.)	1000 seed weight (g)	Seed weight plant^{-1} (g)	Stover weight plant^{-1} (g)
Variety				
V_1	72.52 b	2.95	18.64 a	42.12 a
V_2	81.39 a	2.87	13.88 b	35.93 b
V_3	80.19 a	2.82	14.73 b	35.49 b
$LSD_{0.05}$	1.79	NS	0.86	4.43
CV %	2.27	7.80	5.41	11.55
Square spacing system				
S_1	73.56 d	2.66 b	13.57 d	30.16 d
S_2	74.19 d	2.78 b	12.44 e	29.46 d
S_3	78.10 c	2.95 a	15.22 c	39.46 c
S_4	80.73 b	3.00 a	17.72 b	42.88 b
S_5	83.59 a	3.03 a	19.79 a	47.28 a
$LSD_{0.05}$	1.19	0.145	0.73	1.81
CV %	1.58	5.16	4.74	4.92
Variety × Square spacing system				
V_1S_1	71.03 g	2.80 b-d	15.28 f	34.19 ef
V_1S_2	73.13 f	2.79 b-d	13.56 g	33.33 ef
V_1S_3	68.63 h	3.02 a-d	19.37 c	41.06 cd
V_1S_4	73.63 f	3.16 a	21.60 b	46.86 b
V_1S_5	76.17 e	2.99 a-d	23.39 a	55.13 a
V_2S_1	78.30 e	2.71 de	12.78 g	26.75 g
V_2S_2	73.10 fg	2.79 b-d	11.22 h	27.09 g
V_2S_3	84.30 bc	2.90 a-d	12.70 g	41.74 b-d
V_2S_4	85.60 b	2.93 a-d	15.23 f	41.53 cd
V_2S_5	85.67 b	3.03 a-c	17.46 de	42.57 b-d
V_3S_1	71.33 fg	2.46 e	12.66 g	29.53 fg
V_3S_2	76.33 e	2.75 cd	12.55 gh	27.96 g
V_3S_3	81.37 d	2.92 a-d	13.59 g	35.58 e
V_3S_4	82.97 cd	2.91 a-d	16.34 ef	40.25 d
V_3S_5	88.93 a	3.08 ab	18.51 cd	44.15 bc
$LSD_{0.05}$	2.56	0.32	1.41	5.19
CV %	1.58	5.16	4.74	4.92

** In each column, figures having similar letters or without letters do not differ significantly, where as figures bearing dissimilar letter differ significantly at 5% level of probability.

Variety:
V_1 = Binatil - 2
V_2 = BARI Til - 3
V_3 = BARI Til - 4

Square spacing system:
S_1= 30 cm × 5 cm (Control)
S_2= 20 cm × 20 cm
S_3= 30 cm × 30 cm
S_4= 40 cm × 40 cm
S_5= 50 cm × 50 cm

4.3 Yields

4.3.1 Seed yield (t ha^{-1})

4.3.1.1 Effect of variety

The top most seed yield has shown (1.03 t ha^{-1}) by V_1 and the lower was (0.95 t ha^{-1}) from V_2, which was statistically similar (0.96 t ha^{-1}) with V_3. Here V_2 showed 8.42 % lower yield from V_1. Effect of variety on seed yield is given in Table 12.

4.3.1.2 Effect of square spacing system

The control treatment S_1 showed the superior yield (1.79 t ha^{-1}) and the lowest yield was (0.67 t ha^{-1}) from S_5 the wider square spacing system due to its lower population density though it showed the highest seed weight $plant^{-1}$. Control treatment showed 62.57 % higher yield from S_5.

Though wider spacing possessed higher number of capsules $plant^{-1}$, seeds $capsule^{-1}$ and thousand seed weight, it was unable to compensate for achieving higher number of capsules unit $area^{-1}$, seeds unit area $^{-1}$ and thousand seed weight unit $area^{-1}$ as a result of its poor number of plants unit $area^{-1}$, finally closer square planting become an advanced yielder. Related finding was given by Ngala *et al*. (2013), Umar *et al*. (2012) and Alim (2009), while different finding was detected by Nadeem *et al*. (2015), Sivagamy and Rammohan (2013) and Haruna (2011) as they observe efficient utilization of the resources ensured higher yield of wider spaced plants. Effect of square spacing system on seed yield is given in Table 12.

4.3.1.3 Combined effect of variety and square spacing system

V_1S_1 treatment ranked above in seed yield plant^{-1} (1.88 t ha^{-1}) and the lower was (0.65 t ha^{-1}) from V_2S_5, which was statistically similar (0.66 t ha^{-1} and 0.69 t ha^{-1}) with V_3S_5 and V_1S_5, respectively. Combined effect of variety and square spacing system on seed yield is given in Table 12.

4.3.2 Biological yield (t ha^{-1})

4.3.2.1 Effect of variety

Non significant result was found in the effect of variety on biological yield of sesame. Effect of variety on biological yield is given in Table 12.

4.3.2.2 Effect of square spacing system

Due to higher population density of S_1 the control treatment, the biological yield was also higher (5.74 t ha^{-1}) to it and the lower yield (2.27 t ha^{-1}) was recorded from S_5 however it showed higher above ground dry matter weight plant^{-1}. Similar image also seen in the finding of Tanjila (2008). Diverse observation was found by Nadeem *et al*. (2015) and Ali *et al*. (2005) as it was revealed by them that there was enough possibility of the optimum number of plants (wider spaced) to get adequate nutrients. Effect of square spacing system on biological yield is given in Table 12.

4.3.2.3 Combined effect of variety and square spacing system

The great value of biological yield (6.08 t ha^{-1}) was obtained from V_1S_1, whereas the lowest (2.23 t ha^{-1}) was recorded from V_2S_5 which was statistically at par (2.26 t ha^{-1}, 2.32 t ha^{-1}, 2.45 t ha^{-1} and 2.48 t ha^{-1}) with V_3S_5, V_1S_5, V_1S_4 and V_3S_4, respectively. Combined effect of variety and square spacing system on biological yield is given in Table 12.

4.3.3 Harvest index (HI %)

4.3.3.1 Effect of variety

The highest harvest index (30.63 %) was recorded from V_1 which was statistically similar (29.33 %) with V_3 and the lowest (28.20 %) was from V_2 which was also statistically similar with V_3. Effect of variety on harvest index is given in Table 12.

4.3.3.2 Effect of square spacing system

The highest HI was obtained (31.33 %) from narrow square planting S_1, whereas the lowest (27.71 %) was from a broad square planting S_3 which was statistically similar (29.13 %) with S_4. Similar justification observed from Alim (2009), Karim (2008) and Caliskan *et al*. (2004) where they observe lower inter plant competition of wider spaced plants influenced their abundant growth, which reduced the ratio between seed yield and biological yield. Beside this some different observation was found by Jan *et al*. (2014) and Ali *et al*. (2005). Effect of square spacing system on harvest index is given in Table 12.

4.3.3.3 Combined effect of variety and square spacing system

The highest HI (32.42 %) was recorded from V_2S_1, which was statistically similar (32.19 %, 31.58 %, 31.02 %, 30.55 %, 30.40 % and 29.95 %) with V_1S_3, V_1S_4, V_1S_1, V_3S_1, V_3S_2 and V_1S_5, respectively whereas the lowest value of HI (23.30 %) was obtained from V_2S_3. Combined effect of variety and square spacing system on harvest index is given in Table 12.

Table 12. Effect of variety, square spacing system and combined effect of variety and square spacing system on yields of sesame

Treatment	Seed Yield ($t\ ha^{-1}$)		Biological Yield ($t\ ha^{-1}$)		Harvest Index (%)	
Variety						
V_1	1.03	a	3.36		30.63	a
V_2	0.95	b	3.32		28.20	b
V_3	0.96	b	3.26		29.33	ab
$LSD_{0.05}$	0.04		NS		1.48	
CV %	3.67		6.84		4.98	
Square spacing system						
S_1	1.79	a	5.74	a	31.33	a
S_2	0.91	b	3.10	b	29.37	b
S_3	0.80	c	2.93	c	27.71	c
S_4	0.73	d	2.53	d	29.23	bc
S_5	0.67	e	2.27	e	29.40	b
$LSD_{0.05}$	0.032		0.17		1.64	
CV %	3.31		5.19		5.73	
Variety × Square spacing system						
V_1S_1	1.88	a	6.08	a	31.02	a-d
V_1S_2	0.93	c	3.29	c	28.42	d-f
V_1S_3	0.86	d	2.67	d-f	32.19	ab
V_1S_4	0.77	ef	2.45	fg	31.58	a-c
V_1S_5	0.69	g-i	2.32	g	29.95	a-e
V_2S_1	1.75	b	5.41	b	32.42	a
V_2S_2	0.88	cd	3.01	cd	29.30	b-f
V_2S_3	0.76	ef	3.29	c	23.30	g
V_2S_4	0.71	f-h	2.66	ef	26.89	f
V_2S_5	0.65	i	2.23	g	29.09	c-f
V_3S_1	1.74	b	5.73	b	30.55	a-d
V_3S_2	0.91	cd	3.01	cd	30.40	a-e
V_3S_3	0.78	e	2.82	de	27.63	ef
V_3S_4	0.72	fg	2.48	fg	28.92	c-f
V_3S_5	0.66	hi	2.26	g	29.16	c-f
$LSD_{0.05}$	0.061		0.343		2.92	
CV %	3.31		5.19		5.73	

**In each column, figures having similar letters or without letters do not differ significantly, where as figures bearing dissimilar letter differ significantly at 5% level of probability.

Variety:
V_1 = Binatil - 2
V_2 = BARI Til - 3
V_3 = BARI Til - 4

Square spacing system:
S_1 = 30 cm × 5 cm (Control)
S_2 = 20 cm × 20 cm
S_3 = 30 cm × 30 cm
S_4 = 40 cm × 40 cm
S_5 = 50 cm × 50 cm

4.4 Correlation and regression analysis

4.4.1 Correlation analysis

The correlation between crop growth rate at 70 DAE - harvest, leaf area index at 70 DAE, capsule plant^{-1} at harvest, seeds capsule^{-1}, seed weight plant^{-1} and seed yield are presented in Table 13. Significantly positive correlations were seen between leaf area index at 70 DAE & seed yield (0.9856) and crop growth rate at 70 DAE - harvest & seed yield (0.9262). Due to the higher number of plants m^{-2} and early ground coverage by the populous narrow square planting, enhanced growth was observed which then responsible for the increased seed yield hectare^{-1}.

The highly significant but negative correlations were observed between capsule plant^{-1} at harvest, seeds capsule^{-1}, seed weight plant^{-1} and seed yield. These parameters showed their effectiveness in single plant yield of wider square planting but in per hectare area basis the yield was poor owing to their lower number of plants per unit area, hence the negative correlations were observed. Similar finding was observed from Umar *et al*. (2012).

Table 13. Correlation between seed yield (t ha^{-1}) of square spacing system and crop growth rate at 70 DAE - harvest, leaf area index at 70 DAE, capsule plant^{-1} at harvest, seeds capsule^{-1} and seed weight plant^{-1}

Parameters	CGR at 70 DAE-harvest	LAI at 70 DAE	Capsule plant^{-1} at harvest	Seeds capsule^{-1}	Seed weight plant^{-1}
Yield	0.9262**	0.9856**	-0.4859**	-0.4892**	-0.3717*

*5% level of significance **1% level of significance

4.4.2 Regression analysis

The regression lines between crop growth rate at 70 DAE - harvest, leaf area index at 70 DAE, capsule plant^{-1} at harvest, seeds capsule^{-1}, seed weight plant^{-1} and seed yield are presented in Figure 21. There was perfect relation was observed between crop growth rate at 70 DAE - harvest, leaf area index at 70 DAE, capsule plant^{-1} at harvest, seeds capsule^{-1}, seed weight plant^{-1} and seed yield.

The positive relation was observed between crop growth rate at 70 DAE - harvest, leaf area index at 70 DAE and seed yield as both the variables change in the same direction (as the increasing crop growth rate at 70 to harvest DAE and leaf area index at 70 DAE with decreasing square spacing system showed increasing yield per unit area), but negative was observed between capsule plant^{-1} at harvest, seeds capsule^{-1}, seed weight plant^{-1} and seed yield as both the variables change in the opposite direction (as the increasing number of capsules plant^{-1}, seeds capsule^{-1} and seed weight plant^{-1} with increasing square spacing system showed decrease yield per unit area). The linear equations were presented as follows:

i. $Y_{CGR} = 0.030x + 0.530$

ii. $Y_{LAI} = 0.168x + 0.550$

iii. $Y_{Capsules\ plant^{-1}} = -0.006x + 1.632$

iv. $Y_{Seeds\ capsule^{-1}} = -0.032x + 3.520$

v. $Y_{Seed\ wt.\ plant^{-1}} = -0.043x + 1.660$

Interpretation of the slopes:

i. If the CGR increases by 1 unit, the yield will increase by 0.030 units.

ii. If the LAI increases by 1 unit, the yield will increase by 0.168 units.

iii. If the capsules plant^{-1} increases by 1 unit, the yield will decrease by 0.006 units

iv. If the seeds capsule^{-1} increases by 1 unit, the yield will decrease by 0.032 units.

v. If the seed weight plant^{-1} increases by 1 unit, the yield will decrease by 0.043 units.

These interpretations were only applicable for this research work, not for the crop.

4.4.3 Coefficient of determination

The coefficient of determination (r^2) of crop growth rate at 70 DAE - harvest (0.857) implied that yield can be described almost 86% by crop growth rate at 70 to harvest DAE.

The coefficient of determination (r^2) of leaf area index at 70 DAE (0.971) implied that yield can be described 97% by leaf area index at 70 DAE.

The coefficient of determination (r^2) of capsules plant^{-1} at harvest (0.236) implied that yield can be described almost 24% by capsules plant^{-1} at harvest.

The coefficient of determination (r^2) of seeds capsule^{-1} at harvest (0.239) implied that yield can be described almost 24% by seeds capsule^{-1}.

The coefficient of determination (r^2) of seed weight plant^{-1} at harvest (0.138) implied that yield can be described almost 14% by seed weight plant^{-1}.

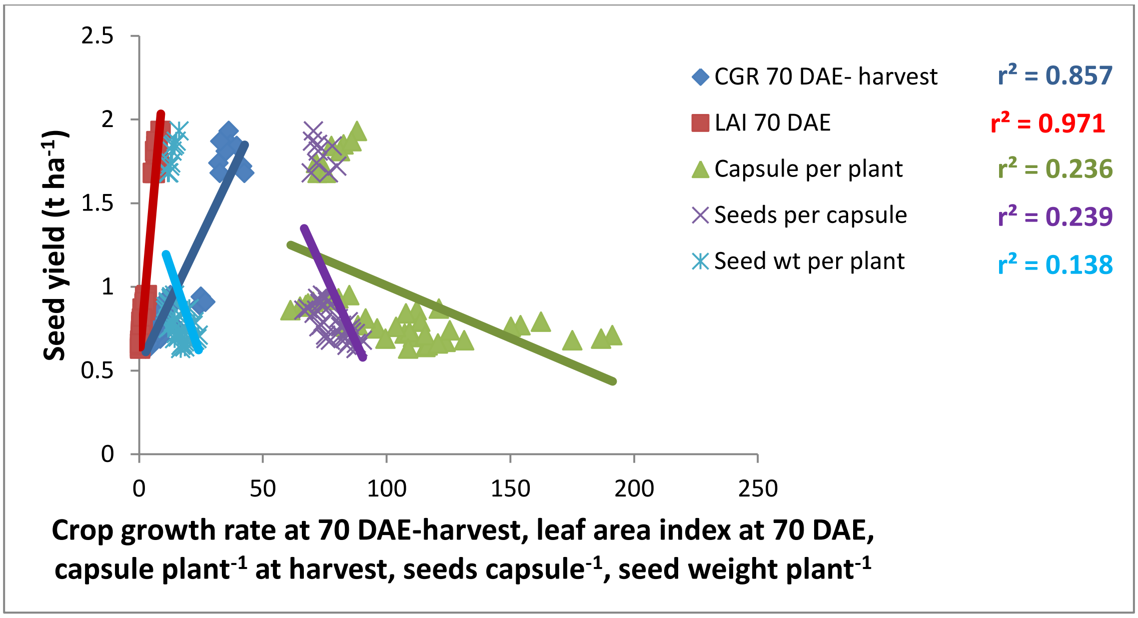

Figure 21. Regression lines between seed yield of square spacing system and crop growth rate at 70-harvest DAE, leaf area index at 70 DAE, capsule plant^{-1} at harvest, seeds capsule^{-1}, seed weight plant^{-1}

CHAPTER 5

SUMMARY AND CONCLUSION

The experiment was accomplished to find out the compatibility of square spacing system on the growth and yield of sesame throughout March, 2015 to June, 2015, at Agronomy field of Sher-e-Bangla Agricultural University, Dhaka-1207.

The experiment was designed according to split plot design with three replications and two factors those were variety and square planting. Three varieties (V_1= Binatil-2, V_2= BARI Til-3 and V_3= BARI Til-4) were assigned to main plot and five square spacing system (control treatment, S_1= 30 cm × 5 cm, S_2= 20 cm × 20 cm, S_3= 30 cm × 30 cm, S_4= 40 cm × 40 cm and S_5= 50 cm × 50 cm) were assigned to sub-plot. There were 15 treatment combinations thus 45 total numbers of plot and each consisted of 2.5 m × 1.5 m. Seeds were sown in a well tilled and fertilized field according to different square planting in different plots on 25 March, 2015.

Data were collected on various parameters such as growth parameters, included- plant height (cm), leaves plant^{-1} (no.), leaf area index (LAI), above ground dry matter weight plant^{-1}(g), crop growth rate (CGR), relative growth rate (RGR) and net assimilation rate (NAR); yield contributing parameters- branches plant^{-1}(no.), capsules plant^{-1} (no.), seeds capsule (no.), 1000 seed weight (g), seed weight plant^{-1} (g), stover weight plant^{-1} (g) and yield parameters- seed yield (t ha^{-1}), biological yield (t ha^{-1}) and harvest index (%). Data were taken at 25, 40, 55 and 70 days after emergence (DAE).

In plant height at 70 DAE non-significant relations was observed among the three varieties. Square planting S_5 given the tallest plant (119.66 cm) at 70

DAE and S_1 given the smallest (102.02 cm). At 70 DAE the largest plant height (126.20 cm) was recorded from V_1S_4 whereas the lowest (94.17 cm) was from V_1S_1.

The highest number of leaves plant^{-1} was (63.14) observed from V_1 and the lowest value (52.43) was from V_3. S_5 treatment at 70 DAE given the highest leaves plant^{-1} (69.93) whereas the S_1 given the lowest (48.60). V_1S_5 showed the highest leaves plant^{-1} (85.17) and V_1S_1 given the lowest (47.80) with the same DAE.

V_1 gained the highest result of leaf area (1451.3 cm^2) and V_3 showed the lowest (1180.8 cm^2) at 70 DAE. S_5 showed the highest LA (1544.6 cm^2) and S_2 given (1065.0 cm^2) the lowest. The highest leaf area was (1844.5 cm^2) obtained from V_1S_5 at 70 DAE and the narrowest (1007.0 cm^2) from V_2S_2.

Variety encoding V_1 expressed the highest leaf area index (LAI) (2.82) at 70 DAE while the lowest (2.39) from V_3. S_1 obtained the highest LAI (7.12) at 70 DAE meanwhile S_5 showed the lowest (0.62). V_1S_1 showed the largest LAI (7.84) at 70 DAE and V_3S_5 the smallest (0.55).

The higher above ground dry matter weight plant^{-1} (60.23 g) was taken from V_1 and the lowest (48.42 g) from V_2 at harvest. S_5 given the highest at harvest and S_2 showed the lowest (40.01). V_1S_5 showed the highest AGDM (79.68 g) at harvest and the lowest (35.65 g) from V_2S_2.

At 70 DAE – harvest V_3 showed the highest crop growth rate (CGR) (16.42 g m^{-2} d^{-1}) and the lowest was (12.28 g m^{-2} d^{-1}) from V_1. S_1 showed the highest CGR value (36.69 g m^{-2} d^{-1}) at 70-harvest DAE and S_5 given the lowest value (3.35 g m^{-2} d^{-1}). At 70-harvest DAE the highest CGR was (41.28 g m^{-2} d^{-1}) showed by V_2S_1 and the lowest (2.84 g m^{-2} d^{-1}) by V_1S_5.

At 70 DAE – harvest V_3 given the highest relative growth rate (RGR) (0.023 g g^{-1} d^{-1}) and the lowest was (0.011 g g^{-1} d^{-1}) from V_1. At 70-harvest DAE S_3 showed the superiority (0.02 g $g^{-1}d^{-1}$) and the lowest value was (0.013 g $g^{-1}d^{-1}$) from S_5. V_3S_2 showed dominance (0.031 g g^{-1} d^{-1}) at 70-harvest DAE and the lowest RGR was (0.009 g g^{-1} d^{-1}) from V_1S_4.

At 55-70 DAE three varieties showed non-significant relationship on net assimilation rate (NAR). At 55-70 DAE S_5 confirmed the highest NAR (0.000826 g cm^{-2} d^{-1}) and the lowest NAR (0.000680 g cm^{-2} d^{-1}) was got from S_2. The highest NAR (0.00093 g cm^{-2} d^{-1}) was obtained from V_2S_5 at 55-70 DAE and the shortest mark was (0.00062 g cm^{-2} d^{-1}) obtained by V_3S_2.

At 70 DAE V_1 given the highest branch number $plant^{-1}$ (10.14) and the lowest was (7.59) from V_2. At 70 DAE the highest branches $plant^{-1}$ (10.88) was recorded from S_5 and the lowest (6.6) was from S_1. At 70 DAE V_1S_5 was showed the highest branches $plant^{-1}$ (14.67) and the lowest (6.16) was observed from V_3S_1.

At harvest V_1 showed the highest capsules $plant^{-1}$ (124.03) and V_2 given the lowest capsules $plant^{-1}$ (93.26). At harvest S_5 given the highest capsules $plant^{-1}$ (141.22) and the lowest number (72.52) from S_2. V_1S_5 treatment showed the highest capsules $plant^{-1}$ (184.43) at harvest and V_2S_2 given the lowest number (64.93).

The highest seeds $capsule^{-1}$ (81.39) was attained from V_2 and the lowest number was recorded (72.52) from $V_{1.}$ S_5 showed the highest number of seeds $capsule^{-1}$ (83.59) whereas S_1 showed the lowest (73.56) number. V_3S_5 was the top scorer in seed number $capsule^{-1}$ (88.93) and V_1S_3 was the lowest (68.63) scorer.

The three varieties had no significance on 1000 seed weight as they showed non- significant result. The highest 1000 seed weight (3.03 g) was recorded by S_5 and the lowest result (2.66 g) by S_1. V_1S_4 given the highest 1000 seed weight (3.16 g) while the lowest weight was (2.46 g) from V_3S_1.

The highest seed weight plant^{-1} was (18.64 g) recorded from V_1 and the lowest (13.88 g) from V_2. The wider square planting S_5 given the highest seed weight plant^{-1} (19.79 g) and the lowest was (12.44 g) from one of the narrower square plantings S_2. The highest seed weight plant^{-1} was taken (23.39 g) from V_1S_5 and the lowest was (11.22 g) from V_2S_2.

The highest stover weight plant^{-1} was (42.12 g) obtained from V_1 and the lowest (35.49 g) from V_3. S_5 ranked higher (47.28 g) in stover weight plant^{-1} whereas the lower value was (29.46 g) recorded from S_2. V_1S_5 shown higher stover weight plant^{-1} (55.13 g) and the lower was (26.75 g) from V_2S_1.

The top most seed yield was shown (1.03 t ha^{-1}) by V_1 and the lower was (0.95 t ha^{-1}) by V_2. The superior yield was showed (1.79 t ha^{-1}) by S_1 and the lowest yield (0.67 t ha^{-1}) by S_5. V_1S_1 treatment ranked above in seed yield (1.88 t ha^{-1}) and V_2S_5 showed the lower (0.65 t ha^{-1}).

On biological yield of sesame non significant result was found with variety. S_1 showed the highest biological yield (5.74 t ha^{-1}) and the lowest (2.27 t ha^{-1}) was recorded from S_5. The highest biological yield (6.08 t ha^{-1}) was obtained from V_1S_1, whereas the lowest was (2.23 t ha^{-1}) from V_2S_5.

The highest harvest index (HI) was recorded (30.63 %) from V_1 and the lowest was (28.20 %) from V_2. The highest HI was obtained (31.33 %) from S_1, whereas the lowest was (27.71 %) from S_3. The highest HI (32.42 %) was observed from V_2S_1 and the lowest value of HI (23.30 %) was obtained from V_2S_3.

Before concluding this chapter it can be said that, as wider square planting was significant with the maximum growth and yield contributing parameters so sesame plant could be better adjusted to square planting. But the ultimate goal, the seed yield was so poor due to lack of population. Finally, it can be said that 30 cm × 5 cm is the optimum spacing for sesame cultivation. Repetition of this work at different AEZs may alter this finding due to the location variation.

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APPENDICES

Appendix I. Monthly average air temperature and rainfall of the experimental site during the period from March, 2015 to June, 2015

Month	Air Temperature (ºC)		Total Rainfall (mm)	Relative humidity (%)
	Maximum	Minimum		
March, 2015	32	20	610	65
April, 2015	34	23	1370	74
May, 2015	33	24	2450	75
June, 2015	32	26	3150	82

Source: www.climatemps.com

Appendix II. Analysis of variance of the data on plant height (cm) of sesame varieties as influenced by square spacing system and their interaction

Sources of variation	df	Mean square of plant height (cm) at days after emergence			
		25	**40**	**55**	**70**
Replication	2	6.20	4406.57	4100.25	2975.58
Variety (A)	2	293.40*	489.82*	48.37^{NS}	6.96^{NS}
Error I	4	9.60	59.65	97.93	84.88
Square spacing (B)	4	28.92*	180.59*	729.51*	660.87*
Variety (A) × Square spacing (B)	8	7.21*	59.97*	83.01*	166.54*
Error II	24	3.58	46.67	52.79	50.79

*Significant at 5% level of significance

^{NS} Non significant

Appendix III. Analysis of variance of the data on leaves $plant^{-1}$ (no.) of sesame varieties as influenced by square spacing system and their interaction

Sources of variation	df	Mean square of leaves $plant^{-1}$ (no.) at days after emergence			
		25	40	55	70
Replication	2	1.46	761.64	596.52	91.42
Variety (A)	2	2.65^{NS}	19.41^{NS}	579.17*	1001.10*
Error I	4	1.22	20.58	69.30	22.75
Square spacing (B)	4	0.68*	673.81*	2367.54*	463.39*
Variety (A) × Square spacing (B)	8	0.29*	46.23*	175.40*	29.03*
Error II	24	0.49	25.79	36.57	12.10

*Significant at 5% level of significance

^{NS} Non significant

Appendix IV. Analysis of variance of the data on leaf area $plant^{-1}$ (cm^2) of sesame varieties as influenced by square spacing system and their interaction

Sources of variation	df	Mean square of leaf area $plant^{-1}$ (cm^2) at days after emergence			
		25	40	55	70
Replication	2	3.81	19884	17807	38164
Variety (A)	2	162.86*	137667*	365671*	322941*
Error I	4	7.15	3708	24708	16132
Square spacing (B)	4	131.12*	276341*	1095286*	421290*
Variety (A) × Square spacing (B)	8	7.83*	6714*	59878*	18288*
Error II	24	2.63	3832	8272	7670

*Significant at 5% level of significance

Appendix V. Analysis of variance of the data on leaf area index of sesame varieties as influenced by square spacing system and their interaction

Sources of variation	df	Mean square of leaf area index at days after emergence			
		25	**40**	**55**	**70**
Replication	2	0.0000041	0.0451	0.305	0.56
Variety (A)	2	0.00031*	0.6290*	0.411*	0.59*
Error I	4	0.000056	0.0246	0.058	0.023
Square spacing (B)	4	0.47571*	51.40*	181.79*	33.49*
Variety (A) × Square spacing (B)	8	0.000045*	0.24*	0.031*	0.06*
Error II	24	0.000029	0.02	0.099	0.11

*Significant at 5% level of significance

Appendix VI. Analysis of variance of the data on above ground dry matter weight plant^{-1} (g) of sesame varieties as influenced by square spacing system and their interaction

Sources of variation	df	Mean square of above ground dry matter weight plant^{-1} (g) at days after emergence				
		25	**40**	**55**	**70**	**Harvest**
Replication	2	0.0096	31.21	23.37	153.37	10.43
Variety (A)	2	0.1238*	3.412*	255.11*	427.77*	636.67*
Error I	4	0.0189	0.156	21.39	28.80	69.79
Square spacing (B)	4	0.3267*	26.21*	370.16*	1176.29*	1297.43*
Variety (A) × Square spacing (B)	8	0.0828*	1.486*	33.21*	21.96*	34.21*
Error II	24	0.0144	0.322	4.58	16.98	11.34

*Significant at 5% level of significance

Appendix VII. Analysis of variance of the data on crop growth rate (g m^{-2} d^{-1}) of sesame varieties as influenced by square spacing system and their interaction

Sources of variation	df	Mean square of crop growth rate (g m^{-2} d^{-1})at days after emergence			
		25-40	40-55	55-70	70-harvest
Replication	2	64.25	24.37	7.20	0.49
Variety (A)	2	2.17^{NS}	269.63*	111.17*	66.91*
Error I	4	1.29	6.85	4.42	3.01
Square spacing (B)	4	3070.63*	3486.40*	6431.75*	1605.88*
Variety (A) × Square spacing (B)	8	1.35*	44.29*	56.72*	48.95*
Error II	24	5.79	8.86	1.92	1.36

*Significant at 5% level of significance

^{NS} Non significant

Appendix VIII. Analysis of variance of the data on relative growth rate (g g^{-1} d^{-1}) of sesame varieties as influenced by square spacing system and their interaction

Sources of variation	df	Mean square of relative growth rate (g g^{-1} d^{-1})at days after emergence			
		25-40	40-55	55-70	70-harvest
Replication	2	0.00078	0.0001	0.00007	0.000027
Variety (A)	2	0.00039^{NS}	0.00088*	0.00009*	0.00053*
Error I	4	0.00014	0.00086	0.0000092	0.000029
Square spacing (B)	4	0.00041*	0.00043*	0.00002*	0.000052*
Variety (A) × Square spacing (B)	8	0.00043*	0.00004*	0.00005*	0.000059*
Error II	24	0.00007	0.000006	0.0000091	0.000013

*Significant at 5% level of significance

^{NS} Non significant

Appendix IX. Analysis of variance of the data on net assimilation rate (g cm^{-2} d^{-1}) of sesame varieties as influenced by square spacing system and their interaction

Sources of variation	df	Mean square of net assimilation rate (g cm^{-2} d^{-1}) at days after emergence		
		25-40	40-55	55-70
Replication	2	0.00000059	0.000000021	0.000000029
Variety (A)	2	0.000000043*	0.000000253*	0.000000011^{NS}
Error I	4	0.0000000044	0.0000000058	0.0000000086
Square spacing (B)	4	0.000000052*	0.000000059*	0.000000031*
Variety (A) × Square spacing (B)	8	0.000000053*	0.000000021*	0.000000028*
Error II	24	0.000000015	0.0000000041	0.0000000068

*Significant at 5% level of significance
^{NS} Non significant

Appendix X. Analysis of variance of the data on branches $plant^{-1}$ (no.) of sesame varieties as influenced by square spacing system and their interaction

Sources of variation	df	Mean square of branches $plant^{-1}$ (no.) at days after emergence		
		40	55	70
Replication	2	3.27	1.51	1.63
Variety (A)	2	0.69^{NS}	3.34*	30.61*
Error I	4	0.19	0.37	0.22
Square spacing (B)	4	3.56*	17.25*	32.44*
Variety (A) × Square spacing (B)	8	0.70*	3.07*	5.82*
Error II	24	0.09	0.24	0.11

*Significant at 5% level of significance
^{NS} Non significant

Appendix XI. Analysis of variance of the data on capsules plant^{-1} (no) of sesame varieties as influenced by square spacing system and their interaction

Sources of variation	df	Mean square of capsules plant^{-1} (no) at days after emergence			
		40	55	70	Harvest
Replication	2	10.31	95.90	103.62	93.89
Variety (A)	2	44.25*	4268.59*	4344.24*	4442.20*
Error I	4	0.68	66.91	84.02	63.68
Square spacing (B)	4	396.15*	4825.03*	7285.64*	7884.53*
Variety (A) × Square spacing (B)	8	33.36*	1207.91*	664.90*	663.83*
Error II	24	1.75	27.36	41.32	27.72

*Significant at 5% level of significance

Appendix XII. Analysis of variance of the data on seeds capsule^{-1} (no.), 1000 seed weight (g), Seed weight plant^{-1} (g) and Stover weight plant^{-1} (g of sesame varieties as influenced by square spacing system and their interaction

Sources of variation	df	Mean square values at days after emergence			
		Seeds capsule^{-1} (no.)	1000 seed weight (g)	Seed weight plant^{-1} (g)	Stover weight plant^{-1} (g)
Replication	2	5.65	0.18	2.96	9.55
Variety (A)	2	347.43*	0.06^{NS}	96.59*	205.59*
Error I	4	3.15	0.05	0.73	19.12
Square spacing (B)	4	164.23*	0.23*	81.40*	554.48*
Variety (A) × Square spacing (B)	8	43.08*	0.03*	4.52*	20.66*
Error II	24	1.52	0.02	0.56	3.47

*Significant at 5% level of significance

^{NS} Non significant

Appendix XIII. Analysis of variance of the data on seed yield (t ha^{-1}), biological yield (t ha^{-1}) and harvest index (%) of sesame varieties as influenced by square at days after emergence and their interaction

Sources of variation	df	Mean square of branches plant^{-1} (no.) at days after emergence		
		Seed yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Replication	2	0.0024	0.019	3.67
Variety (A)	2	0.0257*	0.038^{NS}	22.18*
Error I	4	0.0012	0.051	2.14
Square spacing (B)	4	1.9187*	17.53*	14.98*
Variety (A) × Square spacing (B)	8	0.0019*	0.184*	15.02*
Error II	24	0.0011	0.029	2.84

*Significant at 5% level of significance

^{NS} Non significant

PLATES

Plate no. 1. Image of experimental plot

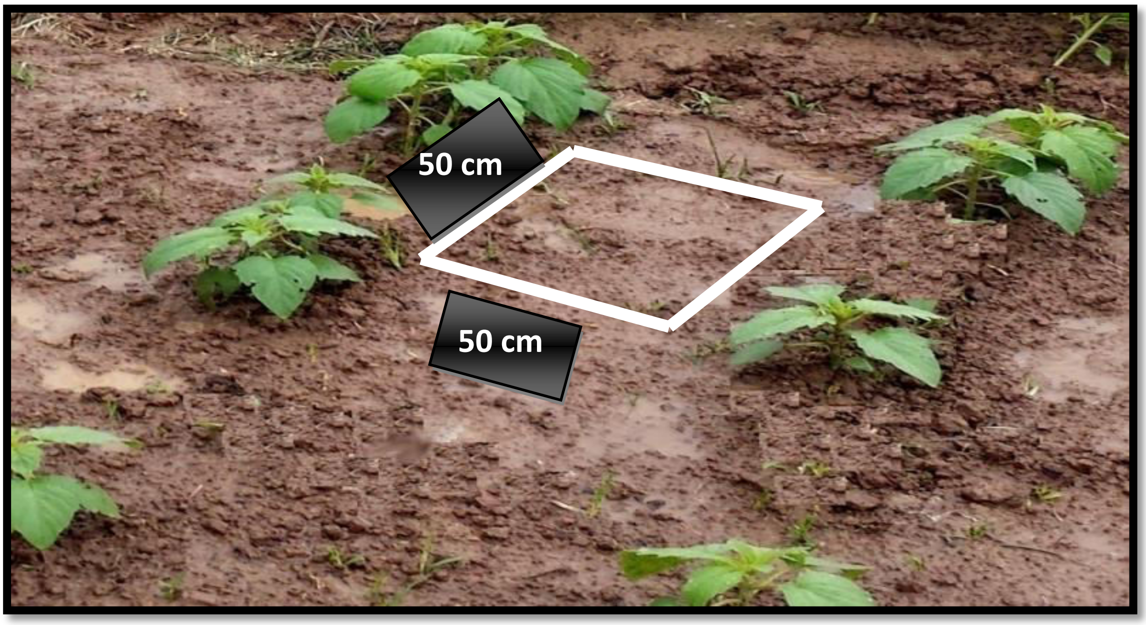

Plate no. 2. Image of 50 cm × 50 cm square spacing

Plate no. 3. Image of flowering stage

Plate no. 4. Image of highest branches of wider square spaced plant

Plate no. 5. Image of capsule bearing plants

Plate no. 6. Image of maturity stage