INFLUENCE OF INTEGRATED NUTRIENT MANAGEMENT AND PLANTING CONFIGURATION ON THE PRODUCTIVITY OF SESAME (*Sesamum indicum* L.)

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CERTIFICATE

This is to certify that the thesis entitled, "INFLUENCE OF INTEGRATED NUTRIENT MANAGEMENT AND PLANTING CONFIGURATION ON THE PRODUCTIVITY OF SESAME (*Sesamum indicum* L.)" submitted to the FACULTY OF AGRICULTURE, SHER-E-BANGLA AGRICULTURAL UNIVERSITY, Dhaka, in partial fulfilment of the requirements for the degree of DOCTOR OF PHILOSOPHY IN AGRONOMY, embodies the result of a piece of bonafide research work carried out by MOHAMMAD MALEK, Registration No. 27514/00697 under my supervision and guidance. No part of the 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.

Dated:
Place: Dhaka, Bangladesh

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SAU, Dhaka

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ABSTRACT

The study was carried out to evaluate some sesame varieties under different nutrient management strategies for enhancing the productivity of sesame during 2014-16. The experiments were conducted in three years. First year experiment was carried out with two factors *viz*., different nutrient levels with different varieties of sesame in split plot design with three replications during March-June 2014. The main plot treatments had four nutrient levels *viz*., 75% of recommended dose of fertilizer(RDF) (N_1), 100% RDF (N_2), 125% of RDF (N_3) and 150% of RDF (N_4) and the subplot treatments included six sesame varieties *viz*., Lal til (Local) (V_1), Atshira (Local) (V_2), T6 (V_3), BARI til-3 (V_4), BARI til-4 (V_5) and Bina til 2 (V_6). RDF indicates a nutrient schedule of 56:72:23 kg N, P_2O_5 and K_2O ha^{-1}. Results revealed that nutrient levels, 150% of RDF produced the highest growth parameters, but 100% of RDF (N_2) produced the highest seed yield (1223 kg ha^{-1}). The least seed yield was observed with N_4 (924 kg ha^{-1}). Among the sesame varieties placed in different sub plots, BARI til-4 showed the best growth and yield contributing parameters giving the highest seed yield (1170 kg ha^{-1}). The least seed yield was registered with V_1 (811.30 kg ha^{-1}). Interaction effect was found significant showing a seed yield of 1481 kg ha^{-1} with N_2V_5. From this trial, the best nutrient level (100% of RDF i.e., 56:72:23 kg N, P_2O_5 and K_2O ha^{-1}) and variety BARI til-4 selected and taken over to the next year of study. In the second year experiment, different sources of organic manures were integrated with chemical fertilizers at three different proportions *viz.,* 25, 50 and 75 percent along with 100 percent organic source and chemical fertilizers alone. The organic sources included vermicompost and FYM. Different plant spacing were associated with different sources of plant nutrients. Nine nutrient sources and four plant spacings were used in this experiment. The experiment was conducted during March-June 2015 in split plot design with three replications consisting of 36 treatment combination. With regard to different sources of nutrients, T_5 (25% RDF through vermicompost + 75% as chemical fertilizer) produced the highest seed yield (1326 kg ha^{-1}), oil yield (581.07 kg ha^{-1}) and protein yield (256.09 kg ha^{-1}) where least seed yield (1204 kg ha^{-1}), oil yield (518.57 kg ha^{-1}) and protein yield (226.55 kg ha^{-1}) was produced by T_6 (100% RDF through FYM). Among the different plant spacing studied, S_3 (30 cm × 15 cm) produced highest yield attributes but highest seed yield (1413 kg ha^{-1}), oil yield (584.11 kg ha^{-1}) and protein yield (250.82 kg ha^{-1}) was obtained from S_1 (30 cm

× 5 cm) where the least seed yield (1102 kg ha^{-1}), oil yield (484.19 kg ha^{-1}) and protein yield (216.09 kg ha^{-1}) was obtained from S_4 (30 cm × 20 cm). Interaction effect of nutrient sources and plant spacing in second year experiment, the highest seed yield, oil yield and protein yield (1437, 608.14 and 269.58 kg ha^{-1}, respectively) were produced with T_5S_1 where lowest seed yield (933.30 kg ha^{-1}), oil yield (412.05 kg ha^{-1}) and protein yield (186.29 kg ha^{-1}) were obtained from T_6S_4. The third year experiment was the repeated experiment of second year and similar trend was found in maximum cases. The highest seed yield, oil yield and protein yield (1442, 609.39 and 271.38 kg ha^{-1}, respectively) were obtained from the treatment combination of T_5S_1 where the lowest (962, 424.43 and 186.29 kg ha^{-1}, respectively) were also obtained from the treatment combination of T_6S_4.

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LIST OF ABBRIVIATIONS

%	=	Percent
@	=	at the rate of
^{0}C	=	Degree Centigrade
AEZ	=	Agro-Eclogical Zone
AGR	=	Absolute Growth Rate
BARI	=	Bangladesh Agricultural Research Institute
CBR	=	Cost Benefit Ratio
CGR	=	Crop Growth Rate
cm	=	Centimeter
CV	=	Coefficient of variance
cv.	=	Cultivar
DAS	=	Days after sowing
Df	=	Degrees of freedom
DM	=	Dry matter
DMP	=	Dry matter production
et al.	=	and others *(at elli)*
etc.	=	Etcetera
FAO	=	Food and Agriculture Organization
g	=	gram (s)
i.e.	=	That is
kg	=	Kilogram
kg/ha	=	Kilogram/hectare
LSD	=	Least Significant Difference
m	=	Meter
MOP	=	Muriate of Potash
pH	=	Hydrogen ion conc.
RGR	=	Relative Growth Rate
t/ha	=	ton/hectare
TSP	=	Triple Super Phosphate
viz.	=	Namely

CHAPTER 1

INTRODUCTION

Sesame (*Sesamum indicum* L.) is one of the oldest cultivated plants in the world and an indigenous oil plant with longest history in Indian sub-continent. It is under cultivation in Asia for over 5000 years (Toan *et al.,* 2010). It was a highly priced oil plant of Babylon and Assyria at least 4000 years ago (Oplinger *et al.,* 1990). Sesame commonly known as til in Bengali is an ancient oilseed crop grown in India and perhaps the oldest oilseed crop in the world. It is grown in an area of 7.54 million hectares with a production of 3.34 million tonnes in the world with a productivity of 443 kg ha^{-1} and also ranks first in the world in terms of sesame-growing area (FAI, 2012). Sesame (2n = 26), which belongs to the Sesamum genus of the Pedaliaceae family, is cultivated in tropical and subtropical regions of Asia, Africa and South America (Zhang *et al*., 2013). Sesame is cultivated in tropical and sub-tropical regions, in plains, up to an elevation of 1200m, and mainly in the dry and hot tropics in the areas with an annual rainfall of 500-1125mm. Sesame production was recorded in the Middle East and India since 4000 years ago. About 60% of the world's sesame production was from Myanmar, India, China, Ethiopia and Nigeria in 2011 (CSA, 2013).

In Bangladesh, sesame occupies a remarkable area under production and contributes second ranked production after rapeseed and mustard. At present about 3554 hactare of land is under sesame cultivation with a production of 2970 metric ton (BBS, 2015). Land area and production under sesame cultivation is decreasing day by day. In 2009-10, about 36 thousand hactare of land was under sesame cultivation where total production was 32306 metric ton (BBS, 2010). In 1995-96, sesame cultivated land was about 77 thousand hactare but in 2009-10 it was stand at 36 thousand hectare (BBS, 1996).

The climatic and edaphic conditions of Bangladesh are quite suitable for the cultivation of sesame crop. Khulna, Jessore, Faridpur, Barisal, Patuakhali, Rajshahi, Pabna, Rangpur, Sylhet, comilla, Dhaka and Mymensingh districts are the leading sesame producing areas of Bangladesh. The crop is cultivated either as a pure stand or as a mixed crop with aus rice, jute, groundnut, millets and sugarcane. The crop can be grown in a wide range of environments, extending from semi-arid tropics and subtropics to temperate regions.

Consequently, the crop has a large diversity in cultivars and cultural practices. This probably indicates a great opportunity for a prolonged and higher increase in productivity of sesame.

The quality of oil is determined by the fatty acid compositions of the oil. Sesame oil contains good quality poly-unsaturated fatty acids *viz.,* 47% oleic and 39% linoleic acid. It is also named as "seeds of immortality" due to the presence of antioxidants such as sesamin and sesaminol that prevents the biological system from the effect of free radicals. Thus it is called as "Queen of Oilseeds. Its oil is used for salad and cooking dishes. Sesame is a quality food, nutritious, edible oil, biomedicine and health care all in one. It is one of the world's ancient spice and oilseed crop grown mainly for seeds that contain 50% oil and 20% protein (Burden, 2005). Among the oil crops, sesame (*Sesamum indicum* L.) has the highest oil content of 46 - 64% (Raja *et al*., 2007). Its grain is an excellent source of high quality oil, protein, carbohydrate, calcium and phosphorous, and ranks among the top thirteen oil seed crops, which makes up to 90% of world edible oil production (NCRI, 2005).

Sesame seeds may be eaten fried, mixed with sugar or in the form of sweat meals and oil is used as cooking oil in southern India and also in Bangladesh. It is also used for anointing the body, for manufacturing perfumed oils and for medicinal purposes. Sesame cake is a rich source of protein, carbohydrates and minerals, such as calcium and phosphorus. Increase in sesame productivity is about 2% for Ethiopia and India, and 2.8% for China in the period of 2000-2011 (FAO, 2012).

To increase the productivity of sesame and land areas under its cultivation, various improved technologies are needed and among them, various agro-techniques, isolating location specific varieties assumes greater significance (Ganga *et al*., 2003).

Climatic factors mainly temperature, rainfall, and day length, soil types, and management practices through different agro-techniques such as variety, population density or spacing, time of sowing, irrigation, fertilizers, pesticides and/or herbicides influence sesame productivity (Adebisi, 2004). In particular, variety, sowing time, population density and/or plant spacing and nutrient levels in the soil play significant roles as determinants of seed yield. Adoption of sustainable variety, suitable sowing date, optimum spacing or population density and maintenance of nutrient status in the soil would fulfill the objective of maximizing the yield of sesame (Monayem *et al*., 2015). The yield of sesame can be increased by 21-53% with adoption of improved technologies such as improved variety, optimum doses of fertilizer, weed management and plant protection. Cropping system of oilseeds and pulses as well as adopted improved production technologies of sesame cultivation to increase their production than sole cropping of either crops or farmer's practices (Padhi and Panigrahi, 2006). Thus, use of improved production technologies of sesame offer a great scope for increasing productivity and profitability.

Lots of varieties is available in the world and local market; however, the farmers are still continuing to grow local varieties with low yields in Bangladesh. Different varieties of sesame yielded differently under different environments (Kumaresan and Nadarajan, 2002) ranging from 848 to 1154 kg ha^{-1}. Sesame yield was highly variable depending upon the growing environment, cultural practices and cultivars (Brigham, 1985). One of the reasons for fluctuation in crop yield seems to be due to sensitive behavior of varieties to different environmental conditions (Ganga *et al*., 2003).

The optimization of population density leads to both better vegetative growth as well as the highest yield (Hossain and Salahuddin, 1994). Population density is important practice to improve the seed yield and quality of sesame. Population density have direct influence on the seed yield of sesame and plant height, branches $plant^{-1}$, capsules $plant^{-1}$, seeds $capsule^{-1}$, seed yield and stover yield have great impact on different levels. Adebisi *et al*. (2005) showed that genotypes differ substantially in number of capsules $plant^{-1}$, capsule weight $plant^{-1}$, seed yield $plant^{-1}$ and 1000 seed weight and concluded that genotypes responded differently to changes in population densities.

Such solution may be integrated with the locally available organic manures to the possible extent. Different types of organic manures are generally used in our crop field. Vermicompost has high nutrient analysis contents, which could well be utilized as manure. Many research evidences showed the positive effect of vermicompost on sesame and soil health (Jaishankar and Wahab 2005; SajjadiNik *et al*., 2010). Appreciable increments in sesame yield were obtained through combined application of organic and inorganic source of nutrients (Veeraputhiran *et al*., 2001 and Hanumanthappa and

Basavaraj, 2008). Norman *et al.* (2005) reported that vermicompost improved the plant growth due to the changes in physico-chemical properties of soils, overall increase in microbial activity and plant growth regulators produced by microorganisms. Ushakumari *et al.* (2006) stated that vermicompost is a potential source of plant nutrient in presence of readily available nutrients, plant growth hormones, vitamins, enzymes, antibiotics and number of beneficial microorganisms. Gopinath *et al.* (2011) reported that application of FYM not only improved the physico-chemical properties of the soil like bulk density, water holding capacity and organic carbon content but also had little effect on residual phosphorus and potassium in the soil.Veeraputhiran *et al.* (2001) revealed that application of FYM @ 2.5 t ha^{-1}in sesame significantly improved the growth attributes *viz.*, plant height, number of branches $plant^{-1}$ and DMP and yield parameters *viz.*, number of capsules $plant^{-1}$ and number of seeds $capsule^{-1}$ as compared to control with 24% yield increase.

Chemical fertilizer is a quick nutrient source of crops. It plays a great role to increase production of a crop as well as balanced nutrition to the soil. Nahar *et al.* (2008) indicated that the number of capsules $plant^{-1}$, seeds $capsule^{-1}$, 1000 seed weight and seed yield increased significantly up to 100 kg N ha^{-1} in varieties T-6 and BARI til-3 but the variety BARI til-2 responded well up to 150 kg N ha^{-1}. The variety Yetka with 150 kg N ha^{-1} registered the highest seed yield, whereas local Ardestan exhibited the lowest in Turkey (Parvaneh and Parviz, 2008). Noorka *et al.* (2011) pointed out that increasing N fertilizer level upto 205 kg ha^{-1} significantly increased capsules $plant^{-1}$, 1000 seed weight, seed weight $plant^{-1}$ and seed yield ha^{-1}.

The other plant nutrient such as phosphorus, potassium, zinc etc. have also great role to increase yield potential. Haruna *et al.* (2010) opined that the application of 26.4 kg P_2O_5 ha^{-1} increased the plant height, number of leaves $plant^{-1}$ and total dry matter production than other levels. Mian *et al.* (2011) opined that the highest seed yield, number of capsules $plant^{-1}$, capsule length, and 1000 seed weight were recorded with 90 kg P_2O_5 ha^{1}. Ojikpong *et al.* (2008) studied that application of K_2O up to 45 kg ha^{-1} significantly increased the seed yield of sesame than that of the other levels (0, 15 and 30 kg ha^{-1}). Application of K_2O up to 40 kg ha^{-1} increased the yield attributes and yield and further increase in K_2O registered non-significant response (Jadav *et al.*, 2010).

Balanced fertilization with NPK was proved beneficial in all the oilseed crops both under rain fed and irrigated conditions (Ghosh *et al.*, 2002). Sesame is a highly nutrient responsive crop. Sesame responded well up to 205 kg N (Noorka *et al*., 2011), 90 kg P_2O5 (Mian *et al.*, 2011) and 60 kg K_2O ha^{-1} (Roy *et al.*, 1995). Integrated use of organic and inorganic fertilizers in a balanced proportion for sustainable sesame production was emphasized (Tiwari *et al.*, 1995; Hegde, 1998; Deshmukh *et al.*, 2002).

Despite the potential for increasing the production and productivity of sesame, there are also a number of challenges inhibiting sesame production and productivity. Among the many production constraints, the most important ones are (Uzun and Cagirgan, 2006);

1) Lack of improved and high yielding varieties for different agro-ecologies with desirable agronomic qualities viz. non-shattering, diseases/pests resistance
2) Low soil fertility and pH status
3) Lack of varieties which respond to inorganic fertilizers
4) Lack of knowledge to practices integrated nutrient management.
5) Non availability of improved quality seed
6) Lack of adequate knowledge of farming and post-harvest crop management
7) Lack of high standard oil processing industries
8) Lack of collaboration among breeders and agronomists

Additional key reason of the crop under different situations and hence brige the gap in oil seed production in Bangladesh, sesame research needs extraordinary prominace through agro-techniques such as identify the suitable varieties, plant spacing and nutrient management approaches etc. in triggering its productivity to exploiz the full potentiality.

Higher productivity in any crop can be achieved through a combination of ideal variety associated with appropriate agronomic practices and keeping all the above facts into deliberation, three field trials on sesame were undertaken consecutively with the following objectives:

1) Identify suitable sesame variety for Kharif season,
2) Determine the optimum population density for higher yield of sesame,
3) Study the response of sesame varieties to different nutrient levels,
4) Formulate an integrated nutrient management strategy for sesame, and
5) Asses the economic potentials of various treatments used in this study.

CHAPTER 2

REVIEW OF LITERATURE

Sesame is an important oil seed crop in Bangladesh which can contribute to a large extent in the national economy. But the research works done on this crop with respect to agronomic practices are inadeqaute. Only some limited study has so far been done in respect of agronomic management practices of the crop particularly the variety and population density. However, a few such studies have been carried out in other parts of the world. Some of the studies relevant to present piece of work from home and abroad have been reviewed in this chapter following the parameters of plant growth and yield.

2.1 Performance of sesame varieties

2.1.1 Growth parameters

2.1.1.1 Plant height

Patil *et al.* (1990) observed the growth characters of *Sesamum* varieties *viz*., Punjab 1, T85, Phule 1 and revealed significant variation in mean plant heights. *Sesamum* genotype Gouri produced significantly taller plants as compared to Madhavi (Rao *et al.,* 1990). Among the varieties, JLT 7 proved significantly superior to Punjab 1 for growth attributes (Ashok *et al*., 1992). Plant height was significantly more in variety E 8 than in DS 1 (Channabasavanna and Setty, 1992).

Tiwari *et al.* (1994) studied the performance of genotypes *viz*., CO 1, TKG 9 and TKG 21 and found that the genotype CO 1 significantly registered the highest plant height of 89.6 cm as compared to variety TKG 9 and TKG 21. Balasubramaniyan *et al.* (1995) observed that *Sesamum* varieties showed significant differences in growth characters; among the two varieties (TMV 3 and VS 350) tested, TMV 3 grew taller plant.

Qayyum *et al.* (1995) indicated that *Sesamum* cultivar Progeny 19-9 grew taller with a height of 72.5 cm when compared with S 17. El-Serogy *et al.* (1997) showed that the cultivar B35 recorded the tallest plants to that of Giza 32. Moorthy *et al.* (1997) conducted field experiments with *Sesamum* varieties *viz*., Kanak, Kalika, OMT 10, Uma, Usha and Vinayak and found that among six varieties, Kalika registered the maximum plant height as compared to other varieties.

Subba *et al.* (1997) demonstrated that the maximum plant height was recorded in *Sesamum* variety YLM 17 followed by YLM 11 as compared to Gouri and Madhavi. Tiwari and Namdeo (1997) stated that all the four varieties studied *viz*., TKG 9, TKG 21, JLSC 8 and JT 7 differed significantly with each other in vegetative growth characters due to genetic variability. Among the varieties tested, JT 7 recorded the maximum plant height compared to TKG 21.

Shanker *et al.* (1999) examined the performance of *Sesamum* varieties *viz*., T_4, T_{12} and T_{78} and found that T_{12} proved better with regard to plant height as compared to T_4 and T_{78}.

Subrahmaniyan and Arulmozhi (1999) considered the response of pre-released *Sesamum* cultivar VS 9104 and ruling variety VRI 1 and found that VS 9104 registered the taller plants as compared to that of VRI 1. Growth character, plant height varied significantly between varieties and B 67 recorded the highest values compared to OTM 10 and OTM 11 Patra (2001).

Subrahmaniyan *et al.* (2001) witnessed that *Sesamum* culture ORM 17 recorded the maximum plant height (106.60 cm) as compared to ORM 7 and ORM 14. Subrahmaniyan *et al.* (2001) explored the performance of *Sesamum* varieties *viz*., TMV 3, TMV 4, TMV 6, VRI 1 and VS 9104 and reported that the variety TMV 6 was the tallest 100.2 cm; as compared to other varieties.

Thakur *et al*. (2001) found that *Sesamum* variety Brajeshwari recorded the highest plant height of 148 cm as compared to Punjab Til No. 1 with 139 cm. Malam Singh Chandawat *et al.* (2003) monitored the performance of Sesamum varieties *viz*., RT 54, RT 46 and TC 25 and reported that the variety RT 46 showed the tallest plants (100.8 cm).

Thanunathan *et al.* (2004) observed significant differences in growth characters due to varieties. Significant differences in growth characters was observed and concluded that *Sesamum* mutant AUSM 3 recorded the highest plant height compared to other *Sesamum* varieties and mutants (Dhandapani *et al.,* 2003).

2.1.1.2 Number of leaves plant^{-1}

Patil *et al.* (1990) observed the growth characters of *Sesamum* varieties *viz.*, Punjab 1, T85, Phule 1 and revealed significant variation in mean number of leaves plant^{-1} between the varieties.

Shanker *et al.* (1999) examined the performance of *Sesamum* varieties viz., T_4, T_{12} and T_{78} and found that T_{12} proved better with regard to number of leaves plant^{-1} as compared to T_4 and T_{78}.

Umar *et al*. (2012) conducted a field study to evaluate the performance of two sesame varieties (NCRIBen001M and NCRIBen002M) in response to nitrogen fertilizer level and intra row spacing, during the wet seasons of 2009 and 2010. The two varieties produced significantly same number of leaves (NL).

2.1.1.3 Number of branches plant^{-1}

Narayan and Narayanan (1987) compared six *Sesamum* genotypes and reported that the number of capsules and yield contribution from the main stem were substantial in less branching cultivars *viz*-, Madhavi, NP 6 and T 12 as compared to relatively high branching Gouri and TMV 3.

Sesamum genotype Gouri produced significantly more number of branches plant^{-1} as compared to Madhavi (Rao *et al.*, 1990). Asha *et al.* (1992) opined that variety Madhavi produced significantly more number of branches m^{-2} than Gouri.

Tiwari *et al.* (1994) studied the performance of genotypes *viz*., CO 1, TKG 9 and TKG 21 and found that the genotype CO 1 significantly registered the highest number of branches plant^{-1} of 3.99 as compared to variety TKG 9 and TKG 21. Balasubramaniyan *et al.* (1995) observed that *Sesamum* varieties showed significant differences in growth characters; among the two varieties (TMV 3 and VS 350) tested, VS 350 produced higher number of branches plant^{-1} as compared to TMV 4.

Moorthy *et al.* (1997) conducted field experiments with *Sesamum* varieties viz., Kanak, Kalika, OMT 10, Uma, Usha and Vinayak and found that among six varieties, Kalika registered the maximum number of branches plant^{-1} as compared to other varieties.

Subba *et al.* (1997) demonstrated that the maximum number of branches plant^{-1} was recorded in *Sesamum* variety YLM 17 followed by YLM 11 as compared to Gouri and Madhavi.

Tiwari and Namdeo (1997) stated that all the four varieties studied *viz*., TKG 9, TKG 21, JLSC 8 and JT 7 differed significantly with each other in vegetative growth characters due to genetic variability. Among the varieties tested, TKG 21 recorded significantly the highest number of branches plant^{-1} compared to TKG 9, JLSC 8 and JT 7.

Shanker *et al.* (1999) examined the performance of *Sesamum* varieties viz., T_4, T_{12} and T_{78} and found that T_{12} proved better with regard to number of branches plant^{-1} as compared to T_4 and T_{78}.

Subrahmaniyan and Arulmozhi (1999) considered the response of pre-released *Sesamum* cultivar VS 9104 and ruling variety VRI 1 and found that VS 9104 registered the highest number of branches plant^{-1} as compared to that of VRI 1. Patra (2001) observed that number of branches plant^{-1} varied significantly between varieties and B 67 recorded the highest values compared to OTM 10 and OTM 11. Subrahmaniyan *et al.* (2001a) witnessed that *Sesamum* culture ORM 17 recorded the maximum number of branches plant^{-1} (5.6) as compared to ORM 7 and ORM 14.

Subrahmaniyan *et al.* (2001) explored the performance of *Sesamum* varieties *viz*., TMV 3, TMV 4, TMV 6, VRI 1 and VS 9104 and reported that the variety VS 9104 recorded significantly the highest values of number of branches plant^{-1} as compared to other varieties. Thakur *et al*. (2001) found that *Sesamum* variety Brajeshwari produced critically the highest number of branches plant^{-1} (4.5) as against the local check (3.8).

Malam *et al.* (2003) monitored the performance of *Sesamum* varieties *viz*., RT 54, RT 46 and TC 25 and reported that the variety RT 54 recorded significantly higher number of branches plant^{-1} as compared to RT 46 and TC 25.

Significant differences in growth characters was observed and concluded that *Sesamum* mutant AUSM 3 recorded the highest number of branches plant^{-1} as compared to other *Sesamum* varieties and mutants (Dhandapani *et al.,* 2003).

Umar *et al*. (2012) conducted a field study to evaluate the performance of two sesame varieties (NCRIBen001M and NCRIBen002M) in response to nitrogen fertilizer level and intra row spacing, during the wet seasons of 2009 and 2010. The two varieties produced significantly same number of primary and secondary branches (NPB).

2.1.1.4 Dry weight plant^{-1}

Patil *et al.* (1990) observed the growth characters of *Sesamum* varieties *viz*., Punjab 1, T85, Phule 1 and revealed significant variation in mean dry matter plant^{-1} between the varieties.

Balasubramaniyan *et al.* (1995) observed that *Sesamum* varieties showed significant differences in growth characters; among the two varieties (TMV 3 and VS 350) tested, TMV 3 produced more dry matter plant^{-1} as compared to TMV 4.

Shanker *et al.* (1999) examined the performance of *Sesamum* varieties viz., T_4, T_{12} and T_{78} and found that T_{12} proved better with regard to dry matter production plant^{-1} as compared to T_4 and T_{78}.

Subrahmaniyan and Arulmozhi (1999) considered the response of pre-released *Sesamum* cultivar VS 9104 and ruling variety VRI 1 and found that VS 9104 registered the highest dry matter production as compared to that of VRI 1. Among the two *Sesamum* varieties, Tanuku Brown and X-79-1, dry matter production was considerably more in first variety (Sumathi and Jaganadham, 1999).

Subrahmaniyan *et al.* (2001) witnessed that *Sesamum* culture ORM 17 recorded the maximum dry matter production (33.2 g plant^{-1}) as compared to ORM 7 and ORM 14. Subrahmaniyan *et al.* (2001) observed the performance of *Sesamum* varieties *viz*., TMV 3, TMV 4, TMV 6, VRI 1 and VS 9104 and reported that the genotype, VS 9104 recorded significantly the highest dry matter production plant^{-1} as compared to other varieties.

Dhandapani *et al.* (2003) found significant differences in growth characters and concluded that *Sesamum* mutant AUSM 3 recorded the highest DMP as compared to other *Sesamum* varieties and mutants.

Umar *et al*. (2012) conducted a field study to evaluate the performance of two sesame varieties (NCRIBen001M and NCRIBen002M) in response to nitrogen fertilizer level and intra row spacing, during the wet seasons of 2009 and 2010. The variety, NCRIBen001M produced significantly higher values for total dry matter (TDM).

2.1.1.5 Leaf area index (LAI)

Patil *et al.* (1990) observed the growth characters of *Sesamum* varieties *viz*., Punjab 1, T85, Phule 1 and revealed significant variation in mean LAI between the varieties.

Tiwari and Namdeo (1997) stated that all the four varieties studied *viz*., TKG 9, TKG 21, JLSC 8 and JT 7 differed significantly with each other in vegetative growth characters and among the varieties tested, JT 7 recorded the maximum leaf area compared to TKG 9, TKG 21 and JLSC 8.

Dhandapani *et al.* (2003) found significant differences in growth characters and concluded that *Sesamum* mutant AUSM 3 recorded the highest LAI as compared to other *Sesamum* varieties and mutants.

Umar *et al*. (2012) conducted a field study to evaluate the performance of two sesame varieties (NCRIBen001M and NCRIBen002M) in response to nitrogen fertilizer level and intra row spacing, during the wet seasons of 2009 and 2010. The variety, NCRIBen001M produced significantly higher values for leaf area index (LAI).

2.1.1.6 Crop growth rate

Umar *et al*. (2012) conducted a field study to evaluate the performance of two sesame varieties (NCRIBen001M and NCRIBen002M) in response to nitrogen fertilizer level and intra row spacing, during the wet seasons of 2009 and 2010. The variety, NCRIBen001M produced significantly higher values for crop growth rate (CGR).

2.1.2 Yield attributes and yield

2.1.2.1 Number of capsule plant^{-1}

Bikram *et al.* (1988) disclosed that number of capsules plant^{-1} was consistently influenced by all the cultivars studied. Tomar (1990) observed that variety N 32 (482 kg ha^{-1}) was superior to JLT (384 kg ha^{-1}) in yield due to more number of capsules plant^{-1}. Rao *et al.* (1990) found that variety Gouri produced significantly the highest number of capsules plant^{-1} on main branch as well as secondary branches as compared to Madhavi that resulted in the highest seed yield. Yadav *et al.* (1991) declared that in the cultivars tested, Madhavi produced significantly more capsules plant^{-1} as compared to TKG 2-86, TNAU (local variety) and TM V 5.

Ashok *et al.* (1992) reported that *Sesamum* variety JLT 7 proved significantly superior to Punjab No. 1 for number of capsules plant^{-1}. Number of capsules plant^{-1} differed significantly among the varieties. It was observed that number of capsules plant^{-1} was significantly more in variety E 8 than in DS 1 (Channabasavanna and Setty, 1992). Channabasavanna and Setty (1992) observed that E8 registered significantly more capsules plant^{-1} and capsules m^{-2} than variety DS 1.

Across the two seasons, G-Till-1 and TMV 3 registered yield increase of 22.3 and 17.7 percent over local cultivar G Till-1 through 20.8 and 28.5 percent higher number of capsules plant^{-1} (Itnal *et al*., 1993).

Balasubramaniyan *et al.* (1995) opined that the variety VS 350 had significantly highest grain yield plant^{-1} than that of TMV 4 and explained with higher number of capsules produced in the main stem. Parameswar *et al.* (1995) observed that the yield increase in variety T_7 was 75.7 percent followed by Kalika and Vinayak over local check due to higher number of capsules plant^{-1}. El-Serogy *et al.* (1997) indicated that the cultivar Giza 32 had the highest number of capsules plant^{-1} among the other entries tried.

Subrahmaniyan *et al.* (2001) studied the performance of *Sesamum* varieties *viz*., TMV 3, TMV 4, TMV 6, VRI 1 and VS 9104 and reported that among the varieties tested, VS 9104 produced significantly the most number of capsules plant^{-1} (95.1).

Significant differences between two varieties *viz*., 92001 and TS 3 was observed with respect to number of capsules plant^{-1} (Riaz *et al.*, 2002). Variation in number of capsules plant^{-1} was noticed significantly among varieties (Govindaraju and Balakrishnan, 2002). Significantly more number of capsules plant^{-1} was observed by Malam *et al.* (2003) due to varietal difference.

Lakshmi and Lakshmamma (2005) conducted experiments with nine varieties at and concluded that the varieties RT 46, Gowri and CO 1 recorded significantly the highest capsule number. Kokilavani *et al.* (2007) evaluated three varieties *viz*., SVPR 1, TMV 3 and TMV 4 and concluded that white *Sesamum* SVPR 1 gave the highest capsules number plant^{-1}.

Umar *et al*. (2012) conducted a field study to evaluate the performance of two sesame varieties (NCRIBen001M and NCRIBen002M) in response to nitrogen fertilizer level and intra row spacing, during the wet seasons of 2009 and 2010. The variety, NCRIBen001M produced significantly higher values for capsules yield (CY).

Ali and Jan (2014) conducted an experiment on the performance of sesame cultivars (*Sesamum indicum* L.) (local black and local white) with different nitrogen levels (0, 40, 80 and 120 kg N ha^{-1}). The cultivar local black had more capsules plant^{-1} (71) as compared to cultivar local white.

Yahaya *et al*. (2014) carried out an experiment to investigate the characteristics and performance of all the accessions entries on seed-oil and yield parameters. Twelve accessions of sesame were used for the experiment. The accessions NG-03, NG-04, NA-01 and BE-02 had the least means with the number of capsules plant^{-1}.

Chongdar *et al*. (2015) carried out an investigation to find the effect of sowing dates and cultivars on yield and economic attributes of summer sesame (*Sesamum indicum* L.). Three cultivars of sesame (Rama, Savitri and Tillotama) were used for the experiment. Cultivar Rama produced the higher values with respect to number of capsules plant^{-1}.

2.1.2.2 Number of seeds capsule^{-1}

Asha *et al*. (1992) found that among the cultivars tested, Madhavi produced significantly more number of seeds capsule^{-1} than Gouri.Significant differences between two varieties *viz*., 92001 and TS 3 was observed with respect to seed weight capsule^{-1} (Riaz *et al.*, 2002). Variation in number of seeds capsule^{-1} was noticed significantly among varieties (Govindaraju and Balakrishnan, 2002). *Sesamum* varieties RT 54 and RT 46 recorded significantly the highest of seeds capsule^{-1} which was higher to variety TC 25 (Malam *et al.*, 2003).

Ali and Jan (2014) conducted an experiment on the performance of sesame cultivars (*Sesamum indicum* L.) (local black and local white) with different nitrogen levels (0, 40, 80 and 120 kg N ha^{-1}). The cultivar local black had more seed capsule^{-1} (61) as compared to cultivar local white.

Chongdar *et al*. (2015) carried out an investigation to find the effect of sowing dates and cultivars on yield and economic attributes of summer sesame (*Sesamum indicum* L.). Three cultivars of sesame (Rama, Savitri and Tillotama) were used for the experiment. Cultivar Rama produced the higher values with respect to number of seeds capsule^{-1}.

2.1.2.3 Capsule length

El-Serogy *et al.* (1997) indicated that the cultivar Giza 32 had the highest capsule length among the other entries tried. Significant differences between two varieties *viz*., 92001 and TS 3 was observed with respect to number of capsule length (Riaz *et al.*, 2002)

Lakshmi and Lakshmamma (2005) conducted experiments with nine varieties at and concluded that the varieties RT 46, Gowri and CO 1 recorded significantly the highest capsule length.

2.1.2.4 Weight of 1000 seeds

Rao *et al.* (1990) found that variety Gouri produced significantly the highest 1000 seed weight as compared to Madhavi that resulted in the highest seed yield. Asha *et al*. (1992)

declared that in the cultivars tested, Madhavi produced significantly more capsules plant^{-1} and number of seeds capsule^{-1}, but inferior in 1000 seed weight than Gouri.

Hamdollah *et al.* (2009) indicated that 1000 grain weight of cultivar TS 3 was significantly the lowest among other *Sesamum* cultivars studied, but it produced the highest grains plant^{-1} and grain yield.

2.1.3 Yield parameters

2.1.3.1 Seed yield ha^{-1}

Monpara *et al.* (2008) observed a newly developed white *Sesamum* variety GT 13 (AT 93) and compared along with two checks *viz*., G Til 1 and G Til 2 at six locations and found that G Til 3 (white seeded) recorded the largest mean seed yield (average of 28 trials) of 697 kg ha^{-1} as against 582 kg ha^{-1} of G Til 1 and G Til 2 (618 kg ha^{-1}) with a yield improvement of 19.8 percent and 12.8 percent over check variety G Til 1 and G Til 2 respectively.

Narayan and Narayanan (1987) compared six *Sesamum* genotypes and found that seed yield of TMV 3 was significantly superior to all other genotypes tested. Further, it was also reported that the seed yield contribution from the main stem were substantial in less branching cultivars *viz*-, Madhavi, NP 6 and T 12 as compared to relatively high branching Gouri and TMV 3.

Bikram *et al.* (1988) indicated that the average seed yield of the cultivar HT 6 was significantly higher by 18.9 and 49.4 percent than that of the cultivars H 7-1 and AT 3. Among the 22 tests conducted, a new variety JLT gave 769 kg ha^{-1} as against 562 kg ha^{-1} of Phule Til No. 1 and 489 kg ha^{-1} of TC 25 which showed 37 and 57 percent higher yield, respectively (Deokar *et al.,* 1989).

Tomar (1990) observed that variety N 32 (482 kg ha^{-1}) was superior to JLT (384 kg ha^{-1}) in yield due to more number of capsules plant^{-1}. Laskar *et al.* (1991) stated that variety B 67 proved better than all the other local varieties in its yield characters.

Yadav *et al.* (1991) declared that in varietal trials, TKG 2-86 gave the highest yield of 7.8 q ha^{-1} and it was 42 percent more than that of local variety TNAU 10 as well as TM V 5 and also suitable for September sowing.

Ashok *et al.* (1992) reported that *Sesamum* variety JLT 7 proved significantly superior to Punjab No. 1 for grain yield. Channabasavanna and Setty (1992) observed that E8 registered significantly more grain yield than variety DS 1. Chimanshette and Dhoble (1992) indicated that *Sesamum* variety JLT 7 produced significantly the highest seed yield and it was 26 percent higher than that of T 85.

Across the two seasons, G-Till-1 and TMV 3 registered yield increase of 22.3 and 17.7 percent over local cultivar G Till-1 through 20.8 and 28.5 percent higher number of capsules $plant^{-1}$ (Itnal *et al*., 1993).

Palaniappan *et al.* (1993) evaluated genotypes (*viz*., TMV 3, TMV 4, TMV 5, TMV 6, CO 1, VS 117, VS 339 and VS 350) in farmer's fields under different situations and reported that the performance of TMV3 and VS350 was superior to other varieties in respect of seed yield. Similarly, significant difference in seed yield between varieties TMV 6 and VS 350 was observed by Balasubramanian *et al.* (1993). Sarma and Kakati (1993) reported that the seed yield of Vinayak (5.08 q ha^{-1}) and TC 25 (4.89 q ha^{-1}) were significantly superior to C 7 (7.3 q ha^{-1}).

Sarma (1994) stated that the seed yield of *Sesamum* varieties Madhavi (7.92 q ha^{-1}) and Gouri (7.78 q ha^{-1}) were significantly superior to TC 25 (4.76 q ha^{-1}). Shinde *et al.* (1994) tested the performance of genotypes *viz*-, JLT 26, Tapi, Phule Til 1 and TC25 and reported that the yield difference among them were significant in all the seasons. The promising variety JLT 26 gave higher yield of 555 kg ha^{-1} which was 28 percent more than TC 25 (414 kg ha^{-1}).

Tiwari *et al*. (1994) observed that there was variation in seed yield among different genotypes and *Sesamum* cultivar CO 1 gave significantly higher seed yield of 3.7 q ha^{-1} as compared to TKG 9 (3.7 q ha^{-1}) and TKG 21 (2.54 q ha^{-1}).

Balasubramaniyan *et al.* (1995) opined that the variety VS 350 had significantly the highest grain yield plant^{-1} than that of TMV 4. Parameswar *et al.* (1995) observed that there was a wide range of variability among the entries with regard to the yield, ranging from 420.1 to 738.6 kg ha^{-1}. The entry T_7 consistently recorded the highest seed yield of 738.6 kg ha^{-1} followed by Kalika (590.6 kg ha^{-1}) and Vinayak (571.5 kg ha^{-1}) which were statistically on par with one another but superior to local check (420.1 kg ha^{-1}). The yield increase in variety T_7 was 75.7 percent over local check due to higher number of capsules plant^{-1}. Qayyum *et al.* (1995) suggested that *Sesamum* seed yield was significantly superior with Progeny 19-9 (1008.35 kg ha^{-1}) as compared to S-17 (881.2 kg ha^{-1}).

According to Jebaraj and Sheriff (1996), variety SVPR 1 had large sized capsules, densely arranged on the main stem and it registered an average seed yield of 1,155 kg ha^{-1} as compared to 848 and 879 kg ha^{-1} with TMV 3 and TMV 4, respectively.

Ganga *et al*. (1997) reported that Swetha Til (white *Sesamum*) was a promising new variety of *Sesamum*; it recorded 45.9 and 67.5 percent higher seed yield than that of the local check Rajeswari and National check TC 25, respectively in rainy season.

The variety YLM 17 yielded significantly more seed than the other three varieties and it was closely followed by YLM 11 (Subba *et al.,* 1997). Tiwari and Namdeo (1997) stated that *Sesamum* genotype TKG 22 gave significantly the highest seed yield (4.97 q ha^{-1}) followed by TKG 67 and check (JT 7/21) except TKG 32.

Among seven promising varieties of *Sesamum* studied *viz.,* Type 13, Shekhar, Type 12, HT 37, Type 4, Type 78 and local; Type 78 gave 27.13 percent higher seed yield than that of the most popular local variety (Singh and Chaubey, 1999).

Significant differences between two varieties *viz*., 92001 and TS 3 was observed with respect to seed weight capsule^{-1} and seed yield (Riaz *et al.*, 2002). Variation in seed yield was noticed significantly among tested varieties (Govindaraju and Balakrishnan, 2002). *Sesamum* varieties RT 54 and RT 46 recorded significantly the highest seed yield which was 54.5 and 11.6 percent higher to varieties TC 25.

The varieties *viz*., AU 1 and SVPR 1 had both genotypic and phenotypic stabilities for most of the important yield contributing characters as well as for seed yield (Thirugnanakumar *et al.,* 2004).

Deshmukh *et al.* (2005) reported that variety RT 54 out yielded all the ten varieties tested and further observed significant differences in yield attributes. Lakshmi and Lakshmamma, (2005) conducted an experiment with nine varieties and concluded that the varieties RT 46, Gowri and CO 1 recorded significantly the higer seed yield. Uzun and Cagirgan (2006) stated that genotype DT 45 had the highest seed yield and were significantly superior to the other genotypes in Turkey.

Abou *et al.* (2007) opined that cultivar Shandaweel surpassed Giza 32 in most of the yield parameters. Seed yield of the culture YLM 66 was significantly superior to YLM 17 over seasons. YLM 66 performed well in AICRP trials in initial varietal evaluation and advanced varietal trial over locations (Gangadhara, 2007).

Kokilavani *et al.* (2007) evaluated three varieties *viz*., SVPR 1, TMV 3 and TMV 4 and concluded that white *Sesamum* SVPR 1 gave the highest seed yield. Olowe (2007) opined that variety Yandev 55 recorded significantly the highest grain yield than E8 by 20 percent.

Suryabala *et al.* (2008) opined that white *Sesamum* cultivar Pragati gave the highest seed yield (24.76 percent) compared to T-78. Hamdollah *et al.* (2009) indicated that thousand grain weight of cultivar TS 3 was significantly the lowest among other *Sesamum* cultivars studied, but it produced the highest grains plant^{-1} and grain yield.

Roy *et al*. (2009) conducted a field experiment to evaluate the effect of row spacing (S_1 = 15 cm, S_2 = 30 cm and S_3 = 45 cm) on the yield and yield contributing characters of sesame using the varieties ($V_1 = T_6$, V_2 = Batiaghata local Til and V_3 = BINA Til). Yield was significantly influenced by the varieties. The highest seed yield was produced by the variety BINA Til while the lowest was by the variety Batiaghata local Til.

Umar *et al*. (2012) conducted a field study to evaluate the performance of two sesame varieties in response to nitrogen fertilizer level and intra row spacing, during the wet seasons of 2009 and 2010. The treatments consisted of four nitrogen levels (20, 40, 60 and 80kgN ha^{-1}), three intra row spacing (5, 10 and 15cm) and two varieties (NCRIBen001M and NCRIBen002M). The variety, NCRIBen001M produced significantly higher values for grain yield per plant (GYP) and grain yield per hectare (GY ha^{-1}) than NCRIBen002M under the same conditions. The study also recommends that, application of 80 kg N ha^{-1} and narrow intra row spacing of 5cm gave the highest grain yield of both varieties.

Ali and Jan (2014) conducted an experiment on the performance of sesame cultivars (*Sesamum indicum* L.) (local black and local white) with different nitrogen levels (0, 40, 80 and 120 kg N ha^{-1}). The cultivar local black had more seed yield (696 kg ha^{-1}) as compared to cultivar local white.

Yahaya *et al*. (2014) carried out an experiment to investigate the characteristics and performance of all the accessions entries on seed-oil and yield parameters. Twelve accessions of sesame were used for the experiment. The accessions NG-03, NG-04, NA-01 and BE-02 had the least means with the number of flowers plant^{-1} and number of capsules plant^{-1}. This is an indication that these Accessions have good potential for high seed yield.

Mesera and Mitiku (2015) conducted a field experiment using seven improved sesame (*Sesamum indicum* L.) varieties (namely: E, Tate, Kelafo-74, Mehando-80, T-85, Adi, and Abasena) under irrigation to select the best performing sesame varieties that will increase productivity and production of sesame in the target areas. The effect of varieties on seed yield was not significant and the best performing varieties of sesame varieties numerically were Mehando-80 (11 qt ha^{-1}), E (10.3 qt ha^{-1}) and T-85 (10 qt ha^{-1}) and would be recommended for the specific community and its vicinity.

Chongdar *et al*. (2015) carried out an investigation to find the effect of sowing dates and cultivars on yield and economic attributes of summer sesame (*Sesamum indicum* L.). Three cultivars of sesame (Rama, Savitri and Tillotama) were used for the experiment. Cultivar Rama recorded the highest seed yield 17.70 percent and 12.06 percent during

2013 and 2014, respectively followed by Savitri and Tillotama. Cultivar Rama also produced the higher values with respect to test weight.

2.1.3.2 Stover yield ha^{-1}

Abou *et al.* (2007) opined that cultivar Shandaweel surpassed Giza 32 in most of the yield parameters. Stover yield of the culture YLM 66 was significantly superior to YLM 17 over seasons. YLM 66 performed well in AICRP trials in initial varietal evaluation and advanced varietal trial over locations (Gangadhara, 2007).

Suryabala *et al.* (2008) opined that white *Sesamum* cultivar Pragati gave the highest stover yield (24.76 percent) compared to T-78. Hamdollah *et al.* (2009) indicated that thousand grain weight of cultivar TS 3 was significantly the lowest among other *Sesamum* cultivars studied, but it produced the highest grains plant^{-1} and grain yield and stover yield.

Ali and Jan (2014) conducted an experiment on the performance of sesame cultivars (*Sesamum indicum* L.) (local black and local white) with different nitrogen levels (0, 40, 80 and 120 kg N ha^{-1}). The cultivar local black had more stover yield (4297 kg ha^{-1}) as compared to cultivar local white.

2.1.3.3 Harvest index

Bikram *et al.* (1988) disclosed that harvest index was consistently influenced by all the cultivars studied and indicated that the average seed yield of the cultivar influenced significantly.

Balasubramaniyan *et al.* (1995) opined that the variety VS 350 had significantly the highest harvest index than that of TMV 4 and explained with higher number of capsules produced in the main stem.

Ali and Jan (2014) conducted an experiment on the performance of sesame cultivars (*Sesamum indicum* L.) (local black and local white) with different nitrogen levels (0, 40, 80 and 120 kg N ha^{-1}). The cultivar local black had harvest index (14%) as compared to cultivar local white.

2.1.4 Quality characters

2.1.4.1 Oil content

Tashiro *et al.* (1990) observed that the average oil content found for the white seeded strains was 55.0 percent and for the black seeded strains 47.8 percent with the difference of 7.2 percent.

Tiwari *et al.* (1994) studied different genotypes *viz.,* CO 1, TKG 9 and TKG 21 and reported that TKG 9 registered the highest oil content of 54.25 percent followed by TKG 21 (53.93 percent) and CO 1 (52.56 percent).

Ansari *et al.* (1995) observed that the oil content was significantly the highest in P253 than Gouri 78 and the difference between varieties regarding oil content might be due to the genetic makeup of the material. Kandasamy *et al.* (1995) suggested that *Sesamum* cultivar VS 350 contained the highest oil content of 51.0 percent when compared to other varieties *viz.,* TMV 3 and TMV 4.

Jebaraj and Sheriff (1996) reported that SVPR 1 (white *Sesamum*) recorded an average oil content of 52.3 percent which was 2.1 percent higher than that of the existing cultivars TMV 3 and TMV 4.

Ganga *et al.* (1997) reported that Swetha Til (white *Sesamum*) was a promising new variety with high oil content (52 percent) as compared to Rajeswari which showed only 50 percent.

Moorthy *et al.* (1997) made a study with six *Sesamum* varieties *viz.,* Kanak, Kalika, OMT 10, Uma, Usha and Vinayak and reported that the highest oil content was recorded in Vinayak followed by Uma and Kalika. Subba *et al.* (1997) reported that *Sesamum* variety YLM 17 registered the highest oil content of 49.2 percent as compared to other varieties.

Tiwari and Namdeo (1997) suggested that all the four varieties *viz.,* TKG 9, TKG 2, JLSC 8 and JT 7 attained variable quantities of seed oil and variety JLSC 8 registered the highest oil content of 57.9 percent as compared to the other varieties.

Baydar *et al.* (1999) observed TSP 933749 line with the highest (63.25 percent) oil content than that of TSP 933229, TR 3821512, TSP 932410 and TSP 932403. Sumathi and Jaganadham (1999b) reported that the highest oil percent was in variety Madhavi followed by cultivar R84-4-2, X-97-1 and Tanuku Brown.

Mishra (2001) observed that *Sesamum* TKG 55 contained 52.3 percent oil, which was 2.53 percent, 0.28 percent and 5.23 percent higher than that of cultivars TC 25, Krishna/JT 21 and JT 7, respectively.

Awasthi *et al.* (2006) evaluated 17 genotypes of *Sesamum* for various biochemical constituents that exhibited wide variation in quality parameters as oil (41.91-53.36 percent) content. They further stated that the genotypes IVT-10, AVT-01 and IVT-18 showed higher values for oil content in that order.

Arslan *et al.* (2007) reported that the oil contents of *Sesamum* seeds ranged from 46.4 to 62.7 percent. Abou *et al.* (2007) stated that on comparing between cultivars, Shandawed 3 surpassed Giza 32 in oil content and unsaturated fatty acids percentage. Raja *et al.* (2007) observed that the oil content was higher in TMV 4 and TMV 6 than KS95010.

Suryabala *et al.*, (2008) found that, T4 registered the highest oil content (50.15) than that of the variety Shekhar. Uzun *et al.* (2008) observed the variation in oil content of different accessions and concluded the oil content of *Sesamum* seeds varied from 41.3 to 62.7 percent. Similar variation in oil content between varieties was also noticed by Zenebe and Hussien (2009).

Significant difference in oil content and oil yield were noticed between varieties (Hamdollah *et al.*, 2009). Nzikou *et al.* (2009) also observed that *Sesamum* seeds contained 5 percent moisture and 48.5 percent crude oil.

Yahaya *et al.* (2014) carried out an experiment to investigate the characteristics and performance of all the accessions entries on seed-oil and yield parameters. The highest seed-oil content was recorded for NG01 (57%), NG02 (57.5%), KG02 (57%), KD (56.5%) and BE01 (56%). This is an indication that these Accessions have good potential for high oil content.

2.1.4.2 Protein content

Awasthi *et al.* (2006) evaluated 17 genotypes of *Sesamum* for various biochemical constituents that exhibited wide variation in quality parameters like protein (10.20-26.59 percent) content. They further stated that the genotypes RT-125, LTK 4 and RT-127 were found superior in seed protein content in that order. Suryabala *et al.* (2008) found that, T4 registered the highest protein content (38.91 percent) than that of the variety Shekhar.

Significant difference in protein content and protein yield was noticed between varieties (Hamdollah *et al.,* 2009). Nzikou *et al.* (2009) also observed that *Sesamum* seeds contained 20 percent crude proteins.

2.1.5 Nutrient uptake

Sarma and Kakati (1993) obtained that *Sesamum* varieties significantly differed in their nutrient uptake. The variety Vinayak recorded the highest N uptake of 61.68 kg ha^{-1} followed by TC 25 and C7 with 55.28 and 4627 kg ha^{-1} respectively.

Muthuswamy and Sreeramulu (1994) studied the nutrient uptake pattern of varieties *viz.*, C 7, TMV 3, TNAU 10 and CO 1 and reported significant fluctuations in their N, P and K uptake.

Tiwari *et al.* (1996) conducted field experiments with genotypes *viz*., TKG 9, TKG 21, JLSC 8 and JT 7 and found that TKG 21 recorded the maximum uptake of 41.90 kg N ha^{-1}, 8.56 kg of P ha^{-1} and 25.86 kg K ha^{-1}.

Katiyar and Prasad (1998) identified good genetic disparity in uptake and utilization of nutrients and reported that Pusa Jai Kisan utilized 59 percent of nutrients as compared to other varieties, which utilized only 48 percent of nutrients.

Sumathi and Jaganadham (1999a) reported that total nitrogen uptake was influenced by *Sesamum* variety Tanuku brown showing the highest N uptake followed by TKG 55 Madhavi and least uptake was recorded by R84-4-2.

Kokilavani *et al.* (2007) observed that white *Sesamum* variety SVPR 1 registered the highest uptake of N, P and K and it was comparable with that of variety TMV 4.

2.1.6 Economic benefit

Chongdar *et al*. (2015) carried out an investigation to find the effect of sowing dates and cultivars on yield and economic attributes of summer sesame (*Sesamum indicum* L.). Three cultivars of sesame (Rama, Savitri and Tillotama) were used for the experiment. Irrespective of cultivars, Rama gave significantly higher economic return as compared to Savitri and Tillotama during 2013 and 2014, respectively.

2.2 Effect of spacing or population density

Plant population per unit area is the most critical factor for obtaining higher yield in sesame. Above or below the threshold level of plant population it would lead to intra-species competition among plants for scarce resources which cause subnormal sesame seed yield. Hence, identification of optimum population for each variety being tested becomes vital. Various reports indicated that the growth and yield attributes and yield of sesame were determined by plant densities. Adoption of suitable and optimum spacing would fulfill the objective of maximizing the yield of sesame (Kalaiselvan *et al*., 2001).

2.2.1 Growth parameters

2.2.1.1 Plant height

Majumdar and Roy (1992) conducted an experiment in sesame with plant population (16, 22 and 33 plants m^{-2}) and observed that increased spacing decreases plant height. Ghosh and Patra (1993) carried out field trials in the dry season with Sesame cv. B-67 (Tilottama) and was grown on sandy loam soil at densities of 167000, 222000 or 333000 plants ha^{-1} and was given no fertilizer, 24 kg N + 4.5 kg P + 13 kg K ha^{-1} or 2, 3, 4 or 5 times these levels. Results indicated that plant height was unaffected with increasing density.

El-Ouesni *et al*. (1994) conducted field trials to study the effects were evaluated of 2 plant population densities (1 or 2 plants $hill^{-1}$) on the growth and yields of sesame cv. Giza 32. 1 plant $hill^{-1}$ resulted in the greatest crop plant height of 134 cm $plant^{-1}$.

Caliskan *et al*. (2004) carried out an experiment on the effects of planting method (row and broadcast) and plant population (102000, 127500, 170000, 255000 and 510000 plants ha^{-1}). The population density significantly affected to all growth. Plant height decreased with increasing plant population. Samson (2005) reported a non significant response on plant height at wide intra row spacing of 15cm and 10cm.

Rahnama and Bakhshandeh (2006) conducted an experiment in the Safi-Abad Agricultural Research Center, Khuzestan Province, Iran, to identify the optimal practice for cultivation of the uni-branched sesame. Rows were adopted at varying spaces of 37.5, 50 and 60 cm while the plants were arranged horizontally at 5, 10, 15 and 20 cm. In this way, the density of the plot was surveyed over an area ranging from 83000 to 530,000 plants ha^{-1}. The maximum seed and oil yield was then estimated at a density of 200,000-250,000 plants ha^{-1}.

Noorka *et al*. (2011) conducted two field experiments with four levels of nitrogen fertilization (55, 105, 155 and 205 Kg ha^{-1}) and three planting distances between hills (10, 15 and 20 cm, respectively). Results revealed that decreasing planting distance from 20 to 15 and 10 cm consistently and significantly increased plant height and height of the first fruiting branch.

2.2.1.2 Number of leaves plant^{-1}

Ghosh and Patra (1993) carried out field trials in the dry season with Sesame cv. B-67 (Tilottama) and was grown on sandy loam soil at densities of 167000, 222000 or 333000 plants ha^{-1}. Results indicated that number of leaves decreased with increasing density.

Caliskan *et al*. (2004) carried out an experiment on the effects of planting method (row and broadcast) and plant population (102000, 127500, 170000, 255000 and 510000 plants ha^{-1}). The population density significantly affected to all growth. Number of leaves decreased with increasing plant population. Samson (2005) reported a significant increase in number of leaves plant^{-1} at wide intra row spacing of 15cm than 10cm.

Umar *et al*. (2012) conducted a field study to evaluate the performance of two sesame varieties in response to nitrogen fertilizer level and intra row spacing (5, 10 and 15cm), during the wet seasons of 2009 and 2010. Narrow intra row spacing of 5 cm between plants significantly decreases number of leaves (NL).

2.2.1.3 Number of branches plant^{-1}

Enyi (1973) observed that the branches plant^{-1} and grain weight of branch decreased with increasing plant density.

Ghosh and Patra (1993) carried out field trials in the dry season with Sesame cv. B-67 (Tilottama) and were grown on sandy loam soil at densities of 167000, 222000 or 333000 plants ha^{-1}. Results indicated that degree of branching decreased with increasing density. BINA (1993) reported that the lowest plant density produced significantly higher number of capsules plant^{-1} in branches.

Caliskan *et al*. (2004) carried out an experiment on the effects of planting method (row and broadcast) and plant population (102000, 127500, 170000, 255000 and 510000 plants ha^{-1}) and found that the population density significantly affected branch number. The number of branches plant^{-1} decreased with increasing plant population.

Fard and Bahrani (2005) carried out an experiment to identify the effects of different nitrogen (N) rates (0, 60 and 90 kg ha^{-1}) and plant densities (10.0, 16.6 and 25.0 plants m^{-2}) on the yield and yield components of sesame (*Sesamum indicum*). Plant density exhibited significant effects on number of branches plant^{-1}. Increasing the plant density decreased the number of branches plant^{-1}. Samson (2005) reported a significant increase in number of branches plant^{-1} at wide intra row spacing of 15 cm than 10 cm.

Umar *et al*. (2012) conducted a field study to evaluate the performance of two sesame varieties in response to nitrogen fertilizer level and intra row spacing (5, 10 and 15cm), during the wet seasons of 2009 and 2010. Narrow intra row spacing of 5 cm between plants significantly decreases number of primary branches (NPB) and number of secondary branches (NSB).

2.2.1.4 Leaf area index

Ghosh and Patra (1993) found from field trials in the dry season with Sesame cv. B-67 (Tilottama) and were grown at densities of 167000, 222000 or 333000 plants ha^{-1}. Results indicated that increasing plant density was correlated with increases in LAI.

Caliskan *et al*. (2004) carried out an experiment on the effects of planting method (row and broadcast) and plant population (102000, 127500, 170000, 255000 and 510000 plants ha^{-1}). The population density significantly affected to all growth. LAI increased with increasing plant population.

Umar *et al*. (2012) conducted a field study to evaluate the performance of two sesame varieties in response to nitrogen fertilizer level and intra row spacing (5, 10 and 15cm), during the wet seasons of 2009 and 2010. Narrow intra row spacing of 5 cm between plants showed significantly increased leaf area index (LAI).

2.2.1.5 Dry mater production

Enyi (1973) observed that the total dry mass $plant^{-1}$ decreased with increasing plant density. Ghosh and Patra (1993) observed from field trials in the dry season with Sesame cv. B-67 (Tilottama) at population densities of 167000, 222000 or 333000 plants ha^{-1} and was given no fertilizer, 24 kg N + 4.5 kg P + 13 kg K ha^{-1} or 2, 3, 4 or 5 times these levels. Results revealed that increasing plant density was correlated with increases in DM production.

Samson (2005) reported a non significant response on total dry matter at wide intra row spacing of 15cm and 10cm.Umar *et al*. (2012) conducted a field study to evaluate the performance of two sesame varieties in response to nitrogen fertilizer level and intra row spacing (5, 10 and 15cm), during the wet seasons of 2009 and 2010. Narrow intra row spacing of 5 cm between plants significantly decreases total dry matter (TDM).

2.2.1.6 Crop growth rate

Ghosh and Patra (1993) carried out field trials in the dry season with Sesame cv. B-67 (Tilottama) and was grown on sandy loam soil at densities of 167000, 222000 or 333000 plants ha^{-1} and was given no fertilizer, 24 kg N + 4.5 kg P + 13 kg K ha^{-1} or 2, 3, 4 or 5 times these levels. Results showed that increasing plant density was correlated with increases in crop growth rate.

Umar *et al*. (2012) conducted a field study to evaluate the performance of two sesame varieties in response to nitrogen fertilizer level and intra row spacing (5, 10 and 15cm), during the wet seasons of 2009 and 2010. Narrow intra row spacing of 5 cm between plants showed significantly increased crop growth rate (CGR).

2.2.2 Yield attributes and yield

2.2.2.1 Number of capsules plant^{-1}

Enyi (1973) observed that the capsules weight plant^{-1}, number of node bearing capsules and filled capsules plant^{-1} decreased with increasing plant density. Singh *et al*. (1988) grown sesame with three plant densities (22, 33 and 66 plants m^{-2}) and observed that capsules plant^{-1} were decreased significantly with an increase in density from 33 to 50 plants m^{-2}.

Channabasavanna and Setty (1992) carried out an experiment with different plant densities (22, 33 and 66 plants m^{-2}) in sesame and observed that number of capsules plant^{-1} differed significantly with varying plant density with the highest capsules plant^{-1} were obtained at the lowest plant density.

Ghungrade *et al*. (1992) stated that wider spacing of 16 cm between rows produced maximum number of capsules plant^{-1} than narrower row spacing (25 cm × 20 cm). They also found that optimum density (20 plants m^{-2}) gave better result.

BINA (1993) reported that medium plant density (50 plants m^{-2}) produced significantly higher capsules plant^{-1} on main stem compared to the other two plant densities of 25 and 75 plants m^{-2}. In multi location trial with population density of sesame, it was observed that the lowest plant density produced significantly higher number of capsules plant^{-1} in branches.

Asaname and Ikeda (1998) observed that yield and its components were greater in higher density than in lower density. Increased yield depended on seeds capsule^{-1} and capsule number m^{-2}.

Caliskan *et al*. (2004) conducted an experiment and found that the population density significantly affected capsule number. Lower number of capsule plant^{-1} was observed with increasing plant population.

Fard and Bahrani (2005) conducted an experiment with different nitrogen (N) rates (0, 60 and 90 kg ha^{-1}) and plant densities (10.0, 16.6 and 25.0 plants m^{-2}). Plant density exhibited significant effects on number of capsules plant^{-1}. Increasing the plant density decreased the number of capsules plant^{-1} but increased seed yield.

Samson (2005) reported a non significant response on number of capsule plant^{-1} at wide intra row spacing of 15cm and 10cm. Adeyemo *et al*. (2005) in a studies involving three inter and intra row spacing of 50 × 15cm (133,333 plant ha^{-1}), 60 × 10cm (166,667 plants ha^{-1} and 75 × 5cm (266,667 plants ha^{-1}) reported decreased in number and weight of capsules plant^{-1} was found with increased population density.

Umar *et al*. (2012) conducted a field study to evaluate the performance of two sesame varieties in response to nitrogen fertilizer level and intra row spacing (5, 10 and 15cm), during the wet seasons of 2009 and 2010. Narrow intra row spacing of 5 cm between plants significantly decreases capsules yield (CY).

Jakusko *et al*. (2013) carried out field experiments to investigate the effects of row spacing on the growth and yield of Sesame (*Sesamum indicum* L.). The treatments consisted of three row spacing (60 × 15cm, 60 × 10cm and 75 × 10cm) with plot size 3m × 2m. The result revealed that there was significant effect of spacing on the number of capsule plant^{-1}.

2.2.2.2 Number of seeds capsule^{-1}

Ghosh and Patra (1993) carried out field trials in the dry season with Sesame cv. B-67 (Tilottama) and was grown on sandy loam soil at densities of 167000, 222000 or 333000 plants ha^{-1} and was given no fertilizer, 24 kg N + 4.5 kg P + 13 kg K ha^{-1} or 2, 3, 4 or 5 times these levels. Results indicated that number of seeds capsules^{-1} decreased with increasing plant density.

Ghosh and Patra (1993) conceded field trials in the dry season with Sesame cv. B-67 (Tilottama) at population densities of 167000, 222000 or 333000 plants ha^{-1}. Results pointed out that number and weight of seeds $capsules^{-1}$ was unaffected with increasing density.

Caliskan *et al*. (2004) carried out an experiment and found that population density significantly affected number of seeds $capsule^{-1}$ and also observed that number of seeds $capsule^{-1}$ decreased with increasing plant population.

Jakusko *et al*. (2013) carried out field experiments to investigate the effects of row spacing on the growth and yield of Sesame (*Sesamum indicum* L.). The treatments consisted of three row spacing (60 × 15cm, 60 × 10cm and 75 × 10cm) with plot size 3m × 2m. The result revealed that there was significant effect of spacing on the number of seeds $capsule^{-1}$.

2.2.2.3 Capsule length

Caliskan *et al*. (2004) carried out an experiment and found that population density significantly affected capsule length and also observed that number of capsule lengthdecreased with increasing plant population.

Jakusko *et al*. (2013) carried out field experiments to investigate the effects of row spacing on the growth and yield of Sesame (*Sesamum indicum* L.). The treatments consisted of three row spacing (60 × 15cm, 60 × 10cm and 75 × 10cm) with plot size 3m × 2m. The result revealed that there was significant effect of spacing on length of capsule.

2.2.2.4 Weight of 1000 seeds

Singh *et al*. (1988) grown sesame with three plant densities (22, 33 and 66 plants m^{-2}) and observed that the lowest plant density (22 plants m^{-2}) gave the highest weight of 1000-seeds and it was decreased significantly with an increase in plant density from 33 to 50 plants m^{-2}.

Majumdar and Roy (1992) conducted an experiment in sesame with plant population (16, 22 and 33 plants m^{-2}) and observed that the 1000-seed weight was marginally improved by increasing spacing.

Caliskan *et al*. (2004) found that population density significantly affected 1000-seed weight and also found that higher population density gave lower 1000-seed weight. Samson (2005) reported a non-significant response on 1000 seed weight at wide intra row spacing of 15cm and 10cm.

Adeyemo *et al*. (2005) in a study involving three inter and intra row spacing of 50 × 15cm (133,333 plant ha^{-1}), 60 × 10cm (166,667 plants ha^{-1} and 75 × 5cm (266,667 plants ha^{-1}) reported decreased in 1000 seed weight was found with increased population density.

Jakusko *et al*. (2013) carried out field experiments to investigate the effects of row spacing on the growth and yield of Sesame (*Sesamum indicum* L.). The treatments consisted of three row spacing (60 × 15cm, 60 × 10cm and 75 × 10cm) with plot size 3m × 2m. The result revealed that there was significant effect of spacing on 1000 seed weight.

2.2.3 Yield parameters

2.2.3.1 Seed yield

Khidir (1981) reported that the optimum plant population is 21 plants m^{-2} for good yield of sesame. Majumdar and Roy (1992) conducted an experiment in sesame with plant population (16, 22 and 33 plants m^{-2}) and observed that the seed yields were significantly increased with increasing plant population.

It has been reported by Adeyemo and Ojo (1991) that plant population of 133,333 to 266,667 plants ha^{-1} were optimal for good growth and yield of sesame plants. However, Olowe and Busari (1996) recommended 166667 to 333,333 plant population ha^{-1} for optimal growth and yield of sesame in semi arid regions of northern Nigeria.

Furthermore, it has been observed by Majumdar and Row (1992) that sesame growing at narrow intra row spacing increased yield, because close spacing ensured early canopy ground cover, captured sunlight more effectively and utilized soil moisture better as long as soil surface are moist, but suffered under drought conditions because of competition for water as a result of high population density.

Chimanshette and Dhoble (1992) reported that wide intra row spacing resulted in low yield ha^{-1}, which attributed to poor light interception but reported a corresponding increase in yield $plant^{-1}$ with wide intra row spacing.

Varying responses of sesame plant growth, yield and yield attributes in studies involving planting density was reported by Adeyemo and Ojo (1991). They all reported significant decrease in growth, yield and yield attributes with increased population density.

Ghosh and Patra (1993) carried out field trials in the dry season with Sesame cv. B-67 (Tilottama) and was grown on sandy loam soil at densities of 167000, 222000 or 333000 plants ha^{-1} and was given no fertilizer, 24 kg N + 4.5 kg P + 13 kg K ha^{-1} or 2, 3, 4 or 5 times these levels. Results indicated that seed yield increased with plant density.

BINA (1993) reported that the highest yield $plant^{-1}$ was obtained from 25 plants m^{-2}. In multi location trial with population density of sesame, it was observed that the lowest plant density produced significantly lower total yield.

El-Ouesni *et al*. (1994) conducted field trials to study the effects of plant population densities (1 or 2 plants $hill^{-1}$) on the growth and yields of sesame cv. Giza 32. 1 plant $hill^{-1}$ resulted in the greatest seed yields of 11.58 g $plant^{-1}$.

Tiwari *et al*. (1994) conducted a field trial during kharif (monsoon) season, sesame cv. TKG-9, TKG-21, JLSC-8 and JT-7 produced mean seed yields of 2.53, 2.80, 2.92 and 1.86 t ha^{-1}, respectively. Yield averaged 2.05 and 3.00 ton with spacing of 30 × 15 i.e., 22 plants m^{-2} and 10 × 10 cm i.e., 100 plants m^{-2}.

Sharma *et al*. (1996) conducted a field experiment with sesame cv. T.C.25 and TKG-9 were grown at densities of 300000, 450000 or 600000 plants ha^{-1} and given 0-90 kg N ha^{-1}. It was found that yield of sesame was not affected by plant density.

Patil *et al*. (1996) conducted a field experiment with sesame cv. Padma was grown at spacings of 30 × 10 cm (33 plants m^{-2}), 30 × 15 cm (22 plants m^{-2}), 45 × 10 cm (22 plants m^{-2}) and 45 × 15 cm (14 plants m^{-2}) and given 0-50 kg N m^{-2}. Mean seed yield (0.58 t ha^{-1}) and net returns were highest at the 30 × 15 cm spacing (i.e., 22 plants m^{-2}) + 50 kg N.

Balasubramaniyan (1996) carried out field trials during summer season on sandy-loam soil. Two sesame genotypes were sown at 3.0, 4.5 or 6.0 × 105 plants ha^{-1} and were given 0, 30, 60 or 90 kg N ha^{-1}. The pre-release genotype VS 350 yielded more (711 kg ha^{-1}) than cv. TMV 3 (636 kg ha^{-1}), and matured 10-12 days earlier. Yield was not significantly affected by plant density.

Moorthy *et al*. (1997) conducted field trials with sesame cv. Kalika, was tested at 6 different plant spacing ranging from 30 × 10 to 50 × 15 cm giving 133000-333000 plants ha^{-1}. Seed yield was highest at 30 × 15 cm spacing followed by the 40 × 10 cm spacing.

Dixit *et al*. (1997) carried out a field experiment during early rabi (winter) season to assess the productivity of sesame cv. TC-25 and Rauss-17 sown at 333000, 444000 or 666000 plants ha^{-1} with application of 0-90 kg N ha^{-1}. Rauss-17 produced significantly higher yields (0.40 t ha^{-1}) and net profit than TC-25. Plant density had no significant effect on seed yield.

Ramanathan and Chandrashekharan (1998) conducted a field experiment at Thanjavur during the summer (March-May) seasons, revealed that nipping of the terminal bud at 25 days after sowing significantly increased the seed yield (764 vs. 658 kg ha^{-1}) of sesame cv. TMV-4 in all years. Among the plant geometries, 45 cm × 15 cm (148148 plants ha^{-1}) was significantly superior to other spacing (30 cm × 30 cm and 45 cm × 30 cm). Asaname and Ikeda (1998) found that yield was greater in higher density than in lower density.

Ricci *et al*. (1999) studied seed yield on the effects of 3 plant densities (10, 15 and 20 plants per meter of row) and of 2 drying processes (in the field and on the paved floor) of sesame cv. IAC-China. The results showed that the density of 20 plants per meter of row resulted in highest yield per hectare, while the density of 10 plants resulted in highest yield per plant.

Subrahmaniyan and Arulmozhi (1999) carried out a field study during summer, sesame cv. VS 9104 and VRI 1 were grown at densities of 111000 or 166000 plants ha^{-1} and given 0, 35, 45 or 55 kg N ha^{-1}. Yield parameters were generally highest with 111000 plants ha^{-1}, while 166000 plants ha^{-1} gave the highest seed yield.

Basavaraj *et al*. (2000) carried out field trials during the summer season to evaluate the performance of sesame varieties DS-1 and E-8 in rice fallows for plant population (3.33 and 6.66 lakh ha^{-1}). Plant population of 6.66 lakh ha^{-1} produced higher seed yield (1736 kg ha^{-1}) and net returns (Rs. 18871 ha^{-1}) than 3.33 lakh ha^{-1} (1621 kg ha^{-1} and Rs. 17319 ha^{-1}, respectively) due to the increase in plant population per unit area.

Subramanian *et al*., (2000) worked with two sesame varieties (VS 9104 and VRII) and two intra row spacing of 30cm and 20cm reported that, wide intra row spacing of 30cm has a favourable influences on seed yield ha^{-1} and the seed yield under intra row spacing of 20 cm was higher than that of 30cm for both varieties.

Subrahmaniyan *et al*. (2001) carried out a field experiment during the rabi seasons, at Vridhachalam, Tamil Nadu, India, to study the response of five sesame genotypes, *viz*. YMV 3, TMV 4, TMV 6, VRI 1 and VS 9104, to two plant densities (111000 and 166000 plants ha^{-1}) and two NPK levels (100 and 150% of the recommended dose). Under a plant density of 111000 plants ha^{-1} (30×30 cm), yield parameters were significantly higher. However, a plant population of 166000 plants ha^{-1} (30×20 cm) significantly recorded a higher seed yield of 768 kg ha^{-1}.

Subrahmaniyan *et al*. (2001) carried out a field experiment during summer, in Vridhachalam, Tamil Nadu, India, to study the response of three root rot resistant sesame cultivars *viz*., ORM 7, ORM 14 and ORM 17 in three spacing (30×10, 30×20 and 30×30 cm) and three NPK levels (100, 125 and 150 percent of the recommended dose). A favourable increase in the yield parameters was observed with a spacing of 30×30 cm i.e., 11 plants m^{-2}.

Amabile *et al*. (2002) conducted a study to determine the best row spacing and sowing density for sesame in the savannah area of the Federal District, Brazil. Sesame cv. CNPA-G3 was sown at densities of 80000, 100000 and 120000 $plant^{-1}$, combined to row spacing of 45, 60, 75 and 90 cm. Grain yield and other plant characteristics were not affected by row spacing and sowing density.

Imayavaramban *et al*. (2002) investigated an experiment to find out the effect of varied plant populations and nitrogen rates on the productivity in sesame cv. VRI 1. The highest plant population of 166666 ha^{-1}significantly recorded the maximum seed yield compared to lesser plant population viz., 133333 and 111111 plants ha^{-1}.

Malik *et al*. (2003) conducted a study to see the influence of different nitrogen levels on productivity of sesame under varying planting geometry (single row flat sowing, paired row planting, ridge sowing and bed sowing). Among sowing methods bed sowing (50/30 cm) gave highest seed yield (0.85 t ha^{-1}).

Caliskan *et al*. (2004) carried out an experiment on the effects of planting method (row and broadcast) and plant population (102000, 127500, 170000, 255000 and 510000 plants ha^{-1}) on yield of sesame. Row planting had positive effects on the yield of the crop and produced around 34% higher seed yield compared to broadcast planting. The population density also significantly affected yield parameters. Increased seed yield was observed with increasing plant population. The highest seed yield was obtained from 510000 plants ha^{-1}, with 1633 and 1783 kg ha^{-1}, respectively in two years.

Adebisi *et al*. (2005) studied in an experiment to assess the impact of three population densities during two seasons on seed yield. Population density of 166667 plants ha^{-1} gave 40% more yield than that at 266667 plants ha^{-1} and was the best for maximizing yield under rain-fed conditions.

Fard and Bahrani (2005) carried out an experiment, considering different nitrogen (N) rates (0, 60 and 90 kg ha^{-1}) and plant densities (10.0, 16.6 and 25.0 plants m^{-2}) and observed that plant density exhibited significant effects on seed yield. Increasing the plant density increased the seed yield.

Samson (2005) reported a non significant response on seed yield plant^{-1} and seed yield ha^{-1} at wide intra row spacing of 15 cm and 10 cm. Adeyemo *et al*., (2005) in a studies involving three inter and intra row spacing of 50 × 15 cm (133,333 plant ha^{-1}), 60 × 10 cm (166,667 plants ha^{-1} and 75 × 5 cm (266,667 plants ha^{-1}) reported that, 60 × 10 cm produced 40% more yield than 75 × 5 cm. They also reported a decreased in seed yield plant^{-1} with increased population density.

Rahnama and Bakhshandeh (2006) conducted an experiment to identify the optimal practice for cultivation of the uni-branched sesame. Rows were adopted at varying spaces of 37.5, 50 and 60 cm while the plants were arranged horizontally at 5, 10, 15 and 20 cm. In this way, the density of the plot was surveyed over an area ranging from 83000 to 530,000 plants ha^{-1}. The maximum seed yield was estimated at a density of 200,000-250,000 plants ha^{-1}.

Roy *et al*. (2009) conducted a field experiment to evaluate the effect of row spacing (S_1 = 15 cm, S_2 = 30 cm and S_3 = 45 cm) on the yield and yield contributing characters of sesame using the varieties ($V_1 = T_6$, V_2 = Batiaghata local Til and V_3 = BINA Til). Yield was significantly influenced by the row spacing. The highest seed yield was produced by row spacing 30 cm while the lowest was by row spacing 45 cm.

Noorka *et al*. (2011) conducted two field experiments with four levels of nitrogen fertilization (55, 105, 155 and 205 Kg ha^{-1}) and three planting distances between hills (10, 15 and 20 cm, respectively). Results revealed that decreasing planting distance from 20 to 15 and 10 cm consistently and significantly increased seed yields ha^{-1}.

Ozturk and Saman (2012) carried out and experiment to determine the effects of different inter-row spacings (30, 40, 50, 60 and 70 cm) and intra-row spacings (5, 10, 20 and 30 cm) on the yield and yield components on sesame cultivar Muganly 57. It was found that wided inter-row spacings and intra-row spacings, resulted in decreased seed yield. The highest seed yield (1115.0 kg ha^{-1}) was obtained from 30×5 cm plant density while the lowest seed yield (677.0 kg ha^{-1}) was recorded from 70×30 cm plant density.

Umar *et al*. (2012) conducted a field study to evaluate the performance of two sesame varieties in response to nitrogen fertilizer level and intra row spacing (5, 10 and 15 cm), during the wet seasons of 2009 and 2010. Narrow intra row spacing of 5 cm between plants significantly decreases grain yield per plant (GYP) but showed increased grain yield per hectare (GY ha^{-1}).

Jakusko *et al*. (2013) carried out field experiment to investigate the effects of row spacing on the growth and yield of Sesame (*Sesamum indicum* L.). The treatments consisted of three row spacing (60 × 15 cm, 60 × 10 cm and 75 × 10 cm) with plot size 3 m × 2 m. The result revealed that there was significant effect of spacing on yield per hectare. From the findings of this study, it is suggested that 75 × 10 cm spacing should be adopted.

2.2.3.2 Stover yield

Fard and Bahrani (2005) studied that plant density exhibited significant effects on biological yield (seed yield + stover yield). Increasing the plant density increased the stover yield.

2.2.3.3 Harvest index

BINA (1993) reported from multi location trials with population density of sesame, that the highest plant population (75 plants m^{-2}) produced the highest harvest index.

Caliskan *et al*. (2004) observed that population density significantly affected yield parameters. Higher harvest index was found with increasing plant population. Fard and Bahrani (2005) found that plant density exhibited significant effects on harvest index. Increasing the plant density increased the harvest index.

2.2.4 Quality parameters

2.2.4.1 Oil yield

Malik *et al*. (2003) conducted a study to see the influence of different nitrogen levels on productivity of sesame under varying planting geometry (single row flat sowing, paired row planting, ridge sowing and bed sowing). Among sowing methods bed sowing (50/30 cm) gave highest seed oil contents (44.06%). Caliskan *et al*. (2004) found that higher population density showed lower percent oil content.

Fard and Bahrani (2005) conducted an experiment and found that plant density exhibited significant effects on oil yield. But oil percentage in seed was a stable yield component and was not affected by plant density.

Rahnama and Bakhshandeh (2006) conducted an experiment to identify the optimal practice for cultivation of the uni-branched sesame. The population density of the plot was surveyed over an area ranging from 83000 to 530,000 plants ha^{-1}. The maximum oil yield was then estimated at a density of 200,000-250,000 plants ha^{-1}.

Noorka *et al*. (2011) conducted two field experiments with four levels of nitrogen fertilization (55, 105, 155 and 205 Kg ha^{-1}) and three planting distances between hills (10, 15 and 20 cm, respectively). Results revealed that decreasing planting distance from 20 to 15 and 10 cm consistently and significantly increased oil yields ha^{-1}.

Ozturk and Saman (2012) carried out and experiment to determine the effects of different inter-row spacings (30, 40, 50, 60 and 70 cm) and intra-row spacings (5, 10, 20 and 30 cm) on the yield and yield components on sesame cultivar Muganly 57. It was evident that wided inter-row spacings and intra-row spacings, resulted in decreased oil yield. The highest oil yield (551.3 kg ha^{-1}) was obtained from 30×5 cm plant density while the lowest oil yield (327.0 kg ha^{-1}) was recorded from 70×30 cm plant density. As a result, in terms of oil yield sesame agriculture, 30 cm row spacing, and 5 cm intra row spacing are the most suitable plant densities.

2.2.4.2 Protein content

Caliskan *et al*. (2004) found that higher population density showed lower percent of protein content.Ozturk and Saman (2012) carried out and experiment to determine the effects of different inter-row spacings (30, 40, 50, 60 and 70 cm) and intra-row spacings (5, 10, 20 and 30 cm) on the yield and yield components on sesame cultivar Muganly 57. Results exposed that wided inter-row spacings and intra-row spacings, resulted in decreased protein yield. The highest protein yield (224.7 kg ha^{-1}) was obtained from 30×5 cm plant density while the lowest protein yield (130.0 kg ha^{-1}) was recorded from 70×30 cm plant density.

2.2.5 Economic performance

Patil *et al*. (1996) conducted a field experiment wisth sesame cv. Padma was grown at spacings of 30 × 10 cm (33 plants m^{-2}), 30 × 15 cm (22 plants m^{-2}), 45 × 10 cm (22 plants m^{-2}) and 45 × 15 cm (14 plants m^{-2}) and given 0-50 kg N ha^{-1}. Net returns was highest at the 30 × 15 cm spacing (i.e., 22 plants m^{-2}) + 50 kg N.

Imayavaramban *et al*. (2002a) conducted an experiment to find out the effect of varied plant populations and nitrogen rates on economic returns in sesame cv. VRI 1. The highest plant population of 166666 ha^{-1} significantly recorded the maximum net income and the benefit: cost ratio compared to lesser plant population *viz*., 133333 and 111111 plants ha^{-1}.

2.3 Effect of chemical fertilizers

2.3.1 Growth parameters

2.3.1.1 Plant height

2.3.1.1.1 Effect of nitrogen

Rao *et al.* (1990) observed that N had profound influence on growth and development of *Sesamum*. Mandal *et al.* (1992) stated that plant height of *Sesamum* increased significantly with increasing N level upto 90 kg N ha^{-1} and observed that the maximum CGR was noticed at 67 kg N ha^{-1}. Jhansi (1995) found that there was a progressive and significant increase in all the growth parameters with each increment in N up to 90 kg ha^{-1}.

Sridhar *et al.* (1997) reported that increasing N level enhanced the plant height. Thakur *et al.* (1998) showed that the plant height was significantly the highest at 45 kg N ha^{-1}. Sankara *et al.* (2000) indicated that nitrogen application @ 60 kg ha^{-1}significantly increased the plant height over 40 kg N ha^{-1}.

Application of 25 percent more nitrogen, to that of the recommended dose significantly increased the growth characters *viz.*, plant height (Senthilkumar *et al.*, 2002). A similar observation was also made by Imayavaramban *et al.* (2002b).

Kathiresan (2002) conducted an experiment during summer season on sesame cv. 'TMV-4' and reported tallest plant with the fertilizer application of 52 kg N + 35 kg P_2O_5 + 35 kg K_2O ha^{-1}. Malik *et al.* (2003) indicated that application of 80 kg N ha^{-1} produced the tallest plants followed by 40 kg N ha^{-1}.Growth attributes such as plant height was increased under 50 percent increased dose of recommended N (Imayavaramban *et al.*, 2004).

The plant height of *Sesamum* was increased sharply from 123.1 to 130.3 cm and 95 to cm due to increase of N levels from 20 to 80 kg ha^{-1} (Duray and Mandal 2006). Muhamman and Gungula (2008) observed that plant height increased with the highest N level (90 kg N ha^{-1}).

Sesamum cultivars *viz*., Shandaweel, Sudanage and Sudan-1 showed significant effect on plant height due to N application up to 200 kg ha^{-1} (El-Nakhlawy and Saheen, 2009). Malla *et al.* (2010) opined that *Sesamum* responded significantly up to 90 kg N ha^{-1} in terms of plant height over 60 kg N ha^{-1}. Budi Hariyono and Moch Romli (2010) opined that application of 83.34 kg N ha^{-1} produced the tallest plants.

Noorka *et al*. (2011) conducted two field experiments with four levels of nitrogen fertilization (55, 105, 155 and 205 Kg ha^{-1}) and three planting distances between hills (10, 15 and 20 cm, respectively). Increasing N fertilizer level up to 205 Kg ha^{-1} significantly increased plant height, and height of the first fruiting branch.

Rupali *et al*. (2015) conducted a field study aimed to evolve efficient and economically viable irrigation schedule and nitrogen management for improving quality, yield and growth of summer sesame var. AKT 101. Experimental results revealed that plant height was significantly higher with nitrogen application at 90 kg N ha^{-1} over 30 and 60 kg N ha^{-1}.

Ali *et al*. (2016) conducted a field trial to determine the effect of nitrogen and sulfur on the growth of sesame. Taller plants (187.1 cm) were observed in plot treated with 70 kg N ha^{-1} over 30, 110 and 150 kg ha^{-1}, and dwarf plants (169 cm) were seen in control plots.

2.3.1.1.2 Effect of phosphorus

Kathiresan (1999) indicated that P level of 35 kg ha^{-1} influenced *Sesamum* plant height. Kalita (1994) reported that plant height was increased up to 40 kg P_2O_5 ha^{-1} and it was on par with 60 kg P_2O_5 ha^{-1}.

The tallest *Sesamum* plants were recorded when phosphorus was applied at 45 kg ha^{-1} (Thanki *et al*., 2004). *Sesamum* plants that received 30 and 60 kg P_2O_5 ha^{-1} recorded plant heights that were significantly taller than the control (Olowe, 2006).

Shehu *et al*.(2010a) indicated that plant height was increasing up to application of 90 kg P_2O_5 ha^{-1}. Haruna *et al*. (2010) opined that the application of 26.4 kg P_2O_5 ha^{-1} increased the plant height than other levels *viz*.,13.2 and 0 kg P_2O_5 ha^{-1}, further, they noticed P application hasten flowering significantly.

Shehu *et al*. (2010) conducted a pot experiment to assess the nitrogen, phosphorus and potassium nutrition on the productivity sesame (*Sesamum indicum* L.). Results indicated that among the three rates of phosphorus (0, 22.5 and 45 kg ha^{-1}) the sesame height was optimum at 22.5 kg P ha^{-1}. Plant height was higher with application of 90 kg P_2O_5 ha^{-1} (Mian *et al*.,2011).

2.3.1.1.3 Effect of potassium

Majumdar *et al.* (1987) reported that an increase in the level of K increased the plant height of *Sesamum*. Significant increase in plant height with application of 20 kg K_2O ha^{-1} was reported by Tiwari *et al.* (1994a).

Ramanathan and Chandrashekharan (1998) witnessed that application of 50 kg K_2O ha^{-1} significantly increased the growth characters of *Sesamum*. Application of potassium @ 40 kg ha^{-1}significantly influenced the growth attributes of *Sesamum* (Jadav *et al.,* 2010).

Kalaiselvan *et al.* (2002) revealed that application of K recorded the maximum plant height of sesame. Kathiresan (2002) found that 150 percent of recommended K (52 kg ha^{-1}) had the tallest plants of sesame.

2.3.1.1.4 Effect of NPK fertilizer

Thorve (1991) reported that the growth attributes *viz*., plant height was significantly influenced by different fertilizer levels of NPKS. Subrahmaniyan *et al.* (2001) stated that each successive increase in the dose of NPK fertilizers up to 150 percent significantly recorded the maximum plant height. Ahmad *et al.* (2001) opined that higher plant height WAS noticed with 120 kg N and 40 kg K_2O ha^{-1}. *Sesamum* plants that received -N at 90 kg ha^{-1} and P at 60 kg ha^{-1} were significantly taller than that of the control plot (Olowe, 2006).

Abdel (2008) opined that the tallest plants were produced with the application of 88 kg N ha^{-1} and 44 kg P_2O_5 ha^{-1} while the shortest plants were produced when none of the fertilizers was applied. Application of 100 percent NPK fertilizer had recorded significantly the tallest plants than that of 50 and 75 percent (Hanumanthappa and Basavaraj, 2008).

2.3.1.2 Number of leaves plant^{-1}

2.3.1.2.1 Effect of nitrogen

Sridhar *et al.* (1997) reported that increasing N level enhanced number of leaves plant^{-1}. Sankara *et al.* (2000) indicated that nitrogen application @ 60 kg ha^{-1}significantly increased the number of leaves plant^{-1}over 40 kg N ha^{-1}.

Malla *et al.* (2010) opined that *Sesamum* responded significantly up to 90 kg N ha^{-1} in terms of number of leaves plant^{-1}over 60 kg N ha^{-1}. Shehu *et al*. (2010) conducted a pot experiment to assess the nitrogen, phosphorus and potassium nutrition on the productivity sesame (*Sesamum indicum* L.). Results showed that among the four N fertilizer rate (0, 37.5, 75 and 112.5 kg ha^{-1}) the highest number of leaves plant^{-1} was recorded from the highest N rate of 112.5 kg ha^{-1}.

Umar *et al*. (2012) conducted a field study to evaluate the performance of two sesame varieties in response to nitrogen fertilizer level (20, 40, 60 and 80 kg N ha^{-1}) and intra row spacing, during the wet seasons of 2009 and 2010. The result indicated that, application of up to 80 kg N ha^{-1} resulted in the significant increase in the number of leaves (NL).

Rupali *et al*. (2015) conducted a field study aimed to evolve efficient and economically viable irrigation schedule and nitrogen management for improving quality, yield and growth of summer sesame var. AKT 101. Experimental results revealed that number of leaves $plant^{-1}$ was significantly higher with nitrogen application at 90 kg N ha^{-1} over 30 and 60 kg N ha^{-1}.

2.3.1.2.2 Effect of phosphorus

Kumbhar (1992) stated that the mean number of functional leaves was the highest due to 45 kg P_2O_5 ha^{-1}. Haruna *et al*. (2010) opined that the application of 26.4 kg P_2O_5 ha^{-1} increased the number of leaves $plant^{-1}$ than other levels *viz*.,13.2 and 0 kg P_2O_5 ha^{-1}. Shehu *et al*. (2010) conducted a pot experiment to assess the nitrogen, phosphorus and potassium nutrition on the productivity sesame (*Sesamum indicum* L.). Results indicated that among the three rates of phosphorus (0, 22.5 and 45 kg ha^{-1}) the number of leaves was optimum at 45 kg P ha^{-1}.

2.3.1.2.3 Effect of potassium

Higher number of leaves $plant^{-1}$ of *Sesamum* registered with 60 kg K_2O ha^{-1} (Sarawagi *et al.*, 1995). Kalaiselvan *et al.* (2002) revealed that application of K recorded the maximum leaves $plant^{-1}$.

Application of potassium @ 40 kg ha^{-1}significantly influenced the growth attributes like number of leaves $plant^{-1}$ of *Sesamum* (Jadav *et al.*, 2010). Shehu *et al*. (2010) conducted a pot experiment to assess the nitrogen, phosphorus and potassium nutrition on the productivity sesame (*Sesamum indicum* L.). Results revealed that among the three rates of three rates of potassium (0, 22.5 and 45 kg ha^{-1}), the number of leaves $plant^{-1}$was optimum at 22.5 kg K ha^{-1}.

2.3.1.2.4 Effect of NPK fertilizer

Thorve (1991) reported that the highest number of functional leaves which was significantly influenced by different fertilizer levels of NPKS. Subrahmaniyan *et al.* (2001a) stated that each successive increase in the dose of NPK fertilizers up to 150 percent significantly recorded the maximum number of leaves plant^{-1}. Application of 75 kg N ha^{-1}, 45 kg P_2O_5ha^{-1} and 22.5 kg K_2O ha^{-1} registered the highest number of leaves (Shehu *et al.*, 2009).

2.3.1.3 Number of branches plant^{-1}

2.3.1.3.1 Effect of nitrogen

Sinharry *et al.* (1990) opined that nitrogen increased the number of primary branches plant^{-1}. Balasubramaniyan (1996) opined that N application had greater effect on branches plant^{-1} noticed that increase in yield upto 90 kg N ha^{-1}. Sridhar *et al.* (1997) reported that increasing N level enhanced number of branches plant^{-1}. Thakur *et al.* (1998) showed that the branches plant^{-1} were significantly the highest at 45 kg N ha^{-1}.

Tiwari *et al.* (2000) opined that growth characters were found significantly the highest at 60 kg N ha^{-1}. Significant increase in growth attributes were recorded with 60 kg N ha^{-1} (Naugraiya and Jhapatsingh, 2004). Sankara *et al.* (2000) indicated that nitrogen application @ 60 kg ha^{-1}significantly increased the number of branches plant^{-1}over 40 kg N ha^{-1}. Growth attributes such as number of branches plant^{-1} was increased under 50 percent increased dose of recommended N (Imayavaramban *et al.*, 2004).

Sesamum cultivars *viz*., Shandaweel, Sudanage and Sudan-1 showed significant effect on d number of branches plant^{-1} due to N application up to 200 kg ha^{-1} (El-Nakhlawy and Saheen, 2009). Budi Hariyono and Moch Romli (2010) opined that application of 83.34 kg N ha^{-1} produced the highest number of branches plant^{-1}.

Shehu *et al*. (2010) conducted a pot experiment to assess the nitrogen, phosphorus and potassium nutrition on the productivity sesame (*Sesamum indicum* L.). Results showed that among the four N fertilizer rate (0, 37.5, 75 and 112.5 kg ha^{-1}) the highest number of branches $plant^{-1}$ was recorded from the highest N rate of 112.5 kg ha^{-1}.

Noorka *et al*. (2011) conducted two field experiments with four levels of nitrogen fertilization (55, 105, 155 and 205 Kg ha^{-1}) and three planting distances between hills (10, 15 and 20 cm, respectively). Increasing N fertilizer level up to 205 Kg ha^{-1} significantly increased number of branches $plant^{-1}$.

Umar *et al*. (2012) conducted a field study to evaluate the performance of two sesame varieties in response to nitrogen fertilizer level (20, 40, 60 and 80 kg N ha^{-1}) and intra row spacing, during the wet seasons of 2009 and 2010. The result indicated that, application of up to 80 kg N ha^{-1} resulted in the significant increase in the number of secondary branches (NSB). But the number of primary branches (NPB) showed no significant response to nitrogen level above 60 kg N ha^{-1}.

Rupali *et al*. (2015) conducted a field study aimed to evolve efficient and economically viable irrigation schedule and nitrogen management for improving quality, yield and growth of summer sesame var. AKT 101. Experimental results revealed that number of branches $plant^{-1}$ was significantly higher with nitrogen application at 90 kg N ha^{-1} over 30 and 60 kg N ha^{-1}.

2.3.1.3.2 Effect of phosphorus

Shehu *et al*. (2010) conducted a pot experiment to assess the nitrogen, phosphorus and potassium nutrition on the productivity sesame (*Sesamum indicum* L.). Results indicated that among the three rates of phosphorus (0, 22.5 and 45 kg ha^{-1}) the number of branches was optimum at 22.5 kg P ha^{-1}. Number of branches $plant^{-1}$ was higher with application of 90 kg P_2O_5 ha^{-1} compared to 70 and 110 kg P_2O_5 ha^{-1} (Mian *et al*.,2011).

2.3.1.3.3 Effect of potassium

Significant increase in number of branches $plant^{-1}$ with application of 20 kg K_2O ha^{-1} was reported by Tiwari *et al.* (1994). Higher number of branches $plant^{-1}$ was registered with 60 kg K_2O ha^{-1} (Sarawagi *et al.*, 1995).

Kalaiselvan *et al.* (2002) revealed that application of K recorded the maximum number of branches plant^{-1}. Application of 29.4 kg K_2O ha^{-1} significantly increased the number of branches plant^{-1} (Thakur and Patel, 2004).

Shehu *et al*. (2010) conducted a pot experiment to assess the nitrogen, phosphorus and potassium nutrition on the productivity sesame (*Sesamum indicum* L.). Results revealed that among the three rates of three rates of potassium (0, 22.5 and 45 kg ha^{-1}), K fertilizer did not affect significantly the number of branches plant^{-1}.

2.3.1.3.4 Effect of NPK fertilizer

Number of branches plant^{-1} increased gradually along with fertilizer level and the highest number of branches plant^{-1} (5.4) was noticed with the application of 96 kg N, 18 kg $P_2O_5$and 52 kg K_2O ha^{-1} (Ghosh and Patra, 1994).

Subrahmaniyan *et al.* (2001) stated that each successive increase in the dose of NPK fertilizers up to 150 percent significantly recorded the maximum number of branches. Ahmad *et al.* (2001) opined that higher number of branches plant^{-1} was noticed with 120 kg N and 40 kg K_2O ha^{-1}. Application of 75 kg N ha^{-1}, 45 kg P_2O_5ha^{-1} and 22.5 kg K_2O ha^{-1} registered the highest number of branches (Shehu *et al.*, 2009).

2.3.1.4 Dry mater production

2.3.1.4.1 Effect of nitrogen

Positive effect on N on dry matter production was noticed by Samui *et al.* (1990). Mandal *et al.* (1992) stated that dry matter production of *Sesamum* increased significantly with increasing N level upto 90 kg N ha^{-1} and observed that the maximum CGR was noticed at 67 kg N ha^{-1}. Praveen *et al.* (1993) reported that each higher level of N significantly enhanced the dry matter plant^{-1} over its preceding level (0, 40 and 80 kg N ha^{-1}). Sridhar *et al.* (1997) reported that increasing N level enhanced the dry matter production.

Malla *et al.* (2010) opined that *Sesamum* responded significantly up to 90 kg N ha^{-1} in terms of dry weight over 60 kg N ha^{-1}. Shehu *et al*. (2010) conducted a pot experiment to assess the nitrogen, phosphorus and potassium nutrition on the productivity sesame

(*Sesamum indicum* L.). Results showed that among the four N fertilizer rate (0, 37.5, 75 and 112.5 kg ha^{-1}) the highest dry matter $plant^{-1}$ was recorded from the highest N rate of 112.5 kg ha^{-1}.

Umar *et al*. (2012) conducted a field study to evaluate the performance of two sesame varieties in response to nitrogen fertilizer level (20, 40, 60 and 80 kg N ha^{-1}) and intra row spacing, during the wet seasons of 2009 and 2010. The result indicated that, application of up to 80 kg N ha^{-1} resulted in the significant increase in the shoot dry matter (SDM).

2.3.1.4.2 Effect of phosphorus

Kumbhar (1992) stated that and dry matter accumulation was the highest due to 45 kg P_2O_5 ha^{-1}. Haruna *et al*. (2010) opined that the application of 26.4 kg P_2O_5 ha^{-1} increased the total dry matter production than other levels viz.,13.2 and 0 kg P_2O_5 ha^{-1}.

Shehu *et al*. (2010) conducted a pot experiment to assess the nitrogen, phosphorus and potassium nutrition on the productivity sesame (*Sesamum indicum* L.). Results indicated that among the three rates of phosphorus (0, 22.5 and 45 kg ha^{-1}) the dry matter $plant^{-1}$ was optimum at 45 kg P ha^{-1}.

2.3.1.4.3 Effect of potassium

Samui *et al.* (1990) opined that application of K at 67.2 kg ha^{-1} produced the highest dry matter at all stages of crop growth. Mandal *et al.* (1992) noticed that increased level of K increased the dry matter production during 40-65 and 65-90 DAS, respectively when the crop was fertilized with 67.2 kg K ha^{-1}.

Roy *et al.* (1995) stated that an increase in K level increased the dry matter linearly and it was higher at 90 days with 66.4 kg K ha^{-1}. Higher dry matter accumulation was registered with 60 kg K_2O ha^{-1} (Sarawagi *et al.*, 1995).

Kalaiselvan *et al.* (2002) revealed that application of K recorded the maximum DMP. Kathiresan (2002) found that 150 percent of recommended K (52 kg ha^{-1}) had the maximum DMP of sesame.

Ojikpong *et al.* (2008) revealed that application of K_2O up to 45 kg ha^{-1} increased the dry matter of *Sesamum*. Shehu *et al*. (2010) conducted a pot experiment to assess the nitrogen, phosphorus and potassium nutrition on the productivity sesame (*Sesamum indicum* L.). Results revealed that among the three rates of three rates of potassium (0, 22.5 and 45 kg ha^{-1}), K fertilizer did not significantly affect the dry matter $plant^{-1}$.

2.3.1.4.4 Effect of NPK fertilizer

Thorve (1991) reported that the growth attributes *viz*., dry matter accumulation $plant^{-1}$ were significantly influenced by different fertilizer levels. Kene *et al*. (1991) reported highest dry matter of sesame cv. 'Phule-1' with the fertilizer application of 40 kg N + 40 kg P_2O_5 + 25 kg K_2O ha^{-1} (2.59 and 0.30 t ha^{-1} and 50.26%, respectively) during kharif season under rainfed situations.

Subrahmaniyan *et al.* (2001) stated that each successive increase in the dose of NPK fertilizers up to 150 percent significantly recorded the maximum dry matter production. Kathiresan (2002) conducted an experiment during summer season on sesame cv. 'TMV-4' and reported maximum dry matter with the fertilizer application of 52 kg N + 35 kg P_2O_5 + 35 kg K_2O ha^{-1}.Application of 75 kg N ha^{-1}, 45 kg $P_2O_5ha^{-1}$ and 22.5 kg K_2O ha^{-1} registered the highest dry matter production (Shehu *et al.*, 2009).

2.3.1.5 Leaf area index

2.3.1.5.1 Effect of nitrogen

Praveen Rao *et al.* (1993) reported that each higher level of N significantly enhanced the LAI over its preceding level (0, 40 and 80 kg N ha^{-1}). Application of 25 percent more nitrogen, to that of the recommended dose significantly increased the growth characters *viz.*, leaf area index (Senthilkumar *et al.*, 2002).

Umar *et al*. (2012) conducted a field study to evaluate the performance of two sesame varieties in response to nitrogen fertilizer level (20, 40, 60 and 80 kg N ha^{-1}) and intra row spacing, during the wet seasons of 2009 and 2010. The result indicated that, application of up to 80 kg N ha^{-1} resulted in the significant increase in the leaf area index (LAI).

Ali *et al*. (2016) conducted a field trial to determine the effect of nitrogen and sulfur on the growth of sesame. The application of N at the rate of 70 kg ha^{-1} resulted in optimum leaf area index (2.2) over 30, 110 and 150 kg ha^{-1}, while control plots have lower leaf area index (1.95).

2.3.1.5.2 Effect of phosphorus

Praveen and Raiheller (1993) observed a clear trend of significant increase in LAI with increase in the level of P from 0 to 26 kg P_2O_5 ha^{-1}.

2.3.1.5.3 Effect of potassium

Kalaiselvan *et al.* (2002) revealed that application of K recorded the maximum LAI of sesame. Kathiresan (2002) found that 150 percent of recommended K (52 kg ha^{-1}) had the highest LAI of sesame.

Application of 29.4 kg K_2O ha^{-1} significantly increased the leaf area index (LAI) OF sesame (Thakur and Patel, 2004).

2.3.1.5.4 Effect of NPK fertilizer

Subrahmaniyan *et al.* (2001a) stated that each successive increase in the dose of NPK fertilizers up to 150 percent significantly recorded the maximum leaf area index (LAI). Ahmad *et al.* (2001) opined that higher leaf area index (LAI) was noticed with 120 kg N and 40 kg K_2O ha^{-1}. Application of 100 percent NPK fertilizer had recorded significantly the highest leaf area index (LAI) than that of 50 and 75 percent (Hanumanthappa and Basavaraj, 2008).

2.3.1.6 Crop growth rate

2.3.1.6.1 Effect of nitrogen

Praveen *et al.* (1993) reported that each higher level of N significantly enhanced the CGR over its preceding level (0, 40 and 80 kg N ha^{-1}).

Umar *et al*. (2012) conducted a field study to evaluate the performance of two sesame varieties in response to nitrogen fertilizer level (20, 40, 60 and 80 kg N ha^{-1}) and intra row spacing, during the wet seasons of 2009 and 2010. The result indicated that, application of up to 80 kg N ha^{-1} resulted in the significant increase in the crop growth rate (CGR).

2.3.1.6.2 Effect of phosphorus

Praveen and Raiheller (1993) observed a clear trend of significant increase in CGR with increase in the level of P from 0 to 26 kg P_2O_5 ha^{-1}.

2.3.1.6.3 Effect of potassium

Mandal *et al.* (1992) noticed that increased level of K increased the dry matter production and crop growth rate (CGR) during 40-65 and 65-90 DAS, respectively when the crop was fertilized with 67.2 kg K ha^{-1}.

Ojikpong *et al.* (2008) revealed that application of K_2O up to 45 kg ha^{-1} increased the crop growth rate (CGR) of *Sesamum*.

2.3.1.6.4 Effect of NPK fertilizer

Sesamum plants that received -N at 90 kg ha^{-1} and P at 60 kg ha^{-1} were significantly higher crop growth rate (CGR) that of the control plot (Olowe, 2006). Application of 75 kg N ha^{-1}, 45 kg $P_2O_5$$ha^{-1}$ and 22.5 kg K_2O ha^{-1} registered the highest crop growth rate (CGR) (Shehu *et al.*, 2009).

2.3.2 Yield and yield attributes

2.3.2.1 Number of capsules plant^{-1}

2.3.2.1.1 Effect of nitrogen

Shrivastava and Tripathi (1992) observed significantly higher yield attributes due to application of 90 kg N ha^{-1} which was on par with 60 kg N ha^{-1}. Prakasha and Thimmegowda (1992) reported 53 percent increased seed yield with higher N rate due to enhanced value of yield attributes *viz*. capsules plant^{-1}.

Ishwar *et al.* (1994) postulated that *Sesamum* recorded positive yield traits *viz*., capsules plant^{-1} upto 60 kg N ha^{-1}. Balasubramaniyan (1996) opined that N application had greater effect on yield parameters *viz*. capsules plant^{-1}upto 90 kg N ha^{-1}. Bennet *et al.* (1996) found increased number of capsules plant^{-1} with N application up to 120 kg ha^{-1}. In Eastern Madhya Pradesh, application of 45 kg N ha^{-1} recorded significantly higher capsules plant^{-1} as compared to 30 kg N ha^{-1} (Thakur *et al.*, 1998).

Each successive increase in dose of N up to 60 kg ha^{-1} significantly increased the capsules $plant^{-1}$ (Prakash *et al.*, 2001). Duray and Mandal (2006) indicated that application of 80 kg N ha^{-1} produced best results in different yield components *viz.*, number of capsules $plant^{-1}$ the effect of 60 kg N ha^{-1} was found at par with 80 kg N ha^{-1}.

Nahar *et al.* (2008) indicated that the number of capsules $plant^{-1}$ increased significantly up to 100 kg N ha^{-1} in varieties T 6 and BARI Til 3 but the variety BARI til 2 responded well up to 150 kg N ha^{-1}.

Noorka *et al*. (2011) conducted two field experiments with four levels of nitrogen fertilization (55, 105, 155 and 205 Kg ha^{-1}) and three planting distances between hills (10, 15 and 20 cm, respectively). Increasing N fertilizer level up to 205 Kg ha^{-1} significantly increased number of capsules $plant^{-1}$.

Umar *et al*. (2012) conducted a field study to evaluate the performance of two sesame varieties in response to nitrogen fertilizer level (20, 40, 60 and 80 kg N ha^{-1}) and intra row spacing, during the wet seasons of 2009 and 2010. The result indicated that, application of up to 80 kg N ha^{-1} resulted in the significant increase in the capsules yield (CY).

Ali and Jan (2014) conducted an experiment on the performance of sesame cultivars (*Sesamum indicum* L.) (local black and local white) with different nitrogen levels (0, 40, 80 and 120 kg N ha^{-1}). Plots treated with 120 kg N ha^{-1} produced maximum capsules m^{-2} (951) and capsules $plant^{-1}$ (86).

Rupali *et al*. (2015) conducted a field study aimed to evolve efficient and economically viable irrigation schedule and nitrogen management for improving quality, yield and growth of summer sesame var. AKT 101. Experimental results revealed that number of capsule $plant^{-1}$ was significantly higher with nitrogen application at 90 kg N ha^{-1} over 30 and 60 kg N ha^{-1}.

2.3.2.1.2 Effect of phosphorus

Maiti and Jana (1985) stated that application of 30 kg P_2O_5 ha^{-1} produced significantly the highest capsules $plant^{-1}$ as compared to other levels of phosphorus. Significantly higher seed yield was recorded with 50 kg P_2O_5 ha^{-1} due to increase in yield attributes *viz.*, capsules $plant^{-1}$ (Prakasha and Thimmegowda, 1992). Kathiresan (1999) indicated that P level of 35 kg ha^{-1} influenced number of capsules $plant^{-1}$ of *Sesamum*.

Mian *et al.* (2011) opined that the highest number of capsules $plant^{-1}$ was recorded with 90 kg P_2O_5 ha^{-1} compared to 70 and 110 kg P_2O_5 ha^{-1}.

2.3.2.1.3 Effect of potassium

Application of potassium markedly increased the yield components *viz.*, number of capsules $plant^{-1}$ (Mandal *et al*., 1992). Tiwari *et al.* (1994) found that application of K_2O significantly increased the number of capsules $plant^{-1}$ of *Sesamum*. Increasing the level of K from 100 to 150 percent of recommended dose, the number of capsules $plant^{-1}$ of *Sesamum* increased significantly (Subrahmaniyan *et al.*, 2001).

Shehu *et al*. (2010) conducted a pot experiment to assess the nitrogen, phosphorus and potassium nutrition on the productivity sesame (*Sesamum indicum* L.). Results revealed that among the three rates of three rates of potassium (0, 22.5 and 45 kg ha^{-1}), the number capsule $plant^{-1}$ was optimum at 45 kg K ha^{-1}. Application of K_2O up to 40 kg ha^{-1} increased the yield attributes and further increase in K_2O registered non-significant response (Jadav *et al.*, 2010).

2.3.2.1.4 Effect of NPK fertilizer

Thorve (1991) observed that the yield attributes *viz.*, number of capsule $plant^{-1}$ was increased with every successive increased level of fertilizer and was maximum with 37.5 kg N and 18.5 kg P_2O_5 ha^{-1}. Application of 120 kg and 40 kg ha^{-1} N and P_2O_5conspicuously increased the number of capsule $plant^{-1}$ (Ahmad *et al.*, 2001).

Bhosale *et al*. (2011) conducted a field experiment during Kharif season on sesame cv. ‘Gujrat Til-2’ in clayey soils and reported significantly higher number of capsules/plant with the fertilizer application of 25 kg N + 25 kg P_2O_5 + 50 kg K_2O ha^{-1}.

2.3.2.2 Number of seeds capsule^{-1}

2.3.2.2.1 Effect of nitrogen

Prakasha and Thimmegowda (1992) reported 53 percent increased seed yield with higher N rate due to enhanced value of yield attributes like seeds capsule^{-1}. Tiwari *et al.* (1994) reported that significant increase in yield attributes was recorded with every successive dose of N application upto 75 kg ha^{-1}.

Jhansi (1995) opined that nitrogen application at 90 kg ha^{-1} resulted in significantly higher yield components except the number of seeds capsule^{-1} compared to its lower levels.

In Eastern Madhya Pradesh, application of 45 kg N ha^{-1} recorded significantly higher seed number capsule^{-1} as compared to 30 kg N ha^{-1} (Thakur *et al.*, 1998). Each successive increase in dose of N up to 60 kg ha^{-1} significantly increased the number of seeds capsule^{-1} (Prakash *et al.*, 2001).

Duray and Mandal (2006) indicated that application of 80 kg N ha^{-1} produced best results in different yield components *viz.*, number of seeds capsule^{-1}, the effect of 60 kg N ha^{-1} was found at par with 80 kg N ha^{-1}.

Nahar *et al.* (2008) indicated that the number of seeds capsule^{-1} increased significantly up to 100 kg N ha^{-1} in varieties T6 and BARI Til 3 but the variety BARI Til 2 responded well up to 150 kg N ha^{-1}.

Shehu *et al*. (2010) conducted a pot experiment to assess the nitrogen, phosphorus and potassium nutrition on the productivity sesame (*Sesamum indicum* L.). Results showed that among the four N fertilizer rate (0, 37.5, 75 and 112.5 kg ha^{-1}) the highest number of seeds capsule^{-1} was recorded from the highest N rate of 112.5 kg ha^{-1}. But the number of seeds capsule^{-1} was not significantly affected by N application.

Rupali *et al*. (2015) conducted a field study aimed to evolve efficient and economically viable irrigation schedule and nitrogen management for improving quality, yield and growth of summer sesame var. AKT 101. Experimental results revealed that number of seeds capsule^{-1} was significantly higher with nitrogen application at 90 kg N ha^{-1} over 30 and 60 kg N ha^{-1}.

2.3.2.2.2 Effect of phosphorus

Significantly higher seed yield was recorded with 50 kg P_2O_5 ha^{-1} due to increase in yield attributes *viz.*, seeds capsule^{-1} (Prakasha and Thimmegowda, 1992). Kathiresan (1999) indicated that P level of 35 kg ha^{-1} influenced number of seeds capsule^{-1} of *Sesamum*.

Shehu *et al*. (2010) conducted a pot experiment to assess the nitrogen, phosphorus and potassium nutrition on the productivity sesame (*Sesamum indicum* L.). Results indicated that among the three rates of phosphorus (0, 22.5 and 45 kg ha^{-1}) the number of seeds capsule^{-1} was optimum at 45 kg P ha^{-1}.

2.3.2.2.3 Effect of potassium

Application of potassium markedly increased the yield components *viz.*, number of seeds capsule^{-1} (Mandal *et al*., 1992). Application of K up to 40 kg ha^{-1} attained maximum yield attributes of sesame (Ghosh *et al.*, 2002). Tiwari *et al.* (1994) found that application of K_2O significantly increased the number of seeds capsule^{-1}.Potassium application increased the number of seeds pod^{-1} but no significant difference was observed between 33.2 and 66.4 kg K_2O ha^{-1} (Roy *et al.*, 1995).

Shehu *et al*. (2010) conducted a pot experiment to assess the nitrogen, phosphorus and potassium nutrition on the productivity sesame (*Sesamum indicum* L.). Results revealed that K fertilizer did not affect significantly the number seeds capsule^{-1} with the three rates of potassium (0, 22.5 and 45 kg ha^{-1}).

2.3.2.2.4 Effect of NPK fertilizer

Thorve (1991) observed that higher number of seeds capsule^{-1} increased with every successive increased level of fertilizer and was maximum with 37.5 kg N and 18.5 kg P_2O_5 ha^{-1}. Itnal *et al.* (1993) opined that application of 50 kg N + 25 kg P_2O_5 ha^{-1} produced the highest number of seeds capsule^{-1}, which was 60 percent greater than control. Application of 120 kg and 40 kg ha^{-1} N and P_2O_5conspicuously increased the number of seeds capsule^{-1} (Ahmad *et al.*, 2001).

Bhosale *et al*. (2011) conducted a field experiment during Kharif season on sesame cv. ‘Gujrat Til-2’ in clayey soils and reported significantly higher number of seeds/capsule with the fertilizer application of 25 kg N + 25 kg P_2O_5 + 50 kg K_2O ha^{-1}.

2.3.2.3 Capsule^{-1} length

2.3.2.3.1 Effect of nitrogen

Prakasha and Thimmegowda (1992) reported 53 percent increased seed yield with higher N rate due to enhanced capsules length. Jhansi (1995) opined that nitrogen application at 90 kg ha^{-1} resulted in significantly higher capsule length.

In Eastern Madhya Pradesh, application of 45 kg N ha^{-1} recorded significantly higher capsule length as compared to 30 kg N ha^{-1} (Thakur *et al.,* 1998). Each successive increase in dose of N up to 60 kg ha^{-1} significantly increased the capsule length (Prakash *et al.,* 2001).

Duray and Mandal (2006) indicated that application of 80 kg N ha^{-1} produced best results in different yield components like capsule length, the effect of 60 kg N ha^{-1} was found at par with 80 kg N ha^{-1}.

Nahar *et al.* (2008) indicated that the capsule length increased significantly up to 100 kg N ha^{-1} in varieties T6 and BARI Til 3 but the variety BARI Til 2 responded well up to 150 kg N ha^{-1}. Noorka *et al.* (2011) pointed out that increasing N fertilizer level upto 205 kg ha^{-1} significantly increased capsule length.

2.3.2.3.2 Effect of phosphorus

Kathiresan (1999) indicated that P level of 35 kg ha^{-1} influenced capsule length of *Sesamum*. Kalaiselvan *et al.* (2002) suggested that application of K significantly increased yield attributes of sesame.

Mian *et al.* (2011) opined that the highest capsule length was recorded with 90 kg P_2O_5 ha^{-1} compared to 70 and 110 kg P_2O_5 ha^{-1}.

2.3.2.3.3 Effect of potassium

Application of potassium markedly increased the capsule length which contributed to higher seed yield of sesame (Mandal *et al*., 1992). Tiwari *et al.* (1994) found that application of K_2O significantly increased the capsule length of sesame significant.

2.3.2.3.4 Effect of NPK fertilizer

Application of 120 kg and 40 kg ha^{-1} N and P_2O_5conspicuously increased the capsule length (Ahmad *et al.*, 2001). The highest capsule length was achieved by the application of 44 kg N and 44 kg P_2O_5 ha^{-1} (Abdel, 2008).

2.3.2.4 Weight of 1000 seeds

2.3.2.4.1 Effect of nitrogen

Ishwar Singh *et al.* (1994) postulated that *Sesamum* recorded positive yield traits *viz*., 1000 seed weight upto 60 kg N ha^{-1}. The maximum values of yield attributes was recorded with 25 percent increased dose of N (Senthilkumar *et al.*, 2000).

Nahar *et al.* (2008) indicated that the 1000 seed weight increased significantly up to 100 kg N ha^{-1} in varieties T 6 and BARI Til 3 but the variety BARI Til 2 responded well up to 150 kg N ha^{-1}.

Noorka *et al*. (2011) conducted two field experiments with four levels of nitrogen fertilization (55, 105, 155 and 205 Kg ha^{-1}) and three planting distances between hills (10, 15 and 20 cm, respectively). Increasing N fertilizer level up to 205 Kg ha^{-1} significantly increased 1000-seed weight.

Ali and Jan (2014) conducted an experiment on the performance of sesame cultivars (*Sesamum indicum* L.) (local black and local white) with different nitrogen levels (0, 40, 80 and 120 kg N ha^{-1}). Plots treated with 120 kg N ha^{-1} produced maximum 1000 seed weight (4.08 g).

2.3.2.4.2 Effect of phosphorus

Significantly higher seed yield of sesame was recorded with 50 kg P_2O_5 ha^{-1} due to increase in yield attributes *viz.*,1000 seed weight (Prakasha and Thimmegowda, 1992).

Mian *et al.* (2011) opined that the highest 1000 seed weight was recorded with 90 kg P_2O_5 ha^{-1} compared to 70 and 110 kg P_2O_5 ha^{-1}.

2.3.2.4.3 Effect of potassium

Application of potassium markedly increased the 1000 seed weight significantly resulted higher seed yield of sesame (Mandal *et al*., 1992). Tiwari *et al.* (1994) found that application of K_2O significantly increased the 1000 seed weight significantly and also noticed with K_2O application to 60 kg ha^{-1} beyond which there was no response. Increasing the level of K from 100 to 150 percent of recommended dose, the 1000 seed weight sesame increased significantly (Subrahmaniyan *et al.,* 2001).

2.3.2.4.4 Effect of NPK fertilizer

Thorve (1991) observed the highest thousand grain weight which was increased with every successive increased level of fertilizer and was maximum with 37.5 kg N and 18.5 kg P_2O_5 ha^{-1}.

Application of 120 kg and 40 kg ha^{-1} N and P_2O_5conspicuously increased the 1000 grain weight (Ahmad *et al.,* 2001). The highest 1000 grain weight was achieved by the application of 44 kg N and 44 kg P_2O_5 ha^{-1} (Abdel, 2008).

2.3.3 Yield parameters

2.3.3.1 Seed yield

2.3.3.1.1 Effect of nitrogen

Shrivastava and Tripathi (1992) observed significantly higher yield due to application of 90 kg N ha^{-1} which was on par with 60 kg N ha^{-1}. Shrivastava and Tripathi (1992) observed significantly higher seed yield due to application of 90 kg N ha^{-1} which was on par with 60 kg N ha^{-1}. Kumar and Prasad (1993) reported that the seed yield increased with N level as compared to control.

Chandrakar *et al.* (1994) found that 150 kg N ha^{-1} resulted in 75 percent higher yield over control. Tiwari *et al.* (1994) reported that significant increase in yield was recorded with every successive dose of N application upto 75 kg ha^{-1}.

Jhansi (1995) opined that nitrogen application at 90 kg ha^{-1} resulted in significantly the maximum seed yield (965 kg ha^{-1}). Balasubramaniyan (1996) opined that N application had greater effect on yield parameters andnoticed that increase in yield upto 90 kg N ha^{-1}.

Application of 60 kg N ha^{-1} gave significant increase in yield during 1992-93 whereas application of 90 kg N ha^{-1} gave significantly higher grain yield and at par with 60 kg N ha^{-1}. Again, in another experiment, application of 40 kg N ha^{-1} gave significantly higher yield (406 kg ha^{-1}) as compared to 55 kg N ha^{-1} (388 kg ha^{-1}) and 25 kg ha^{-1} (389 kg ha^{-1}), whereas in other experiment, it was reported that higher yield of 1453 kg ha^{-1} was recorded with 50 kg N ha^{-1} (Anon, 1996).

Bennet *et al.* (1996) found the seed yield did not significantly increase with N application above 60 kg ha^{-1}. In Madhya Pradesh, the highest *Sesamum* yield of 930 kg ha^{-1} was obtained under 60 kg N ha^{-1} as against 410 kg ha^{-1} and 658 kg ha^{-1}obtained from 0 and 30 kg N ha^{-1} respectively (Mishra, 1996).

Sridhar *et al.* (1997) opined that increasing levels of N application up to 60 kg ha^{-1} was better for favourable yield in *Sesamum*. Ramanathan and Chandrashekharan (1998) found that 100 kg N ha^{-1} gave significantly higher yield (811 kg ha^{-1}) to that of other lower doses. Application of 45 kg N ha^{-1} recorded significantly higher seed yield (5.5 q ha^{-1}) as compared to 30 kg N ha^{-1} (Thakur *et al.,* 1998).

The maximum values of seed yield were recorded with 25 percent increased dose of N (Senthilkumar *et al.,* 2000). The maximum values of yield were recorded with 25 percent increased dose of N (Senthilkumar *et al.,* 2000). Imayavaramban *et al.* (2002) observed that application of 25 percent additional dose of N to the recommended level significantly recorded maximum seed yield than that of other levels.

Malik *et al*. (2003) conducted a study to see the influence of different nitrogen levels (0, 40 and 80 kg ha^{-1}) on productivity of sesame under varying planting geometry. Among nitrogen levels, N_2 (80 kg ha^{-1}) treatment gave maximum seed yield (0.79 t ha^{-1}).

Research in alluvial soil of India during the dry season showed that the *Sesamum* yield increased 94.2 percent due to 90 kg N ha^{-1} (Sarkar and Saha, 2005).

Nahar *et al.* (2008) indicated that seed yield increased significantly up to 100 kg N ha^{-1} in varieties T 6 and BARI Til 3 but the variety BARI Til 2 responded well up to 150 kg N ha^{-1}. The variety Yetka with 150 kg N ha^{-1}registered the highest seed yield, whereas local Ardestan exhibited the lowest in Turkey (Parvaneh and Parviz, 2008).

Noorka *et al*. (2011) conducted two field experiments with four levels of nitrogen fertilization (55, 105, 155 and 205 Kg ha^{-1}) and three planting distances between hills (10, 15 and 20 cm, respectively). Increasing N fertilizer level up to 205 Kg ha^{-1} significantly increased seed weight $plant^{-1}$ and seed yields ha^{-1}.

Umar *et al*. (2012) conducted a field study to evaluate the performance of two sesame varieties in response to nitrogen fertilizer level (20, 40, 60 and 80 kg N ha^{-1}) and intra row spacing, during the wet seasons of 2009 and 2010. The result indicated that, application of up to 80 kg N ha^{-1} resulted in the significant increase in the grain yield per plant (GYP) and grain yield per hectare (GY ha^{-1}).

Ali and Jan (2014) conducted an experiment on the performance of sesame cultivars (*Sesamum indicum* L.) (local black and local white) with different nitrogen levels (0, 40, 80 and 120 kg N ha^{-1}). Plots treated with 120 kg N ha^{-1} produced maximum seed yield (833 kg ha^{-1}).

Rupali *et al*. (2015) conducted a field study aimed to evolve efficient and economically viable irrigation schedule and nitrogen management for improving quality, yield and growth of summer sesame var. AKT 101. Experimental results revealed that Nitrogen application at 90 kg ha^{-1} recorded significantly highest seed yield (kg ha^{-1}) over 30 and 60 kg N ha^{-1}.

2.3.3.1.2 Effect of phosphorus

Jadhav *et al*. (1992) opined that every higher level of phosphorus was significantly superior to its lower level in producing more grain yield, except the differences, which were at par between 50 and 75 kg P_2O_5 ha^{-1}.

Significantly higher seed yield was recorded with 50 kg P_2O_5 ha^{-1} due to increase in yield attributes *viz.*, capsules $plant^{-1}$, seeds $capsule^{-1}$ and seed yield $plant^{-1}$ (Prakasha and Thimmegowda, 1992).

Highest seed yield was recorded under 40 kg P_2O_5 ha^{-1} and it was at par with 60 kg P_2O_5 ha^{-1}. Khade *et al.* (1996) indicated that seed yield increased with upto 50 kg P_2O_5 ha^{-1}. Kathiresan (1999) indicated that P level of 35 kg ha^{-1} influenced the seed yield of *Sesamum.*

Shehu *et al*. (2010) conducted a pot experiment to assess the nitrogen, phosphorus and potassium nutrition on the productivity sesame (*Sesamum indicum* L.). Results indicated that among the three rates of phosphorus (0, 22.5 and 45 kg ha^{-1}) the seed yield was optimum at 45 kg P ha^{-1}. Mian *et al.* (2011) opined that the highest seed yield was recorded with 90 kg P_2O_5 ha^{-1}.

2.3.3.1.3 Effect of potassium

Application of potassium markedly increased the seed yield of sesame significantly (Mandal *et al*., 1992). Majumdar *et al.* (1988) suggested that application of K_2O at 63 kg ha^{-1}increased the yield under lateritic sandy loam soil of West Bengal. Kalaiselvan *et al.* (2002) suggested that application of K significantly increased yield of *Sesamum*. Increasing recommended level of K_2O to 150 percent resulted in higher seed yield (Kathiresan, 2002).

Tiwari *et al.* (1994) found that application of K_2O significantly increased the seed yield of *Sesamum*. Significant improvement in seed yield was noticed with K_2O application to 60 kg ha^{-1} beyond which there was no response.

Sarawagi *et al.* (1995) opined that significant seed yield and harvest index of summer

Sesamum with 60 to 90 kg K_2O ha^{-1} which were on par among themselves compared to control. Application of 50 kg K_2O ha^{-1} significantly increased the seed yield of *Sesamum* (Ramanathan and Chandrashekharan, 1998).

Increasing the level of K from 100 to 150 percent of recommended dose, seed yield of *Sesamum* increased significantly (Subrahmaniyan *et al.*, 2001b). Ojikpong *et al.* (2008) studied that application of K_2O up to 45 kg ha^{-1} significantly increased the seed yield of *Sesamum* than that of the other levels (0, 15 and 30 kg ha^{-1}).

Shehu *et al*. (2010) conducted a pot experiment to assess the nitrogen, phosphorus and potassium nutrition on the productivity sesame (*Sesamum indicum* L.). Results revealed that among the three rates of three rates of potassium (0, 22.5 and 45 kg ha^{-1}), K fertilizer did not affect significantly the seed yield ha^{-1}.

Application of K up to 40 kg ha^{-1} attained maximum yield (Ghosh *et al.,* 2002). Application of K_2O up to 40 kg ha^{-1} increased the yield and further increase in K_2O registered non-significant response (Jadav *et al.,* 2010).

2.3.3.1.4 Effect of NPK fertilizer

Rao and Yaseen (1980) evaluated the effect of NPK fertilization on sesamum in red sandy loam soils and concluded that soil application of 40 kg N + 40 kg P_2O_5 + 20 kg K_2O ha^{-1} was enough in recording maximum seed yield for sesame cv. 'T-85'.

Velazquaz *et al*. (1986) obtained maximum and economic seed yield of sesame with fertilizer application of 100 kg N, 80 Kg P and 80 kg K ha^{-1} and 45.4 kg N, 38.8 kg P and 32 kg K ha^{-1} respectively.

Kene *et al*. (1991) reported highest seed yield of sesame cv. 'Phule-1' with the fertilizer application of 40 kg N + 40 kg P_2O_5 + 25 kg K_2O ha^{-1} (2.59 and 0.30 t ha^{-1} and 50.26%, respectively) during kharif season under rainfed situations. Dwivedi and Namdeo (1992) reported highest seed yield of sesame cv. 'JT-7' with the fertilizer application of 45 kg N + 30 kg P_2O_5 ha^{-1} under rainfed conditions in clay loam soils.

Jadhav *et al.* (1992) reported that grain yield was recorded when 120 kg N and 75 kg P_2O_5 ha^{-1} was applied, which was statistically on par with 120 kg N and 50 kg P_2O_5 ha^{-1}. Seed yield increased for every further increase in the rate of N and K application upto 80 and 60 kg ha^{-1}, respectively (Mandal *et al.*, 1992). Expressively higher grain yield was obtained with 50 kg N and 25 kg P_2O_5 ha^{-1} compared to 25 kg N and 12.5 kg P_2O_5 ha^{-1} (Kanade *et al.*, 1992).

Kanade *et al*. (1992) and Itnal *et al*. (1993) reported higher seed yields of sesame with application of higher doses of fertilizer (50 kg N and 25 kg P_2O_5 ha^{-1}) as compared to lower doses under rainfed condition.

Itnal *et al.* (1993) opined that application of 50 kg N + 25 kg P_2O_5 ha^{-1} produced the highest yield, which was 69 percent greater than control. Mondal *et al*. (1993) found maximum seed yield of sesame cv. ‘B-67’ with the application of 75% NPK (RDF) + 5 t FYM ha^{-1} in sandy loam soils.

Ghosh and Patra (1994) reported the highest seed yield (12.5 q ha^{-1}) of sesame cv. ‘Tilottama’ with the application of 96 kg N + 18 kg P_2O_5 + 52 kg K_2O ha^{-1} in lateritic sandy loam soils.

Tiwari *et al*. (1994) reported the maximum seed yield of sesame cv. ‘CST-785’ during kharif season with the fertilizer application of 60 kg N + 30 kg P_2O_5 + 20 kg K_2O ha^{-1} in sandy loam soils.According to Kalita (1994) sesame responded well to fertilizer application of 30 kg N + 30 kg P_2O_5 + 20 kg K_2O ha^{-1} in sandy loam soils.

Mankar *et al*. (1995) conducted the experiment during kharif season on sesame and reported highest seed yield, straw yield, harvest index and oil content with application of 75 kg N + 50 kg P_2O_5 ha^{-1}. According to Sharma *et al*. (1995) application of 60 kg N + 40 kg P_2O_5 + 20 kg K_2O ha^{-1} to sesame cv. ‘JT-7’ was enough for optimizing seed yield.

Tiwari *et al*. (1995) conducted the experiments on sesame cv. ‘TKG-55’ reported maximum seed yield with the application of 40 kg N + 30 kg P_2O_5 + 20 kg K_2O ha^{-1} during kharif season under rainfed conditions.

Abolel and Abo (1996) reported highest seed yield (14.0 q ha^{-1}) of sesame cv. 'B-67' during summer season with the application of 75% NPK + 10 t FYM ha^{-1} in sandy loam soils. Venkatakrishnan and Ravichandran (1996) reported higher yield attributes and seed yield of sesame cv. 'TMV-4' during kharif season with the application of 96 kg N + 18 kg P_2O_5 + 52 kg K_2O ha^{-1}.

Singh *et al*. (1996) conducted a field experiment on sesame during kharif season under rainfed situations. They reported significantly higher number of growth parameters, yield attributes and finally the seed yields with the application of 90 kg N + 40 kg P_2O_5 + 20 kg K_2O ha^{-1}.

Ramnathan and Chandrashekharan (1998) reported the maximum seed yield of summer sesame (811 kg ha^{-1}) with fertilizer application of 100 kg N + 20 kg P_2O_5 + 20 kg K_2O ha^{-1}. Ramanathan and Chandrashekharan (1998) stated that application of 50 percent over and above recommended dose of N and K (35:25 kg ha) recorded 15 percent more yield as compared to the recommended dose. Thakur *et al*. (1998) reported significant increase in seed yields of sesame with the application of fertilizer dose upto 45 kg N + 30 kg P_2O_5 ha^{-1}.

Basavaraj *et al*. (2000) conducted a field trial on sesame during Kharif season. They reported highest sesame seed yield with fertilizer application of 60 kg N + 75 kg P_2O_5 + 40 kg K_2O ha^{-1}. Kathiresan (2002) conducted an experiment during summer season on sesame cv. 'TMV-4' and reported significantly higher seed yield with the fertilizer application of 52 kg N + 35 kg P_2O_5 + 35 kg K_2O ha^{-1}.

Sharma (2005) conducted a field trial during Kharif season under rainfed situation and reported significantly higher seed yields with the fertilizer application of 60 kg N + 40 kg P_2O_5 + 20 kg K_2O ha^{-1}.

Tripathi and Rajput (2007) reported the highest seed yield of sesame cv. 'JTS-8' during kharif season with the fertilizer application of 60 kg N + 30 kg P_2O_5 + 15 kg K_2O ha^{-1}.

Deshumukh and Duhoon (2008) reported maximum seed yield of sesame cv. 'JTS-8' during kharif season with the fertilizer application of 60 kg N + 40 P_2O_5 + 30 kg K_2O +

20 kg S ha^{-1}.The highest seed yield was achieved by the application of 44 kg N and 44 kg P_2O_5 ha^{-1} (Abdel, 2008).

Shehu *et al*. (2010) conducted a pot experiment to assess the nitrogen, phosphorus and potassium nutrition on the productivity sesame (*Sesamum indicum* L.). The treatments consisted of the combinations of four rates of nitrogen fertilizer (0, 37.5, 75 and 112.5 kg ha^{-1}), three rates of phosphorus (0, 22.5 and 45 kg ha^{-1}) and three rates of potassium (0, 22.5 and 45 kg ha^{-1}). In conclusion, application of 75 kg N ha^{-1}, 45 kg P ha^{-1} and 22.5 kg K ha^{-1} produced the highest seed yield.

Vaghani *et al*. (2010) conducted a field experiment on clayey soil during Kharif season on sesame cv. 'GTil-2' under rainfed situation. They reported significantly higher seed yields with the fertilizer application of 100 kg N + 25 kg P_2O_5 + 80 kg K_2O + 40 kg S ha^{-1}.

Katwate *et al*. (2010) conducted a field trial during Kharif season under rainfed situation and concluded that sesame cv. 'Tapi (JLT-7)' was most suitable with fertilizer application of 37.5 kg N + 18.5 kg P_2O_5 ha^{-1} for maximizing sesame production.

Bhosale *et al*. (2011) conducted a field experiment during Kharif season on sesame cv. 'Gujrat Til-2' in clayey soils and reported significantly highest seed yield with the fertilizer application of 25 kg N + 25 kg P_2O_5 + 50 kg K_2O ha^{-1}. While refining the fertility schedules in a multi location testing, the sesame crop responded in yield increase upto 100 kg N + 80 kg P_2O_5 + 60 kg K_2O ha^{-1}.

2.3.3.2 Stover yield

2.3.3.2.1 Effect of nitrogen

Jhansi (1995) opined that nitrogen application at 90 kg ha^{-1} resulted in significantly the maximum Stover yield (3378 kg ha^{-1}). Application of 45 kg N ha^{-1} recorded significantly higher stover yield as compared to 30 kg N ha^{-1} (Thakur *et al.*, 1998).

Nahar *et al.* (2008) indicated that stover yield increased significantly up to 100 kg N ha^{-1} in varieties T 6 and BARI Til 3 but the variety BARI Til 2 responded well up to 150 kg N ha^{-1}.

Ali and Jan (2014) conducted an experiment on the performance of sesame cultivars (*Sesamum indicum* L.) (local black and local white) with different nitrogen levels (0, 40, 80 and 120 kg N ha^{-1}). Plots treated with 120 kg N ha^{-1} produced maximum stover yield (5351 kg ha^{-1}).

2.3.3.2.2 Effect of phosphorus

Highest stover yield was recorded under 40 kg P_2O_5 ha^{-1} and it was at par with 60 kg P_2O_5 ha^{-1}. Kathiresan (1999) indicated that P level of 35 kg ha^{-1} influenced the stover yield of *Sesamum*.

Yield characters were found superior when the crop received 45 kg P_2O_5 ha^{-1} over lower levels (Thanki *et al.,* 2004; Shehu *et al.,* 2010). Mian *et al.* (2011) opined that the highest stover yield was recorded with 90 kg P_2O_5 ha^{-1}.

2.3.3.2.3 Effect of potassium

Tiwari *et al.* (1994a) found that application of K_2O significantly increased the stover yield of *Sesamum*. Significant improvement in stover yield was noticed with K_2O application to 60 kg ha^{-1} beyond which there was no response.

Sarawagi *et al.* (1995) opined that significant stover yield of summer *Sesamum* with 60 to 90 kg K_2O ha^{-1} which were on par among themselves compared to control.

2.3.3.2.4 Effect of NPK fertilizer

Jadhav *et al.* (1992) reported that stover yield was recorded when 120 kg N and 75 kg P_2O_5 ha^{-1} was applied, which was statistically on par with 120 kg N and 50 kg P_2O_5 ha^{-1}. Expressively higher stover yield was obtained with 50 kg N and 25 kg P_2O_5 ha^{-1} compared to 25 kg N and 12.5 kg P_2O_5 ha^{-1} (Kanade *et al.,* 1992). Application of 120 kg and 40 kg ha^{-1} N and P_2O_5 conspicuously increased the stover yield (Ahmad *et al.,* 2001).

Vaghani *et al*. (2010) conducted a field experiment on clayey soil during Kharif season on sesame cv. 'GTil-2' under rainfed situation. They reported significantly higher stover yields with the fertilizer application of 100 kg N + 25 kg P_2O_5 + 80 kg K_2O + 40 kg S ha^{-1}.

Bhosale *et al*. (2011) conducted a field experiment during Kharif season on sesame cv. 'Gujrat Til-2' in clayey soils and reported significantly higher stover yield with the fertilizer application of 25 kg N + 25 kg P_2O_5 + 50 kg K_2O ha^{-1}.

2.3.3.3 Harvest index

2.3.3.3.1 Effect of nitrogen

Shrivastava and Tripathi (1992) observed significantly higher harvest index due to application of 90 kg N ha^{-1} which was on par with 60 kg N ha^{-1}. Application of 45 kg N ha^{-1} recorded significantly higher harvest index as compared to 30 kg N ha^{-1} (Thakur *et al.*, 1998).

Ali and Jan (2014) conducted an experiment on the performance of sesame cultivars (*Sesamum indicum* L.) (local black and local white) with different nitrogen levels (0, 40, 80 and 120 kg N ha^{-1}). Plots treated with 120 kg N ha^{-1} produced highest harvest index (15%).

2.3.3.3.2 Effect of phosphorus

Khade *et al.* (1996) indicated that harvest index increased with upto 50 kg P_2O_5 ha^{-1}. Kathiresan (1999) indicated that P level of 35 kg ha^{-1} influenced the harvest index of sesame. Yield characters were found superior when the crop received 45 kg P_2O_5 ha^{-1} over lower levels (Thanki *et al.,* 2004; Shehu *et al.,* 2010).

2.3.3.3.3 Effect of potassium

Tiwari *et al.* (1994) found that application of K_2O significantly increased the harvest index of sesame. Significant improvement in harvest index was noticed with K_2O application to 60 kg ha^{-1} beyond which there was no response. Sarawagi *et al.* (1995)

opined that significant harvest index of summer sesame was with 60 to 90 kg K_2O ha^{-1} which were on par among themselves compared to control.

2.3.3.3.4 Effect of NPK fertilizer

Application of 120 kg and 40 kg ha^{-1} N and P_2O_5conspicuously increased the harvest index (Ahmad *et al.,* 2001). The highest harvest index was achieved by the application of 44 kg N and 44 kg P_2O_5 ha^{-1} (Abdel, 2008).

2.3.4 Quality parameters

2.3.4.1 Oil yield

2.3.4.1.1 Effect of nitrogen

Malik *et al*. (2003) conducted a study to see the influence of different nitrogen levels (0, 40 and 80 kg ha^{-1}) on productivity of sesame under varying planting geometry. Among nitrogen levels, N_2 (80 kg ha^{-1}) treatment gave maximum seed oil content (45.88%).

Noorka *et al*. (2011) conducted two field experiments with four levels of nitrogen fertilization (55, 105, 155 and 205 Kg ha^{-1}) and three planting distances between hills (10, 15 and 20 cm, respectively). Increasing N fertilizer level up to 205 Kg ha^{-1} significantly increased seed oil content (%) and oil yields ha^{-1}.

Rupali *et al*. (2015) conducted a field study aimed to evolve efficient and economically viable irrigation schedule and nitrogen management for improving quality, yield and growth of summer sesame var. AKT 101. Experimental results revealed that Nitrogen application at 90 kg ha^{-1} recorded significantly highest oil yield (kg ha^{-1}) over 30 and 60 kg N ha^{-1}.

2.3.4.1.2 Effect of NPK fertilizer

Kene *et al*. (1991) reported highest oil content of sesame cv. ‘Phule-1’ with the fertilizer application of 40 kg N + 40 kg P_2O_5 + 25 kg K_2O ha^{-1} (2.59 and 0.30 t ha^{-1} and 50.26%, respectively) during kharif season under rainfed situations.Thakur *et al*. (1998) reported significant increase oil yields of sesame with the application of fertilizer dose upto 45 kg N + 30 kg P_2O_5 ha^{-1}.

Vaghani *et al*. (2010) conducted a field experiment on clayey soil during Kharif season on sesame cv. 'GTil-2' under rainfed situation. They reported significantly higher oil yield with the fertilizer application of 100 kg N + 25 kg P_2O_5 + 80 kg K_2O + 40 kg S ha^{-1}.

2.3.4.2 Protein yield

2.3.4.2.1 Effect of NPK fertilizer

Thakur *et al*. (1998) reported significant increase in protein yields of sesame with the application of fertilizer dose upto 45 kg N + 30 kg P_2O_5 ha^{-1}.

Vaghani *et al*. (2010) conducted a field experiment on clayey soil during Kharif season on sesame cv. 'GTil-2' under rainfed situation. They reported significantly higher protein yield with the fertilizer application of 100 kg N + 25 kg P_2O_5 + 80 kg K_2O + 40 kg S ha^{-1}.

2.3.5 Economic benefit

2.3.5.1 Effect of nitrogen

Rupali *et al*. (2015) conducted a field study aimed to evolve efficient and economically viable irrigation schedule and nitrogen management for improving quality, yield and growth of summer sesame var. AKT 101. Experimental results revealed that among the nutrient levels (30, 60 and 90 kg N ha^{-1}), each successive dose from 50 to 150% RDF increased net returns with B:C ratio.

2.3.5.2 Effect of NPK fertilizer

Menon and Unnithan (1985) reported that application of 34 kg N + 17 kg P_2O_5 + 34 kg K_2O ha^{-1} as a profitable balanced dose for sesame.

Bajpai *et al*. (2000) conducted field experiment during Kharif season on sesame. They concluded that application of 60 kg N + 40 kg P_2O_5 + 20 Kg K_2O ha^{-1} was enough for yield optimization and obtaining higher net monetary returns.

Basavaraj *et al*. (2000) conducted a field trial on sesame during Kharif season. They reported highest sesame net monetary returns with fertilizer application of 60 kg N + 75 kg P_2O_5 + 40 kg K_2O ha^{-1}.

Sharma (2005) conducted a field trial during Kharif season under rainfed situation and reported significantly higher monetary returns with the fertilizer application of 60 kg N + 40 kg P_2O_5 + 20 kg K_2O ha^{-1}.

Tripathi and Rajput (2007) reported the highest net monetary returns of sesame cv. 'JTS-8' during kharif season with the fertilizer application of 60 kg N + 30 kg P_2O_5 + 15 kg K_2O ha^{-1}.

Deshumukh and Duhoon (2008) reported maximum net monetary returns of sesame cv. 'JTS-8' during kharif season with the fertilizer application of 60 kg N + 40 P_2O_5 + 30 kg K_2O + 20 kg S ha^{-1}.

2.4 Role of organic manure and integrated plant nutrient supply system

2.4.1 Farm yard manure

Farmyard manure (FYM) occupies important position among organic manures and it proved its ability in enhancing crop production. FYM is a conventional source of nutrient, lost its relative importance with rapid use of fertilizers. Organic manures are bulky in nature (Alok *et al.*, 1995) and seem to act directly by increasing the crop yield either by acceleration of respiratory process or by cell permeability or by hormonal growth action.

Application of FYM after decomposition released organic acids, which act as binding agents for soil aggregates, decreased the bulk density, favoured the water holding capacity of soil and reduced the leaching loss in coarse textured soils. The beneficial effects of FYM on various physico-chemical properties of soil and to sustain high levels of yield were reported by El-Habbasha *et al.* (2007). According to Fertilizer Recommended Guide (2012) the nutrient status of N, P and K in farmyard manure was 1.6±0.16%, 0.83±0.08% and 1.7±0.17% respectively.

Gopinath *et al.* (2011) reported that application of FYM not only improved the physico-chemical properties of the soil like bulk density, water holding capacity and organic carbon content but also had little effect on residual phosphorus and potassium in the soil.

2.4.2 Vermicompost

Pollution of land, water and air by the accumulation of wastes pose a sequel of environment and health problems. Hence, managing wastes has become important and several attempts are made to solve the problems. The utilization of waste material through earthworms has given the concept of vermicomposting. Vermicompost is an established organic soil amendment that is produced by non-thermophilic process in which the organic matter is broken down through interactions between earthworms and microorganisms under aerobic condition. Vermicompost offers a balanced nutritional release pattern to plants, providing nutrients such as available nitrogen, soluble potassium, exchangeable calcium, magnesium and phosphorus that can be taken up readily by plants (Edwards, 1998; Edwards and Fletcher, 1988). As the breakdown of organic wastes by earthworms in a non-thermophilic process, vermicompost has much greater microbial biodiversity and activity (Edwards, 1998; Edwards, 2004).

Norman *et al.* (2005) reported that vermicompost improved the plant growth due to the changes in physico-chemical properties of soils, overall increase in microbial activity and plant growth regulators produced by microorganisms. Roy and Singh (2006) stated that increased growth and yield components of crops due to application of vermicompost was mainly because of microbial stimulation effect and N supplied through gradual mineralization in a steady manner throughout the crop growth period.

Ushakumari *et al.* (2006) stated that vermicompost is a potential source of plant nutrient by presence of readily available nutrients, plant growth hormones, vitamins, enzymes, antibiotics and number of beneficial microorganisms. Vermicompost have been considered as a soil additive to reduce the use of mineral fertilizers because they provided required nutrients, increased cation exchange capacity and improved water holding capacity; however, the effect of vermicompost on soil properties and crop yield depends on its chemical composition (Tejada and Gonzalez, 2009).

The application of orgnic resources like vermicompost to soil is essential to maintain soil fertility and productivity in agricultural systems. Vermicompost contributes to soil health by releasing different essential plant nutrients with a considerable amount. According to Agarwal (1999); nutrient content in vermicompost ranged from 2.5-3.0%, 1.8-2.9%, 1.4-

2.0% for N, P and K respectively. Similar findings were also observed by Sohela *et al*. (2012) and it was found that from this study; the N, P and K status in vermicompost was 2.9%, 1.8% and 1.2% respectively in 2007 and 2.5%, 1.6% and 1.1% respectively in 2008.

2.4.3 Integrated plant nutrient supply system

In view of escalating input costs and growing concerns on sustainability and soil health, reliance on Integrated Plant Nutrient Supply (IPNS) systems is assuming greater importance in recent days.

Singh *et al.* (1997) reported 61.6 and 60.6 percent increase in seed yield with the application of poultry manure (10 t ha^{-1} and 120 kg N ha^{-1}, respectively) over control during summer. They also observed an increased organic carbon content with the combined application of 120 kg N ha^{-1} + poultry manure. In an experiment on integrated nutrient management in sesame.

Duhoon *et al.* (2001) reported that, sesame yield was significantly improved by application of fertilizers in combination with organic manures in different soil types (Vertisols, AlfisolsandInceptisols).

The highest yield of sesame was recorded in the treatment which received 50 per cent N through urea + 50% N through FYM + 50% of recommended phosphorous in addition to soil application of phosphorus solubilizing bacteria (PSB) @ 600 g ha^{-1} + 100 percent recommended dose of potassium.

2.5 Effect of organic manure

2.5.1 Growth parameters

2.5.1.1 Plant height

2.5.1.1.1 Effect of Farm yard manure (FYM)

Appreciable increments in plant height was obtained through the soil incorporation of FYM at 15 t ha^{-1} over control in sesame (Mahendranath *et al.*, 1994). Veeraputhiran *et al.* (2001) revealed that application of FYM @ 2.5 t ha^{-1}significantly improved the plant height as compared to control with 24 percent yield increase. FYM application increased the plant height of sesame than control in clay loam soil (Hanumanthappa and Basavaraj, 2008).

2.5.1.1.2 Effect of Vermicompost

Jaishankar and Wahab (2005) opined that application of recommended dose of NPK + vermicompost @ 5 t ha^{-1} recorded the highest plant height of sesame in clay loam soil.

Application of vermicompost @ 10 t ha^{-1} increased the plant height of sesamum (SajjadiNik *et al.,* 2010). Application of vermicompost increased the shoot length of sesame (Vijayakumari and Hiranmai, 2012).

2.5.1.2 Number of leaves $plant^{-1}$

2.5.1.2.1 Effect of Farm yard manure (FYM)

Veeraputhiran *et al.* (2001) revealed that application of FYM @ 2.5 t ha^{-1}significantly improved the growth attributes *viz.,* number of leaves $plant^{-1}$ as compared to control with 24 percent yield increase. FYM application increased the number of leaves $plant^{-1}$ of sesame than control in clay loam soil (Hanumanthappa and Basavaraj, 2008).

2.5.1.2.2 Effect of Vermicompost

Jaishankar and Wahab (2005) opined that application of recommended dose of NPK + vermicompost @ 5 t ha^{-1} recorded the highest number of leaves $plant^{-1}$ of sesame in clay loam soil.

2.5.1.3 Number of branches $plant^{-1}$

2.5.1.3.1 Effect of Farm yard manure (FYM)

Appreciable increments in number of branches $plant^{-1}$ were obtained through the soil incorporation of FYM at 15 t ha^{-1} over control in sesame (Mahendranath *et al.,* 1994).

Veeraputhiran *et al.* (2001) revealed that application of FYM @ 2.5 t ha^{-1}significantly improved the number of branches $plant^{-1}$ as compared to control with 24 percent yield increase.

2.5.1.3.2 Effect of Vermicompost

Jaishankar and Wahab (2005) opined that application of recommended dose of NPK + vermicompost @ 5 t ha^{-1} recorded the highest growth parameters *viz.*, number of branches $plant^{-1}$ of sesame in clay loam soil.

Application of vermicompost @ 10 t ha^{-1} increased the number of branches $plant^{-1}$ of sesame (Sajjadi Nik *et al.*, 2010).

2.5.1.4 Dry mater production

2.5.1.4.1 Effect of Farm yard manure (FYM)

Veeraputhiran *et al.* (2001) revealed that application of FYM @ 2.5 t ha^{-1}significantly improved the DMP as compared to control with 24 percent yield increase.

FYM application increased the DMP of sesame than control in clay loam soil at (Hanumanthappa and Basavaraj, 2008).

2.5.1.4.2 Effect of Vermicompost

Jaishankar and Wahab (2005) opined that application of recommended dose of NPK + vermicompost @ 5 t ha^{-1} recorded the highest DMP of sesame in clay loam soil.

Shaikh *et al.* (2010) indicated that integrated application of 75% of RDF + 5 t vermicompost ha^{-1} influenced the highest DMP of summer sesame. Application of vermicompost increased the dry matter production (DMP) of sesame (Vijayakumari and Hiranmai, 2012).

2.5.1.5 Leaf area index

2.5.1.5.1 Effect of Farm yard manure (FYM)

FYM application increased the growth attributes *viz.*, LAI of sesame than control in clay loam soil (Hanumanthappa and Basavaraj, 2008). Application of FYM was superior to mustard cake application in achieving higher LAI of sesame (Barik and Fulmali, 2011).

2.5.1.5.2 Effect of Vermicompost

Jaishankar and Wahab (2005) opined that application of recommended dose of NPK +

vermicompost @ 5 t ha^{-1} recorded the highest growth parameters *viz*., leaf area index (LAI) of sesame in clay loam soil.

2.5.1.6 Crop growth rate

2.5.1.6.1 Effect of Farm yard manure (FYM)

Parasuraman and Rajagopal (1998) at Coimbatore indicated that incorporation of FYM @ 12.5 t ha^{-1} resulted in higher seed crop growth rate (CGR) as compared to incorporation of coir waste @ 5 t ha^{-1} (998 kg ha^{-1}).

Veeraputhiran *et al.* (2001) revealed that application of FYM @ 2.5 t ha^{-1}significantly improved the crop growth rate (CGR) as compared to control with 24 percent yield increase.

FYM application increased the crop growth rate (CGR) of sesame than control in clay loam soil (Hanumanthappa and Basavaraj, 2008).

2.5.1.6.2 Effect of Vermicompost

Jaishankar and Wahab (2005) opined that application of recommended dose of NPK + vermicompost @ 5 t ha^{-1} recorded the highest crop growth rate (CGR) of sesame in clay loam soil. Application of vermicompost increased the crop growth rate (CGR) of sesame (Vijayakumari and Hiranmai, 2012).

2.5.2 Yield and yield attributes

2.5.2.1 Number of capsules $plant^{-1}$

2.5.2.1.1 Effect of Farm yard manure (FYM)

Parasuraman and Rajagopal (1998) indicated that incorporation of FYM @ 12.5 t ha^{-1} resulted in higher number of capsule $plant^{-1}$ as compared to incorporation of coir waste @ 5 t ha^{-1} (998 kg ha^{-1}).

Veeraputhiran *et al.* (2001) revealed that application of FYM @ 2.5 t ha^{-1}significantly improved the number of capsules $plant^{-1}$ as compared to control with 24 percent yield increase. FYM application increased the capsules plant^{-1} of sesame than control in clay loam soil (Hanumanthappa and Basavaraj, 2008).

2.5.2.1.2 Effect of Vermicompost

Jaishankar and Wahab (2005) opined that application of recommended dose of NPK + vermicompost @ 5 t ha^{-1} recorded the highest yield parameters *viz.*, number of capsules plant^{-1} of sesame in clay loam soil. Application of vermicompost @ 10 t ha^{-1} increased the number of capsules plant^{-1}of sesamum (SajjadiNik *et al.*, 2010).

2.5.2.2 Number of seeds capsule^{-1}

2.5.2.2.1 Effect of Farm yard manure (FYM)

Veeraputhiran *et al.* (2001) revealed that application of FYM @ 2.5 t ha^{-1}significantly improved the yield parameters *viz.*, number of seeds capsule^{-1} as compared to control with 24 percent yield increase.

Jaishankar and Wahab (2005) from the findings of the field trials conducted by them to find out the effect of INM on growth and yield of sesame reported that application of RDF + 5 t Vermicompost ha^{-1} as a most suitable treatment in recording higher number of seeds capsule^{-1}. FYM application increased the number of seeds capsule^{-1}of sesame than control in clay loam soil (Hanumanthappa and Basavaraj, 2008).

2.5.2.2.2 Effect of Vermicompost

Jaishankar and Wahab (2005) opined that application of recommended dose of NPK + vermicompost @ 5 t ha^{-1} recorded the highest number of seeds capsule^{-1} of sesame in clay loam soil. Shaikh *et al.* (2010) indicated that integrated application of 75% of RDF + 5 t vermicompost ha^{-1} influenced the number of seeds capsule^{-1} of summer sesame.

2.5.2.3 Capsule^{-1} length

2.5.2.3.1 Effect of Farm yard manure (FYM)

Veeraputhiran *et al.* (2001) revealed that application of FYM @ 2.5 t ha^{-1}significantly improved capsule length as compared to control with 24 percent yield increase.

2.5.2.3.2 Effect of Vermicompost

Application of vermicompost increased the capsule length of sesame (Vijayakumari and Hiranmai, 2012).

2.5.2.4 Weight of 1000 seeds

2.5.2.4.1 Effect of Farm yard manure (FYM)

Veeraputhiran *et al.* (2001) revealed that application of FYM @ 2.5 t ha^{-1}significantly improved the yield parameters *viz.*, 1000 seed weight as compared to control.

FYM application increased the yield attributes *viz.*, 1000 seed weight of sesame than control in clay loam soil (Hanumanthappa and Basavaraj, 2008).

2.5.2.4.2 Effect of Vermicompost

Application of vermicompost @ 10 t ha^{-1} increased the 1000 seed weight of sesamum (SajjadiNik *et al.*, 2010). Shaikh *et al.* (2010) indicated that integrated application of 75% of RDF + 5 t vermicompost ha^{-1} influenced the 1000 seed weight of summer sesame.

2.5.3 Yield parameters

2.5.3.1 Seed yield

2.5.3.1.1 Effect of Farm yard manure (FYM)

Mandal *et al.* (1990) reported good response in seed yield of sesame through balanced fertilizer management in conjunction with adequate amount of FYM. Mandal *et al.* (1992) opined that application of FYM at 10 t ha^{-1} with each nutrient level of up to 90 kg N ha^{-1} and 67.2 kg K_2O ha^{-1} significantly increased the seed yield of sesame compared with the same level of nutrients without FYM. Studies conducted at Vridhachalam (Tamil Nadu) showed that application of FYM @ 5 t ha^{-1} recorded higher yield of sesame as compared to no manure (Anon, 1997).

The pooled analysis of three years data of AICRP on sesame trials conducted at Karke indicated that application of FYM @ 5 t ha^{-1}recorded significantly higher yield of sesame as compared to neem cake applied @ 250 kg ha^{-1} and control (Anon, 1998).

Parasuraman and Rajagopal (1998) at Coimbatore indicated that incorporation of FYM @ 12.5 t ha^{-1} resulted in higher seed yield (1108 kg ha^{-1}) as compared to incorporation of coir waste @ 5 t ha^{-1} (998 kg ha^{-1}).

Veeraputhiran *et al.* (2001) revealed that application of FYM @ 2.5 t ha^{-1}significantly improved the yield of sesame as compared to control with 24 percent yield increase. Application of FYM (5 t ha^{-1}) produced significantly the highest seed yield of sesame than that of control (Narkhede *et al.,* 2001).

Maragatham *et al.* (2006) reported that application of FYM @ 12.5 t ha^{-1} resulted in the highest seed yield of sesame in clay loam soil at Coimbatore. Suganya and Sivasamy (2007) concluded that application of FYM @ 20 t ha^{-1} could bring out large scale improvement ensuring better yield of crops. FYM application increased the seed yield of sesame than control in clay loam soil (Hanumanthappa and Basavaraj, 2008).

Application of FYM was superior to mustard cake application in achieving higher yield attributes and yield of sesame (Barik and Fulmali, 2011). Haruna and Abimiku (2012) carried out field experiments to assess the effects of poultry manure, cow manure and sheep manure on the performance of sesame crop. The seed yield ha^{-1} in both years were also optimized with the application of 2.5 t ha^{-1} of poultry manure (1914.07 and 1933.20 kg ha^{-1} in 2008 and 2009, respectively) compared with any other applied rates of sheep and cow manure and is therefore recommended.

2.5.3.1.2 Effect of Vermicompost

Jaishankar and Wahab (2005) opined that application of recommended dose of NPK + vermicompost @ 5 t ha^{-1} recorded the highest seed yield of sesame in clay loam soil.

Application of vermicompost @ 10 t ha^{-1} increased the seed yield and oil content of sesamum (Sajjadi Nik *et al.,* 2010). Shaikh *et al.* (2010) indicated that integrated application of 75% of RDF + 5 t vermicompost ha^{-1} influenced the yield of summer sesame. Application of vermicompost increased the yield of sesame (Vijayakumari and Hiranmai, 2012).

2.5.3.2 Stover yield

2.5.3.2.1 Effect of Farm yard manure (FYM)

Mandal *et al.* (1990) reported good response in stover yield of sesame through balanced fertilizer management in conjunction with adequate amount of FYM. Appreciable increments in stover yield were obtained through the soil incorporation of FYM at 15 t ha^{-1} over control in sesame (Mahendranath Reddy *et al.*, 1994).

Application of FYM was superior to mustard cake application in achieving higher stover yield of sesame (Barik and Fulmali, 2011).

2.5.3.2.2 Effect of Vermicompost

Shaikh *et al.* (2010) indicated that integrated application of 75% of RDF + 5 t vermicompost ha^{-1} influenced the stover yield of summer sesame. Application of vermicompost increased the stover yield of sesame (Vijayakumari and Hiranmai, 2012).

2.5.3.3 Harvest index

2.5.3.3.1 Effect of Farm yard manure (FYM)

Parasuraman and Rajagopal (1998) at Coimbatore indicated that incorporation of FYM @ 12.5 t ha^{-1} resulted in higher harvest index as compared to incorporation of coir waste @ 5 t ha^{-1} (998 kg ha^{-1}).

Application of FYM was superior to mustard cake application in achieving higher harvest index of sesame (Barik and Fulmali, 2011).

2.5.3.3.2 Effect of Vermicompost

Jaishankar and Wahab (2005) opined that application of recommended dose of NPK + vermicompost @ 5 t ha^{-1} recorded the highest harvest index of sesame in clay loam soil.

Application of vermicompost @ 10 t ha^{-1} increased the harvest index of sesame (SajjadiNik *et al.*, 2010).

2.6 Effect of integrated plant nutrient supply system through chemical fertilizer and organic manure

2.6.1 Growth parameters

2.6.1.1 Plant height

Imayavaramban *et al.* (2002) stated that integrated nutrient supply system of FYM @ 12.5 t ha^{-1} + recommended NPK at 35:23:23 kg ha^{-1} + application of *Azospirillum* and phosphobacteria @ 10 kg ha^{-1} favourably improved the varied growth of sesame in clay loam soil. Integrated application of recommended dose of NPK (35:23:23 kg N, $P_2O_5$and K_2O ha^{-1}) + vermicompost @ 5 t ha^{-1} registered the highest growth parameters in clay loam soil (Jaishankar and Wahab, 2005). Barik and Fulmali (2011) indicated that combined use of FYM at 10 t ha^{-1} along with 75% recommended dose of NPK fertilizers registered the highest growth parameters of sesame.

Thanunathan *et al.* (2001) conducted studies on the effect of integrated nutrient management in sesame on clay loam soils and found that combined application of FYM @ 12.5 t ha^{-1} and 100 percent chemical fertilizer (35:23:23 kg N, P_2O_5 and K_2O ha^{-1}) registered the tallest plants in sandy clay loam soil. Deshmukh *et al.* (2002) reported that application of 50 percent N through urea + 50 percent N through FYM + 50 percent P and 100 percent K through fertilizer produced the highest plant height.

Jaishankar and Wahab (2005) from the findings of the field trials conducted by them to find out the effect of INM on growth and yield of sesame reported that application of RDF + 5 t Vermicompost ha^{-1} as a most suitable treatment in recording higher plant height.

2.6.1.2 Number of leaves plant^{-1}

Integrated nutrient supply system of FYM, vermicompost and NPK registered the highest growth parameters of sesame (Imayavaramban *et al.*, 2002; Jaishankar and Wahab, 2005 and Barik and Fulmali, 2011).

Thanunathan *et al.* (2001) conducted studies on the effect of integrated nutrient management in sesame on clay loam soils and found that combined application of FYM

@ 12.5 t ha^{-1} and 100 percent chemical fertilizer (35:23:23 kg N, P_2O_5 and K_2O ha^{-1}) registered the highest number of leaves $plant^{-1}$ in sandy clay loam soil.

2.6.1.3 Number of branches $plant^{-1}$

Integrated nutrient supply system of FYM, vermicompost and NPK registered the highest growth parameters of sesame (Imayavaramban *et al.,* 2002; Jaishankar and Wahab, 2005, Barik and Fulmali, 2011).

Thanunathan *et al.* (2001) conducted studies on the effect of integrated nutrient management in sesame on clay loam soils and found that combined application of FYM @ 12.5 t ha^{-1} and 100 percent chemical fertilizer (35:23:23 kg N, P_2O_5 and K_2O ha^{-1}) registered the largest number of branches $plant^{-1}$ in sandy clay loam soil.

Deshmukh *et al.* (2002) reported that application of 50 percent N through urea + 50 percent N through FYM + 50 percent P and 100 percent K through fertilizer produced the highest number of branches $plant^{-1}$. Number of branches $plant^{-1}$ was the highest with integrated application of poultry manure (15 t ha^{-1}), N (120 kg ha^{-1}) and P_2O_5 (13.2 kg ha^{-1}) (Haruna *et al.,* 2010).

2.6.1.4 Dry mater production

Jaishankar and Wahab (2005) from the findings of the field trials conducted by them to find out the effect of INM on growth and yield of sesame reported that application of RDF + 5 t Vermicompost ha^{-1} as a most suitable treatment in recording higher dry matter production.Integrated nutrient supply system of FYM, vermicompost and NPK registered the highest growth parameters of sesame (Barik and Fulmali, 2011).

Significantly superior DMP of sesame were recorded with 25 percent N through FYM + 75% N through urea than 50% N as FYM + 50% N as urea in clay soil of Dharwad (Purushottam and Hiremath, 2008). DMP was the highest with integrated application of poultry manure (15 t ha^{-1}), N (120 kg ha^{-1}) and P_2O_5 (13.2 kg ha^{-1}) (Haruna *et al.,* 2010).

Haruna (2011) conducted field trials to study the growth and yield of sesame as affected by poultry manure, nitrogen and phosphorus. The experiments consisted of four levels of poultry manure (0, 5.0, 10.0, and 15.0 t ha^{-1}), three levels of nitrogen in the form of urea

(0, 60, and 120 kg N ha^{-1}) and three levels of phosphorus in the form of single super phosphate (0, 13.2 and 26.4 kg P ha^{-1}). The results showed that net assimilation rate was highest at 15 t ha^{-1} of poultry manure, 120 kg N ha^{-1} and 13.2 kg P ha^{-1}.

2.6.1.5 Leaf area index

Thanunathan *et al.* (2001) conducted studies on the effect of integrated nutrient management in sesame on clay loam soils and found that combined application of FYM @ 12.5 t ha^{-1} and 100 percent chemical fertilizer (35:23:23 kg N, P_2O_5 and K_2O ha^{-1}) registered the highest LAI in sandy clay loam soil.

El-Habbasha *et al.* (2007) opined that application of 75 percent as chemical fertilizer + 25 percent as FYM recorded the highest LAI and followed by 50 percent chemical + 50 percent FYM under sandy soil.

Significantly superior LAI of sesame were recorded with 25 percent N through FYM + 75% N through urea than 50% N as FYM + 50% N as urea in clay soil of Dharwad (Purushottam and Hiremath, 2008).

Haruna (2011) conducted field trials to study the growth and yield of sesame as affected by poultry manure, nitrogen and phosphorus. The experiments consisted of four levels of poultry manure (0, 5.0, 10.0, and 15.0 t ha^{-1}), three levels of nitrogen in the form of urea (0, 60, and 120 kg N ha^{-1}) and three levels of phosphorus in the form of single super phosphate (0, 13.2 and 26.4 kg P ha^{-1}). The results showed that leaf area index was highest at 15 t ha^{-1} of poultry manure, 120 kg N ha^{-1} and 13.2 kg P ha^{-1}.

2.6.1.6 Crop growth rate

Deshmukh *et al.* (2002) reported that application of 50 percent N through urea + 50 percent N through FYM + 50 percent P and 100 percent K through fertilizer showed the highest crop growth rate (CGR).

Crop growth rate (CGR) was the highest with integrated application of poultry manure (15 t ha^{-1}), N (120 kg ha^{-1}) and P_2O_5 (13.2 kg ha^{-1}) (Haruna *et al.*, 2010). Integrated nutrient supply system of FYM, vermicompost and NPK registered the highest growth parameters of sesame (Barik and Fulmali, 2011).

2.6.2 Yield and yield attributes

2.6.2 .1 Number of capsules plant^{-1}

Thanunathan *et al.* (2001) conducted studies on the effect of integrated nutrient management in sesame on clay loam soils and found that combined application of FYM @ 12.5 t ha^{-1} and 100 percent chemical fertilizer (35:23:23 kg N, P_2O_5 and K_2O ha^{-1}) registered the highest number of capsules plant^{-1} in sandy clay loam soil.

Integrated nutrient supply system of FYM, vermicompost and NPK registered the highest yield attributes of sesame (Imayavaramban *et al.,* 2002a). Deshmukh *et al.* (2002) reported that application of 50 percent N through urea + 50 percent N through FYM + 50 percent P and 100 percent K through fertilizer produced the highest capsules plant^{-1}.

Jaishankar and Wahab (2005) from the findings of the field trials conducted by them to find out the effect of INM on growth and yield of sesame reported that application of RDF + 5 t Vermicompost ha^{-1} as a most suitable treatment in recording higher number of capsules plant^{-1}.

El-Habbasha *et al.* (2007) opined that application of 75 percent as chemical fertilizer + 25 percent as FYM recorded the highest number of capsules plant^{-1} and followed by 50 percent chemical + 50 percent FYM under sandy soil.

Ghosh *et al*. (2013) carried out field experiments to study the effect of nutrient management in summer sesame and its residual effect on succeeding kharif black gram. The crop growth was better with integrated application of 50% recommended dose of NPK through fertilizer (RDF), 50% N through vermicompost (VC) or FYM in sesame. Here, 100% RDF = 80:40:40 kg N: P_2O_5: K_2O ha^{-1}. The number of capsules plant^{-1} of sesame increased significantly due to integrated application of 50% RDF+50% N through FYM in sesame during both the years. However, the treatment was at par with those of 75% RDF+25% N through FYM or VC and 50% RDF+50% N through VC.

Vani *et al*. (2017) conducted a field study aimed to evolve efficient integrated nutrient management for improving yield and quality of summer sesamum on sandy loam soil. Application of 100% RDN gave the highest number of capsule plant^{-1} and was at par with

100% RDN+1% foliar spray of Humic acid, 100 % RDN +1% foliar spray- Fulvic acid and followed by 75 % RDN + 25% N through Vermicompost.

2.6.2.2 Number of seeds capsule^{-1}

Barik and Fulmali (2011) indicated that combined use of FYM at 10 t ha^{-1} along with 75% recommended dose of NPK fertilizers registered the highest yield attributes of sesame.

Significantly superior number of seeds capsule^{-1} of sesame was recorded with 25 percent N through FYM + 75% N through urea than 50% N as FYM + 50% N as urea in clay soil of Dharwad (Purushottam and Hiremath, 2008). Number of seeds capsule^{-1} was the highest with integrated application of poultry manure (15 t ha^{-1}), N (120 kg ha^{-1}) and P_2O_5 (13.2 kg ha^{-1}) (Haruna *et al.*, 2010).

Ghosh *et al*. (2013) carried out field experiments to study the effect of nutrient management in summer sesame and its residual effect on succeeding kharif black gram. The crop growth was better with integrated application of 50% recommended dose of NPK through fertilizer (RDF), 50% N through vermicompost (VC) or FYM in sesame. Here, 100% RDF = 80:40:40 kg N: P_2O_5: K_2O ha^{-1}. The number of seeds capsule^{-1} of sesame increased significantly due to integrated application of 50% RDF+50% N through FYM in sesame during both the years. However, the treatment was at par with those of 75% RDF+25% N through FYM or VC and 50% RDF+50% N through VC.

Vani *et al*. (2017) conducted a field study aimed to evolve efficient integrated nutrient management for improving yield and quality of summer sesamum on sandy loam soil. Application of 100% RDN gave the highest number of seeds capsule^{-1} and was at par with 100% RDN+1% foliar spray of Humic acid, 100 % RDN +1% foliar spray- Fulvic acid and followed by 75 % RDN + 25% N through Vermicompost.

2.6.2.3 Capsule^{-1} length

Integrated application of recommended dose of NPK (35:23:23 kg N, $P_2O_5$and K_2O ha^{-1}) + vermicompost @ 5 t ha^{-1} registered the highest yield parameters of sesame in clay loam soil at Annamalainagar (Jaishankar and Wahab, 2005).

El-Habbasha *et al.* (2007) opined that application of 75 percent as chemical fertilizer + 25 percent as FYM recorded the highest capsule length and followed by 50 percent chemical + 50 percent FYM under sandy soil.

Barik and Fulmali (2011) indicated that combined use of FYM at 10 t ha^{-1} along with 75% recommended dose of NPK fertilizers registered the highest capsule length of sesame.

Vani *et al*. (2017) conducted a field study aimed to evolve efficient integrated nutrient management for improving yield and quality of summer sesamum on sandy loam soil. Application of 100% RDN gave the highest capsule length and was at par with 100% RDN+1% foliar spray of Humic acid, 100 % RDN +1% foliar spray- Fulvic acid and followed by 75 % RDN + 25% N through Vermicompost.

2.6.2.4 Weight of 1000 seeds

Integrated application of recommended dose of NPK (35:23:23 kg N, $P_2O_5$and K_2O ha^{-1}) + vermicompost @ 5 t ha^{-1} registered the 1000 seed weight of sesame in clay loam soil at Annamalainagar (Jaishankar and Wahab, 2005).

El-Habbasha *et al.* (2007) opined that application of 75 percent as chemical fertilizer + 25 percent as FYM recorded the highest 1000 seed weight of sesame and followed by 50 percent chemical + 50 percent FYM under sandy soil.

Barik and Fulmali (2011) indicated that combined use of FYM at 10 t ha^{-1} along with 75% recommended dose of NPK fertilizers registered the highest 1000 seed weight of sesame.

Vani *et al*. (2017) conducted a field study aimed to evolve efficient integrated nutrient management for improving yield and quality of summer sesamum on sandy loam soil. Application of 100% RDN gave the highest 1000 seed weight and was at par with 100% RDN+1% foliar spray of Humic acid, 100 % RDN +1% foliar spray- Fulvic acid and followed by 75 % RDN + 25% N through Vermicompost.

2.6.3 Yield parameters

2.6.3.1 Seed yield

Thanunathan *et al.* (2001) conducted studies on the effect of integrated nutrient management in sesame on clay loam soils and found that combined application of FYM @ 12.5 t ha^{-1} and 100 percent chemical fertilizer (35:23:23 kg N, P_2O_5 and K_2O ha^{-1}) registered the highest seed yield in sandy clay loam soil.

Deshmukh *et al.* (2002) reported that application of 50 percent N through urea + 50 percent N through FYM + 50 percent P and 100 percent K through fertilizer produced the highest seed yield due to improvement in growth parameters (plant height and number of branches $plant^{-1}$) and yield attributing characters (capsules $plant^{-1}$, test weight of seeds and seed yield $plant^{-1}$).

According to Tiwari *et al*. (1995) in sandy soils of integrated use of NPK + FYM increased the seed yields mainly due to increase in yield components under poor fertility conditions. At the same place/same year they further added that yield of sesame was 28.7% higher due to application of 40 kg N + 30 kg P_2O_5 + 20 kg K_2O + 2.5 t FYM ha^{-1}.

According to Narkhede *et al*. (2001a) application of castor cake 1 t ha^{-1} + farmyard manure (FYM) 5 t ha^{-1} + RDF (50 kg N ha^{-1}) in two equal split (50% as basal + 50% at 30 DAS) was the most effective integrated nutrient management strategy to maximize the productivity of sesame cv. 'Padma' during kharif season in medium black soils.

According to Narkhede *et al*. (2001b) integrated application of 1 t FYM ha^{-1} + 40 kg N + 30 kg P_2O_5 + 20 kg K_2O ha^{-1} recorded significantly higher seed yield of sesame in medium black soils during kharif season.

Deshmukh *et al*. (2002) reported highest seed yield of sesame (cv. 'TKG-22') with the integrated use of 50%N through Urea+50%N through FYM mainly due to improvement in plant height, branches $plant^{-1}$, capsules $plant^{-1}$.

In a multilocational study, integrated nutrient management as 50% N through urea + 50% N through farm yard manure + full recommended P and 50% N through urea + 50% N through thumba cake/neem cake + full recommended P was found as efficient integrated nutrient management (INM) with regard to sustainable seed yields of sesame at all locations (Deshmukh *et al*., 2009).

Shashidhara *et al*. (2009) reported the highest yield of sesame during kharif season with the fertilizer application of 40 kg N+25 kgP_2O_5+25 kg K_2O+5t FYM ha^{-1} in Vertisols.

Chaurasia *et al*. (2009) conducted the field experiments during Kharif seasons on sesame cv. 'JTS-8'. From the results of the experiment they reported significant increase in seed yield with integrated use of 60 kg N + 40 kg P_2O_5 + 20 kg K_2O ha^{-1} + 2.5 t FYM. The highest productivity and net monetary return was also noted in same treatment.

Deshmukh *et al*. (2010) conducted field trial in clayey soil on sesame during summer season. From the results they reported that yield and yield attributes were significantly superior with the application of 60 kg N + 40 kg P_2O_5 + 20 kg K_2O ha^{-1} + 5 t each of FYM and Vermicompost ha^{-1}.

Javia *et al*. (2010) conducted field experiment during kharif season in sandy loam soils of dry farming research station Nana Khandhasar (Gujarat) on nutrient management in sesame crop. From the results of the experiment they reported maximum seed yield with the application of 25Kg N + 25 Kg P_2O_5 + 5 t FYM ha^{-1}. Barik and Fulmali (2011) indicated that combined use of FYM at 10 t ha^{-1} along with 75% recommended dose of NPK fertilizers registered the highest yield of sesame.

From the results of multilocational trials conducted on sesame the maximum seed yields were noticed with substitution of RDF by 10 t FYM ha^{-1} at Jalgaon, Mandor and Nagpur, while 2.5 t Vermicompost ha^{-1} resulted in higher yields at Jabalpur and Tikamgarh (Anon. 2013).

Imayavaramban *et al.* (2002) stated that integrated nutrient supply system of FYM @ 12.5 t ha^{-1} + recommended NPK at 35:23:23 kg ha^{-1} + application of *Azospirillum* and phosphobacteria @ 10 kg ha^{-1} favourably improved the yield of sesame in clay loam soil.

Integrated application of recommended dose of NPK (35:23:23 kg N, $P_2O_5$and K_2O ha^{-1}) + vermicompost @ 5 t ha^{-1} registered the highest yield of sesame in clay loam soil (Jaishankar and Wahab, 2005).

El-Habbasha *et al.* (2007) opined that application of 75 percent as chemical fertilizer + 25 percent as FYM recorded the highest seed weight plant^{-1} and followed by 50 percent chemical + 50 percent FYM under sandy soil.

Significantly superior seed yield of sesame was recorded with 25 percent N through FYM + 75% N through urea than 50% N as FYM + 50% N as urea in clay soil of Dharwad (Purushottam and Hiremath, 2008).

Meena *et al.* (2009) reported that application of 20 kg N and 5 t FYM ha^{-1} registered the highest seed yield than application of 40 kg N alone. The highest seed yield of sesame was obtained with 100% RDF + 2.5 t FYM (Anon. 2010).

Application of 25:25 kg N and P_2O_5 ha^{-1} + 5 t FYM ha^{-1} registered significantly higher seed yield of sesame over chemical fertilizer alone (Javia *et al*., 2010). Barik and Fulmali (2011) indicated that combined use of FYM at 10 t ha^{-1} along with 75% recommended dose of NPK fertilizers registered the highest yield of sesame.

Haruna (2011) conducted field trials to study the growth and yield of sesame as affected by poultry manure, nitrogen and phosphorus. The experiments consisted of four levels of poultry manure (0, 5.0, 10.0, and 15.0 t ha^{-1}), three levels of nitrogen in the form of urea (0, 60, and 120 kg N ha^{-1}) and three levels of phosphorus in the form of single super phosphate (0, 13.2 and 26.4 kg P ha^{-1}). The results showed that Grain yield ha^{-1} was optimized at 5 t ha^{-1} of poultry manure, 60 kg N ha^{-1} and 13.2 kg P ha^{-1}.

Haruna and Aliyu (2012) conducted field trials to study the yield and economic return of sesame cv. Ex-Sudan as influenced by poultry manure, nitrogen, and phosphorus application. The experiment consisted of four rates of poultry manure (0, 5.0, 10.0, and 15.0 t ha^{-1}), three levels of nitrogen in the form of urea (0, 60, and 120 kg N ha^{-1}) and three levels of phosphorus in the form of single super phosphate (0, 13.2 and 26.4 kg P ha^{-1}) applied to the treatments. Yield of sesame was better at 5 t ha^{-1}, 60 kg N ha^{-1} and 13.2 kg P ha^{-1} of poultry manure, nitrogen and phosphorus application rates respectively. Applications of 5 t poultry manure ha^{-1}, 60 kg nitrogen ha^{-1} and 13.2 of phosphorus ha^{-1} seems to be the ideal rates for sesame production and is therefore recommended.

Ghosh *et al*. (2013) carried out field experiments to study the effect of nutrient management in summer sesame and its residual effect on succeeding kharif black gram. The crop growth was better with integrated application of 50% recommended dose of NPK through fertilizer (RDF), 50% N through vermicompost (VC) or FYM in sesame. Here, 100% RDF = 80:40:40 kg N: P_2O_5: K_2O ha^{-1}. Seed yield of sesame increased significantly due to integrated application of 50% RDF+50% N through FYM in sesame during both the years. However, the treatment was at par with those of 75% RDF+25% N through FYM or VC and 50% RDF+50% N through VC. Integrated use of fertilizer and organic manure produced higher seed yield of sesame compared to 100% RDF through fertilizer alone. Further, substitution of 25% N through FYM produced higher seed of sesame than that of 100% RDF. Integrated use of 50% RDF + 50% N through FYM recorded 12.2, 20 and 15.6% higher yield over 100% RDF.

Islam *et al*. (2013) carried out an experiment to observe the comparative performance of integrated plant nutrients management system through the use of organic (cowdung, cowdung slurry) manure and inorganic fertilizer. The experiment was consisted with four treatments. Higher seed yield (1.31 t ha^{-1}) of sesame was obtained from T_3 (Cowdung slurry @ 5 t ha^{-1} + IPNS basis inorganic fertilizer dose for high yield goal) that was statistically identical to T_2 (Cowdung @ 5 t ha^{-1} + IPNS basis inorganic fertilizer dose for high yield goal) and T_1 (Soil test based inorganic fertilizer dose for high yield goal) and the lower (1.01 t ha^{-1}) from T_4 (Fertilizer dose usually practiced by the farmers).

Kumar and Ramesh (2014) conducted two field experiments to assess the impact of organic farming practices on sesame. Five organic manure treatments *viz*. T_1- Farmers' practice (FYM 10 t/ha, no chemical fertilizers, broad casting), T_2- Improved practices (FYM @10 t/ha, 40:20:20 kg NPK/ha, line sowing), T_3- FYM @ 18 t/ha), T_4- Vermicompost @ 6 t/ha) and T_5- Neem cake @ 1.7 t/ha were arranged randomly. Results of the kharif experiment showed that improved practices T_2 (FYM @10 t/ha, 40:20:20 kg NPK/ha, line sowing) recorded highest yield (3.72 q ha^{-1}) as it may be supplemented with all the required nutrients followed by T_5 (Neem cake @ 1.7 t ha^{-1}) (2.44 q ha^{-1}). Rabi experimentation also showed that Improved practices T_2 (FYM @ 10 t ha^{-1}, 40: 20:20 kg NPK ha^{-1}, Line Sowing) recorded significantly highest yield (5.86 q ha^{-1}), however organic treatments T_3, T_4 and T_5 were at par. T_1- Farmers' practice (FYM 10 t ha^{-1}, no chemical fertilizers, broad casting) recorded lowest yield.

Vani *et al*. (2017) conducted a field study aimed to evolve efficient integrated nutrient management for improving yield and quality of summer sesamum on sandy loam soil. Significantly higher seed yield was observed with 100% RDN which was at par with 100% RDN+1% foliar spray of Humic acid.

2.6.3.2 Stover yield

Integrated application of recommended dose of NPK (35:23:23 kg N, $P_2O_5$and K_2O ha^{-1}) + vermicompost @ 5 t ha^{-1} registered the highest stover yield of sesame in clay loam soil (Jaishankar and Wahab, 2005).

Significantly superior stalk yield of sesame was recorded with 25 percent N through FYM + 75% N through urea than 50% N as FYM + 50% N as urea in clay soil of Dharwad (Purushottam and Hiremath, 2008).

Stover yield was the highest with integrated application of poultry manure (15 t ha^{-1}), N (120 kg ha^{-1}) and P_2O_5 (13.2 kg ha^{-1}) (Haruna *et al.*, 2010). Barik and Fulmali (2011) indicated that combined use of FYM at 10 t ha^{-1} along with 75% recommended dose of NPK fertilizers registered the highest stover yield of sesame.

2.6.3.3 Harvest index

Significantly superior harvest index of sesame was recorded with 25 percent N through FYM + 75% N through urea than 50% N as FYM + 50% N as urea in clay soil of Dharwad (Purushottam and Hiremath, 2008).

Application of 25:25 kg N and P_2O_5 ha^{-1} + 5 t FYM ha^{-1} registered significantly higher harvest index of sesame over chemical fertilizer alone (Javia *et al*., 2010). Harvest index was the highest with integrated application of poultry manure (15 t ha^{-1}), N (120 kg ha^{-1}) and P_2O_5 (13.2 kg ha^{-1}) (Haruna *et al.*, 2010).

Barik and Fulmali (2011) indicated that combined use of FYM at 10 t ha^{-1} along with 75% recommended dose of NPK fertilizers registered the highest harvest index of sesame.

2.6.4 Quality parameters

2.6.4.1 Oil yield

Ghosh *et al*. (2013) carried out field experiments to study the effect of nutrient management in summer sesame and its residual effect on succeeding kharif black gram. The crop growth was better with integrated application of 50% recommended dose of NPK through fertilizer (RDF), 50% N through vermicompost (VC) or FYM in sesame. Here, 100% RDF = 80:40:40 kg N: P_2O_5: K_2O ha^{-1}. Oil yield of sesame increased significantly due to integrated application of 50% RDF+50% N through FYM in sesame during both the years. However, the treatment was at par with those of 75% RDF+25% N through FYM or VC and 50% RDF+50% N through VC. Integrated use of fertilizer and organic manure produced higher oil yield of sesame compared to 100% RDF through fertilizer alone. Further, substitution of 25% N through FYM produced higher oil yield of sesame than that of 100% RDF.

Vani *et al*. (2017) conducted a field study aimed to evolve efficient integrated nutrient management for improving yield and quality of summer sesamum on sandy loam soil. Significantly higher oil yield was observed with 100% RDN which was at par with 100% RDN+1% foliar spray of Humic acid.

2.6.5 Economic benefit

Haruna and Aliyu (2012) conducted field trials to study the yield and economic return of sesame cv. Ex-Sudan as influenced by poultry manure, nitrogen, and phosphorus application. The experiment consisted of four rates of poultry manure (0, 5.0, 10.0, and 15.0 t ha^{-1}), three levels of nitrogen in the form of urea (0, 60, and 120 kg N ha^{-1}) and three levels of phosphorus in the form of single super phosphate (0, 13.2 and 26.4 kg P ha^{-1}) applied to the treatments. Economic returns was better at 5 t ha^{-1}, 60 kg N ha^{-1} and 13.2 kg P ha^{-1} of poultry manure, nitrogen and phosphorus application rates respectively.

Islam *et al*. (2013) carried out an experiment to observe the comparative performance of integrated plant nutrients management system through the use of organic (cowdung, cowdung slurry) manure and inorganic fertilizer. The experiment was consisted with four treatments *viz*. T_1: Soil test based inorganic fertilizer dose for high yield goal, T_2: Cowdung @ 5 t ha^{-1} + IPNS basis inorganic fertilizer dose for high yield goal, T_3: Cowdung slurry @ 5 t ha^{-1} + IPNS basis inorganic fertilizer dose for high yield goal and T_4: Fertilizer dose usually practiced by the farmers. The highest gross return (271100 Tk ha^{-1}) was obtained from T_3 followed by T_2 and the lowest (225650 Tk ha^{-1}) from T_1 treatment. The highest MBCR (4.15) was recorded from T_3 followed by T_2 and the minimum (2.31) from T_2 treatment.

Deshmukh *et al*. (2002) reported higher net monetary returns and of benefit-cost ratio sesame (cv. 'TKG-22') with the integrated use of 50%N through Urea+50%N through FYM

In a multilocational study, integrated nutrient management as 50% N through urea + 50% N through farm yard manure + full recommended P and 50% N through urea + 50% N through thumba cake/neem cake + full recommended P was found as efficient integrated nutrient management (INM) with regard to sustainable higher monetary advantages of sesame at all locations (Deshmukh *et al*., 2009).

Javia *et al*. (2010) conducted field experiment during kharif season in sandy loam soils of dry farming research station Nana Khandhasar (Gujarat) on nutrient management in sesame crop. From the results of the experiment they reported maximum net monetary return with the application of 25Kg N + 25 Kg P_2O_5 + 5 t FYM ha^{-1}.

Narkhede *et al*. (2001b) reported higher monetary returns and benefit cost ratio with to application of 1 t ha^{-1} FYM + 40 kg N + 30 kg P_2O_5 + 20 kg K_2O ha^{-1} in sesame during kharif season on medium black soils.

Tripathi and Rajput (2007) reported highest net monetary returns of cv. 'JTS-8' during kharif season with the fertilizer application of 60 kg N + 30 kg P_2O_5 + 15 kg K_2O ha^{-1} in sandy loam soils.

Deshmukh and Duhoon (2008) reported higher net monetary returns of cv. 'JTS-8' during kharif season with the fertilizer application of 60 kg N + 40 kg P_2O_5 + 30 kg K_2O + 20 kg S ha^{-1} in clay loam soils.

Highest net monetary returns and profitability of sesame was obtained with application of 5 t FYM ha^{-1}, before 15 days of sowing (DOR, 2010). Application of 1 t oil cake ha^{-1} was found remunerative in recording higher NMR and B:C ratio of sesame (DOR, 2012).

2.7 Combined effect among variety, chemical fertilizer, organic manure and spacing

2.7.1 Seed yield

Prasanna Kumara *et al*. (2014) conducted a field experiment to study the response of sesame genotypes (DS-1, E-8 and DSS-9) to levels of fertilizer (RDF; 40:25:25 kg NPK ha^{-1}, respectively and 150% recommended NPK) and planting geometry (30 × 10 cm, 30 × 20 cm, 45 × 10 cm and 45 × 20 cm). Cultivar DS-1 recorded significantly higher seed yields (788 kg ha^{-1}) with application of recommended NPK (40:25:25 kg ha^{-1}) and 30 × 10 cm planting geometry.

2.7.2 Oil yield

Prasanna Kumara *et al*. (2014) conducted a field experiment to study the response of sesame genotypes (DS-1, E-8 and DSS-9) to levels of fertilizer (RDF; 40:25:25 kg NPK ha^{-1}, respectively and 150% recommended NPK) and planting geometry (30 × 10 cm, 30 × 20 cm, 45 × 10 cm and 45 × 20 cm). Cultivar DS-1 recorded significantly higher oil yields (332 kg ha^{-1}) with application of recommended NPK (40:25:25 kg ha^{-1}) and 30 × 10 cm planting geometry.

2.7.3 Economic benefit

Prasanna *et al*. (2014) conducted a field experiment to study the response of sesame genotypes (DS-1, E-8 and DSS-9) to levels of fertilizer (RDF; 40:25:25 kg NPK ha^{-1}, respectively and 150% recommended NPK) and planting geometry (30 × 10 cm, 30 × 20 cm, 45 × 10 cm and 45 × 20 cm). DS-1 with closer spacing of 30 × 10 cm and 100 percent NPK resulted in significantly higher net returns and B:C ratio (Rs. 20650/- and 2.89, respectively).

2.7.4 Nutrient uptake

Prasanna *et al*. (2014) conducted a field experiment to study the response of sesame genotypes (DS-1, E-8 and DSS-9) to levels of fertilizer (RDF; 40:25:25 kg NPK ha^{-1}, respectively and 150% recommended NPK) and planting geometry (30 × 10 cm, 30 × 20 cm, 45 × 10 cm and 45 × 20 cm). DS-1 with 150 percent recommended NPK recorded higher N uptake (77.57 kg ha^{-1}) over DS-1 with recommended NPK (73.21kg ha^{-1}) with spacing 30 × 10 cm. P uptake was also higher in same genotype (DS-1) and fertilizer level (150 percent recommended NPK) (3.82 kg ha^{-1}) over cv. DSS- 9 receiving recommended NPK and spacing (30 × 10 cm). Higher soil available N was observed in DS-1 with 150 percent NPK and 45 × 20 cm (264 kg ha^{-1}) over DSS-9 with recommended NPK and spacing (228 kg ha^{-1}).

2.8 Correlation between seed yield with growth and yield characters

The relationship between seed yield of sesame crop and various growth and yield characters were reported by several researchers.

Adeyemo and Ojo (1991) reported that seed yield had a significant correlation with number of capsules, seed yield per plant, number of seed per capsules, number of primary branches, length of capsules, 1000 seed weight and stand count of sesame plant.

Subramanian and Subramanian (1994) reported that, seed yield had a positive significant correlation with number of capsules, number of primary branches, number of capsules, number of seed per capsule and 1000 seed weight.

Onginjo *et al* (2009) in a correlation studies involving 30 selected mutant lines and 2 cultivars reported that, seed yield had a strong positive and significant relationship with biomass yield, harvest index and 1000 seed weight but plant height, oil content, number of capsules and number of days to flowering had a weak positive significant correlation with seed yield.

Roy *et al*. (2009) conducted a field experiment to evaluate the effect of row spacing (S_1 = 15 cm, S_2 = 30 cm and S_3 = 45 cm) on the yield and yield contributing characters of sesame using the varieties ($V_1 = T_6$, V_2 = Batiaghata local Til and V_3 = BINA Til). Seed yield was well correlated with capsules plant^{-1} and seeds capsule^{-1}.

Engin *et al* (2010) in a study conducted in Australia involving 345 sesame genotypes originated from 29 different sesame producing countries worlwide reported that, plant height, number of branches and 1000 seed weight had a positive significant correlation with seed yield.

In another correlation studies conducted in Nigeria by Muhamman *et al* (2010) revealed that, number of branches, plant height and leaf area had a positive significant correlation with seed yield of sesame crop, while 1000 seed weight and days to 50% flowering showed a non significant relationship with seed yield.

CHAPTER 3

MATERIALS AND METHODS

Three years field experiments were conducted during 2014-2016 to screen a suitable sesame variety and augment its yield addopting appropriate agronomic management practices. The 1st year experiment consisted of screening a suitable sesame variety under different nutrient level carried out during March-June 2014. From this trial, the best nutrient level and variety were shortlisted based upon the yield performance and take over to the next year. In the 2nd year; trial variety and nutrient levels were picked from 1st year, were trialed with different population density/spacing and different sources of organic and inorganic (manures + fertilizers) fertilizers. First year experiment was carried out during March-June 2014, second year during March-June 2015 and third year during March-June 2016.

3.1 Materials

3.1.1 Field location

The research work was carried out at the research field of Agronomy Department, Sher-e-Bangla Agricultural University (SAU), Dhaka. The experimental fields were located at 90° 33′ E longitude and 23° 71′ N latitude at a height of 9 m above the sea level. The location of the experimental field is presented in Appendix I.

3.1.2 Weather and climate

The climate of the experimental area was sub-tropical and was characterized by high temperature, heavy rainfall during Kharif-1 season (March-June) and scanty rainfall during Rabi season (October-March) associated with moderately low temperature. The monthly average temperature, humidity, rainfall and sunshine hours prevailed at the experimental area during the cropping season are presented in Appendix II(a) and II(b).

3.1.3 Soil

The land belongs to the Agro-ecological zone “Madhupur tract” (AEZ-28) having the Red Brown Trace Soils of Tejgaon series. The soil of the experimental site was well drained and medium high. The physical and chemical properties of soil of the experimental site are sandy loam in texture and having soil pH varied from 5.45-5.61. Organic matter content was very low (0.83). The physical composition such as sand, silt, clay content was 40%, 40% and 20%, respectively. The physical and chemical characteristics of the experimental field soil are furnished in AppendixIII and IV.

3.1.4 Crop and variety

The sesame varieties *viz.*, Laltil (Local variety), Atshira (Local variety), T-6, BARI til 3, BARI til 4 and Bina til 2 were chosen for the study. Laltil variety collected from Upazilla Agricultural Officer, Ullapara, Sirajgonj. Atshira variety collected from Agricultural Extension Officer, Khoksha, Kustia. T6, BARI til 3 and BARI til 4 varieties were collected from Bangladeh Agricultural Research Institute (BARI), Joydeppur, Gazipur. Bina til 2 variety was collected from Bangladesh Institute of Nuclear Agriculture (BINA).

3.1.5 Manures and fertilizers

Farm yard manure (FYM) was collected from Farm Division, Sher-e-Bangla Agricultural University. Vermicompost was collected from known market. The nutrient content of Farm yard manure and Vermicompost used for the experiment are furnished in Appendix V. The fertilizers used in the study were urea, tripple super phosphate and murate of potash to supply N, P and K, respectively, supplied from SAU farm stock.

3.2 Methods

3.2.1 1st Year Experiment: Study on the effect of varied nutrient levels and variety on the yield of sesame

3.2.1.1 Experimental details

The experiment was carried out at the research field of Agronomy Department, Sher-e-Bangla Agricultural University, Dhaka during March-June 2014. The experimental details are given in Table 3.1 and the layout is furnished in AppendixVI.

Table 3.1. Experimental details (1st year)

Particulars	Specifications
Location	Research field of Agronomy Department, Sher-e-Bangla Agricultural University, Dhaka
Design	Split plot
Replication	3

Total number of plots	72
Plot size	3m × 2m
Total treatment combinations	24
Date of Seed Sowing	03.03.2014

3.2.1.2 Treatments of the experiment

3.2.1.2.1 Main plot treatments

Nutrient levels	N_1	=	75% of RDF(43:54:23 kg N, P_2O_5 and K_2O ha^{-1})
	N_2	=	100% of RDF(58:72:30 kg N, P_2O_5 and K_2O ha^{-1})
	N_3	=	125% of RDF(72:90:38 kg N, P_2O_5 and K_2O ha^{-1})
	N_4	=	150% of RDF(86:108:45 kg N, P_2O_5 and K_2O ha^{-1})

RDF = Recommended dose of fertilizer (as per fertilizer recommended guide, 2012, BARC)

3.2.1.2.2 Sub-plot treatments

Varieties	V_1	=	Laltil (Local)
	V_2	=	Atshira (Local)
	V_3	=	T-6
	V_4	=	BARI til-3
	V_5	=	BARI til- 4
	V_6	=	Bina til 2

3.2.1.2.3 Details of treatment combination

N_1V_1 = 75% of RDF(43:54:23 kg N, P_2O_5 and K_2O ha^{-1})× Laltil (Local)
N_1V_2 = 75% of RDF(43:54:23 kg N, P_2O_5 and K_2O ha^{-1})× Atshira (Local)
N_1V_3 = 75% of RDF(43:54:23 kg N, P_2O_5 and K_2O ha^{-1})× T-6
N_1V_4 = 75% of RDF(43:54:23 kg N, P_2O_5 and K_2O ha^{-1})× BARI til- 3
N_1V_5 = 75% of RDF(43:54:23 kg N, P_2O_5 and K_2O ha^{-1} × BARI til- 4
N_1V_6 = 75% of RDF(43:54:23 kg N, P_2O_5 and K_2O ha^{-1})× Bina til 2
N_2V_1 = 100% of RDF(58:72:30 kg N, P_2O_5 and K_2O ha^{-1})× Laltil (Local)
N_2V_2 = 100% of RDF(58:72:30 kg N, P_2O_5 and K_2O ha^{-1})× Atshira (Local)
N_2V_3 = 100% of RDF(58:72:30 kg N, P_2O_5 and K_2O ha^{-1})× T-6
N_2V_4 = 100% of RDF(58:72:30 kg N, P_2O_5 and K_2O ha^{-1})× BARI til- 3
N_2V_5 = 100% of RDF(58:72:30 kg N, P_2O_5 and K_2O ha^{-1})× BARI til -4
N_2V_6 = 100% of RDF(58:72:30 kg N, P_2O_5 and K_2O ha^{-1})× Bina til 2
N_3V_1 = 125% of RDF(72:90:38 kg N, P_2O_5 and K_2O ha^{-1})× Laltil (Local)
N_3V_2 = 125% of RDF(72:90:38 kg N, P_2O_5 and K_2O ha^{-1})× Atshira (Local)
N_3V_3 = 125% of RDF(72:90:38 kg N, P_2O_5 and K_2O ha^{-1})× T-6
N_3V_4 = 125% of RDF(72:90:38 kg N, P_2O_5 and K_2O ha^{-1})× BARI til- 3
N_3V_5 = 125% of RDF(72:90:38 kg N, P_2O_5 and K_2O ha^{-1})× BARI til -4

N_3V_6 = 125% of RDF(72:90:38 kg N, P_2O_5 and K_2O ha^{-1})× Bina til 2
N_4V_1 = 150% of RDF(86:108:45 kg N, P_2O_5 and K_2O ha^{-1})× Laltil (Local)
N_4V_2 = 150% of RDF(86:108:45 kg N, P_2O_5 and K_2O ha^{-1})× Atshira (Local)
N_4V_3 = 150% of RDF(86:108:45 kg N, P_2O_5 and K_2O ha^{-1})× T-6
N_4V_4 = 150% of RDF(86:108:45 kg N, P_2O_5 and K_2O ha^{-1})× BARI til- 3
N_4V_5 = 150% of RDF(86:108:45 kg N, P_2O_5 and K_2O ha^{-1})× BARI til-4 4
N_4V_6 = 150% of RDF(86:108:45 kg N, P_2O_5 and K_2O ha^{-1})× Bina til 2

3.2.1.3 Collection of experimental data for 1st year experiment

3.2.1.3.1 Growth characters

1. Plant height (cm) at 15 days interval up to harvest
2. Number of leaves $plant^{-1}$ at 15 days interval up to harvest
3. Number of branches $plant^{-1}$ at 15 days interval up to harvest
4. Dry matter production
5. Leaf area index
6. Absolute Growth Rate
7. Crop Growth Rate
8. Relative Growth Rate

3.2.1.3.2 Yield attributes and yield

1. Number of capsules $plant^{-1}$
2. Number of seeds $capsule^{-1}$
3. Capsule length (cm)
4. 1000-seed weight (g)
5. Seed yield (kg ha^{-1})
6. Stover yield (kg ha^{-1})
7. Harvest index (%)

3.2.1.4 Crop management and procedure of recording data

3.2.1.4.1 Crop management

3.2.1.4.1.1 Field preparation

The land was first opened with the tractor drawn disc plough. Ploughed soil was then brought into desirable fine tilth by 6 operations of ploughing and harrowing. The stubble and weeds were removed. The plots were spaded one day before planting and the basal dose of fertilizers was incorporated thoroughly before planting.

3.2.1.4.1.2 Germination test

Before sowing, germination test was carried out in the laboratory and percentage of germination was found to be over 95.

3.2.1.4.1.3 Seed rate and sowing

A seed rate was followed uniformly as per treatment. The seeds were mixed with 4 times its volume of dry sand. Row spacing was done in the prepared flat bed surface at a spacing of 30 cm. Seeds of sesame were sown as per treatment in lines following different line to line distance. Seeds were placed 2-3 cm depth and then rows were covered with loose soil properly.

3.2.1.4.1.4 Manures and fertilizers application

Manures and fertilizers were applied as per treatment mention in section 3.2.1.2.3. N, P_2O_5 and K_2O were applied in the form of urea, TSP and MoP. Half of N and entire dose of K_2O and P_2O_5 were applied at basal and the remaining N was provided in two equal splits at 20 and 30 DAS corresponding to hoeing and weeding operations, wherever chemical fertilizers were used. The farm yard manure (FYM), and vermicompost were given only at basal as per the treatment schedule.

3.2.1.4.1.5 Emergence of seedlings

Seedling emergence started after 5 days and completed within 8 days of sowing. After establishment, keeping the healthy seedlings within a distance of 5 cm, 10 cm, 15 cm and 20 cm, respectively as per treatment and the remaining seedlings were carefully uprooted by hand pulling in case of second and third year experiments.

3.2.1.4.1.6 Irrigation

Pre-sowing irrigation was given to maintain equal germination. After sowing of seeds two irrigations were provided during the entire life cycle. First and second irrigations were done at 25 and 55 days after sowing (DAS), respectively.

3.2.1.4.1.7 Drainage

Drainage operation for draining out of rainwater and excess irrigation water was done as and when required for proper growth and development of the crop.

3.2.1.4.1.8 Weeding

The experimental field was weeded at 20 and 30 days after sowing. The weeding was done manually by using Nirani. Demarcation boundaries and drainage channels were also kept weed free.

3.2.1.4.1.9 Thinning

The field was sufficiently irrigated before thinning. The seedlings were thinned out to remove the excess plants and to retain two plants in each hill on 15 DAS. The second thinning was completed on 25 DAS to retain only one plant in each hill with a spacing of treatments requirement between the plants in each row, so that required plant population was maintained as per treatment.

3.2.1.4.1.10 Plant protection

Adequate protective measures were taken to protect the crop against insect pests and diseases. The crops were attacked by insects at the time of vegetative stage. It was controlled by spraying Nitro (Cypermethrin + Chlorpyriphus) 20 EC @ 2 ml L^{-1} water was sprayed to control hawkmoth and jute hairy caterpillar at the time of pod formation. Spraying was done in the afternoon while the pollinating bees were away from the field. Care was also taken to avoid bird's damage with suitable bird scare provisions.

3.2.1.4.1.11 Harvesting and threshing

When 80 percent of the pods turned yellowish and seed attaind their natural deep reddish color, the crop was considered ready for harvest. Harvesting was done in morning hours to avoid shettering. From the center of each plot, the mature crop an area of 1 m^2 harvested at ground level with the help of sickle irrespective of different years and treatments. Crop harvesting was completed within the period 30th May – 3rd June. The harvested plants were sun dried on the threshing floor. After sun drying, the biological yield (seed + stalk) for the net harvested areas was recorded. Thereshing was done manually, seeds were sun dried and cleaned and weighed for calculation of seed yield (kg ha^{-1}).

3.2.1.4.2 Procedure of recording data

For recording biometric observations, five plants out side the centeral 1 m^2 of effecting harvesting area from each plot was chosen by random sampling and tagged. These plants were used for recording observations as given below.

3.2.1.4.2.1 Growth characters

3.2.1.4.2.2 Plant height (cm)

The plant height was measured from the cotyledonary node to growing tip of the longest branch on 30, 45, 60, 75 DAS and at harvest. The mean was computed for five plants in all treatments of each replication and expressed in cm.

3.2.1.4.2.3 Number of branch plant^{-1}

The mean number of branches of five plants in each plot from all the treatments was recorded. This value was expressed as number of branches plant^{-1}.

3.2.1.4.2.4 Leaf area index

The leaf area index (LAI) is the ratio of leaf area to the soil area it occupies. It was measured in terms of total leaf area (cm^2) per square meter of the land area. The functional leaves of the five plants, (selected at random) avoiding the centeral 01 (one) m^2 of effecting harvesting area were used for leaf area estimation. Ten leaves were randomly selected from each test plant and their area were measured with (Portable Area Meter Model LI-3000, USA). These leaves were properly dried in oven at 80^0 C till each leaf reached a constant weight. By using the measured leaf area and weight, the leaf area for the rest leaves of the test plants were calculated. Leaf area per squre meter were computed in (cm^2) by calculating the leaf area of the test plants. The leaf area index (LAI) was worked out by using the formula of Hunt (1981).

$$LAI = \frac{\text{Total leaf area } (cm^2)}{\text{Unit land area } (cm^2)}$$

3.2.1.4.2.5 Dry matter production

Five sample plants in each plot were selected at random in the sample rows outside the centeral 1 m^2 of effective harvesting area and cut close to the ground surface on 30, 45, 60, 75 DAS and at harvest. They were first air dried for one hour, then oven dried at 80±5°C till a constant weight was attained. The dry weight of the sample plants was weighed and the biomass was computed to kg ha^{-1}.

3.2.1.4.2.6 Absolute Growth Rate (AGR)

AGR expresses the dry matter accumulation per unit time and was calculated by using formula suggested by Radford (1967) and expressed in g $plant^{-1}$ day^{-1}. AGR was worked out for 30-45 DAS, 45-60 DAS, 60-75 DAS and 75 DAS - harvest.

$$AGR = \frac{(W_2 - W_1)}{(t_2 - t_1)}$$

Where,

W_1 = dry weight of the plant at time t_1
W_2 = dry weight of the plant at time t_2
t_2 and t_1 = time interval in days

3.2.1.4.2.7 Crop Growth Rate

CGR is the rate of dry matter production per unit of ground area per unit of time (Watson, 1952) and was worked out by the formula,

$$CGR = \frac{(W_2 - W_1)}{(t_2 - t_1)} \times \frac{1}{A} \text{ g cm}^{-2} \text{ day}^{-1}$$

Where,

W_1 = dry weight of the plant at time t_1
W_2 = dry weight of the plant at time t_2
A = land area covered by the plant in cm^2
t_2 and t_1 = time interval in days

3.2.1.4.2.8 Relative Growth Rate

RGR indicates the rate of increase in dry weight per unit of dry weight already present and was calculated by the formula given by Blackman (1919) and expressed in g g^{-1}

day^{-1}. RGR was worked out for 30-45 DAS, 45-60 DAS, 60-75 DAS and 75 DAS - harvest.

$$RGR = \frac{\log_e W_2 - \log_e W_1}{(t_2 - t_1)} \quad g\ g^{-1}\ day^{-1}$$

Where,

W_1 = dry weight of the plant at time t_1
W_2 = dry weight of the plant at time t_2
t_2 and t_1 = time interval in days

3.2.1.4.3 Yield attributes and yield

3.2.1.4.3.1 Number of capsule plant^{-1}

The total number of seed bearing, matured and non-matured capsules were counted in the main stem as well as primary, secondary and tertiary branches from the five tagged plants in each treatment at harvest stage and the mean value was calculated and expressed in number.

3.2.1.4.3.2 Number of seeds capsule^{-1}

Five capsules in each sample plants were selected at random from each treatment and were dehisced after sun drying. The total number of seeds was counted and the mean seed number capsule^{-1} were calculated and recorded.

3.2.1.4.3.3 Capsule length (cm)

The capsule length was measured from taking the five capsules of each of 5 randomly selected sample plants, taking one capsule from bottom, another from middle and the rest from the top of the plant and then averaged values were taken.

3.2.1.4.3.4 Weight of 1000-seed (g)

One thousand cleaned, sun-dried seeds were counted randomly from each harvested sample and weighed by using a digital electric balance and the weight was expressed in gram.

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

After complete threshing and cleaning, the seeds were sundried plot treatment wise till a constant weight was obtained. Weight of seed of the demarcated area (1 m^2) at the centre of each plot was taken. Then the seed yield was weighed and recorded separately and expressed in t ha^{-1}. Pooled yield was calculated by averaging from second and third year experiment`s seed yield.

3.2.1.4.3.6 Stover yield (t ha^{-1})

The weight of the plants containing grain was taken. By subtracting the grain weight from the total weight. The biomass weights were calculated after threshing and separation of grain from the sample area and then expressed in t ha^{-1} in dry weight basis.

3.2.1.4.3.7 Harvest index (%)

The harvest index was calculated on the ratio of grain yield to biological yield and expressed in terms of percentage. It was calculated by using the following formula suggested by Verma and Singh (1977) -

$$HI = \frac{\text{Seed yield}}{\text{Biological yield}} \times 100$$

Where, Biological yield = Seed yield + Stover yield

3.2.1.4.4 Soil analysis

Composite pre-sowing soil samples were collected randomly from the experimental fields and analyzed for physico-chemical properties. Post harvest soil samples drawn from each plot were air dried and gently beaten with a wooden mallet and sieved through 2 mm nylon sieve mesh. Then the soil samples were analyzed for organic carbon and available N, P and K.

3.2.1.4.4.1 Available nitrogen

Post harvest soil available N was estimated by Alkaline permanganate method as described by Subbiah and Asija (1956) and expressed in kg ha^{-1}.

3.2.1.4.4.2 Available phosphorus

Post harvest soil available P was estimated by adopting the method given by Olsen *et al.* (1954) and expressed in kg ha^{-1}.

3.2.1.4.4.3 Available potassium

Post harvest soil available K was estimated as described by Stanford and English (1949) and expressed in kg ha^{-1}.

3.2.1.4.5 Plant analysis

The sample plants collected plot-wise at the time of harvest were dried at 80±5°C ground in a Willey mill and sieved through 20 mm mesh screen. The powdered plant samples were analyzed for N, P and K content adopting standard procedures.

3.2.1.4.5.1 Nitrogen uptake

The N content of the plant samples from each treatment plot was estimated by the Microkjeldahl method as suggested by Yoshida *et al* (1976). The total N uptake was computed by multiplying the crop biomass with the N content and recorded in kg ha^{-1}.

3.2.1.4.5.2 Phosphorus uptake

The P content of the plant sample, from each treatment plot was analyzed colorimetrically from the Triple acid extract (Jackson, 1973) and the phosphorus uptake was worked out by multiplying the crop biomass with the P_2O_5 content and recorded in kg ha^{-1}.

3.2.1.4.5.3 Potassium uptake

The K content of the plant samples from each treatment plot was estimated by flame photometer from the Triple acid extract (Jackson, 1973). The potassium uptake was worked out by multiplying the crop biomass with the K_2O content and expressed in kg ha^{-1}.

3.2.1.4.6 Quality parameters

3.2.1.4.6.1 Oil content

The oil content of the sesame seed collected from each treatment plot were estimated by Nuclear Magnetic Resonance Spectrometry method. The oil content was expressed in percent.

3.2.1.4.6.2 Oil yield (kg ha $^{-1}$)

Oil yield was calculated by multiplying the oil content with seed yield as follows – suggested by Verma and Singh (1977) -

$$\text{Oil yield (kg ha}^{-1}\text{)} = \frac{\text{Oil \%} \times \text{Seed yield (kg ha}^{-1}\text{)}}{100}$$

3.2.1.4.6.3 Crude protein content

Seed samples were taken and analyzed for total N content of seed and was multiplied by the factor 6.25 (Doubetz and Wells, 1968) to get the crude protein content of the seeds and expressed in percent.

3.2.1.4.6.4 Crude protein yield

The crude protein content of sesame seeds was multiplied with seed yield to arrive at crude protein yield kg ha $^{-1}$.

3.2.1.4.7 Economic Performance

3.2.1.4.7.1 Calculating costs against each treatment

From beginning to end the cost of cultivation of sesame in each treatment was calculated from each operation of cultivation and total cost was expressed as total cost of production.

3.2.1.4.7.2 Calculating returns against each treatment

Gross income and net income were worked out for each treatment by using the following formulae and expressed in Tk. ha $^{-1}$.

Gross return = Total production (t ha $^{-1}$) × Market price (Tk. ha $^{-1}$)

Net return = Gross return – Total cost of production

3.2.1.4.7.3 Determining cost benefit ratio (BCR)

Benefit cost ratio was worked out for each treatment by using the following formula

$$\text{BCR} = \frac{\text{Gross income}}{\text{Total cost of production}}$$

3.2.2 2nd Year Experiment: Influence of spacing and intregated nutrients on the seed yield, oil and protein content of sesame

From the 1st year study, the best results *viz*., test variety, BARI til 4, season (March-June 2014) and nutrient level N_2 (100% of RDF) (56:72:23 kg N, P_2O_5 and K_2O ha^{-1}) were short listed and chosen as the basis for the 2nd year of study. Second experiment was conducted during March-June 2015. The experimental details are given in Table 3.2 and the layout is furnished in Appendix VII. The treatment details are given below:

Table 3.2. Experimental details

Particulars	**Specifications**
Location	Research field of Agronomy Department, Sher-e-Bangla Agricultural University, Dhaka
Total treatment combination	36
Replication	3
Plot size	3m × 2m
Design	Split Plot
Total number of plots	108
Line to Line Distance	30 cm
Plant to Plant Distance	05 cm
Date of Seed Sowing	05.03.2015
Duration of experiment	March-June, 2015

3.2.2.1 Treatments details

3.2.2.1.1 Main plot treatments

Integrated Plant Nutrient	T_1	=	RDF (Selected as best treatment from 1st year studies and hence here after referred as RDF)
	T_2	=	100% RDF through vermicomost
	T_3	=	75% RDF through vermicomost + 25 % as chemical fertilizer
	T_4	=	50% RDF through vermicompost + 50% as chemical fertilizer
	T_5	=	25% RDF through vermicompost + 75% as chemical fertilizer
	T_6	=	100% RDF through FYM
	T_7	=	75% RDF through FYM + 25% as chemical fertilizer
	T_8	=	50% RDF through FYM + 50% as chemical fertilizer
	T_9	=	25% RDF through FYM + 75% as chemical fertilizer

RDF = Recommended dose of fertilizer (as per fertilizer recommended guide, 2012, BARC)

3.2.2.1.2 Sub plot treatments

Plant Spacing	S_1 = 30 cm × 5 cm (400 plants plot^{-1}) S_2 = 30 cm × 10 cm (200 plants plot^{-1}) S_3 = 30 cm × 15 cm (130 plants plot^{-1}) S_4 = 30 cm × 20 cm (100 plants plot^{-1})

3.2.2.1.3 Details of treatment combination

T_1S_1 = RDF and 30 cm × 5 cm
T_1S_2 = RDF and 30 cm × 10 cm
T_1S_3 = RDF and 30 cm × 15 cm
T_1S_4 = RDF and 30 cm × 20 cm
T_2S_1 = 100% RDF through vermicomost and 30 cm × 5 cm
T_2S_2 = 100% RDF through vermicomost and 30 cm × 10 cm
T_2S_3 = 100% RDF through vermicomost and 30 cm × 15 cm
T_2S_4 = 100% RDF through vermicomost and 30 cm × 20 cm
T_3S_1 = 75% RDF through vermicomost + 25 % as chemical fertilizer and 30 cm × 5 cm
T_3S_2 = 75% RDF through vermicomost + 25 % as chemical fertilizer and 30 cm × 10 cm
T_3S_3 = 75% RDF through vermicomost + 25 % as chemical fertilizer and 30 cm × 15 cm
T_3S_4 = 75% RDF through vermicomost + 25 % as chemical fertilizer and 30 cm × 20 cm
T_4S_1 = 50% RDF through vermicompost + 50% as chemical fertilizer and 30 cm × 5 cm
T_4S_2 = 50% RDF through vermicompost + 50% as chemical fertilizer and 30 cm × 10 cm
T_4S_3 = 50% RDF through vermicompost + 50% as chemical fertilizer and 30 cm × 15 cm
T_4S_4 = 50% RDF through vermicompost + 50% as chemical fertilizer and 30 cm × 20 cm
T_5S_1 = 25% RDF through vermicompost + 75% as chemical fertilizer and 30 cm × 5 cm
T_5S_2 = 25% RDF through vermicompost + 75% as chemical fertilizer and 30 cm × 10 cm
T_5S_3 = 25% RDF through vermicompost + 75% as chemical fertilizer and 30 cm × 15 cm
T_5S_4 = 25% RDF through vermicompost + 75% as chemical fertilizer and 30 cm × 20 cm
T_6S_1 = 100% RDF through FYM and 30 cm × 5 cm
T_6S_2 = 100% RDF through FYM and 30 cm × 10 cm
T_6S_3 = 100% RDF through FYM and 30 cm × 15 cm
T_6S_4 = 100% RDF through FYM and 30 cm × 20 cm
T_7S_1 = 75% RDF through FYM + 25% as chemical fertilizer and 30 cm × 5 cm
T_7S_2 = 75% RDF through FYM + 25% as chemical fertilizer and 30 cm × 10 cm
T_7S_3 = 75% RDF through FYM + 25% as chemical fertilizer and 30 cm × 15 cm
T_7S_4 = 75% RDF through FYM + 25% as chemical fertilizer and 30 cm × 20 cm
T_8S_1 = 50% RDF through FYM + 50% as chemical fertilizer and 30 cm × 5 cm
T_8S_2 = 50% RDF through FYM + 50% as chemical fertilizer and 30 cm × 10 cm
T_8S_3 = 50% RDF through FYM + 50% as chemical fertilizer and 30 cm × 15 cm
T_8S_4 = 50% RDF through FYM + 50% as chemical fertilizer and 30 cm × 20 cm
T_9S_1 = 25% RDF through FYM + 75% as chemical fertilizer and 30 cm × 5 cm
T_9S_2 = 25% RDF through FYM + 75% as chemical fertilizer and 30 cm × 10 cm
T_9S_3 = 25% RDF through FYM + 75% as chemical fertilizer and 30 cm × 15 cm
T_9S_4 = 25% RDF through FYM + 75% as chemical fertilizer and 30 cm × 20 cm

3.2.2.2 Collection of experimental data for 2nd year experiment

3.2.2.2.1 Growth characters

1. Plant height (cm) at 15 days interval up to harvest.
2. Number of branch at 15 days interval up to harvest.
3. Dry matter production
4. Absolute Growth Rate
5. Crop Growth Rate
6. Relative Growth Rate

3.2.2.2.2 Yield attributes and yield

1. Number of capsules plant^{-1}
2. Number of seeds capsule $^{-1}$
3. Effective capsules plant $^{-1}$
4. Non- effective capsules plant^{-1}
5. Capsule length(cm)
6. 1000-seed weight(gm)
7. Seed yield kg ha^{-1}
8. Stover yield kg ha^{-1}
9. Harvest index (%)

3.2.2.2.3 Quality parameters

1. Oil content
2. Oil yield kg ha^{-1}
3. Crude protein content
4. Crude protein yield kg ha^{-1}

3.2.2.2.4 Economic Performance of the Study

1. Calculating costs against each treatment
2. Calculating returns against each treatment
3. Determining benefit cost ratio

3.2.2.2.5 Plant analysis

1. Nitrogen uptake
2. Phosphorus uptake
3. Potassium uptake

3.2.3 3rd Year Experiment: The experiment conducted in the second year was repeated in third year. The experimental details of 3rd experiment was same as experiment 2 are given in Table 3.2 and the layout is furnished in Appendix VIII. The experiment was conducted during March-June 2016.

3.3 Statistical analysis

The data on various observations recorded during the investigation were statistically analyzed by using analysis of variance (ANOVA) technique with the help of computer package MSTAT-C program. The mean differences among the treatments were tested by least significant difference (LSD) at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER 4

RESULTS AND DISCUSSION

Results obtained from the present investigation have been presented and discussed in this chapter. The data / results have been presented in different tables and figures and discussed possible interpretations are drawn and data compared as far as possible with the results of other research works are as follows:

4.1 1st year Experiment: Study on the effect of varied nutrient levels and variety on the yield of sesame (*Sesamum indicum* L.)

4.1.1 Growth parameters

4.1.1.1 Plant height

Different nutrient levels applied to different sesame for different varieties showed significant variation (Fig. 4.1 and Appendix IX and XXXV). Results revealed that higher nutrients level applied to the soil for sesame showed higher plant height at all growth stages whereas lower plant height was observed with the application of lower nutrient rates. With regard to nutrient levels, application of 150% of RDF (N_4) enrolled the tallest plants (29.93, 84.55, 106.00, 118.00 and 133.00 cm at 30, 45, 60, 75 DAS and at harvest, respectively). This was followed by 125% of RDF (N_3) and 100% RDF (N_2). The shortest plant (26.27, 76.54, 99.27, 107.20 and 124.40 cm at 30, 45, 60, 75 DAS and at harvest respectively) was recorded with 75% of RDF (N_1). Several research findings have been presented here which supported the present finding in respect of plant height affected by different levels of plant nutrients. Thorve (1991) reported that the plant height was significantly influenced by different fertilizer levels. Muhamman and Gungula (2008) observed that plant height increased with the highest N level (90 kg N ha^{-1}). The tallest *Sesamum* plants were recorded when phosphorus was applied at 45 kg ha^{-1} (Thanki *et al.*, 2004). Plant height was higher with application of 90 kg P_2O_5 ha^{-1} (Mian *et al.*, 2011). Kathiresan (2002) found that 150 percent of recommended K (52 kg ha^{-1}) had the tallest plants. Application of potassium @ 40 kg ha^{-1} significantly influenced the growth attributes of *Sesamum* (Jadav *et al.*, 2010).

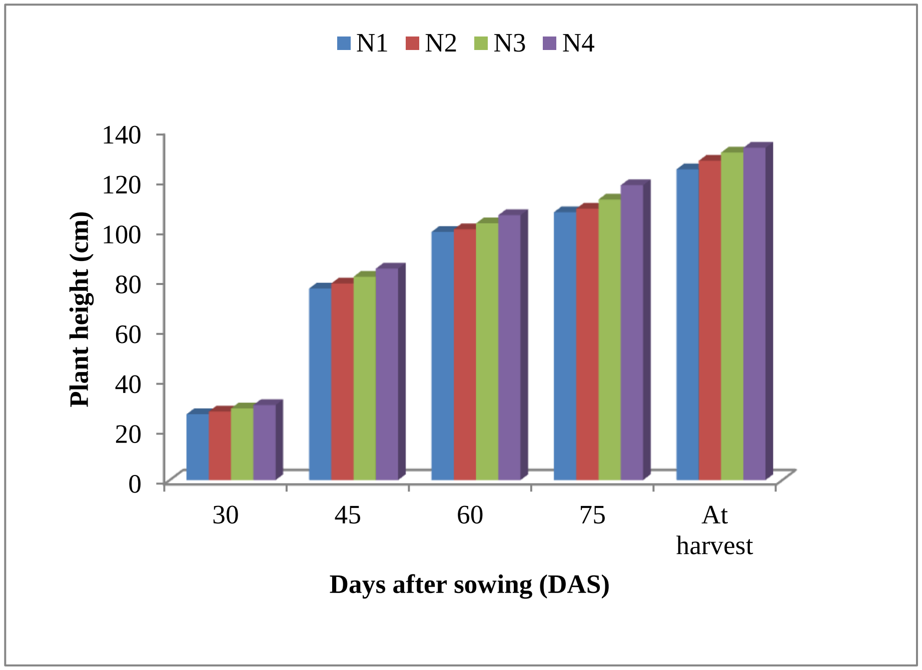

Fig. 4.1 Plant height of sesame as influenced by different levels of nutrients during March-June 2014 ($LSD_{0.05}$ = 0.720, 0.866, 0.873, 1.014 and 1.175 at 30, 45, 60, 75 DAS and harvest, respectively)

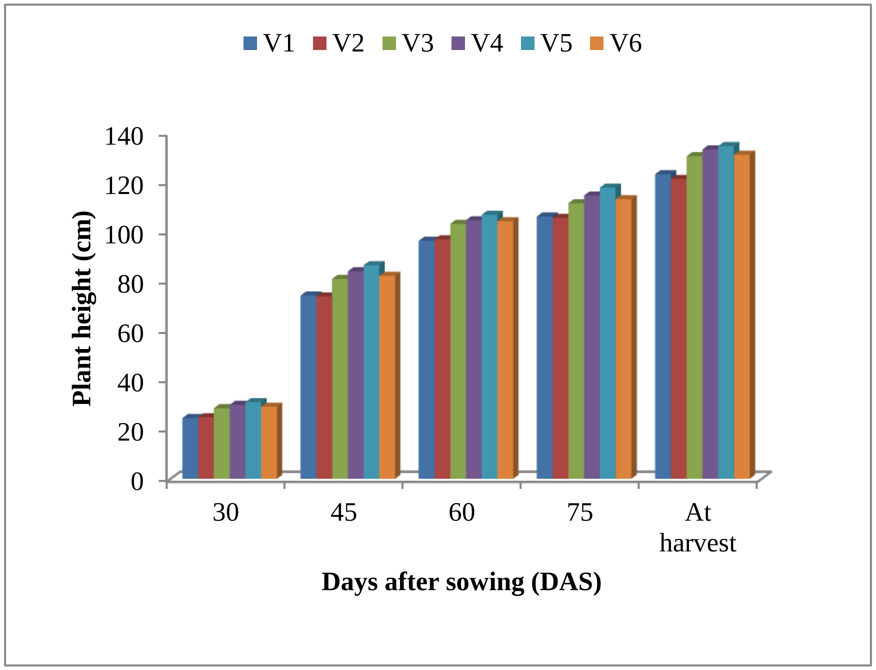

Fig. 4.2 Plant height of sesame as influenced by different varieties during March-June 2014 ($LSD_{0.05}$ = 1.056, 1.209, 0.776, 1.242 and 1.439 at 30, 45, 60, 75 DAS and harvest, respectively)

N_1 = 75% of RDF (43:54:23 kg N, P_2O_5 and K_2O ha^{-1}), N_2 = 100% of RDF (58:72:30 kg N, P_2O_5 and K_2O ha^{-1}), N_3 = 125% of RDF (72:90:38 kg N, P_2O_5 and K_2O ha^{-1}), N_4 = 150% of RDF (86:108:45 kg N, P_2O_5 and K_2O ha^{-1})

V_1 = Lal til (Local), V_2 = Atshira (Local), V_3 = T-6, V_4 = BARI til-3, V_5 = BARI til-4, V_6 = Bina til 2

Plant height differed significantly among the varieties (Fig. 4.2 and Appendix X and XXXV). Among the varieties V_5 (BARI til-4) recorded the maximum plant height (31.00, 86.44, 106.90, 117.90 and 134.70 cm at 30, 45, 60, 75 DAS and at harvest, respectively) and it was at par with V_4 (BARI til-3) as was observed at the time of harvest. V_6 (Bina til 2) registered the plant height that came next in order. The lowest plant height (24.92, 73.82, 96.97, 105.60 and 121.40 cm at 30, 45, 60, 75 DAS and at harvest, respectively) was observed with local variety V_2 (Atshira) and it was closely proceeded by local variety V_1 (Lal til). Similar findings were found by several researchers. Tiwari and Namdeo (1997) stated that varieties differed significantly with each other in respect of vegetative growth characters due to genetic variability. Similar findings were observed by Channabasavanna and Setty (1992), Rao *et al*, (1990), Tiwari *et al.* (1994), Malam and Chandawat *et al.* (2003) and Patil *et al.* (1990). They observed that plant height varied significantly due to varietal difference.

Regarding the combined effect of different nutrients with different varieties of sesame indicated significant variation during cropping season (Table 4.1 and Appendix XXXV). Combination between different nutrient levels × varieties, N_4V_5 registered the maximum plant height (33.97, 93.49, 113.80, 129.20 and 139.10 cm at 30, 45, 60, 75 DAS and at harvest, respectively) which was statistically similar with N_4V_4 at the time of harvest followed by N_3V_4, N_3V_5, N_3V_6 and N_4V_3. The shortest plants were recorded with N_1V_2 (23.15, 70.90, 93.69, 102.80 and 112.90 cm at 30, 45, 60, 75 DAS and at harvest respectively). However, N_1V_1 was at par with N_1V_2 followed by N_2V_1 and N_2V_2.

Table 4.1 Combined effect of different levels of nutrients and varieties on plant height of sesame during March-June 2014

Treatment	Plant height (cm)				
	30 DAS	45 DAS	60 DAS	75 DAS	At harvest
N_1V_1	23.21	72.67	93.96	105.80	120.60
N_1V_2	23.15	70.90	93.69	102.80	112.90
N_1V_3	26.49	76.10	101.0	107.50	126.70
N_1V_4	28.33	80.58	102.5	109.60	128.80
N_1V_5	29.19	81.45	102.6	109.90	130.40
N_1V_6	27.23	77.53	101.8	107.50	126.90
N_2V_1	24.10	73.59	94.37	105.90	122.70
N_2V_2	24.47	74.02	96.19	106.10	123.10
N_2V_3	27.63	77.86	102.0	107.60	127.90
N_2V_4	29.45	82.31	102.8	110.00	131.10
N_2V_5	30.07	83.51	104.1	113.90	133.90
N_2V_6	28.30	80.36	102.4	107.90	128.00
N_3V_1	24.61	74.86	97.54	106.20	124.70
N_3V_2	25.69	74.92	98.60	106.70	124.90
N_3V_3	29.55	82.96	103.6	112.80	132.60
N_3V_4	30.55	85.11	104.8	115.60	134.70
N_3V_5	30.79	87.31	107.0	118.40	135.30
N_3V_6	30.45	82.75	104.6	114.30	134.70
N_4V_1	26.40	75.70	99.47	107.00	125.30
N_4V_2	26.38	75.45	99.41	106.90	124.90
N_4V_3	30.59	86.67	106.3	118.30	135.10
N_4V_4	31.41	88.02	108.6	123.70	138.50
N_4V_5	33.97	93.49	113.8	129.20	139.10
N_4V_6	30.85	87.99	108.5	123.10	135.30
$LSD_{0.05}$	1.327	2.683	1.368	1.629	1.698
CV (%)	10.256	13.627	11.394	9.948	12.832

N_1 = 75% of RDF (43:54:23 kg N, P_2O_5 and K_2O ha^{-1}), N_2 = 100% of RDF (58:72:30 kg N, P_2O_5 and K_2O ha^{-1}), N_3 = 125% of RDF (72:90:38 kg N, P_2O_5 and K_2O ha^{-1}), N_4 = 150% of RDF (86:108:45 kg N, P_2O_5 and K_2O ha^{-1})

V_1 = Lal til (Local), V_2 = Atshira (Local), V_3 = T-6, V_4 = BARI til-3, V_5 = BARI til-4, V_6 = Bina til 2

4.1.1.2 Number of leaves plant^{-1}

Regarding the effect of different nutrient levels, significant variation was found for number of leaves plant^{-1} (Fig. 4.3 and Appendix XI and XXXVI). Results revealed that higher nutrients level applied to the soil for sesame showed higher number of leaves plant^{-1} at all growth stages. It was found that the application of 150% of RDF (N_4) showed the highest number of leaves plant^{-1} (11.44, 52.67, 73.50, 96.33 and 81.33 at 30, 45, 60, 75 DAS and at harvest, respectively) which was statistically similar with N_2 (100% of RDF) at harvest and this was followed by 125% of RDF (N_3). The lowest number of leaves plant^{-1} (10.17, 44.83, 67.39, 84.61 and 62.22 at 30, 45, 60, 75 DAS and at harvest, respectively) was recorded with 75% of RDF (N_1). Supported findings were narrated by Thorve (1991) and he reported that the number of functional leaves plant^{-1} was significantly influenced by different fertilizer levels. Application of 75 kg N ha^{-1}, 45 kg P_2O_5ha^{-1} and 22.5 kg K_2O ha^{-1} registered the highest number of leaves (Shehu *et al.,* 2009).

Number of leaves plant^{-1} differed significantly among the varieties (Fig. 4.4 and Appendix XII and XXXVI). Among the different sesame varieties, tested V_5 (BARI til-4) recorded the maximum number of leaves plant^{-1} (12.50, 58.58, 78.50, 103.90 and 95.57 at 30, 45, 60, 75 DAS and at harvest, respectively) followed by V_4 (BARI til-3) at all growth stages. The least number of leaves plant^{-1} (9.67, 42.42, 64.08, 79.92 and 53.83 at 30, 45, 60, 75 DAS and at harvest respectively) was observed with local variety V_1 (Lal til) which was statistically similar with V_2 (Atshira) at 30, 60 DAS and at harvest followed by V_6 (Bina til 2). The present findings were supported by Patil *et al.* (1990) and Shanker *et al.* (1999) and they also showed significant variation on number of leaves plant^{-1} due to cause of varietal performance.

Regarding the combined effect of different nutrients with different varieties of sesame indicated significant variation in respect of number of leaves plant^{-1} (Table 4.2 and Appendix XXXVI). Combination between different nutrient levels × varieties, N_4V_5 registered the maximum number of leaves plant^{-1} (13.67, 65.00, 82.00, 111.30 and 109.00 at 30, 45, 60, 75 DAS and at harvest respectively) followed N_4V_5 and N_2V_4. During the cropping season and at all growth stages under observation, the lowest number of leaves plant^{-1} was recorded with N_1V_1 (9.00, 38.00, 60.67, 70.00 and 41.33 at 30, 45, 60, 75 DAS and at harvest, respectively) which was statistically identical with N_1V_2 at 30, 45 DAS and at harvest followed by N_2V_1 and N_2V_2.

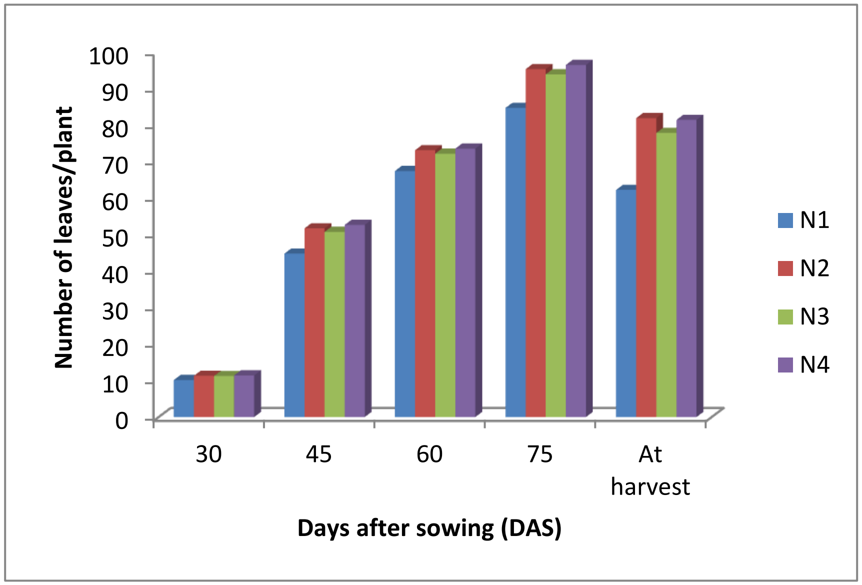

Fig. 4.3 Number of leaves plant^{-1} of sesame as influenced by different levels of nutrients during March-June 2014 ($LSD_{0.05}$ = 0.228, 0.675, 0.769, 0.967 and 1.137 at 30, 45, 60, 75 DAS and harvest, respectively)

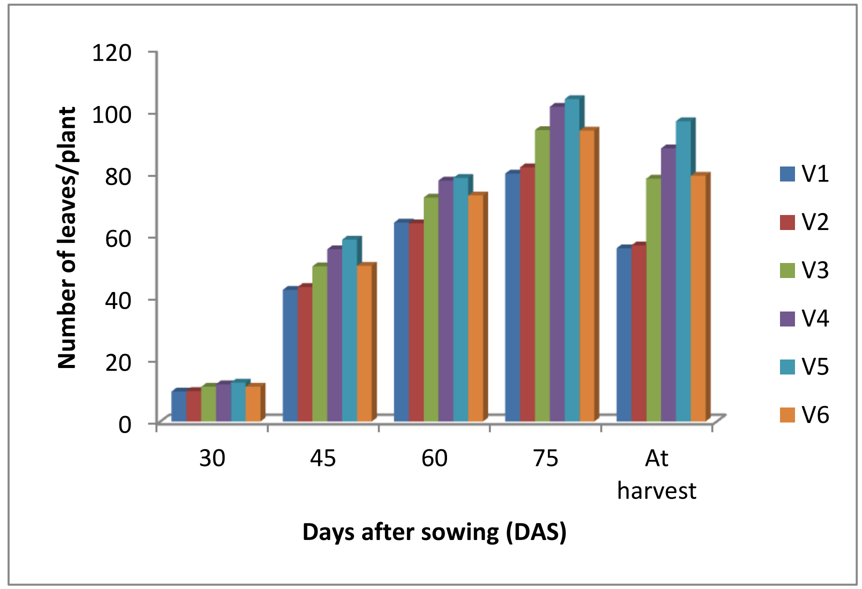

Fig. 4.4 Number of leaves/plant of sesame as influenced by different varieties during March-June 2014 ($LSD_{0.05}$ = 0.419, 0.883, 1.496, 1.441 and 1.617 at 30, 45, 60, 75 DAS and harvest, respectively)

N_1 = 75% of RDF (43:54:23 kg N, P_2O_5 and K_2O ha^{-1}), N_2 = 100% of RDF (58:72:30 kg N, P_2O_5 and K_2O ha^{-1}), N_3 = 125% of RDF (72:90:38 kg N, P_2O_5 and K_2O ha^{-1}), N_4 = 150% of RDF (86:108:45 kg N, P_2O_5 and K_2O ha^{-1})

V_1 = Lal til (Local), V_2 = Atshira (Local), V_3 = T-6, V_4 = BARI til-3, V_5 = BARI til-4, V_6 = Bina til 2

Table 4.2 Combined effect of different levels of nutrients and varieties on number of leaves plant^{-1} of sesame during March-June 2014

Treatment	Number of leaves plant^{-1}				
	30 DAS	45 DAS	60 DAS	75 DAS	At harvest
N_1V_1	9.000	38.00	60.67	70.00	41.33
N_1V_2	9.000	38.67	61.33	74.00	43.33
N_1V_3	10.67	47.33	70.00	90.33	67.67
N_1V_4	10.67	48.33	71.00	91.00	76.00
N_1V_5	11.00	49.00	71.00	91.67	77.33
N_1V_6	10.67	47.67	70.33	90.67	67.67
N_2V_1	9.000	40.67	63.00	79.00	53.00
N_2V_2	9.667	43.67	63.00	82.33	53.33
N_2V_3	11.33	50.33	72.00	94.67	81.33
N_2V_4	12.67	58.33	80.67	106.7	94.33
N_2V_5	13.67	65.00	82.00	111.3	109.0
N_2V_6	11.67	52.33	77.67	97.00	87.00
N_3V_1	10.33	44.33	64.00	82.67	63.00
N_3V_2	10.33	45.00	65.00	84.67	64.67
N_3V_3	11.33	52.00	75.00	96.67	83.00
N_3V_4	12.00	58.00	78.67	102.0	87.33
N_3V_5	12.67	56.00	79.00	104.7	88.67
N_3V_6	11.00	49.33	71.00	92.00	80.00
N_4V_1	10.33	46.67	68.67	88.00	66.00
N_4V_2	10.33	46.00	66.00	86.67	65.67
N_4V_3	11.33	50.33	71.67	94.00	81.00
N_4V_4	12.67	57.33	80.33	106.0	94.33
N_4V_5	12.67	64.33	82.00	108.0	99.00
N_4V_6	11.33	51.33	72.33	95.33	82.00
$LSD_{0.05}$	1.115	1.550	3.414	2.882	4.611
CV (%)	8.93	10.27	13.88	14.25	12.58

N_1 = 75% of RDF (43:54:23 kg N, P_2O_5 and K_2O ha^{-1}), N_2 = 100% of RDF (58:72:30 kg N, P_2O_5 and K_2O ha^{-1}), N_3 = 125% of RDF (72:90:38 kg N, P_2O_5 and K_2O ha^{-1}), N_4 = 150% of RDF (86:108:45 kg N, P_2O_5 and K_2O ha^{-1})

V_1 = Lal til (Local), V_2 = Atshira (Local), V_3 = T-6, V_4 = BARI til-3, V_5 = BARI til-4, V_6 = Bina til 2

4.1.1.3 Number of branches plant^{-1}

Significant effect was observed in number of branches plant^{-1} due to different levels of nutrients (Fig. 4.5 and Appendix XIIIand XXXVII). It was found that the application of N_2 (100% of RDF) signed up the highest number of branches plant^{-1} (0.611, 3.11, 3.50, 4.11 and 5.39 at 30, 45, 60, 75 DAS and at harvest, respectively) followed by N_3 (125% of RDF) and N_4 (150% of RDF) at all growth stages. The lowest number of branches plant^{-1} (0.00, 2.61, 3.00, 3.00 and 4.28 at 30, 45, 60, 75 DAS and at harvest respectively) was recorded from 75% of RDF (N_1). *Sesamum* cultivars showed significant effect on number of branches plant^{-1} due to N application up to 200 kg ha^{-1}(El-Nakhlawy and Saheen, 2009). Shehu *et al*. (2010a) indicated that number of branches plant^{-1} was increasing up to application of 90 kg P_2O_5 ha^{-1}. Number of branches was higher with application of 90 kg P_2O_5 ha^{-1} (Mian *et al*., 2011). Application of 29.4 kg K_2O ha^{-1} significantly increased the number of branches plant^{-1} (Thakur and Patel, 2004). Application of 75 kg N ha^{-1}, 45 kg P_2O_5ha^{-1} and 22.5 kg K_2O ha^{-1} registered the highest number of branches (Shehu *et al.*, 2009).

Number of branches plant^{-1} differed significantly among the varieties (Fig. 4.6 and Appendix XIVand XXXVII). Among the different sesame varieties, the maximum number of branches plant^{-1} (1.10, 3.42, 4.00, 4.67 and 5.83 at 30, 45, 60, 75 DAS and at harvest, respectively) was obtained from V_5 (BARI til-4) which was closely followed by V_4 (BARI til-3). The least number of branches plant^{-1} (0.00, 2.58, 2.75, 2.75 and 3.91 at 30, 45, 60, 75 DAS and at harvest, respectively) was observed with local variety V_1 (Lal til) which was statistically similar with V_2 (Atshira) at all growth stages followed by V_3 (T-6). The results obtained by Balasubramaniyan *et al.* (1995), Malam *et al.* (2003) and Moorthy *et al.* (1997) were conformity with the present findings. They observed that number of branches plant^{-1} was significantly influenced by different varieties.

Significant influence was found in terms of combined effect of different levels of nutrients with different varieties of sesame regarding number of branches plant^{-1} (Table 4.3 and Appendix XXXVII). Results indicated that combination N_2V_5 listed the maximum number of branches plant^{-1} (2.00, 3.67, 4.33, 5.33 and 6.67 at 30, 45, 60, 75 DAS and at harvest, respectively) which was statistically similar with N_2V_4 and N_4V_5 followed N_2V_6, N_3V_4, N_3V_5 and N_4V_4. During the cropping season, all growth stages under observation, the lowest number of branches plant^{-1} was recorded from N_1V_1 (0.00, 2.33, 2.33, 2.33 and 3.00 at 30, 45, 60, 75 DAS and at harvest, respectively) followed by N_1V_2, N_2V_1, N_2V_2 and N_3V_1.

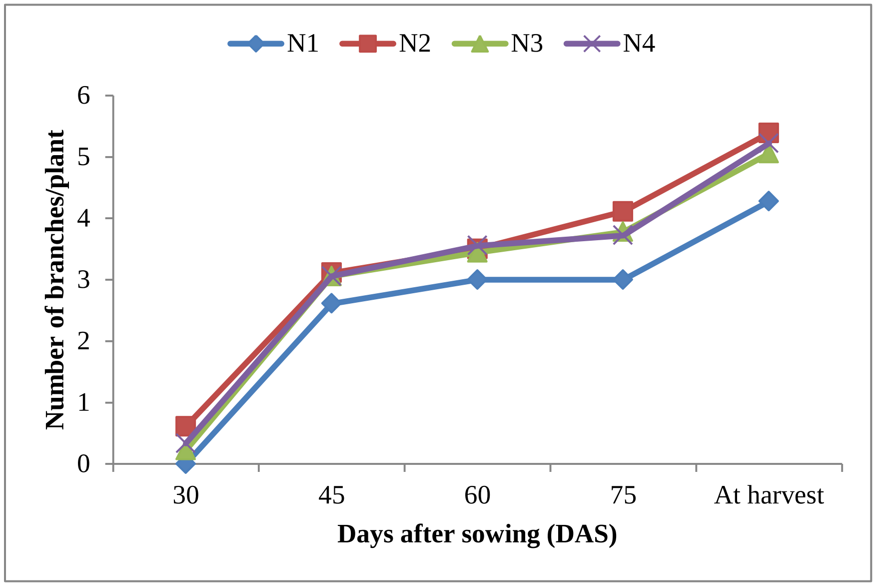

Fig. 4.5 Number of branches/plant of sesame as influenced by different levels of nutrients during March-June 2014 ($LSD_{0.05}$ = 0.104, 0.146, 0.127, 0.254 and 0.227 at 30, 45, 60, 75 DAS and harvest, respectively)

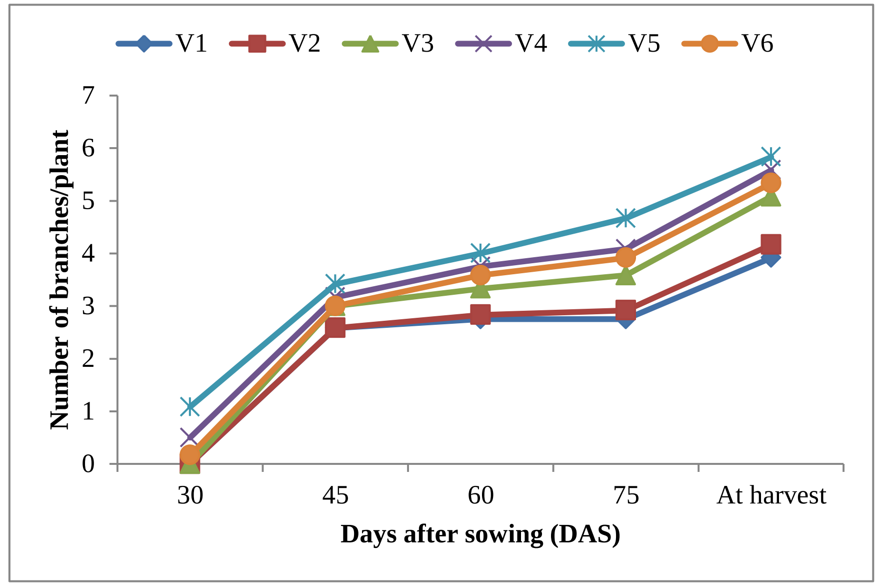

Fig. 4.6 Number of branches/plant of sesame as influenced by different varieties during March-June 2014 ($LSD_{0.05}$ = 0.097, 0.228, 0.279, 0.241 and 0.252 at 30, 45, 60, 75 DAS and harvest, respectively)

N_1 = 75% of RDF (43:54:23 kg N, P_2O_5 and K_2O ha^{-1}), N_2 = 100% of RDF (58:72:30 kg N, P_2O_5 and K_2O ha^{-1}), N_3 = 125% of RDF (72:90:38 kg N, P_2O_5 and K_2O ha^{-1}), N_4 = 150% of RDF (86:108:45 kg N, P_2O_5 and K_2O ha^{-1})

V_1 = Lal til (Local), V_2 = Atshira (Local), V_3 = T-6, V_4 = BARI til-3, V_5 = BARI til-4, V_6 = Bina til 2

Table 4.3 Combined effect of different plant nutrients and varieties on number of branches plant^{-1} of sesame during March-June 2014

Treatment	Number of branches plant^{-1}				
	30 DAS	45 DAS	60 DAS	75 DAS	At harvest
N_1V_1	0.000	2.333	2.333	2.333	3.000
N_1V_2	0.000	2.333	2.667	2.667	4.000
N_1V_3	0.000	2.667	3.000	3.000	4.667
N_1V_4	0.000	2.667	3.000	3.000	4.667
N_1V_5	0.000	3.000	3.333	3.667	4.667
N_1V_6	0.000	2.667	3.333	3.333	4.667
N_2V_1	0.000	2.667	2.667	2.667	4.000
N_2V_2	0.000	2.667	2.667	3.000	4.000
N_2V_3	0.000	3.000	3.333	3.667	5.333
N_2V_4	1.000	3.333	4.000	5.000	6.333
N_2V_5	2.000	3.667	4.333	5.333	6.667
N_2V_6	0.667	3.333	4.000	5.000	6.000
N_3V_1	0.000	2.667	2.667	3.000	4.000
N_3V_2	0.000	2.667	3.000	3.000	4.333
N_3V_3	0.000	3.333	3.667	4.000	5.333
N_3V_4	0.667	3.333	4.000	4.333	5.667
N_3V_5	0.667	3.333	4.000	4.667	5.667
N_3V_6	0.000	3.000	3.333	3.667	5.333
N_4V_1	0.000	2.667	3.000	3.000	4.667
N_4V_2	0.000	2.667	3.000	3.000	4.333
N_4V_3	0.000	3.000	3.333	3.667	5.000
N_4V_4	0.333	3.333	4.000	4.000	5.667
N_4V_5	1.667	3.667	4.333	5.000	6.333
N_4V_6	0.000	3.000	3.667	3.667	5.333
$LSD_{0.05}$	1.167	0.4903	0.5092	0.482	0.545
CV (%)	2.14	5.27	7.59	6.37	6.96

N_1 = 75% of RDF (43:54:23 kg N, P_2O_5 and K_2O ha^{-1}), N_2 = 100% of RDF (58:72:30 kg N, P_2O_5 and K_2O ha^{-1}), N_3 = 125% of RDF (72:90:38 kg N, P_2O_5 and K_2O ha^{-1}), N_4 = 150% of RDF (86:108:45 kg N, P_2O_5 and K_2O ha^{-1})

V_1 = Lal til (Local), V_2 = Atshira (Local), V_3 = T-6, V_4 = BARI til-3, V_5 = BARI til-4, V_6 = Bina til 2

4.1.1.4 Dry weight plant^{-1}

Dry weight plant^{-1} was found significant due to different levels of nutrients at different growth stages (Fig. 4.7 and Appendix XVand XXXVIII). In relation to the effect of different nutrient levels, it was found that the application of N_2 (100% of RDF) marked the highest dry weight plant^{-1} (1.86, 3.56, 18.13, 28.85 and 54.83 g at 30, 45, 60, 75 DAS and at harvest, respectively) followed by N_3 (125% of RDF) and N_4 (150% of RDF) at all growth stages. The lowest dry weight plant^{-1} (1.37, 2.86, 13.09, 26.52 and 47.00 g at 30, 45, 60, 75 DAS and at harvest respectively) was recorded from 75% of RDF (N_1) followed by N_4 (150% of RDF). Thorve (1991) reported that the dry matter accumulation plant^{-1} was significantly influenced by different fertilizer levels. Malla *et al.* (2010) opined that *Sesamum* responded significantly up to 90 kg N ha^{-1} in terms of plant dry weight over 60 kg N ha^{-1}. Haruna *et al*. (2010) opined that the application of 26.4 kg P_2O_5 ha^{-1} increased the total dry matter production than other levels *viz*. 13.2 and 0 kg P_2O_5 ha^{-1}. Ojikpong *et al.* (2008) revealed that application of K_2O up to 45 kg ha^{-1} increased the dry matter of *Sesamum*. Application of 75 kg N ha^{-1}, 45 kg P_2O_5ha^{-1} and 22.5 kg K_2O ha^{-1} registered the highest dry matter production (Shehu *et al.*, 2009).

Dry weight plant^{-1} of sesame influenced significantly by the different varieties (Fig. 4.8 and Appendix XVIand XXXVIII). Among the different sesame varieties, the maximum dry weigh plant^{-1} (1.91, 3.94, 18.66, 28.67 and 55.71 g at 30, 45, 60, 75 DAS and at harvest respectively) was obtained from V_5 (BARI til-4) followed by V_4 (BARI til-3) and V_6 (Bina til 2). The lowest dry weigh plant^{-1} (1.15, 2.45, 9.90, 26.36 and 43.84 g at 30, 45, 60, 75 DAS and at harvest respectively) was observed with local variety V_1 (Lal til) followed by local variety V_2 (Atshira). Subrahmaniyan and Arulmozhi (1999), Shanker *et al.* (1999), Malam *et al.* (2003) and Subrahmaniyan *et al.* (2001) also recorded significant growth characters like dry matter production plant^{-1} as compared to other varieties.

Significant influence was found in terms of combined effect of different nutrients with different varieties of sesame regarding dry weight plant^{-1} (Table 4.4 and Appendix XXXVIII). Results indicated that combination between different nutrient levels and varieties, N_2V_5 listed the maximum dry weight plant^{-1} (2.31, 4.50, 22.45, 35.48 and 63.13 g at 30, 45, 60, 75 DAS and at harvest, respectively) followed N_2V_4 and N_2V_3. Under observation of all growth stages, the lowest dry weight plant^{-1} was recorded from N_1V_1 (0.87, 2.11, 8.75, 21.42 and 40.43 g at 30, 45, 60, 75 DAS and at harvest, respectively) followed by N_1V_2 and N_2V_1.

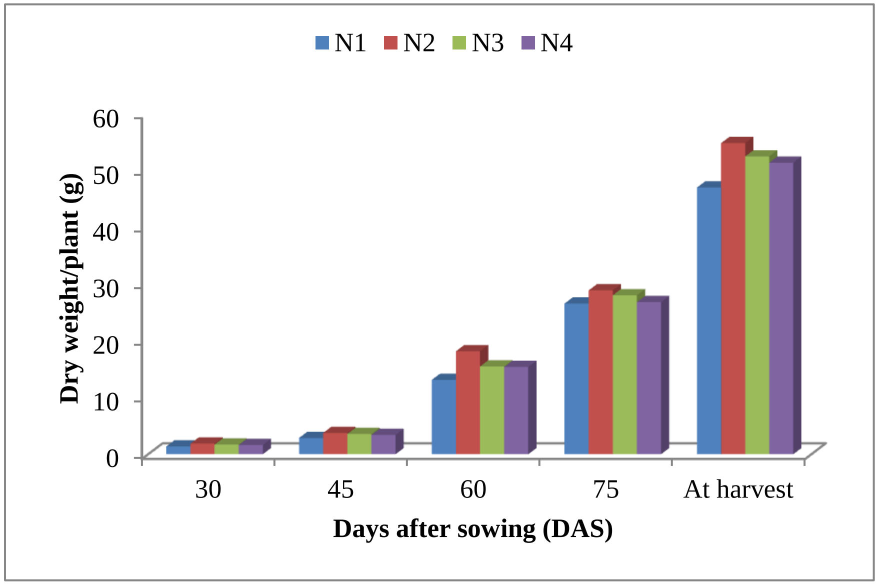

Fig. 4.7 Dry weight plant^{-1} of sesame as influenced by different levels of plant nutrients during March-June 2014 ($LSD_{0.05}$ = 0.209, 0.160, 0.302, 0.325 and 0.605 at 30, 45, 60, 75 DAS and harvest, respectively)

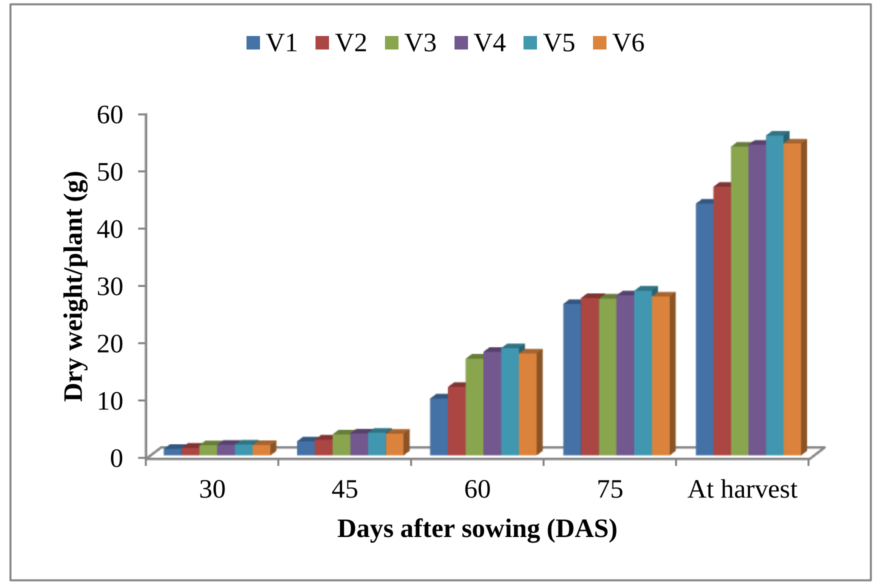

Fig. 4.8 Dry weight plant^{-1} of sesame as influenced by different varieties during March-June 2014 ($LSD_{0.05}$ = 0.078, 0.104, 0.369, 0.370 and 0.275 at 30, 45, 60, 75 DAS and harvest, respectively)

N_1 = 75% of RDF (43:54:23 kg N, P_2O_5 and K_2O ha^{-1}), N_2 = 100% of RDF (58:72:30 kg N, P_2O_5 and K_2O ha^{-1}), N_3 = 125% of RDF (72:90:38 kg N, P_2O_5 and K_2O ha^{-1}), N_4 = 150% of RDF (86:108:45 kg N, P_2O_5 and K_2O ha^{-1})

V_1 = Lal til (Local), V_2 = Atshira (Local), V_3 = T-6, V_4 = BARI til-3, V_5 = BARI til-4, V_6 = Bina til 2

Table 4.4 Combined effect of different plant nutrients and varieties on dry weight plant^{-1} of sesame during March-June 2014

Treatment	Dry weight plant^{-1} (g)				
	30 DAS	45 DAS	60 DAS	75 DAS	At harvest
N_1V_1	0.873	2.110	8.753	21.42	40.43
N_1V_2	1.000	2.317	9.037	24.46	42.21
N_1V_3	1.553	3.083	14.55	26.59	48.67
N_1V_4	1.593	3.223	15.28	26.83	50.27
N_1V_5	1.623	3.257	15.76	27.14	51.55
N_1V_6	1.573	3.197	15.14	26.70	48.86
N_2V_1	1.240	2.580	10.30	24.73	45.36
N_2V_2	1.407	2.907	12.86	26.36	48.30
N_2V_3	2.010	4.133	19.57	30.26	58.81
N_2V_4	2.157	4.287	22.00	32.44	60.16
N_2V_5	2.313	4.497	22.45	35.48	63.13
N_2V_6	2.043	4.140	21.60	30.46	53.19
N_3V_1	1.097	2.393	9.333	24.65	42.81
N_3V_2	1.400	2.853	11.59	25.48	48.02
N_3V_3	1.883	3.963	17.08	27.75	55.55
N_3V_4	1.940	4.097	17.91	29.92	55.62
N_3V_5	1.973	4.120	19.39	29.98	57.23
N_3V_6	1.930	4.040	17.41	28.94	55.62
N_4V_1	1.373	2.717	11.20	25.16	46.76
N_4V_2	1.517	2.937	14.16	26.38	48.58
N_4V_3	1.677	3.413	16.18	27.20	52.02
N_4V_4	1.740	3.717	16.89	27.43	53.84
N_4V_5	1.737	3.903	17.05	27.73	54.45
N_4V_6	1.690	3.710	16.73	27.32	52.59
$LSD_{0.05}$	0.1375	0.2143	0.9032	0.9498	1.954
CV (%)	5.87	7.34	10.63	12.93	13.58

N_1 = 75% of RDF (43:54:23 kg N, P_2O_5 and K_2O ha^{-1}), N_2 = 100% of RDF (58:72:30 kg N, P_2O_5 and K_2O ha^{-1}), N_3 = 125% of RDF (72:90:38 kg N, P_2O_5 and K_2O ha^{-1}), N_4 = 150% of RDF (86:108:45 kg N, P_2O_5 and K_2O ha^{-1})

V_1 = Lal til (Local), V_2 = Atshira (Local), V_3 = T-6, V_4 = BARI til-3, V_5 = BARI til-4, V_6 = Bina til 2

4.1.1.5 Leaf area index (LAI)

LAI was obviously influenced due to different nutrient levels (Fig. 4.9 and Appendix XVII and XXXIX). With regard to various nutrient levels, 150% of RDF (N_4) showed the maximum LAI (1.57, 2.24, 3.58, 4.92 and 3.43 at 30, 45, 60, 75 DAS and at harvest respectively) followed by N_4 (150% of RDF). The lowest LAI (0.94, 1.87, 2.52, 3.58 and 2.45 at 30, 45, 60, 75 DAS and at harvest respectively) was recorded from 75% of RDF (N_1) followed by N_2 (100% of RDF). The leaf area index of *Sesamum* increased sharply due to increase of N levels from 20 to 80 kg ha^{-1} (Duray and Mandal, 2006). Haruna *et al*. (2010) opined that the application of 26.4 kg P_2O_5 ha^{-1} increased the leaf area index than other levels *viz*., 13.2 and 0 kg P_2O_5 ha^{-1}. Kalaiselvan *et al.* (2002) revealed that application of K recorded the maximum leaf area index of sesame.

Leaf area index (LAI) of sesame was influenced significantly by the different varieties (Fig. 4.10 and Appendix XVIII and XXXIX). Among the different sesame varieties, the maximum LAI (1.57, 2.44, 3.63, 5.00 and 3.49 at 30, 45, 60, 75 DAS and at harvest respectively) was obtained from V_5 (BARI til-4) which was closely followed by V_4 (BARI til-3). The lowest LAI (0.76, 1.70, 2.37, 3.25 and 2.35 at 30, 45, 60, 75 DAS and at harvest respectively) was observed with local variety V_1 (Lal til) which was statistically identical with local variety V_2 (Atshira). Similar results were observed by several findings conducted by Umar *et al*. (2012). They observed that varietal performance significantly influenced the leaf area index (LAI) of sesame. Malam and Chandawat *et al.* (2003) and Tiwari and Namdeo (1997) recorded significant differences in growth characters. They observed significant variation on leaf area index (LAI) as compared to other *Sesamum* varieties and mutants.

Significant influence was found in terms of combined effect of different nutrients and varieties regarding LAI (Table 4.5 and Appendix XXXIX). Results revealed that there was no significant effect on LAI at 30 DAS but at 45, 60, 75 DAS and at harvest significant variation was found. Results indicated that combination between different nutrient levels and varieties, N_4V_5 listed the maximum LAI (2.96, 4.63, 6.32 and 4.18 at 45, 60, 75 DAS and at harvest respectively) which was statistically similar with N_4V_4 followed N_4V_6. Under observation of all growth stages, the lowest LAI was recorded from N_1V_1 (1.12, 1.67, 2.88 and 1.60 at 45, 60, 75 DAS and at harvest respectively) which was statistically identical with N_1V_2 followed by N_2V_1 and N_2V_2.

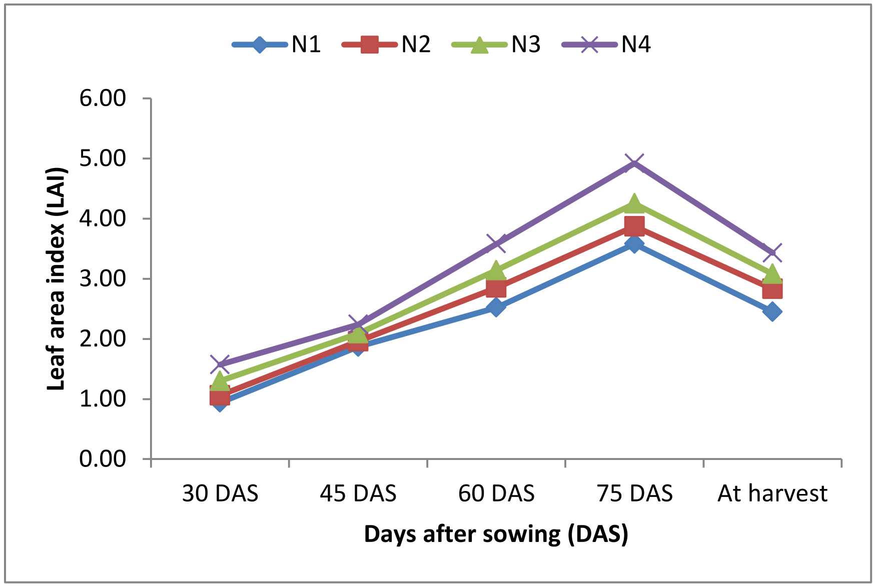

Fig. 4.9 LAI of sesame as influenced by different levels of plant nutrients during March-June 2014 ($LSD_{0.05}$ = 0.453, 0.458, 0.715, 0.894 and 0.834 at 30, 45, 60, 75 DAS and harvest, respectively)

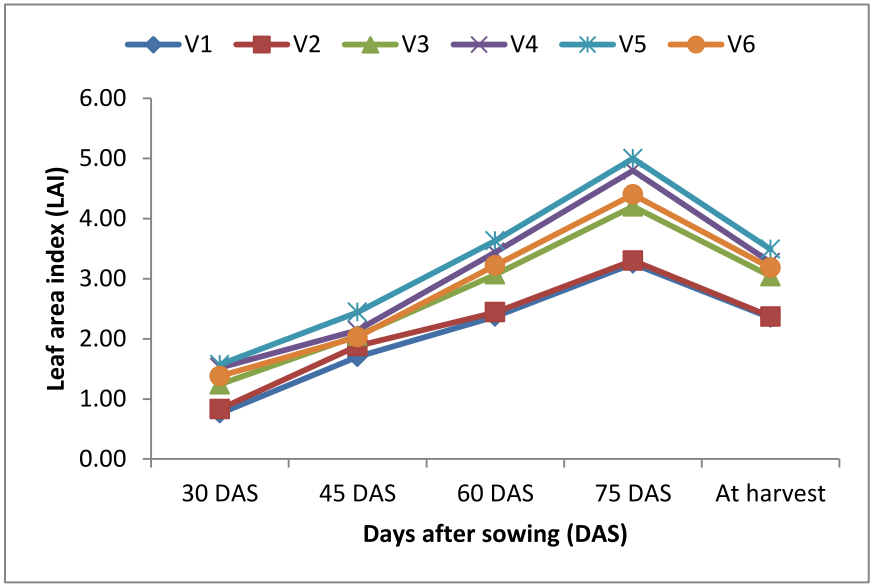

Fig. 4.10 LAI of sesame as influenced by different varieties during March-June 2014 ($LSD_{0.05}$ = 0.637, 0.566, 1.229, 0.723 and 0.624 at 30, 45, 60, 75 DAS and harvest, respectively)

N_1 = 75% of RDF (43:54:23 kg N, P_2O_5 and K_2O ha^{-1}), N_2 = 100% of RDF (58:72:30 kg N, P_2O_5 and K_2O ha^{-1}), N_3 = 125% of RDF (72:90:38 kg N, P_2O_5 and K_2O ha^{-1}), N_4 = 150% of RDF (86:108:45 kg N, P_2O_5 and K_2O ha^{-1})

V_1 = Lal til (Local), V_2 = Atshira (Local), V_3 = T-6, V_4 = BARI til-3, V_5 = BARI til-4, V_6 = Bina til 2

Table 4.5 Combined effect of different levels of nutrients and varieties on LAI of sesame during March-June 2014

Treatment	Leaf area index (LAI)				
	30 DAS	45 DAS	60 DAS	75 DAS	At harvest
N_1V_1	0.52	1.12	1.67	2.88	1.60
N_1V_2	0.64	1.29	1.88	2.94	1.72
N_1V_3	1.00	2.07	2.73	3.60	2.70
N_1V_4	1.26	2.30	2.95	4.11	2.90
N_1V_5	1.23	2.55	3.10	4.20	2.98
N_1V_6	1.01	1.90	2.81	3.77	2.78
N_2V_1	0.74	2.33	2.48	3.18	2.53
N_2V_2	0.79	2.42	2.52	3.26	2.44
N_2V_3	1.01	2.11	2.83	3.90	2.80
N_2V_4	1.30	1.35	3.17	4.38	2.94
N_2V_5	1.43	1.92	3.22	4.52	3.30
N_2V_6	1.12	1.62	2.90	3.98	2.96
N_3V_1	0.81	1.86	2.56	3.33	2.60
N_3V_2	0.95	2.40	2.64	3.42	2.58
N_3V_3	1.34	1.77	3.20	4.41	3.12
N_3V_4	1.55	2.20	3.48	4.81	3.37
N_3V_5	1.65	2.32	3.55	4.94	3.48
N_3V_6	1.52	1.98	3.42	4.60	3.33
N_4V_1	0.98	1.48	2.77	3.62	2.66
N_4V_2	0.96	1.42	2.71	3.56	2.67
N_4V_3	1.61	2.25	3.52	4.87	3.55
N_4V_4	1.97	2.72	4.14	5.88	3.88
N_4V_5	1.99	2.96	4.63	6.32	4.18
N_4V_6	1.88	2.60	3.73	5.24	3.64
$LSD_{0.05}$	NS	0.247	0.355	0.621	0.337
CV (%)	4.08	5.254	6.39	6.58	5.71

N_1 = 75% of RDF (43:54:23 kg N, P_2O_5 and K_2O ha^{-1}), N_2 = 100% of RDF (58:72:30 kg N, P_2O_5 and K_2O ha^{-1}), N_3 = 125% of RDF (72:90:38 kg N, P_2O_5 and K_2O ha^{-1}), N_4 = 150% of RDF (86:108:45 kg N, P_2O_5 and K_2O ha^{-1})

V_1 = Lal til (Local), V_2 = Atshira (Local), V_3 = T-6, V_4 = BARI til-3, V_5 = BARI til-4, V_6 = Bina til 2

4.1.2 Growth performance

4.1.2.1 Absolute growth rate (AGR)

Absolute growth rate (AGR) was significantly influenced by different nutrient levels (Table 4.6 and Appendix XL). Results revealed that the highest AGR (0.815 g plant^{-1} day^{-1}) was obtained from 100% of RDF (N_2) followed by with N_3 (125% of RDF) and N_4 (150% of RDF). The lowest AGR (0.681 g plant^{-1} day^{-1}) was recorded from N_1 (75% of RDF).

Significant influence was found for absolute growth rate (AGR) as influenced by different sesame varieties (Table 4.7 and Appendix XL). Among the different sesame varieties, the maximum AGR (0816 g plant^{-1} day^{-1}) was obtained from V_5 (BARI til-4) which was statistically similar with V_4 (BARI til-3) and V_6 (Bina til 2). The lowest AGR (0.637 g plant^{-1} day^{-1}) was observed from local variety V_1 (Lal til) followed by local variety V_2 (Atshira).

Absolute growth rate (AGR) was significantly influenced by combined effect of different levels of nutrients and varieties (Table 4.8 and Appendix XL). Results signified that combination between different nutrient levels and varieties, N_2V_5 listed the maximum AGR (0.910 g plant^{-1} day^{-1}) which was statistically identical with N_2V_4 followed by N_2V_6. The lowest AGRwas recorded from N_1V_1 (0.590 g plant^{-1} day^{-1}) which was statistically similar with N_1V_2 and N_3V_1 followed by N_2V_1 and N_4V_1.

4.1.2.2 Crop growth rate (CGR)

Crop growth rate (CGR) was significantly influenced by different nutrient levels (Table 4.6 and Appendix XL). Results revealed that the highest CGR (5.436 g cm^{-2} day^{-1}) was obtained from 100% of RDF (N_2) followed by with N_3 (125% of RDF) and N_4 (150% of RDF). The lowest CGR (4.540 g cm^{-2} day^{-1}) was recorded from N_1 (75% of RDF). Similar result was also observed by Shehu *et al.* (2009) and was found that application of 75 kg N ha^{-1}, 45 kg P_2O_5ha^{-1} and 22.5 kg K_2O ha^{-1} registered the highest crop growth rate (CGR)

Significant influence was found for crop growth rate (CGR) as influenced by different sesame varieties (Table 4.7 and Appendix XL). Among the different sesame varieties, the maximum CGR (5.442 g cm^{-2} day^{-1}) was obtained from V_5 (BARI til-4) which was statistically similar with V_4 (BARI til-3) followed by V_6 (Bina til 2). The lowest CGR (4.248 g cm^{-2} day^{-1}) was observed from local variety V_1 (Lal til) followed by local variety V_2 (Atshira). Umar *et al*. (2012) also found significant variation on crop growth rate due to varietal difference.

Crop growth rate (CGR) was significantly influenced by combined effect of different nutrients and varieties (Table 4.8 and Appendix XL). Results signified that combination between different nutrient levels and varieties, N_2V_5 listed the maximum CGR (6.067 g cm^{-2} day^{-1}) which was statistically similar with N_2V_4 followed by N_2V_6 and N_2V_3. The lowest CGR was recorded from N_1V_1 (3.936 g cm^{-2} day^{-1}) which was statistically similar with N_1V_2 followed by N_3V_1 and N_2V_1.

4.1.2.3 Relative growth rate (RGR)

Relative growth rate (RGR) was not significantly influenced by different nutrient levels (Table 4.6and Appendix XL). But results revealed that the highest RGR (0.02312 g g^{-1} day^{-1}) was obtained from 75% of RDF (N_1) while the lowest RGR (0.02254 g g^{-1} day^{-1}) was recorded from 100% of RDF (N_2).

Non-significant influence was found for relative growth rate (RGR) as influenced by different sesame varieties (Table 4.7 and Appendix XL). But the maximum RGR (0.02351 g g^{-1} day^{-1}) was obtained from local variety V_1 (Lal til) where the lowest RGR (0.02212 g g^{-1} day^{-1}) was observed from V_5 (BARI til-4).

Relative growth rate (RGR) was not also significantly influenced by combined effect of different nutrients and varieties (Table 4.8 and Appendix XL). But the results signified that the maximum RGR (0.02483 g g^{-1} day^{-1}) was from N_1V_1 where the lowest RGR (0.0215 g g^{-1} day^{-1}) was recorded from N_2V_5.

Table 4.6 Growth performance of sesame influenced by different levels of nutrients during March-June 2014

Treatment	Growth performance		
	AGR (g plant^{-1} day^{-1})	CGR (g cm^{-2} day^{-1})	RGR (g g^{-1} day^{-1})
N_1	0.681	4.540	0.0231
N_2	0.815	5.436	0.0225
N_3	0.758	5.053	0.0227
N_4	0.743	4.950	0.0226
$LSD_{0.05}$	0.042	0.245	NS
CV (%)	8.44	7.30	9.72

N_1 = 75% of RDF (43:54:23 kg N, P_2O_5 and K_2O ha^{-1}), N_2 = 100% of RDF (58:72:30 kg N, P_2O_5 and K_2O ha^{-1}), N_3 = 125% of RDF (72:90:38 kg N, P_2O_5 and K_2O ha^{-1}), N_4 = 150% of RDF (86:108:45 kg N, P_2O_5 and K_2O ha^{-1})

Table 4.7 Growth performance of sesame influenced by different varieties during March-June, 2014

Treatment	Growth performance		
	AGR (g plant^{-1} day^{-1})	CGR (g cm^{-2} day^{-1})	RGR (g g^{-1} day^{-1})
V_1	0.637	4.248	0.0235
V_2	0.678	4.523	0.0231
V_3	0.776	5.172	0.0224
V_4	0.804	5.362	0.0229
V_5	0.816	5.442	0.0221
V_6	0.784	5.224	0.0223
$LSD_{0.05}$	0.037	0.149	NS
CV (%)	5.97	3.64	9.72

V_1 = Lal til (Local), V_2 = Atshira (Local), V_3 = T-6, V_4 = BARI til-3, V_5 = BARI til-4, V_6 = Bina til 2

Table 4.8 Combined effect of different plant nutrients and varieties on growth performance of sesame during March-June 2014

Treatment	Growth performance		
	AGR (g plant^{-1} day^{-1})	CGR (g cm^{-2} day^{-1})	RGR (g g^{-1} day^{-1})
N_1V_1	0.590	3.936	0.02483
N_1V_2	0.615	4.101	0.02433
N_1V_3	0.703	4.688	0.02240
N_1V_4	0.726	4.843	0.02293
N_1V_5	0.745	4.967	0.02207
N_1V_6	0.706	4.707	0.02217
N_2V_1	0.658	4.390	0.02280
N_2V_2	0.699	4.667	0.02227
N_2V_3	0.848	5.652	0.02287
N_2V_4	0.909	6.057	0.02273
N_2V_5	0.910	6.067	0.02150
N_2V_6	0.867	5.781	0.02310
N_3V_1	0.622	4.151	0.02367
N_3V_2	0.696	4.640	0.02303
N_3V_3	0.801	5.336	0.02197
N_3V_4	0.803	5.353	0.02367
N_3V_5	0.825	5.498	0.02200
N_3V_6	0.802	5.342	0.02163
N_4V_1	0.678	4.517	0.02273
N_4V_2	0.703	4.683	0.02277
N_4V_3	0.751	5.010	0.02250
N_4V_4	0.778	5.184	0.02230
N_4V_5	0.787	5.245	0.02290
N_4V_6	0.759	5.064	0.02227
$LSD_{0.05}$	0.033	0.180	NS
CV (%)	18.356	18.279	17.54

N_1 = 75% of RDF (43:54:23 kg N, P_2O_5 and K_2O ha^{-1}), N_2 = 100% of RDF (58:72:30 kg N, P_2O_5 and K_2O ha^{-1}), N_3 = 125% of RDF (72:90:38 kg N, P_2O_5 and K_2O ha^{-1}), N_4 = 150% of RDF (86:108:45 kg N, P_2O_5 and K_2O ha^{-1})

V_1 = Lal til (Local), V_2 = Atshira (Local), V_3 = T-6, V_4 = BARI til-3, V_5 = BARI til-4, V_6 = Bina til 2

4.1.3 Yield attributes

4.1.3.1 Number of capsule plant^{-1}

Number of capsule plant^{-1} was influenced due to different nutrient levels (Fig. 4.11 and Appendix XIX and XLI). Regarding nutrient levels, the number of capsules plant^{-1} was highest (77.28) from 100% of RDF (N_2) followed by N_3 (125% of RDF). The lowest number of capsule plant^{-1} (63.83) was recorded from 75% of RDF (N_1) which was statistically similar with N_4 (150% of RDF). Prakasha and Thimmegowda (1992) reported 53 percent increased seed yield with higher N rate due to enhanced value of yield attributes *viz*., capsules plant^{-1}. Bennet *et al.* (1996) found increased number of capsules plant^{-1} with N application up to 120 kg ha^{-1}. Each successive increase in dose of N up to 60 kg ha^{-1} significantly increased the capsules plant^{-1} (Prakash *et al.,* 2001). Nahar *et al.* (2008) indicated that the number of capsules plant^{-1} increased significantly up to 100 kg N ha^{-1}. Significantly higher seed yield was recorded with 50 kg P_2O_5 ha^{-1} due to increase in capsules plant^{-1} (Prakasha and Thimmegowda, 1992). Mian *et al.* (2011) opined that the highest number of capsules plant^{-1} was recorded with 90 kg P_2O_5 ha^{-1}. Increasing the level of K from 100 to 150 percent of recommended dose, the number of capsules plant^{-1} of *Sesamum* increased significantly (Subrahmaniyan *et al.,* 2001).

Number of capsule plant^{-1} of sesame was influenced significantly by the different sesame varieties (Fig. 4.12 and Appendix XX and XLI). Among the different sesame varieties, the maximum number of capsule plant^{-1} (77.33) was obtained from V_5 (BARI til-4) followed by V_4 (BARI til-3). The lowest number of capsule plant^{-1} (56.58) was observed from local variety V_1 (Lal til) followed by local variety V_2 (Atshira). El-Serogy *et al.* (1997), Deshmukh *et al.* (2005), Kokilavani *et al.* (2007) and Riaz Ahmad *et al.* (2002) indicated that number of capsules plant^{-1} differed significantly by different varieties.

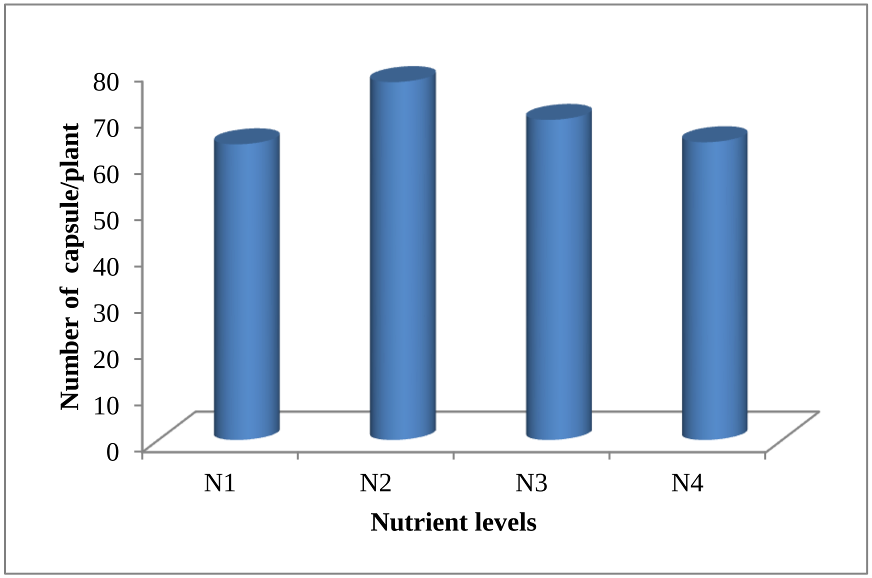

Fig. 4.11 Number of capsule plant^{-1} of sesame as influenced by different levels of plant nutrients during March-June 2014 ($LSD_{0.05}$ = 1.214)

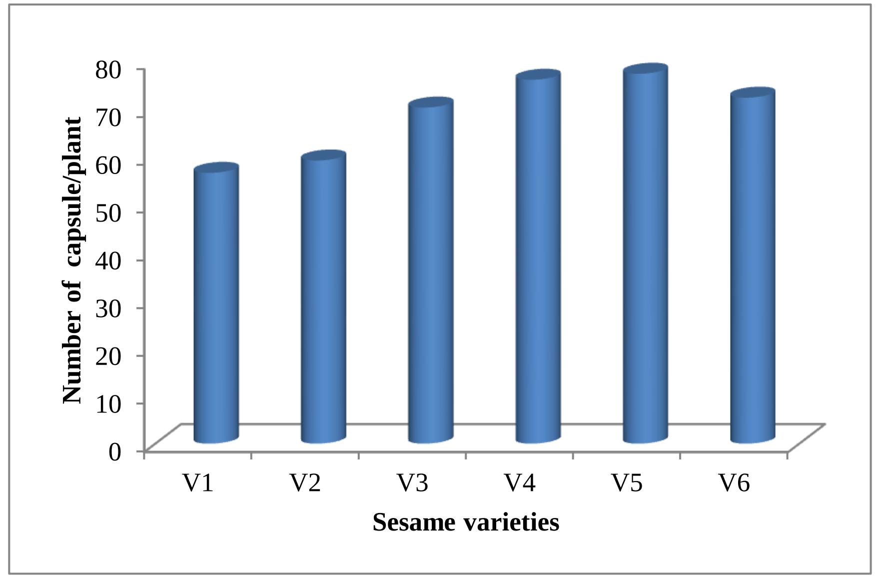

Fig. 4.12 Number of capsule plant^{-1} of sesame as influenced by different varieties during March-June 2014 ($LSD_{0.05}$ = 0.929)

N_1 = 75% of RDF (43:54:23 kg N, P_2O_5 and K_2O ha^{-1}), N_2 = 100% of RDF (58:72:30 kg N, P_2O_5 and K_2O ha^{-1}), N_3 = 125% of RDF (72:90:38 kg N, P_2O_5 and K_2O ha^{-1}), N_4 = 150% of RDF (86:108:45 kg N, P_2O_5 and K_2O ha^{-1})

V_1 = Lal til (Local), V_2 = Atshira (Local), V_3 = T-6, V_4 = BARI til-3, V_5 = BARI til-4, V_6 = Bina til 2

Number of capsule plant^{-1} was significantly influenced by combined effect of different levels of nutrients and varieties (Table 4.9 and Appendix XLI). Results signified that combination between different nutrient levels and varieties, N_2V_5 listed the maximum number of capsule plant^{-1} (94.67) which was statistically identical with N_2V_4 followed by N_2V_6. The lowest number of capsule plant^{-1} was recorded from N_4V_1 (55.33) which were statistically similar with $N_3V_1$and N_2V_1.

4.1.3.2 Number of seeds capsule^{-1}

Number of seeds capsule^{-1} was significantly influenced due to different nutrient levels (Fig. 4.13 and Appendix XIXand XLI). Regarding nutrient levels, the number of seeds capsule^{-1} was highest (79.53) from 100% of RDF (N_2) followed by N_3 (125% of RDF). The lowest number of seeds capsule^{-1} (72.76) was recorded from 150% of RDF (N_4) which was statistically similar with N_1 (125% of RDF). Nahar *et al.* (2008) indicated that the seeds capsule^{-1} increased significantly up to 100 kg N ha^{-1}. Kathiresan (1999) indicated that P level of 35 kg ha^{-1} influenced number of seeds capsule^{-1} of *Sesamum*. Application of potassium markedly increased the number of seeds capsule^{-1} (Mandal *et al*., 1992). Tiwari *et al.* (1994) found that application of K_2O significantly increased the seeds capsule^{-1} of *Sesamum*.

Number of seeds capsule^{-1} of sesame influenced significantly by the different varieties (Fig. 4.14 and Appendix XX and XLI). Among the different sesame varieties, the maximum number of seeds capsule^{-1} (80.76) was obtained from V_5 (BARI til-4) followed by V_4 (BARI til-3). The lowest number of seeds capsule^{-1} (65.82) was observed from local variety V_1 (Lal til) followed by local variety V_2 (Atshira). Variation in number of seeds capsule^{-1} was noticed significant among varieties (Govindaraju and Balakrishnan, 2002). Ali and Jan (2014) and Chongdar *et al*. (2015) also observed aariation in number of seeds capsule^{-1} due to different varietal performance on number of seeds capsule^{-1}.

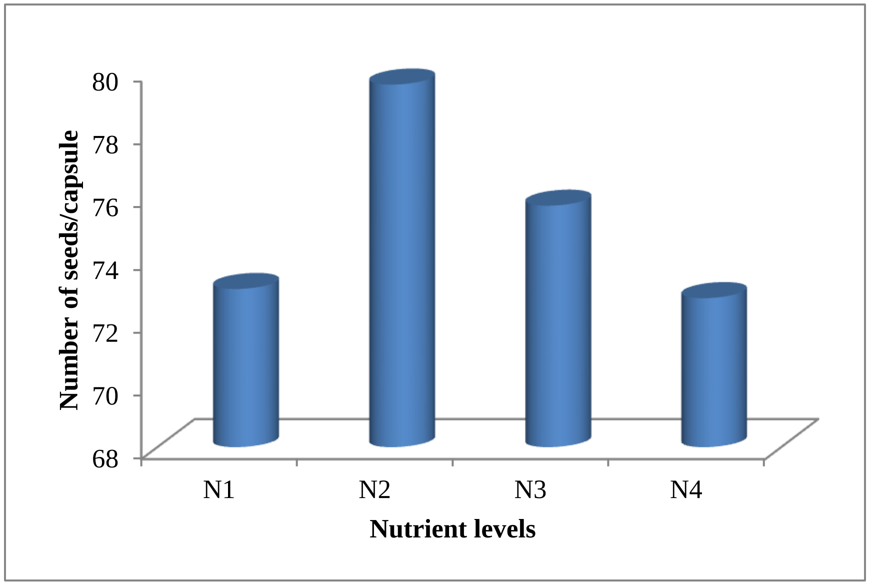

Fig. 4.13 Number of seeds capsule^{-1} of sesame as influenced by different levels of nutrients during March-June 2014 ($LSD_{0.05}$ = 1.406)

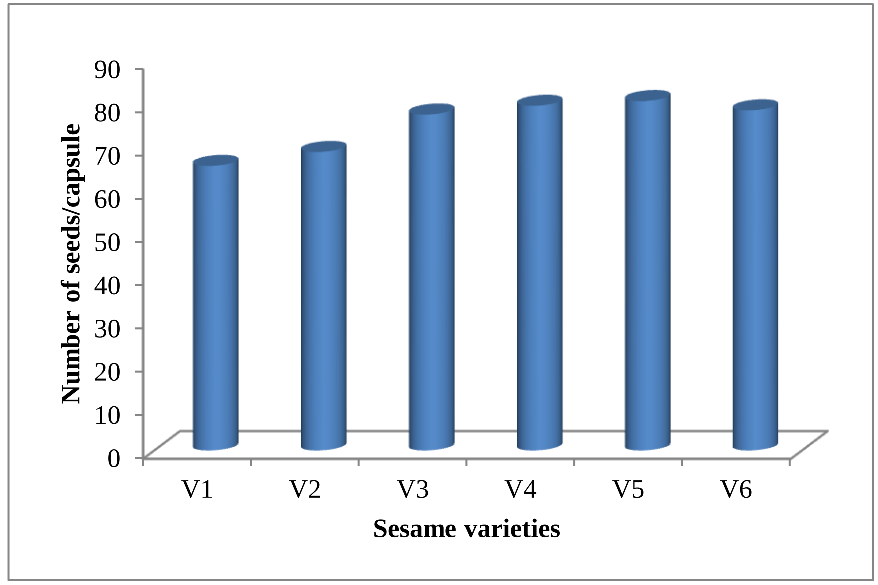

Fig. 4.14 Number of seeds capsule^{-1} of sesame as influenced by different varieties during March-June 2014 ($LSD_{0.05}$ = 0.969)

N_1 = 75% of RDF (43:54:23 kg N, P_2O_5 and K_2O ha^{-1}), N_2 = 100% of RDF (58:72:30 kg N, P_2O_5 and K_2O ha^{-1}), N_3 = 125% of RDF (72:90:38 kg N, P_2O_5 and K_2O ha^{-1}), N_4 = 150% of RDF (86:108:45 kg N, P_2O_5 and K_2O ha^{-1})

V_1 = Lal til (Local), V_2 = Atshira (Local), V_3 = T-6, V_4 = BARI til-3, V_5 = BARI til-4, V_6 = Bina til 2

Number of seeds capsule^{-1} was significantly influenced by combined effect of different nutrients level and varieties (Table 4.9 and Appendix XLI). Results signified that combination nutrient levels and varieties of N_2V_5 listed the maximum number of seeds capsule^{-1} (88.13) which was statistically similar with N_2V_4 followed by N_2V_6. The lowest number of seeds capsule^{-1} was recorded from N_4V_1 (61.53) followed by N_4V_2 and N_3V_1.

4.1.3.3 Capsule length

Capsule length was significantly influenced due to different nutrient levels (Fig. 4.15 and Appendix XIXand XLI). Regarding nutrient levels, the capsule length was highest (3.19 cm) from 100% of RDF (N_2) followed by N_3 (125% of RDF). The lowest capsule length (2.13 cm) was recorded from 150% of RDF (N_4) which was statistically similar with N_1 (75% of RDF). Different variety had significant response on different nutrient rates. Like T6 and BARI Til 3 showed increased capsule length up to 100 kg N ha^{-1} but the variety BARI Til 2 responded well up to 150 kg N ha^{-1} (Nahar *et al.*, 2008). Mian *et al.* (2011) opined that the highest capsule length was recorded with 90 kg P_2O_5 ha^{-1} compared to 70 and 110 kg P_2O_5 ha^{-1}. Tiwari *et al.* (1994) found that application of K_2O significantly increased the capsule length of sesame significantly. The highest capsule length was achieved by the application of 44 kg N and 44 kg P_2O_5 ha^{-1} (Abdel, 2008).

Capsule length of sesame influenced significantly by the different sesame varieties (Fig. 4.16 and Appendix XX and XLI). Among the different sesame varieties, the maximum capsule length (2.31 cm) was obtained from V_5 (BARI til-4) which was statistically similar with V_3 (T-6), V_4 (BARI til-3) and V_6 (Bina til 2). The lowestcapsule length (2.05 cm) was observed from local variety V_1 (Lal til) followed by local variety V_2 (Atshira). Similar result also found by Jebaraj and Mohamed (1996). They observed different varieties possessed different sized capsules. Riaz *et al.* (2002) and Lakshmi and Lakshmamma (2005) also found similar results regarding capsule length of sesame and observed that different variety showed different capsule length.

Capsule length was significantly influenced by combined effect of different levels of nutrients and varieties (Table 4.9 and Appendix XLI). Results signified that combination nutrient levels and varieties, N_2V_5 listed the maximum capsule length (2.43 cm) which was statistically identical with N_2V_4 and closely followed by N_2V_6. The lowest capsule lengthwas recorded from N_4V_1 (1.82 cm) followed by N_4V_2.

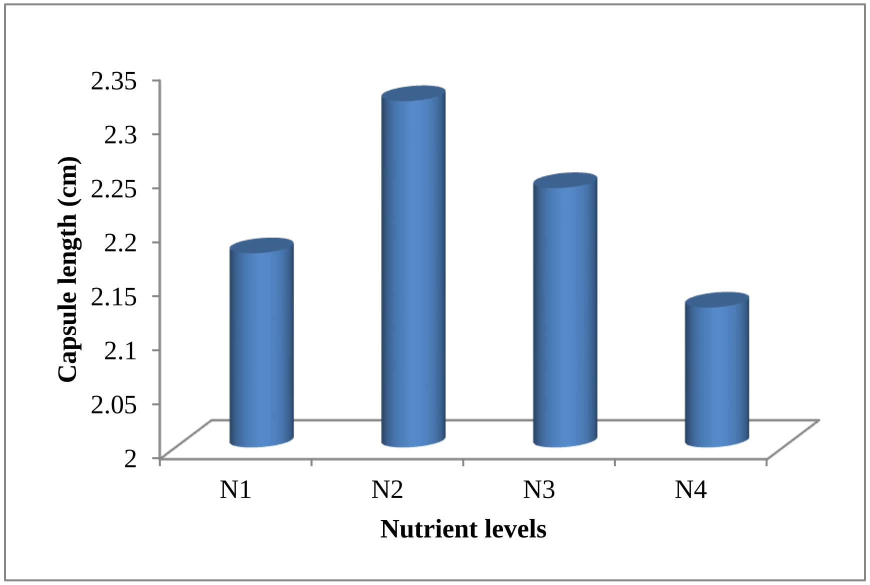

Fig. 4.15 Capsule length of sesame as influenced by different levels of nutrients during March-June 2014 ($LSD_{0.05}$ = 0.060)

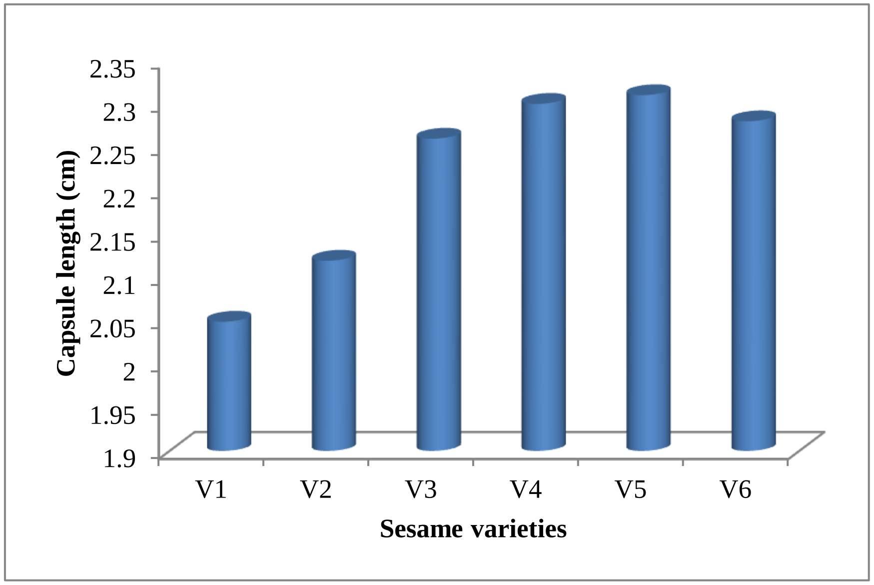

Fig. 4.16 Capsule length of sesame as influenced by different varieties during March-June 2014 ($LSD_{0.05}$ = 0.052)

N_1 = 75% of RDF (43:54:23 kg N, P_2O_5 and K_2O ha^{-1}), N_2 = 100% of RDF (58:72:30 kg N, P_2O_5 and K_2O ha^{-1}), N_3 = 125% of RDF (72:90:38 kg N, P_2O_5 and K_2O ha^{-1}), N_4 = 150% of RDF (86:108:45 kg N, P_2O_5 and K_2O ha^{-1})

V_1 = Lal til (Local), V_2 = Atshira (Local), V_3 = T-6, V_4 = BARI til-3, V_5 = BARI til-4, V_6 = Bina til 2

4.1.3.4 Weight of 1000 seed

Weight of 1000 seeds was apparently influenced significantly due to different nutrient levels (Fig. 4.17 and Appendix XIXand XLI). Regarding nutrient levels, the weight of 1000 seeds was highest (2.78 g) from 100% of RDF (N_2) followed by N_3 (125% of RDF). The lowest weight of 1000 seeds (2.60 g) was recorded from 75% of RDF (N_1) which was statistically similar with N_4 (150% of RDF). Ishwar Singh *et al.* (1994) recorded higher 1000 seed weight of *Sesamum* upto 60 kg N ha^{-1}. Each successive increase in dose of N up to 60 kg ha^{-1} significantly increased 1000 seed weight (Prakash *et al.,* 2001). Nahar *et al.* (2008) indicated that the 1000 seed weight increased significantly up to 100 kg N ha^{-1}. Mian *et al.* (2011) opined that the highest 1000 seed weight was recorded with 90 kg P_2O_5 ha^{-1}. Application of potassium markedly increased the 1000 seed weight (Mandal *et al*., 1992).

Weight of 1000 seeds of sesame influenced significantly by the different varieties (Fig. 4.18 and Appendix XX and XLI). Among the different sesame varieties, the maximum weight of 1000 seeds (2.81 g) was obtained from V_5 (BARI til-4) which was statistically similar with V_4 (BARI til-3) and V_6 (Bina til 2). The lowest weight of 1000 seeds (2.45 g) was observed from local variety V_2 (Atshira) which was statistically similar with local variety, V_1 (Lal til). Similar results on 1000 seed weight was found from Rao *et al.* (1990) and Yadav *et al.* (1991) which supported the present findings. They observed that HYV variety gave higher 1000 seed weight than local variety. Hamdollah *et al.* (2009) also showed similar result on 1000 seed weight.

Weight of 1000 seeds was significantly influenced by combined effect of different nutrients and varieties (Table 4.9 and Appendix XLI). Results signified that combination between different nutrient levels and varieties, N_2V_5 listed the maximum weight of 1000 seeds (3.00 g) which was statistically identical with N_2V_4 followed by N_2V_3 and N_2V_6. The lowest weight of 1000 seedswas recorded from N_4V_1 (2.47 g) which were statistically similar with N_2V_1, N_3V_1, N_3V_2, N_4V_1 and N_4V_2.

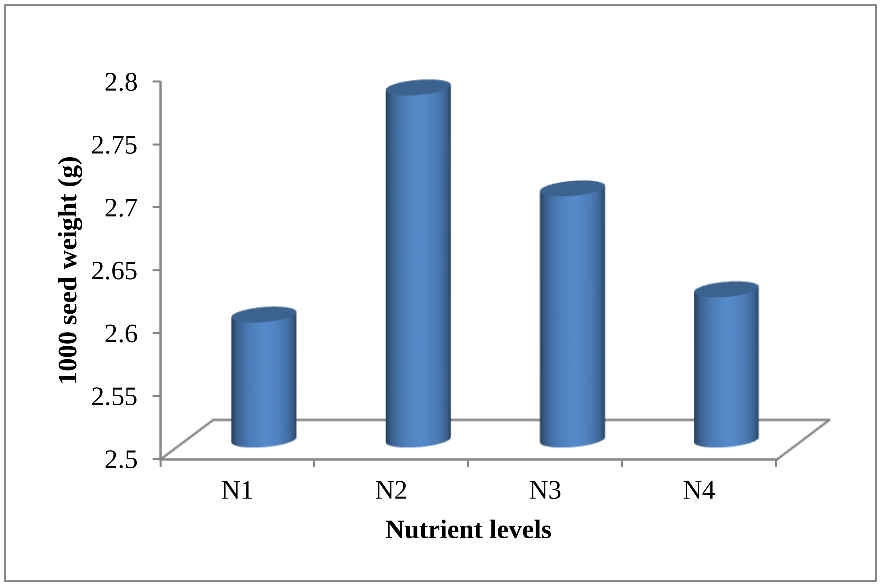

Fig. 4.17 Weight of 1000 seeds of sesame as influenced by different levels of plant nutrients during March-June 2014 ($LSD_{0.05}$ = 0.037)

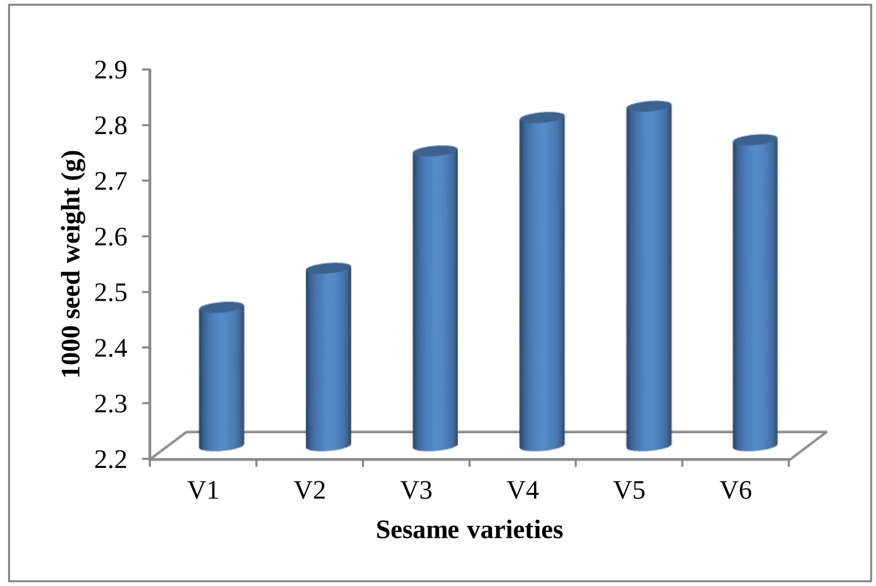

Fig. 4.18 Weight of 1000 seeds of sesame as influenced by different variety during March-June 2014 ($LSD_{0.05}$ = 0.069)

N_1 = 75% of RDF (43:54:23 kg N, P_2O_5 and K_2O ha^{-1}), N_2 = 100% of RDF (58:72:30 kg N, P_2O_5 and K_2O ha^{-1}), N_3 = 125% of RDF (72:90:38 kg N, P_2O_5 and K_2O ha^{-1}), N_4 = 150% of RDF (86:108:45 kg N, P_2O_5 and K_2O ha^{-1})

V_1 = Lal til (Local), V_2 = Atshira (Local), V_3 = T-6, V_4 = BARI til-3, V_5 = BARI til-4, V_6 = Bina til 2

Table 4.9 Combined effect of different plant nutrients and varieties on yield contributing parameters of sesame during March-June 2014

Treatment	Yield contributing parameters			
	Number of capsule $plant^{-1}$	Number of seeds $capsule^{-1}$	Capsule length (cm)	1000 seed weight (g)
N_1V_1	58.67	68.30	2.15	2.467
N_1V_2	63.67	72.77	2.17	2.600
N_1V_3	64.67	72.90	2.17	2.633
N_1V_4	65.00	75.57	2.20	2.633
N_1V_5	66.33	75.80	2.23	2.633
N_1V_6	64.67	72.97	2.20	2.633
N_2V_1	56.33	67.47	2.13	2.467
N_2V_2	61.67	69.43	2.16	2.533
N_2V_3	76.67	82.33	2.36	2.867
N_2V_4	93.00	85.33	2.42	2.967
N_2V_5	94.67	88.13	2.43	3.000
N_2V_6	81.33	84.50	2.41	2.867
N_3V_1	56.00	65.97	2.10	2.433
N_3V_2	59.67	68.77	2.15	2.500
N_3V_3	72.00	78.40	2.27	2.800
N_3V_4	75.33	80.10	2.32	2.833
N_3V_5	76.67	81.20	2.35	2.833
N_3V_6	75.00	79.70	2.28	2.800
N_4V_1	55.33	61.53	1.82	2.433
N_4V_2	51.67	65.17	2.02	2.433
N_4V_3	67.67	77.00	2.23	2.633
N_4V_4	71.00	77.67	2.24	2.733
N_4V_5	71.67	77.90	2.24	2.767
N_4V_6	68.33	77.30	2.24	2.700
$LSD_{0.05}$	2.975	3.026	0.052	0.090
CV (%)	10.84	12.58	7.34	6.94

N_1 = 75% of RDF (43:54:23 kg N, P_2O_5 and K_2O ha^{-1}), N_2 = 100% of RDF (58:72:30 kg N, P_2O_5 and K_2O ha^{-1}), N_3 = 125% of RDF (72:90:38 kg N, P_2O_5 and K_2O ha^{-1}), N_4 = 150% of RDF (86:108:45 kg N, P_2O_5 and K_2O ha^{-1})

V_1 = Lal til (Local), V_2 = Atshira (Local), V_3 = T-6, V_4 = BARI til-3, V_5 = BARI til-4, V_6 = Bina til 2

4.1.4 Yield parameters

4.1.4.1 Seed yield ha^{-1}

Seed yield ha^{-1} was significantly influenced due to different nutrient levels (Fig. 4.19and Appendix XXI and XLII). Seed yield ha^{-1} was highest (1223 kg ha^{-1}) from 100% of RDF (N_2) followed by N_3 (125% of RDF). The lowest seed yield ha^{-1} (924 kg ha^{-1}) was recorded from 150% of RDF (N_4) followed by N_1 (75% of RDF). The highest seed yield from 100% of RDF (N_2) might be due to higher number of capsules $plant^{-1}$, number of seeds $capsule^{-1}$, capsule length and 1000 seed weight with this treatment. Jadhav *et al.* (1992) also reported that highest grain yield was recorded when 120 kg N and 75 kg P_2O_5 ha^{-1} was applied on account of higher number of capsules $plant^{-1}$ and number of seeds $capsule^{-1}$, which was statistically on par with 120 kg N and 50 kg P_2O_5 ha^{-1}. Seed yield increased for every further increase in the rate of N and K application upto 80 and 60 kg ha^{-1}, respectively (Mandal *et al.*, 1992). Nahar *et al.* (2008) indicated that the seed yield increased significantly up to 100 kg N ha^{-1}. Kathiresan (1999) indicated that P level of 35 kg ha^{-1} influenced seed yield of *Sesamum*. Mian *et al.* (2011) opined that the highest seed yield was recorded with 90 kg P_2O_5 ha^{-1}. Bhosale *et al*. (2011) found that sesame cv. 'Gujrat Til 2' reported significantly highest seed yield with the fertilizer application of 25 kg N + 25 kg P_2O_5 + 50 kg K_2O ha^{-1}. Application of potassium markedly increased the seed yield (Mandal *et al*., 1992). Increasing the level of K from 100 to 150 percent of recommended dose, the seed yield of sesame increased significantly (Subrahmaniyan *et al.*, 2001).

Significant influence was found for seed yield ha^{-1} as influenced by different sesame varieties (Fig. 4.20 and Appendix XXII and XLII). Among the different sesame varieties, the maximum seed yield ha^{-1} (1170kg ha^{-1}) was obtained from V_5 (BARI til-4) followed by V_4 (BARI til-3). The lowest seed yield ha^{-1} (811.30kg ha^{-1}) was observed from local variety V_1 (Lal til) followed by local variety V_2 (Atshira). Production capacity of yield contributing characters *viz*. number of capsules $plant^{-1}$, number of seeds $capsule^{-1}$, capsule length and weight of 1000 seeds was highest with this variety compared to other tested variety and resulted highest seed yield. Suryabala *et al.* (2008), Thanunathan *et al.* (2004) and Monpara *et al.* (2008) also found yield of sesame varied significantly due to different varieties according to producing capability of yield contributing parameters.

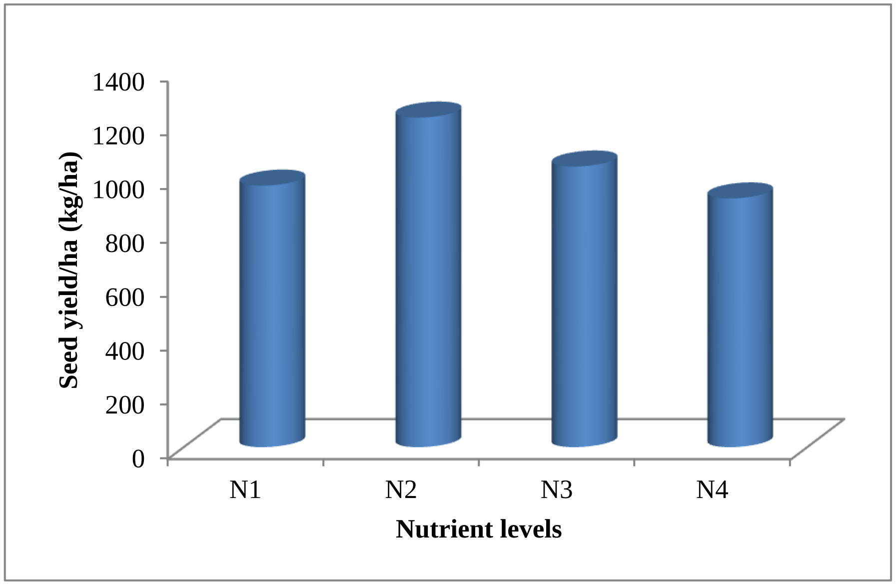

Fig. 4.19 Seed yield ha^{-1} of sesame as influenced by different levels of plant nutrients during March-June 2014 ($LSD_{0.05}$ = 13.43)

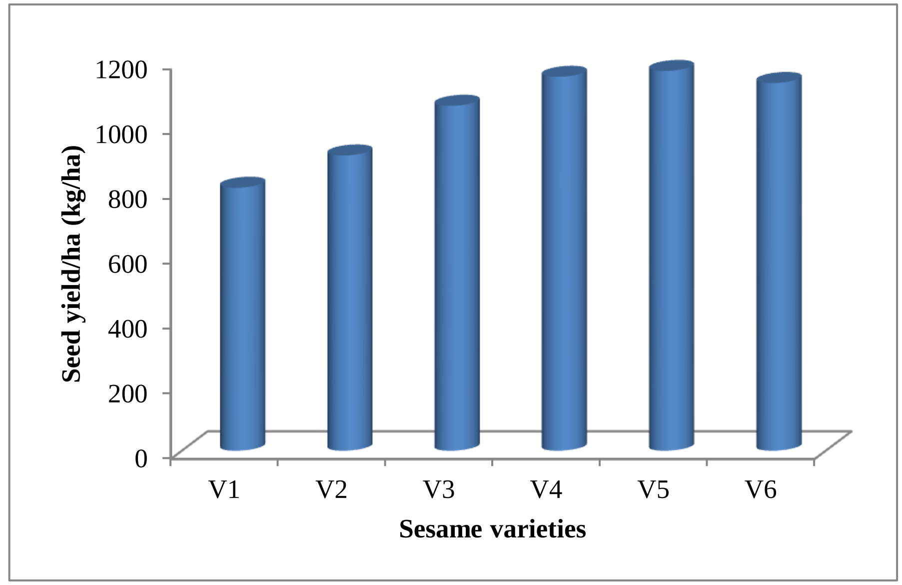

Fig. 4.20 Seed yield ha^{-1} of sesame as influenced by different varieties during March-June 2014 ($LSD_{0.05}$ = 16.44)

N_1 = 75% of RDF (43:54:23 kg N, P_2O_5 and K_2O ha^{-1}), N_2 = 100% of RDF (58:72:30 kg N, P_2O_5 and K_2O ha^{-1}), N_3 = 125% of RDF (72:90:38 kg N, P_2O_5 and K_2O ha^{-1}), N_4 = 150% of RDF (86:108:45 kg N, P_2O_5 and K_2O ha^{-1})

V_1 = Lal til (Local), V_2 = Atshira (Local), V_3 = T-6, V_4 = BARI til-3, V_5 = BARI til-4, V_6 = Bina til 2

Seed yield ha^{-1} was significantly influenced by combined effect of different levels of nutrients and varieties (Table 4.10 and Appendix XLII). Results signified that combination between different nutrient levels and varieties, N_2V_5 listed the maximum seed yield ha^{-1} (1481 kg ha^{-1}) which was statistically similar with N_2V_4 followed by N_2V_6. The lowest seed yield ha^{-1} was recorded from N_4V_1 (670kg ha^{-1}) which was followed by N_4V_2.

4.1.4.2 Stover yield ha^{-1}

Significant variation was observed in case of stover yield ha^{-1} influenced by different nutrient levels (Fig.4.21 and Appendix XXI and XLII). Concerning different nutrient levels, the stover yield ha^{-1} was highest (1473 kg ha^{-1}) from 100% of RDF (N_2) followed by N_3 (125% of RDF). The lowest stover yield ha^{-1} (1274kg ha^{-1}) was recorded from 75% of RDF (N_1) which was followed by N_4 (150% of RDF). Ali and Jan (2014) reported that plots treated with 120 kg N ha^{-1} produced maximum stover yield (5351 kg ha^{-1}). Mian *et al.* (2011) opined that the highest stover yield was recorded with 90 kg P_2O_5 ha^{-1}. Sarawagi *et al.* (1995) opined that significant stover yield of summer *Sesamum* with 60 to 90 kg K_2O ha^{-1}. Vaghani *et al*. (2010) reported that significantly higher stover yields was achieved with the fertilizer application of 100 kg N + 25 kg P_2O_5 + 80 kg K_2O + 40 kg S ha^{-1}. Bhosale *et al*. (2011) also observed significantly higher stover yield was with the fertilizer application of 25 kg N + 25 kg P_2O_5 + 50 kg K_2O ha^{-1}.

Stover yield ha^{-1} of sesame influenced significantly by the different varieties (Fig. 4.22 and Appendix XXII and XLII). Among the different sesame varieties, the maximum stover yield ha^{-1} (1476kg ha^{-1}) was obtained from V_5 (BARI til-4) which was statistically similar with V_4 (BARI til-3) and V_6 (Bina til 2) followed by V_3 (T-6). The lowest stover yield ha^{-1} (1139kg ha^{-1}) was observed from local variety V_1 (Lal til) followed by local variety V_2 (Atshira). Suryabala *et al.* (2008), Hamdollah *et al.* (2009) and Ali and Jan (2014) opined that different *Sesamum* cultivars showed significant variation on stover yield.

Statistically significant variation was observed by combined effect of different nutrients and varieties regarding stover yield ha^{-1} (Table 4.10 and Appendix XLII). Results signified that

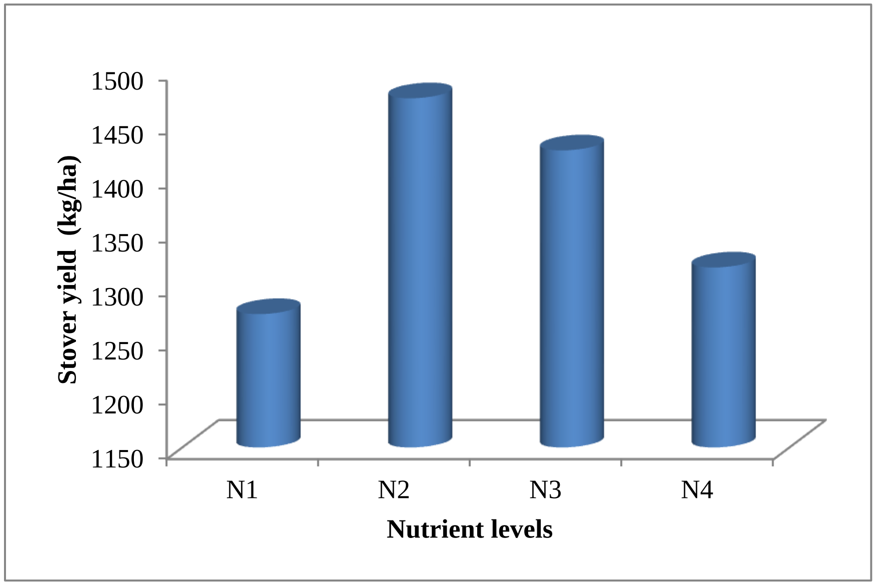

Fig. 4.21 Stover yield ha^{-1} of sesame as influenced by different levels of nutrients during March-June 2014 ($LSD_{0.05}$ = 16.45)

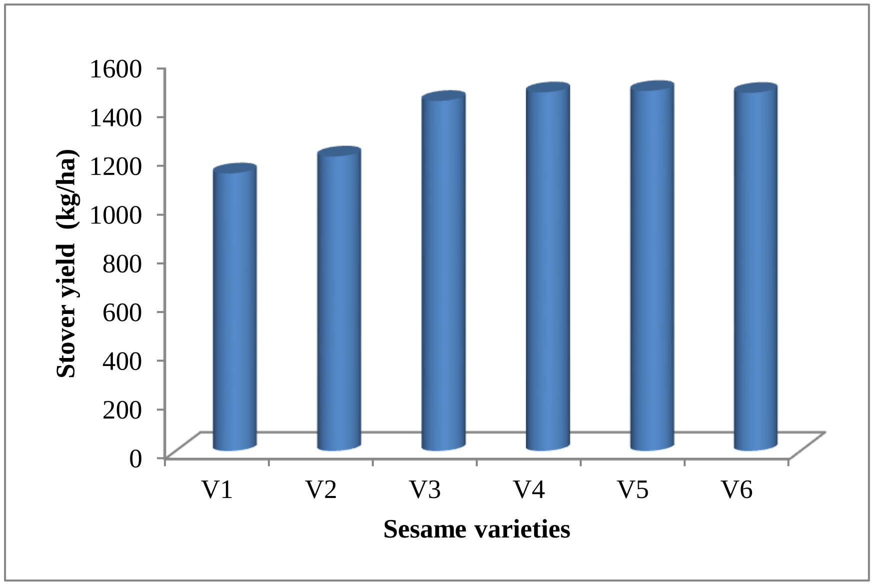

Fig. 4.22 Stover yield ha^{-1} of sesame as influenced by different varieties during March-June 2014 ($LSD_{0.05}$ = 14.82)

N_1 = 75% of RDF (43:54:23 kg N, P_2O_5 and K_2O ha^{-1}), N_2 = 100% of RDF (58:72:30 kg N, P_2O_5 and K_2O ha^{-1}), N_3 = 125% of RDF (72:90:38 kg N, P_2O_5 and K_2O ha^{-1}), N_4 = 150% of RDF (86:108:45 kg N, P_2O_5 and K_2O ha^{-1})

V_1 = Lal til (Local), V_2 = Atshira (Local), V_3 = T-6, V_4 = BARI til-3, V_5 = BARI til-4, V_6 = Bina til 2

the combination between different nutrient levels and varieties, N_2V_5 listed the maximum stover yield ha^{-1} (1715kg ha^{-1}) which was statistically similar with N_2V_4 followed by N_2V_6, N_2V_3 and N_3V_5. The lowest stover yield $ha^{-1}$was recorded from N_4V_1 (1043kg ha^{-1}) which was followed by N_4V_2 and N_3V_1.

4.1.4.3 Harvest index

Harvest index was apparently influenced significantly due to different nutrient levels (Fig. 4.23 and Appendix XXI and XLII). Regarding nutrient levels, the harvest index was highest (45.36%) from 100% of RDF (N_2) followed by N_1 (75% of RDF). The lowest harvest index (41.23%) was recorded from 150% of RDF (N_4) which was statistically similar with N_3 (125% of RDF). Ali and Jan (2014) reported that 120 kg N ha^{-1} produced highest harvest index. Khade *et al.* (1996) indicated that harvest index increased with upto 50 kg P_2O_5 ha^{-1}. Sarawagi *et al.* (1995) opined that significant harvest index of summer sesame was with 60 to 90 kg K_2O ha^{-1}. The highest harvest index was achieved by the application of 44 kg N and 44 kg P_2O_5 ha^{-1} (Abdel, 2008).

Significant influence was found for harvest index as influenced by different sesame varieties (Fig.4.24 and Appendix XXII and XLII). Among the different sesame varieties, the maximum harvest index (44.22%) was obtained from V_5 (BARI til 4) which was statistically similar with V_4 (BARI til-3). The lowest harvest index (41.60%) was observed from local variety V_1 (Lal til) followed by local variety V_2 (Atshira). Similar result was also found by Balasubramaniyan *et al.* (1995) and they opined that different variety had significant effect on harvest index. They also opined that HYV possess higher harvest index than check variety. Ali and Jan (2014) also found significant variation with sesame varieties on harvest index.

Harvest index was significantly influenced by combined effect of different levels of nutrients and varieties (Table 4.10 and Appendix XLII). Results signified that combination between different nutrient levels and varieties, N_2V_5 listed the maximum harvest index (46.34%) followed by N_2V_6, and N_2V_4. The lowest harvest indexwas recorded from N_4V_2 (35.87%) followed by N_4V_1 and N_4V_5.

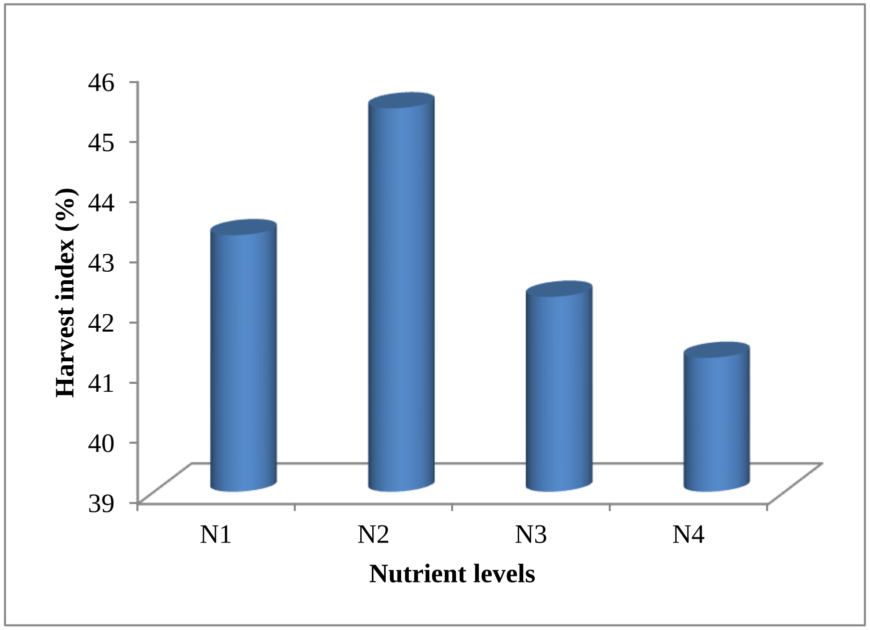

Fig. 4.23 Harvest index of sesame as influenced by different levels of nutrients during March-June 2014 (1st year experiment) ($LSD_{0.05}$ = 0.679)

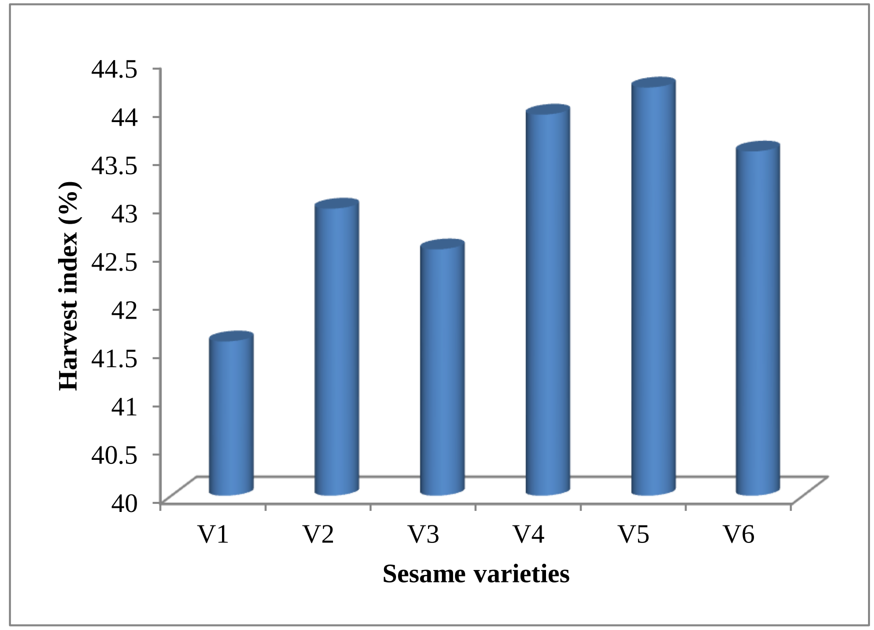

Fig. 4.24 Harvest index of sesame as influenced by different varieties during March-June 2014 ($LSD_{0.05}$ = 0.713)

N_1 = 75% of RDF (43:54:23 kg N, P_2O_5 and K_2O ha^{-1}), N_2 = 100% of RDF (58:72:30 kg N, P_2O_5 and K_2O ha^{-1}), N_3 = 125% of RDF (72:90:38 kg N, P_2O_5 and K_2O ha^{-1}), N_4 = 150% of RDF (86:108:45 kg N, P_2O_5 and K_2O ha^{-1})

V_1 = Lal til (Local), V_2 = Atshira (Local), V_3 = T-6, V_4 = BARI til-3, V_5 = BARI til-4, V_6 = Bina til 2

Table 4.10 Combined effect of different levels of nutrients and varieties on Yield parameters of sesame during March-June 2014

Treatment	Yield parameters		
	Seed yield ha^{-1} (kg)	Stover yield ha^{-1} (kg)	Harvest index (%)
N_1V_1	908.00	1203.00	42.85
N_1V_2	965.30	1247.00	42.66
N_1V_3	974.70	1280.00	43.23
N_1V_4	990.70	1317.00	41.76
N_1V_5	1005.00	1343.00	40.22
N_1V_6	984.00	1286.00	41.62
N_2V_1	868.00	1182.00	39.52
N_2V_2	961.30	1239.00	43.53
N_2V_3	1161.00	1622.00	42.10
N_2V_4	1449.00	1706.00	45.93
N_2V_5	1481.00	1715.00	46.34
N_2V_6	1408.00	1664.00	45.83
N_3V_1	798.70	1128.00	38.91
N_3V_2	958.70	1238.00	43.62
N_3V_3	1105.00	1512.00	42.17
N_3V_4	1132.00	1530.00	41.42
N_3V_5	1135.00	1621.00	38.15
N_3V_6	1120.00	1519.00	40.32
N_4V_1	670.70	1043.00	36.92
N_4V_2	756.00	1106.00	35.87
N_4V_3	1011.0	1356.00	42.98
N_4V_4	1027.00	1468.00	39.61
N_4V_5	1059.00	1489.00	39.18
N_4V_6	1021.00	1438.00	42.03
$LSD_{0.05}$	33.22	41.16	0.7933
CV (%)	13.57	14.28	8.76

N_1 = 75% of RDF (43:54:23 kg N, P_2O_5 and K_2O ha^{-1}), N_2 = 100% of RDF (58:72:30 kg N, P_2O_5 and K_2O ha^{-1}), N_3 = 125% of RDF (72:90:38 kg N, P_2O_5 and K_2O ha^{-1}), N_4 = 150% of RDF (86:108:45 kg N, P_2O_5 and K_2O ha^{-1})

V_1 = Lal til (Local), V_2 = Atshira (Local), V_3 = T-6, V_4 = BARI til-3, V_5 = BARI til-4, V_6 = Bina til 2

4.2 2nd year (March-June 2015) and 3rd year (March-June 2016) Experiments: Influence of spacing and intregated nutrients on the seed yield, oil and protein content yield of sesame

4.2.1 Growth parameters

4.2.1.1 Plant height

Different sources of plant nutrients applied to sesame showed significant variation in terms of plant height in both the years of March-June 2015 and 2016 i.e. 2nd and 3rd experiment respectively (Fig. 4.25 and Appendix XXIII and XLIII). Results revealed that nutrient source from synthetic fertilizer for sesame showed highest plant height at all growth stages in both the years. With this regard, application of 100% of RDF through synthetic fertilizer (T_1) showed the tallest plants (29.68, 83.29, 104.80, 103.90 and 99.97 cm in the 2nd experiment and 30.03, 83.50, 104.95, 104.28 and 100.07 cm in the 3rd experiment at 30, 45, 60, 75 DAS and at harvest, respectively) followed by T_5 (25% RDF through vermicompost + 75% as chemical fertilizer) and T_9 (25% RDF through FYM + 75% as chemical fertilizer) where the shortest plant (26.66, 71.94, 98.38, 97.54 and 93.05 cm in the 2nd experiment and 27.35, 72.32, 98.57, 98.04 and 93.36 cm in the 3rd experiment at 30, 45, 60, 75 DAS and at harvest, respectively) was recorded with T_6 (100% RDF through FYM) followed by T_7 (75% RDF through FYM + 25% as chemical fertilizer) and T_2 (100% RDF through vermicomost). Deshmukh *et al.* (2002) reported that application of 50 percent N through urea + 50 percent N through FYM + 50 percent P and 100 percent K through fertilizer produced the highest plant height. Thanunathan *et al.* (2001) found that combined application of FYM @ 12.5 t ha^{-1} and 100 percent chemical fertilizer (35:23:23 kg N, P_2O_5 and K_2O ha^{-1}) registered the tallest plants.

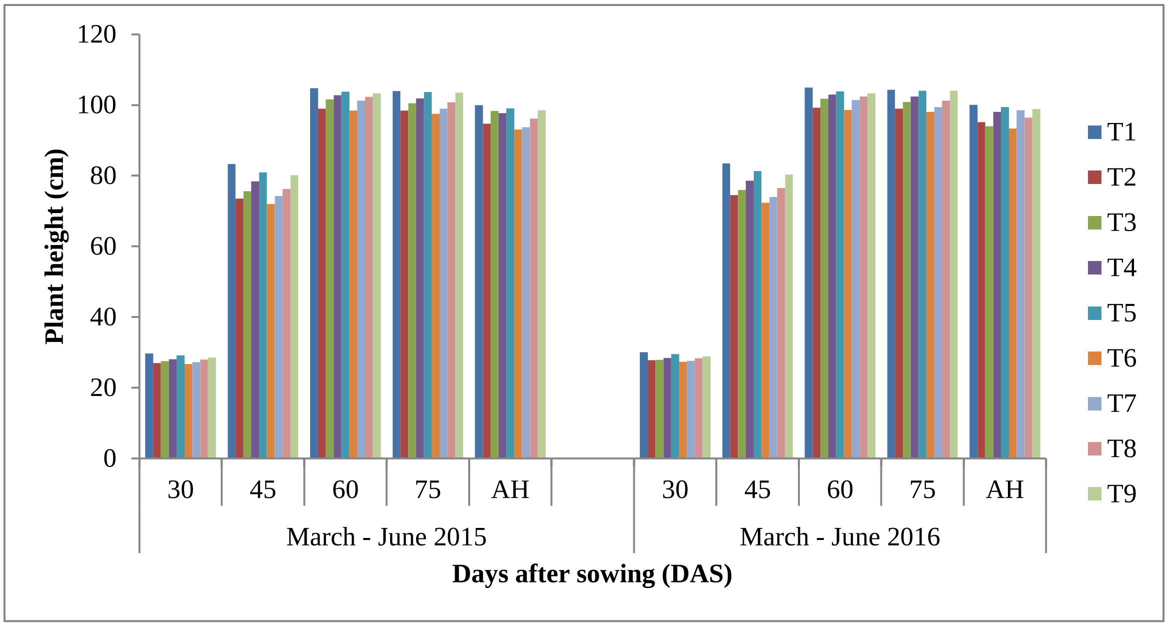

Fig. 4.25 Plant height of sesame as influenced by different sources of plant nutrients during 2015 and 2016 ($LSD_{0.05}$ = 0.598, 0.984, 0.857, 0.854 and 0.857 in 2015 and 0.584, 0.871, 0.883, 0.868 and 0.796 in 2016 at 30, 45, 60, 75 DAS and at harvest, respectively)

T_1=RDF (Selected as best treatment from 1st year experiment studies; 56:72:23 kg N, P_2O_5 and K_2O ha^{-1}), T_2=100% RDF through vermicomost, T_3=75% RDF through vermicomost + 25 % as chemical fertilizer, T_4=50% RDF through vermicompost + 50% as chemical fertilizer, T_5=25% RDF through vermicompost + 75% as chemical fertilizer, T_6=100% RDF through FYM, T_7=75% RDF through FYM + 25% as chemical fertilizer, T_8=50% RDF through FYM + 50% as chemical fertilizer and T_9=25% RDF through FYM + 75% as chemical fertilizer

Plant height also differed significantly with different plant spacing in both the years of March-June 2015 and March-June 2016 i.e. 2nd and 3rd experiment respectively (Fig. 4.26 and Appendix XXIV and XLIII). Maintaining different plant spacing, closer spacing showed higher plant height. With this consideration, S_1 (30 cm × 5 cm; 400 plants $plot^{-1}$) showed the tallest plant (31.97, 90.20, 108.30, 110.40 and 106.40 cm in the 2nd experiment and 32.32, 90.48, 108.42, 110.69 and 106.43 cm in the 3rd experiment at 30, 45, 60, 75 DAS and at harvest, respectively) where S_2 (30 cm × 10 cm; 200 plants $plot^{-1}$) registered the plant height came next in order. The least plant height (23.94, 62.57, 93.9992.54 and 85.93 cm in the 2nd experiment and 2324.62, 62.82, 94.19, 92.93 and 86.21 cm in the 3rd experiment at 30, 45, 60, 75 DAS and at harvest, respectively) was observed from S_4 (30 cm × 20 cm; 100 plants $plot^{-1}$) followed by S_3 (30 cm × 15 cm; 130 plants $plot^{-1}$). Ghosh and Patra (1993) observed that plant height was unaffected with increasing density. Majumdar and Roy (1992) also found increased spacing showed decreased plant height significantly. But Caliskan *et al.* (2004) observed plant height decreased with increasing plant population.

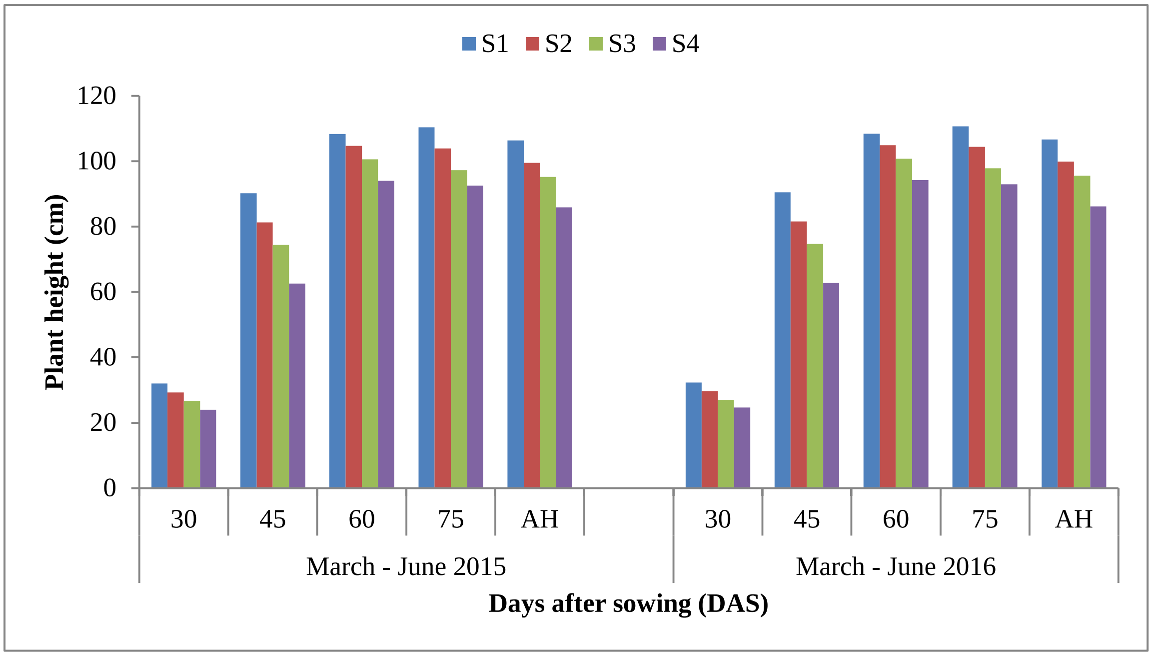

Fig. 4.26 Plant height of sesame influenced by different plant spacing during 2015 and 2016 ($LSD_{0.05}$ = 0.434, 0.656, 0.667, 0.789 and 0.711 in 2015 and 0.448, 0.576, 0.659, 0.714 and 0.723 in 2016 at 30, 45, 60, 75 DAS and at harvest, respectively)

S_1=30 cm × 5 cm (400 plants plot^{-1}), S_2=30 cm × 10 cm (200 plants plot^{-1}), S_3=30 cm × 15 cm (130 plants plot^{-1}) and S_4=30 cm × 20 cm (100 plants plot^{-1})

Regarding the combined effect of different sources of nutrients with different plant spacing indicated significant variation in case of plant height in both the years of March-June 2015 and March-June 2016, respectively (Table 4.11 and Appendix XLIII). It was found that the maximum plant height (34.50, 100.50, 112.80, 115.50 and 108.00 cm in the 2nd experiment and 34.82, 100.79, 112.71, 115.84 and 108.23 cm in the 3rd experiment at 30, 45, 60, 75 DAS and at harvest, respectively) was obtained by T_1S_1 which was closely followed by T_5S_1 for both the seasons. During both the cropping seasons, all growth stages under observation, the shortest plants were recorded with T_6S_4 (21.77, 52.39, 85.35, 87.55 and 74.85 cm in the 2nd experiment and 23.02, 52.68, 85.55, 88.06 and 75.22 cm in the 3rd experiment at 30, 45, 60, 75 DAS and at harvest, respectively) which was statistically similar with T_7S_4 for both the seasons.

Table 4.11 Combined effect of different sources of plant nutrient sources and spacing on plant height of sesame during March – June 2015 and March – June 2016

Treatment	Plant height (cm)									
	2nd Experiment (March-June 2015)					3rd Experiment (March-June 2016)				
	30 DAS	45 DAS	60 DAS	75 DAS	At harvest	30 DAS	45 DAS	60 DAS	75 DAS	At harvest
T_1S_1	34.50	100.5	112.80	115.50	108.00	34.82	100.79	112.71	115.84	108.23
T_1S_2	30.71	85.42	106.10	105.40	102.20	31.09	85.42	106.30	105.78	101.83
T_1S_3	27.87	76.73	102.80	98.80	96.37	28.21	77.02	103.12	99.31	96.74
T_1S_4	25.67	70.49	97.47	96.02	93.31	26.00	70.78	97.67	96.19	93.68
T_2S_1	30.75	87.10	106.90	106.40	105.00	31.10	87.76	107.10	106.91	105.37
T_2S_2	28.33	77.71	104.20	103.00	97.28	28.67	78.00	104.67	103.51	97.89
T_2S_3	26.23	71.95	98.45	96.20	97.27	26.59	72.24	98.65	96.64	94.85
T_2S_4	22.65	57.42	86.46	88.15	82.13	25.15	57.71	86.66	88.66	83.20
T_3S_1	30.88	87.27	107.30	108.80	106.40	31.23	87.56	107.50	109.31	106.30
T_3S_2	29.16	79.90	104.50	103.60	98.32	29.51	80.52	104.87	103.91	98.69
T_3S_3	26.36	74.43	99.13	96.70	94.67	26.71	74.72	99.33	97.21	95.04
T_3S_4	23.64	60.63	95.27	92.85	94.48	23.98	60.92	95.47	93.08	82.50
T_4S_1	32.17	91.10	108.30	109.50	106.60	32.52	91.39	108.40	110.01	106.97
T_4S_2	29.43	82.86	104.80	104.70	100.70	29.77	82.83	105.00	105.21	101.17
T_4S_3	26.72	75.16	101.80	97.96	95.87	27.07	75.45	102.00	98.47	96.24
T_4S_4	24.10	64.47	96.37	95.39	87.54	24.45	64.76	96.57	95.90	87.91
T_5S_1	33.59	92.49	109.50	115.30	107.80	33.94	92.78	109.53	115.38	108.03
T_5S_2	30.15	84.70	105.50	105.30	101.30	30.52	85.17	105.70	105.81	101.67
T_5S_3	27.36	76.27	102.70	98.37	96.27	27.71	76.56	102.90	98.88	96.64
T_5S_4	25.35	70.31	97.22	95.85	90.91	25.70	70.60	97.42	96.08	90.97
T_6S_1	30.71	87.03	106.50	106.30	104.50	31.07	87.32	106.70	106.81	104.87
T_6S_2	28.15	77.25	103.20	100.20	97.19	28.50	77.88	103.40	100.71	97.56
T_6S_3	25.99	71.09	98.43	96.07	94.21	26.34	71.38	98.63	96.56	94.58
T_6S_4	21.77	52.39	85.35	87.55	74.85	23.02	52.68	85.55	88.06	75.22
T_7S_1	30.86	87.13	107.00	107.40	105.10	31.21	87.24	107.28	107.91	105.10
T_7S_2	28.50	78.13	104.30	103.50	97.65	28.85	78.42	104.50	104.01	98.02
T_7S_3	26.33	74.11	99.00	96.44	94.59	26.67	74.40	99.20	96.95	95.09
T_7S_4	23.25	57.60	94.58	88.37	75.35	23.60	57.89	94.78	88.88	75.72
T_8S_1	31.95	87.55	107.70	108.90	106.50	32.30	87.84	107.90	108.78	106.87
T_8S_2	29.34	81.57	104.60	104.20	100.30	29.68	81.65	104.27	104.98	100.57
T_8S_3	26.65	74.65	100.90	96.73	94.76	27.00	74.94	101.10	97.24	95.13
T_8S_4	24.00	61.22	96.11	93.25	82.83	24.35	61.51	96.31	93.76	96.88
T_9S_1	32.34	91.67	108.50	115.10	107.80	32.71	91.67	108.70	115.24	107.90
T_9S_2	29.76	84.46	105.30	105.10	101.20	30.11	84.75	105.50	105.61	101.57
T_9S_3	26.89	75.92	102.40	98.32	96.04	27.24	76.21	101.80	99.39	96.06
T_9S_4	25.02	68.57	97.04	95.42	89.14	25.36	68.57	97.31	95.79	89.79
$LSD_{0.05}$	0.5970	1.967	1.153	2.365	2.132	0.834	1.009	1.352	2.114	1.793
CV (%)	4.57	7.56	9.20	10.43	8.35	6.56	8.33	9.23	7.12	8.53

T_1=RDF (Selected as best treatment from 1st year studies and hencehere after referred as RDF), T_2=100% RDF through vermicomost, T_3=75% RDF through vermicomost + 25 % as chemical fertilizer, T_4=50% RDF through vermicompost + 50% as chemical fertilizer, T_5=25% RDF through vermicompost + 75% as chemical fertilizer, T_6=100% RDF through FYM, T_7=75% RDF through FYM + 25% as chemical fertilizer, T_8=50% RDF through FYM + 50% as chemical fertilizer and T_9=25% RDF through FYM + 75% as chemical fertilizer, S_1=30 cm × 5 cm (400 plants plot^{-1}), S_2=30 cm × 10 cm (200 plants plot^{-1}), S_3=30 cm × 15 cm (130 plants plot^{-1}) and S_4=30 cm × 20 cm (100 plants plot^{-1})

4.2.1.2 Number of leaves plant^{-1}

Different sources of plant nutrients applied to sesame showed significant variation in terms of number of leaves plant^{-1}in both the years of March-June 2015 and March-June 2016, respectively (Fig. 4.27 and Appendix XXV and XLIV). Among the treatments, T_5 (25% RDF through vermicompost + 75% as chemical fertilizer) showed the highest number of leaves plant^{-1} (9.33, 20.75, 36.42, 41.17 and 34.75 at 30, 45, 60, 75 DAS and at harvest, respectively) during March-June, 2015 (Fig. 4.27); the corresponding value during March-June, 2016 (9.34, 20.76, 36.31, 41.32 and 35.71 at 30, 45, 60, 75 DAS and at harvest, respectively) from 25% RDF through vermicompost + 75% as chemical fertilizer (T_5) was on par with T_1(100% RDF through chemical fertilizer) at all the situations (Fig. 4.27). The lowest number of leaves plant^{-1} (8.58, 18.67, 34.33, 39.75 and 33.00 at 30, 45, 60, 75 DAS and at harvest, respectively) was recorded with T_6 (100% RDF through FYM) during March-June, 2015; the consequent value during March-June, 2016 i.e. 3rd experiment (8.56, 18.79, 34.34, 39.85 and 34.16 at 30, 45, 60, 75 DAS and at harvest respectively) was also obtained from T_6 (100% RDF through FYM) that was on par with T_2 (100% RDF through vermicomost). Haruna *et al.* (2010) found that number of leaves plant^{-1} was the highest with integrated application of poultry manure (15 t ha^{-1}), N (120 kg ha^{-1}) and P_2O_5 (13.2 kg ha^{-1}).

Number of leaves plant^{-1} also differed significantly with different plant spacing in both the years of March-June 2015 and March-June 2016 i.e. 2nd and 3rd experiment respectively (Fig. 4.28 and Appendix XXVI and XLIV). Maintaining different plant spacing, closer spacing showed lower number of leaves plant^{-1}. Results reveled that S_3 (30 cm × 15 cm; 130 plants plot^{-1}) showed the maximum number of leaves plant^{-1} (9.33, 20.83, 37.26, 42.00 and 34.96 at 30, 45, 60, 75 DAS and at harvest, respectively) during March-June 2015. S_3 (30 cm × 15 cm; 130 plants plot^{-1}) also showed maximum number of leaves plant^{-1} (9.29, 20.91, 37.22, 42.09 and 34.89 at 30, 45, 60, 75 DAS and at harvest respectively) during March-June 2016 followed by S_4 (30 cm × 20 cm; 100 plants plot^{-1}) at all the situations. The lowest number of leaves plant^{-1} (8.56, 18.07, 32.74, 38.59 and 32.33 during 2nd experiment and 63, 18.10, 32.68, 38.72 and 33.33 during 3rd experiment at 30, 45, 60, 75 DAS and at harvest, respectively) was observed from S_1 (30 cm × 5 cm; 400 plants plot^{-1}) followed by S_2 (30 cm × 10 cm; 200

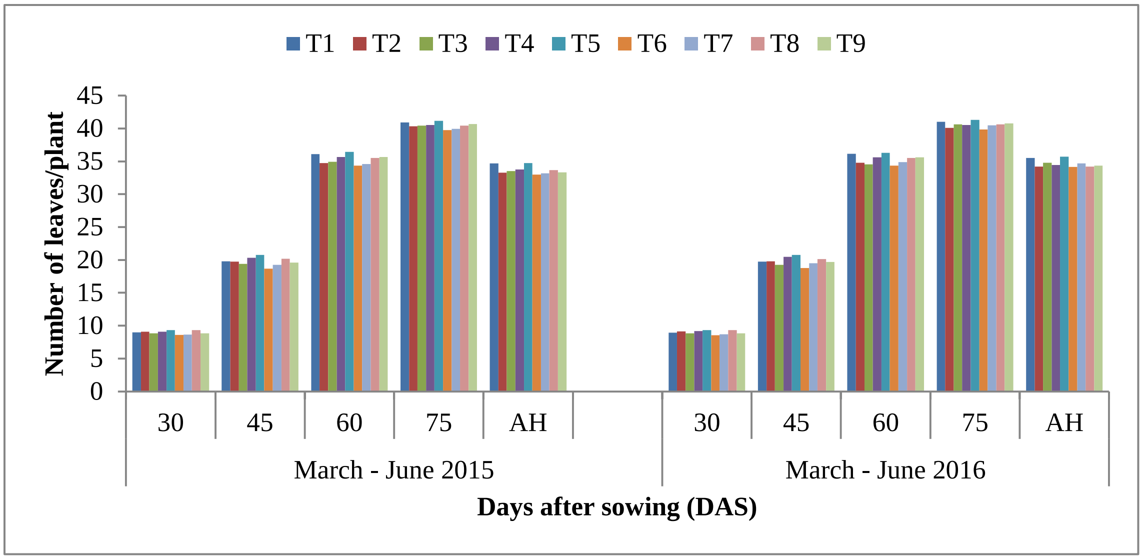

Fig. 4.27 Number of leaves plant^{-1} of sesame as influenced by different sources of plant nutrients during 2015 and 2016 ($LSD_{0.05}$ = 0.212, 0.342, 0.372, 0.403 and 0.455 in 2015 and 0.207, 0.335, 0.381, 0.426 and 0.461 in 2016 at 30, 45, 60, 75 DAS and at harvest, respectively)

T_1=100% RDF through chemical fertilizer, T_2=100% RDF through vermicomost, T_3=75% RDF through vermicomost + 25 % as chemical fertilizer, T_4=50% RDF through vermicompost + 50% as chemical fertilizer, T_5=25% RDF through vermicompost + 75% as chemical fertilizer, T_6=100% RDF through FYM, T_7=75% RDF through FYM + 25% as chemical fertilizer, T_8=50% RDF through FYM + 50% as chemical fertilizer and T_9=25% RDF through FYM + 75% as chemical fertilizer

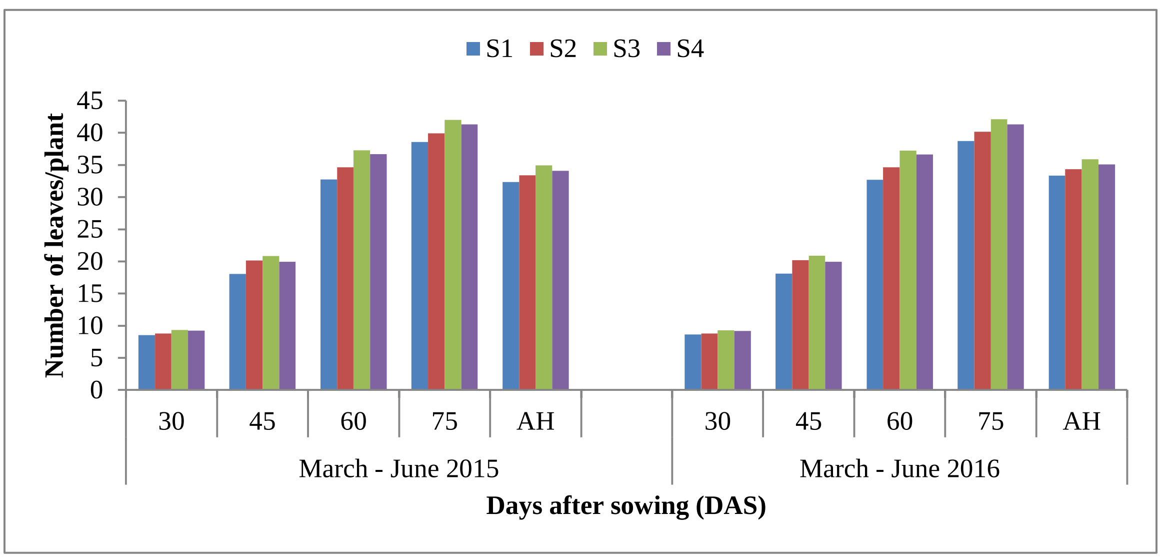

Fig. 4.28 Number of leaves plant^{-1} of sesame as influenced by plant spacing during 2015 and 2016 ($LSD_{0.05}$ = 0.286, 0.228, 0.281, 0.206 and 0.239 in 2015 and 0.206, 0.235, 0.291 0.216 and 0.229 in 2016 at 30, 45, 60, 75 DAS and harvest, respectively)

S_1=30 cm × 5 cm (400 plants plot^{-1}), S_2=30 cm × 10 cm (200 plants plot^{-1}), S_3=30 cm × 15 cm (130 plants plot^{-1}) and S_4=30 cm × 20 cm (100 plants plot^{-1})

plants plot^{-1}) at all the situations. Such results on number of leaves plant^{-1} might be due to cause of differed plant spacing. Higher plant spacing provide more sunlight, more branching advantages and above all less competition of nutrient uptake. Similar results were observed by Samson (2005) and reported a significant increase in number of leaves plant^{-1} at wide intra row spacing of 15cm than 10cm. Umar *et al*. (2012) found that narrow intra row spacing of 5 cm between plants significantly decreases number of leaves (NL).

Regarding the combined effect of different sources of nutrients with different plant spacing pointed out significant variation in case of number of leaves plant^{-1}in both the years of March-June 2015 and March-June, 2016, respectively (Table 4.12 and Appendix XLIV). It was found that the maximum number of leaves plant^{-1}from 2nd experiment (10.00, 24.33, 40.00, 43.67 and 36.67 at 30, 45, 60, 75 DAS and at harvest respectively) was obtained by $T_5S_3$and from the 3rd experiment the maximum number of leaves plant^{-1} (10.03, 24.26, 39.98, 43.77 and 37.44 at 30, 45, 60, 75 DAS and at harvest respectively) was obtained from the same treatment combination followed by T_1S_3, T_3S_3at all the situations. Again, the lowestnumber of leaves plant^{-1} from 2nd experiment (March-June, 2015) was recorded fromT_6S_1 (7.67, 16.33, 30.67, 37.67 and 30.00 at 30, 45, 60, 75 DAS and at harvest, respectively); the parallel value during March-June, 2016 (3rd experiment) (8.26, 16.37, 30.42, 37.88 and 30.89 at 30, 45, 60, 75 DAS and at harvest, respectively) was also recorded from T_6S_1 followed by T_2S_2, T_7S_1 and T_9S_1 at all the situations.

Table 4.12 Combined effect of different sources of plant nutrients and spacings on number of leaves plant^{-1} of sesame during March – June 2015 and 2016

Treatment	Number of leaves plant^{-1}									
	2nd Experiment					3rd Experiment				
	30 DAS	45 DAS	60 DAS	75 DAS	At harvest	30 DAS	45 DAS	60 DAS	75 DAS	At harvest
T_1S_1	8.67	19.67	33.33	39.00	32.33	8.81	19.48	33.53	39.43	33.21
T_1S_2	9.00	19.67	35.00	40.33	35.33	8.92	19.82	35.31	40.48	36.21
T_1S_3	9.00	21.43	39.67	43.00	36.33	8.70	21.32	39.42	42.76	37.21
T_1S_4	9.33	18.33	36.33	41.33	34.67	9.37	18.37	36.31	41.32	35.44
T_2S_1	8.67	17.33	32.00	38.33	33.00	8.70	17.37	31.98	38.43	34.16
T_2S_2	8.00	20.00	34.67	39.33	32.00	8.03	20.20	34.76	39.65	32.83
T_2S_3	10.00	20.33	35.33	40.33	33.33	10.14	20.37	35.31	40.43	34.32
T_2S_4	9.67	21.33	37.00	41.67	34.33	9.59	21.26	36.98	41.77	35.32
T_3S_1	8.33	17.00	33.00	38.67	33.67	7.70	17.04	32.64	38.88	34.66
T_3S_2	8.33	18.67	34.33	40.00	30.33	8.37	18.71	34.53	40.43	31.21
T_3S_3	9.33	23.00	35.33	42.33	36.00	9.26	23.04	35.31	42.32	34.66
T_3S_4	9.00	18.33	35.67	40.67	35.00	8.92	18.26	35.76	40.77	36.33
T_4S_1	9.00	19.67	33.33	38.67	33.00	9.03	19.71	33.31	38.77	33.99
T_4S_2	9.33	20.67	34.67	40.00	32.67	9.37	20.71	34.65	39.93	34.44
T_4S_3	9.33	18.00	36.33	41.00	34.67	9.26	18.04	36.20	41.10	35.66
T_4S_4	9.67	23.00	38.33	42.33	33.67	9.70	23.37	38.31	42.32	33.66
T_5S_1	8.67	18.00	33.67	39.33	31.67	8.81	18.04	33.65	39.43	32.66
T_5S_2	8.67	22.33	35.00	40.33	32.00	8.70	22.37	34.64	40.65	33.16
T_5S_3	10.00	24.33	40.00	43.67	36.67	10.03	24.26	39.98	43.77	37.44
T_5S_4	9.00	18.33	37.00	41.33	35.33	9.14	18.37	36.98	41.43	36.32
T_6S_1	7.67	16.33	30.67	37.67	30.00	8.26	16.37	30.42	37.88	30.99
T_6S_2	9.00	18.67	34.33	39.33	35.33	9.03	18.71	34.31	39.43	36.32
T_6S_3	9.00	19.00	37.00	41.67	35.00	9.03	19.37	37.31	41.77	35.83
T_6S_4	9.00	20.67	35.33	40.33	32.67	8.92	20.71	35.31	40.32	33.66
T_7S_1	9.00	18.33	32.33	38.33	32.00	9.03	18.59	32.31	38.32	32.93
T_7S_2	9.00	19.00	34.33	40.00	33.33	9.14	19.04	34.20	40.10	34.32
T_7S_3	8.33	21.67	37.33	42.33	35.67	8.37	21.71	37.31	42.65	36.66
T_7S_4	8.33	18.67	35.67	40.67	33.67	8.37	18.71	35.65	40.77	34.77
T_8S_1	8.67	18.00	33.00	38.67	34.33	8.70	18.04	32.98	38.77	36.32
T_8S_2	9.33	22.67	34.67	40.00	33.33	9.37	22.48	34.76	40.43	36.99
T_8S_3	9.67	18.67	36.00	40.67	36.00	9.59	18.71	35.98	40.77	34.21
T_8S_4	9.67	21.33	38.33	42.33	35.33	9.70	21.37	38.31	42.43	35.32
T_9S_1	8.33	18.33	33.33	38.67	30.00	8.48	18.26	33.31	38.54	31.06
T_9S_2	8.33	19.67	34.67	40.00	32.67	8.37	19.82	34.76	40.43	33.77
T_9S_3	9.33	21.00	38.33	43.00	33.67	9.26	21.37	38.20	43.26	36.99
T_9S_4	9.33	19.33	36.33	41.00	34.00	9.15	19.26	36.20	40.93	35.16
$LSD_{0.05}$	0.445	0.5599	0.7448	1.088	0.741	0.328	0.421	0.535	0.486	0.449
CV (%)	11.55	16.63	8.82	8.25	9.34	6.34	7.22	9.32	8.33	7.13

T_1=100% RDF through chemical fertilizer, T_2=100% RDF through vermicomost, T_3=75% RDF through vermicomost + 25 % as chemical fertilizer, T_4=50% RDF through vermicompost + 50% as chemical fertilizer, T_5=25% RDF through vermicompost + 75% as chemical fertilizer, T_6=100% RDF through FYM, T_7=75% RDF through FYM + 25% as chemical fertilizer, T_8=50% RDF through FYM + 50% as chemical fertilizer and T_9=25% RDF through FYM + 75% as chemical fertilizer, S_1=30 cm × 5 cm (400 plants plot^{-1}), S_2=30 cm × 10 cm (200 plants plot^{-1}), S_3=30 cm × 15 cm (130 plants plot^{-1}) and S_4=30 cm × 20 cm (100 plants plot^{-1})

4.2.1.3 Number of branches plant^{-1}

Significant varation was found for number of branches plant^{-1} influenced by different sources of plant nutrients applied to sesame in both the years of March-June, 2015 and 2016, respectively (Fig. 4.29 and Appendix XXVII and XLV). Results revealed that T_5 (25% RDF through vermicompost + 75% as chemical fertilizer)showed the highest number of branches plant^{-1} (6.33, 6.50, 7.00 and 7.58 at 45, 60, 75 DAS and at harvest, respectively) in the 2nd experiment (March-June, 2015) followed by T_1(100% RDF through chemical fertilizer) and T_4(50% RDF through vermicompost + 50% as chemical fertilizer). Treatment, T_5 (25% RDF through vermicompost + 75% as chemical fertilizer) also showed the highest number of branches plant^{-1} (6.48, 7.11, 7.67 and 8.14 at 45, 60, 75 DAS and at harvest, respectively) in the 3rd experiment (March-June, 2016) followed by T_1 (100% RDF through chemical fertilizer), T_3 (75% RDF through vermicomost + 25 % as chemical fertilizer), T_4 (50% RDF through vermicompost + 50% as chemical fertilizer) and T_9 (25% RDF through FYM + 75% as chemical fertilizer).The lowest number of branches plant^{-1} (5.67, 6.00, 6.33 and 6.75 at 45, 60, 75 DAS and at harvest respectively in the 2nd experiment and 5.87, 6.78, 7.01 and 7.34 at 45, 60, 75 DAS and at harvest respectively in the 3rd experiment) was recorded with T_6 (100% RDF through FYM) followed by T_2 (100% RDF through vermicomost)at all the situations. Several findings were conformity with the present study. Number of branches plant^{-1} was highest with integrated application of poultry manure (15 t ha^{-1}), N (120 kg ha^{-1}) and P_2O_5 (13.2 kg ha^{-1}) (Haruna *et al.*, 2010). Deshmukh *et al.* (2002) reported that application of 50 percent N through urea + 50 percent N through FYM + 50 percent P and 100 percent K through fertilizer produced the highest number of branches plant^{-1}. Thanunathan *et al.* (2001) found that combined application of FYM @ 12.5 t ha^{-1} and 100 percent chemical fertilizer (35:23:23 kg N, P_2O_5 and K_2O ha^{-1}) registered the largest number of branches plant^{-1}.

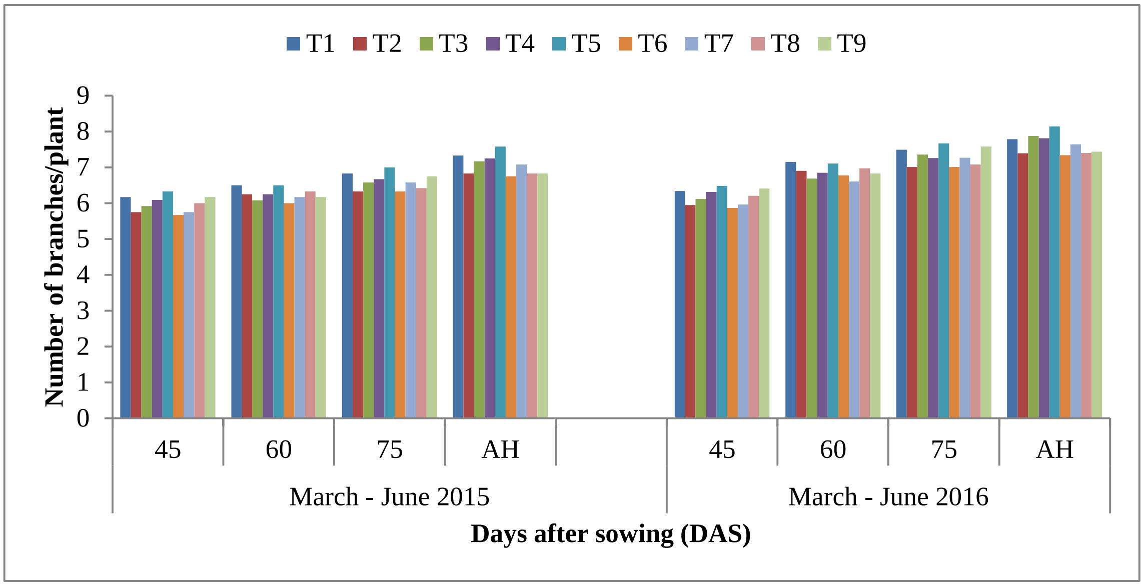

Fig. 4.29 Number of branches plant^{-1} of sesame as influenced by different plant nutrient sourcesduring 2015 and 2016 ($LSD_{0.05}$ = 0.121, 0.137, 0.146 and 0.190 in 2015 and 0.116, 0.135, 0.149 and 0.187 in 2016 at 45, 60, 75 DAS and at harvest respectively)

T_1= 100% RDF through chemical fertilizer, T_2=100% RDF through vermicomost, T_3=75% RDF through vermicomost + 25 % as chemical fertilizer, T_4=50% RDF through vermicompost + 50% as chemical fertilizer, T_5=25% RDF through vermicompost + 75% as chemical fertilizer, T_6=100% RDF through FYM, T_7=75% RDF through FYM + 25% as chemical fertilizer, T_8=50% RDF through FYM + 50% as chemical fertilizer and T_9=25% RDF through FYM + 75% as chemical fertilizer

Number of branches plant^{-1} also differed significantly with different plant spacingsin both the years of March-June 2015 and 2016, respectively (Fig. 4.30 and Appendix XXVIII and XLV). Results exposed that S_3(30 cm × 15 cm; 130 plants plot^{-1}) showed the maximum number of branches plant^{-1} (6.44, 6.56, 7.00 and 7.44 at 45, 60, 75 DAS and at harvest, respectively) in the 2nd experiment and also in the 3rd experiment (6.64, 6.17, 7.69 and 8.03 at 45, 60, 75 DAS and at harvest, respectively) followed by S_4 (30 cm × 20 cm; 100 plants plot^{-1}) at all the situations. The lowest number of branches plant^{-1} in the 2nd experiment (5.33, 5.70, 6.11 and 6.37 at 45, 60, 75 DAS and at harvest, respectively) was observed from S_1 (30 cm × 5 cm; 400 plants plot^{-1}) and this spacing treatment also gave lowest number of branches plant^{-1} in the 3rd experiment (5.54, 6.34, 6.79 and 6.93 at 45, 60, 75 DAS and at harvest, respectively) followed by S_2 (30 cm × 10 cm; 200 plants plot^{-1}) at all the situations.The present findings were also supported by several research works. Fard and Bahrani (2005) observed that plant density exhibited significant effects on number of branches per plant. Caliskan *et al*. (2004) found that population density significantly affected branch number, and it is decreased with increasing plant population. Ghosh and Patra (1993) were also observed that degree of branching decreased with increasing density.

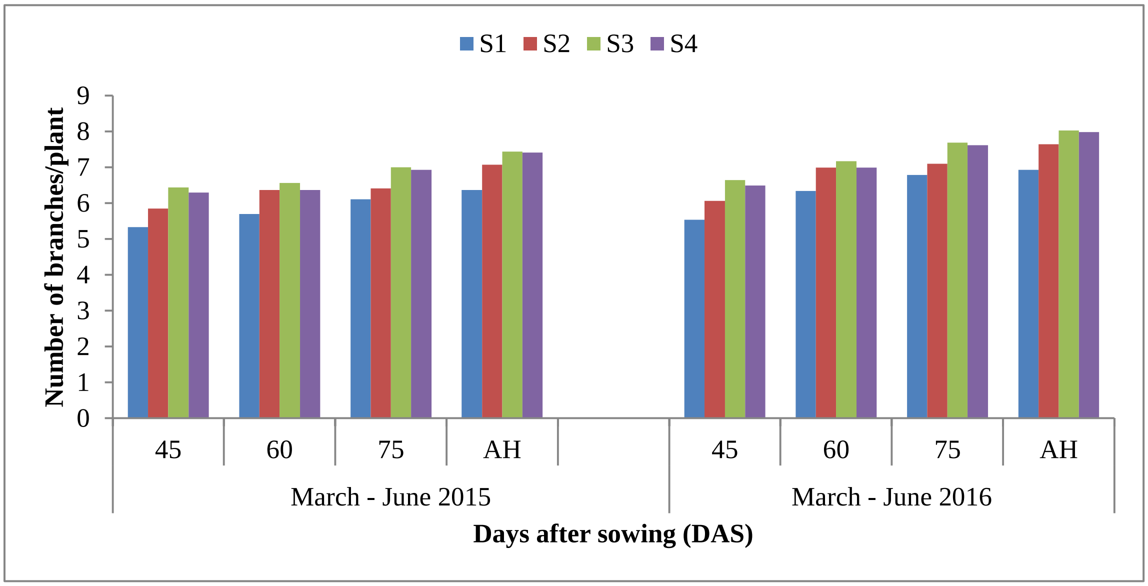

Fig. 4.30 Number of branches plant^{-1} of sesame as influenced by plant spacingduring 2015 and 2016 ($LSD_{0.05}$ = 0.104, 0.118, 0.120 and 0.140 in 2015 and 0.124, 0.127, 0.108 and 0.151 in 2016 at 45, 60, 75 DAS and at harvest, respectively)

S_1=30 cm × 5 cm (400 plants plot^{-1}), S_2=30 cm × 10 cm (200 plants plot^{-1}), S_3=30 cm × 15 cm (130 plants plot^{-1}) and S_4=30 cm × 20 cm (100 plants plot^{-1})

Different sources of plant nutrients with different plant spacing showed significant variation on number of branches plant^{-1}in both the years of March-June 2015 and March-June 2016, respectively (Table 4.13 and Appendix XLV). In the 2nd experiment the maximum number of branches plant^{-1}(7.00, 7.33, 7.67 and 8.33 at 45, 60, 75 DAS and at harvest, respectively) was obtained by the treatment combination of T_5S_3 and this combination also gave highest number of branches plant^{-1} (7.39, 7.97, 8.43 and 8.87 at 45, 60, 75 DAS and at harvest, respectively) in the 3rd experiment which was statistically similar with T_1S_3 at all the situations. Again, the lowest number of branches plant^{-1} in the 2nd experiment (4.67, 4.70, 5.33 and 5.00 at 45, 60, 75 DAS and at harvest, respectively) and also in the 3rd experiment (4.84, 5.25, 6.04 and 5.53 at 45, 60, 75 DAS and at harvest, respectively) were recorded from the treatment combination of T_6S_1 followed by T_1S_1at all the situations.

Table 4.13 Combined effect of different sources of plant nutrients and spacing on number of branches plant^{-1} of sesame during March – June 2015 and 2016

Treatment	Number of branches plant^{-1}							
	2nd Experiment				3rd Experiment			
	45 DAS	60 DAS	75 DAS	At harvest	45 DAS	60 DAS	75 DAS	At harvest
T_1S_1	5.67	6.00	6.00	6.33	5.95	6.68	6.72	6.92
T_1S_2	6.00	6.33	6.00	6.67	6.17	7.01	6.75	7.31
T_1S_3	6.67	7.30	7.67	8.00	6.84	7.97	8.40	8.63
T_1S_4	6.33	6.33	7.33	7.67	6.39	6.92	8.04	8.31
T_2S_1	5.00	6.00	6.00	6.67	5.17	6.72	6.65	7.20
T_2S_2	5.67	6.67	5.67	6.67	5.84	7.25	6.43	7.20
T_2S_3	6.00	5.67	6.67	7.00	6.27	6.25	7.32	7.63
T_2S_4	6.33	6.67	7.00	7.00	6.50	7.36	7.65	7.53
T_3S_1	5.33	5.67	6.33	6.33	5.50	6.25	7.04	6.87
T_3S_2	5.67	6.33	7.00	7.00	5.95	6.92	7.65	7.60
T_3S_3	6.67	6.00	6.33	8.00	6.84	6.68	6.98	8.53
T_3S_4	6.00	6.33	7.00	8.00	6.17	6.92	7.75	8.53
T_4S_1	5.67	5.67	6.33	7.33	5.95	6.25	6.98	7.92
T_4S_2	6.00	6.33	6.33	7.00	6.17	6.97	6.98	7.53
T_4S_3	6.00	6.33	6.67	7.33	6.17	6.92	7.43	7.87
T_4S_4	6.67	6.67	7.00	7.33	6.95	7.25	7.65	7.92
T_5S_1	5.67	6.00	6.33	6.00	5.84	6.68	6.98	6.53
T_5S_2	6.00	6.33	7.33	6.33	6.17	6.92	8.04	6.87
T_5S_3	7.00	7.33	7.67	8.33	7.39	7.97	8.43	8.87
T_5S_4	6.33	7.00	6.67	7.67	6.50	7.58	7.32	8.31
T_6S_1	4.67	4.70	5.33	5.00	4.84	5.25	6.04	5.53
T_6S_2	5.67	7.00	7.00	7.67	5.95	7.58	7.65	8.31
T_6S_3	6.33	6.67	7.00	7.67	6.50	7.36	7.65	8.20
T_6S_4	6.00	6.33	7.00	7.00	6.17	6.92	7.72	7.53
T_7S_1	5.00	5.33	6.00	6.67	5.27	5.92	6.65	7.31
T_7S_2	5.67	6.33	5.67	7.00	5.84	7.01	6.32	7.53
T_7S_3	6.33	6.00	7.00	6.67	6.50	6.58	7.75	7.20
T_7S_4	6.00	6.33	6.67	6.67	6.27	6.92	7.32	7.31
T_8S_1	5.33	6.00	6.00	7.00	5.50	6.72	6.65	7.53
T_8S_2	6.00	6.33	6.33	7.67	6.17	6.92	7.04	8.53
T_8S_3	6.00	5.67	6.67	7.67	6.33	6.25	7.32	8.31
T_8S_4	6.67	7.00	7.67	8.00	6.84	7.25	7.32	8.20
T_9S_1	5.67	6.00	6.67	6.00	5.84	6.58	7.43	6.60
T_9S_2	6.00	5.67	6.33	7.33	6.27	6.36	7.04	7.92
T_9S_3	6.67	6.67	6.67	7.00	6.95	7.68	8.32	7.63
T_9S_4	6.33	6.00	6.67	7.00	6.59	6.68	7.43	7.60
$LSD_{0.05}$	0.264	0.355	0.384	0.421	0.358	0.386	0.429	0.443
CV (%)	4.06	5.32	7.08	8.54	6.337	9.275	8.624	8.937

T_1= 100% RDF through chemical fertilizer, T_2=100% RDF through vermicomost, T_3=75% RDF through vermicomost + 25 % as chemical fertilizer, T_4=50% RDF through vermicompost + 50% as chemical fertilizer, T_5=25% RDF through vermicompost + 75% as chemical fertilizer, T_6=100% RDF through FYM, T_7=75% RDF through FYM + 25% as chemical fertilizer, T_8=50% RDF through FYM + 50% as chemical fertilizer and T_9=25% RDF through FYM + 75% as chemical fertilizer, S_1=30 cm × 5 cm (400 plants plot^{-1}), S_2=30 cm × 10 cm (200 plants plot^{-1}), S_3=30 cm × 15 cm (130 plants plot^{-1}) and S_4=30 cm × 20 cm (100 plants plot^{-1})

4.2.1.4 Dry weight plant^{-1}

Significant varation was found for dry weight plant^{-1} at all growth stages except 30, 45 and 60 DAS in the 2nd experiment (March-June 2015) but in the 3rd experiment (March-June, 2016) 30 and 45 DAS showed non-significant variation among the treatments influenced by different sources of plant nutrients (Fig. 4.31 and Appendix XXIX and XLVI). In the 2nd experiment, T_5 (25% RDF through vermicompost + 75% as chemical fertilizer) gave the highest dry weight plant^{-1} (6.10.74 and 32.84 g at 75 DAS and at harvest, respectively) which was also observed in the 3rd experiment (7.38, 12.43 and 31.15 g at 60, 75 DAS and at harvest, respectively) followed by T_3 (75% RDF through vermicomost + 25 % as chemical fertilizer) at all the situations. The lowest dry weight plant^{-1}in the 2nd experiment (9.44 and 27.47 g at 75 DAS and at harvest respectively) and in the 3rd experiment ^{1} (7.15, 11.74 and 26.17 g at 75 DAS and at harvest respectively) was recorded with T_8 (50% RDF through FYM + 50% as chemical fertilizer) followed by T_6 (100% RDF through FYM) and T_9 (% RDF through FYM + 75% as chemical fertilizer) at all the situations. Several researcheswere also similar with the present study. Dry matter production (DMP) was the highest with integrated application of poultry manure (15 t ha^{-1}), N (120 kg ha^{-1}) and P_2O_5 (13.2 kg ha^{-1}) (Haruna *et al.,* 2010). El-Habbasha *et al.* (2007) opined that significantly superior DMP was recorded with 25 percent N through FYM + 75% N through urea than 50% N as FYM + 50% N as urea.

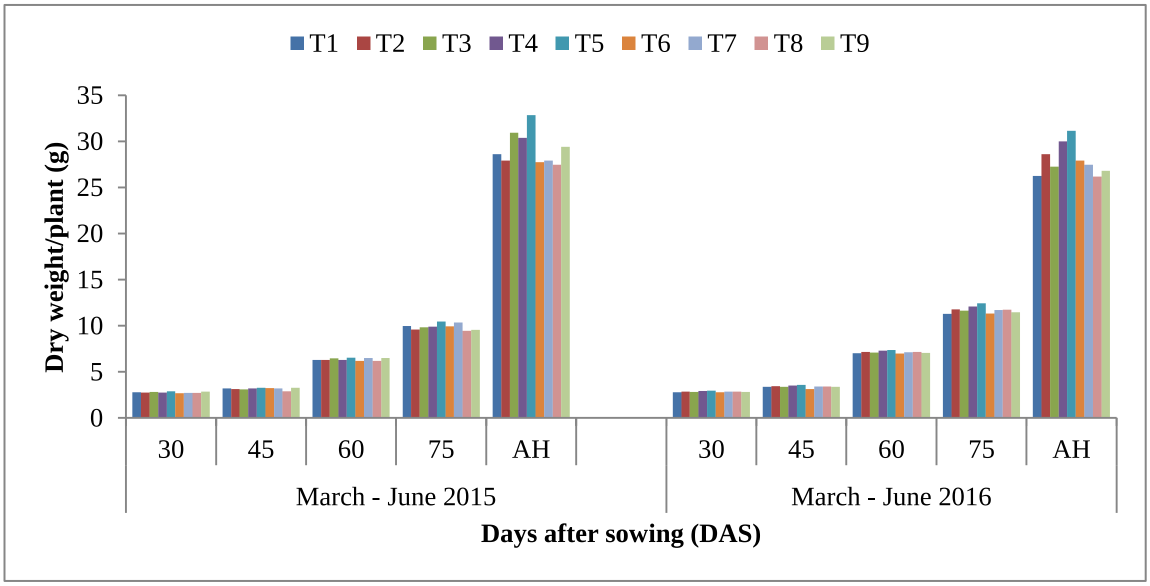

Fig. 4.31 Dry weight plant^{-1} of sesame as influenced by different plant nutrient sources during 2015 and 2016 ($LSD_{0.05}$ = NS, 0.302, 0.151, 0.197 and 0.17 in 2015 and NS, 0.316, 0.148, 0.188 and 0.169 in 2016 at 30, 45, 60, 75 DAS and at harvest, respectively)

T_1= 100% RDF through chemical fertilizer, T_2=100% RDF through vermicomost, T_3=75% RDF through vermicomost + 25 % as chemical fertilizer, T_4=50% RDF through vermicompost + 50% as chemical fertilizer, T_5=25% RDF through vermicompost + 75% as chemical fertilizer, T_6=100% RDF through FYM, T_7=75% RDF through FYM + 25% as chemical fertilizer, T_8=50% RDF through FYM + 50% as chemical fertilizer and T_9=25% RDF through FYM + 75% as chemical fertilizer

The experiment in both the years i.e. March-June 2015 and March-June, 2016 (2nd and 3rd experiment, respectively), dry weight plant^{-1}at all growth stages differed significantly except 30, 45 and 60 DAS affected by different plant spacing (Fig. 4.32 and Appendix XXX and XLVI). Results exposed that S_3(30 cm × 15 cm; 130 plants plot^{-1}) showed the maximum dry weight plant^{-1}in the 2nd experiment (2.86, 3.30, 6.60, 10.76 and 33.30 g at 30, 45, 60, 75 DAS and at harvest respectively) and also in the 3rd experiment (2.95, 3.56, 7.37, 12.33 and 31.30 g at 30, 45, 60, 75 DAS and at harvest respectively) followed by S_4 (30 cm × 20 cm; 100 plants plot^{-1}). The lowest dry weight plant^{-1}in the 2nd experiment (2.71, 3.02, 6.21, 9.20 and 25.40 g at 30, 45, 60, 75 DAS and at harvest respectively) and also in the 3rd experiment (2.69, 3.15, 6.81, 10.83 and 23.43 g at 30, 45, 60, 75 DAS and at harvest respectively) was observed from S_1 (30 cm × 5 cm; 400 plants plot^{-1}) followed by S_2 (30 cm × 10 cm; 200 plants plot^{-1}). The result obtained from the present studyregarding dry weight plant^{-1}was supported by Ghosh and Patra

(1993). Ghosh and Patra (1993) indicated that increasing plant density was correlated with increases in DM production. Enyi (1973) also observed that the total dry mass plant^{-1} decreased with increasing plant density. Samson (2005) reported a non significant response on total dry matter at wide intra row spacing of 15cm and 10cm. but Umar *et al*. (2012) reported that narrow intra row spacing of 5 cm between plants significantly decreases total dry matter (TDM).

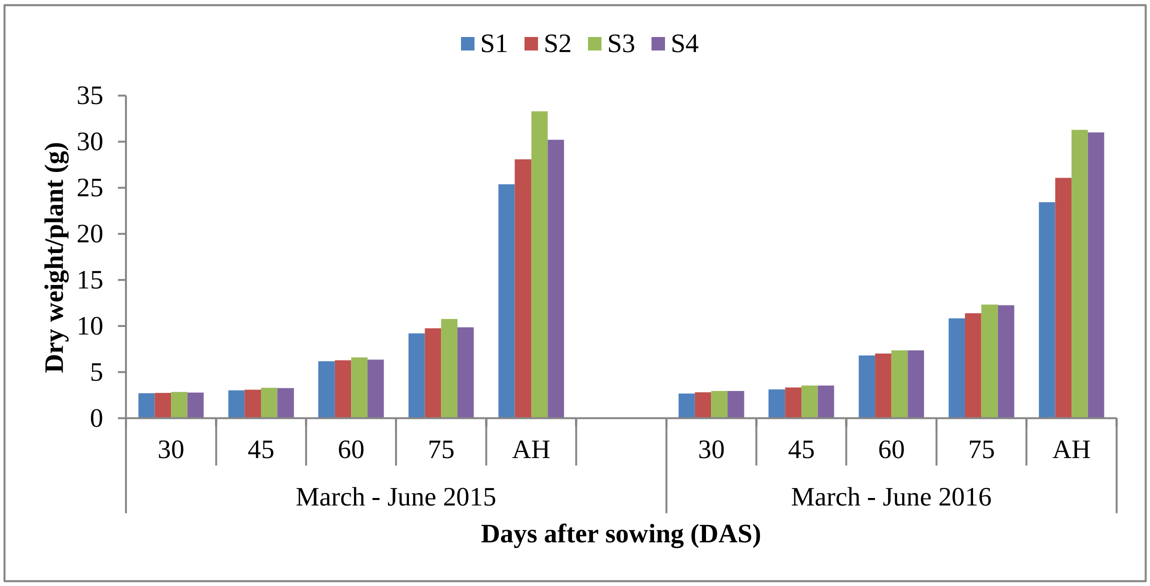

Fig. 4.32 Dry weight plant^{-1} of sesame as influenced by plant spacingduring 2015 and 2016 ($LSD_{0.05}$ = NS, 0.060, 0.101, 0.113 and 0.131 in 2015 and NS, 0.056, 0.113, 0.124 and 0.145 in 2016 at 30, 45, 60, 75 DAS and at harvest, respectively)

S_1=30 cm × 5 cm (400 plants plot^{-1}), S_2=30 cm × 10 cm (200 plants plot^{-1}), S_3=30 cm × 15 cm (130 plants plot^{-1}) and S_4=30 cm × 20 cm (100 plants plot^{-1})

Combination of different sources of plant nutrients and different plant spacing showed significant variation on dry weight plant^{-1}at all growth stages except 30 and 45 DAS in both the years of March-June 2015 and 2016 i.e. 2nd and 3rd experiment respectively (Table 4.14 and Appendix XLVI). The maximum dry weight plant^{-1} in the 2nd experiment (3.03, 3.64, 7.04, 11.89 and 38.00 g at 30, 45, 60, 75 DAS and at harvest, respectively) and also in the 3rd experiment (7.81, 13.73 and 36.73 g at 60, 75 DAS and at harvest, respectively) was obtained by the treatment combination of T_5S_3. Again, the lowest dry weight plant^{-1} in the 2nd experiment (2.52, 2.62, 5.76, 8.33 and 22.33 g at 30, 45, 60, 75 DAS and at harvest, respectively) and also in the 3rd experiment (2.25, 2.62, 6.53, 10.13 and 21.03 g at 30, 45, 60, 75 DAS and at harvest, respectively) was recorded from the treatment combination of T_8S_1.

Table 4.14 Combined effect of different sources of plant nutrients and spacing on Dry weight plant^{-1} of sesame during March - June 2015, and 2016

Treatment	Dry weight plant^{-1} (g)									
	2nd Experiment					3rd Experiment				
	30 DAS	45 DAS	60 DAS	75 DAS	At harvest	30 DAS	45 DAS	60 DAS	75 DAS	At harvest
T_1S_1	2.78	3.10	6.29	9.75	24.66	2.65	3.19	6.73	10.14	21.73
T_1S_2	2.72	3.18	6.57	10.55	29.09	2.77	3.33	6.91	11.26	25.14
T_1S_3	2.88	3.24	6.30	10.15	31.22	2.84	3.45	7.12	11.58	28.03
T_1S_4	2.83	3.26	6.10	9.41	29.55	2.92	3.51	7.32	12.13	30.05
T_2S_1	2.77	3.10	5.95	9.22	25.11	2.72	3.31	6.88	11.15	24.36
T_2S_2	2.90	3.10	6.09	9.42	27.56	2.84	3.38	7.06	11.48	26.27
T_2S_3	2.73	3.14	6.14	9.53	29.33	2.91	3.50	7.26	12.13	29.95
T_2S_4	2.58	3.18	6.56	10.23	29.69	2.99	3.61	7.43	12.39	33.82
T_3S_1	2.81	2.95	6.30	8.70	25.99	2.66	3.21	6.79	11.02	23.37
T_3S_2	2.85	3.08	6.50	9.99	31.50	2.82	3.35	7.02	11.36	25.95
T_3S_3	2.83	3.23	6.88	10.55	36.22	2.87	3.48	7.16	11.94	28.30
T_3S_4	2.76	3.21	6.45	10.14	35.89	2.96	3.52	7.35	12.26	31.37
T_4S_1	2.65	3.08	6.02	8.34	23.00	2.74	3.31	6.88	11.22	24.69
T_4S_2	2.78	3.23	6.10	9.66	29.60	2.84	3.40	7.07	11.48	26.61
T_4S_3	2.75	3.15	6.44	9.67	33.78	3.06	3.69	7.65	12.94	34.59
T_4S_4	2.91	3.44	6.65	11.11	35.11	3.04	3.63	7.59	12.68	34.17
T_5S_1	2.59	3.12	6.33	9.45	26.66	2.76	3.33	6.90	11.24	25.14
T_5S_2	2.69	3.29	6.27	10.44	27.91	2.84	3.41	7.08	11.55	27.79
T_5S_3	3.03	3.64	7.04	11.89	38.00	3.12	3.86	7.81	13.73	36.73
T_5S_4	2.88	3.34	6.35	10.49	33.00	3.08	3.71	7.72	13.19	34.92
T_6S_1	2.70	2.96	6.00	9.33	24.89	2.70	3.29	6.88	11.06	23.81
T_6S_2	2.76	3.03	6.13	9.66	26.44	2.83	3.37	7.06	11.47	26.27
T_6S_3	2.65	3.40	6.39	10.88	32.66	2.90	3.48	7.24	12.05	29.14
T_6S_4	2.63	3.28	6.24	9.88	29.55	2.99	3.59	7.41	12.37	32.48
T_7S_1	2.59	3.05	6.18	9.44	25.66	2.69	3.26	6.87	11.05	23.59
T_7S_2	2.61	2.99	6.36	9.65	26.44	2.83	3.35	7.04	11.47	26.18
T_7S_3	2.77	3.26	6.62	9.77	26.44	2.99	3.56	7.37	12.29	31.72
T_7S_4	2.91	3.38	6.82	10.33	31.33	2.90	3.48	7.20	11.98	28.39
T_8S_1	2.52	2.62	5.76	8.33	22.33	2.25	2.62	6.53	10.13	21.03
T_8S_2	2.81	3.10	6.29	10.38	27.57	2.80	3.33	6.95	11.27	25.16
T_8S_3	2.99	3.37	6.58	11.38	31.74	2.93	3.51	7.35	12.15	30.23
T_8S_4	2.78	3.29	6.58	10.33	27.47	2.85	3.45	7.13	11.72	28.27
T_9S_1	2.82	3.12	6.01	9.22	24.48	2.66	3.20	6.79	10.50	23.19
T_9S_2	2.76	3.16	6.24	9.22	27.22	2.81	3.34	7.01	11.35	25.36
T_9S_3	2.99	3.47	6.96	10.33	35.45	2.95	3.51	7.35	12.20	30.44
T_9S_4	2.98	3.29	6.59	9.52	30.44	2.85	3.45	7.14	11.82	28.27
$LSD_{0.05}$	NS	NS	0.073	0.1793	0.3942	NS	NS	0.368	0.487	0.522
CV (%)	2.62	4.07	7.24	11.72	12.59	4.557	4.938	6.228	9.551	8.634

T_1= 100% RDF through chemical fertilizer, T_2=100% RDF through vermicomost, T_3=75% RDF through vermicomost + 25 % as chemical fertilizer, T_4=50% RDF through vermicompost + 50% as chemical fertilizer, T_5=25% RDF through vermicompost + 75% as chemical fertilizer, T_6=100% RDF through FYM, T_7=75% RDF through FYM + 25% as chemical fertilizer, T_8=50% RDF through FYM + 50% as chemical fertilizer and T_9=25% RDF through FYM + 75% as chemical fertilizer, S_1=30 cm × 5 cm (400 plants plot^{-1}), S_2=30 cm × 10 cm (200 plants plot^{-1}), S_3=30 cm × 15 cm (130 plants plot^{-1}) and S_4=30 cm × 20 cm (100 plants plot^{-1})

4.2.2 Growth performance

4.2.2.1 Absolute growth rate (AGR)

Absolute growth rate(AGR) was not significantly influenced by different nutrient sources both at March-June 2015 and 2016 i.e. 2nd and 3rd experiment respectively (Table 4.15 and Appendix XLVII) gave the highest AGR in the 2nd experiment (0.46 g plant^{-1} day^{-1}) but in the 3rd experiment the highest AGR (0.43 g plant^{-1} day^{-1}) was found from T_5 (25% RDF through vermicompost + 75% as chemical fertilizer). The treatment, T_6 (100% RDF through FYM) gave the lowest AGR (0.38 g plant^{-1} day^{-1}) in the 2nd experiment but in the 3rd experiment T_8 (50% RDF through FYM + 50% as chemical fertilizer) gave the lowest AGR (0.35 g plant^{-1} day^{-1}).

Significant influence was not alo found for absolute growth rate(AGR)as influenced by different plant spacings both at March-June 2015 and 2016, respectively (Table 4.16 and Appendix XLVII). Among the different plant spcing, the maximum AGR in the 2nd experiment (0.47 g plant^{-1} day^{-1}) and in the 3rd experiment (0.43 g plant^{-1} day^{-1}) were obtained from S_1 (30 cm × 5 cm; 400 plants plot^{-1}) where the lowest AGR in the 2nd experiment (0.35 g plant^{-1} day^{-1}) and in the 3rd experiment (0.32 g plant^{-1} day^{-1}) were observed from S_4 (30 cm × 20 cm; 100 plants plot^{-1}).

Absolute growth rate(AGR)was significantly influenced by combined effect of different nutrient sources and plant spacingsboth at March-June 2015 and 2016, respectively (Table 4.17 and Appendix XLVII). Results signified that combination between different nutrient sources and plant spacings, T_3S_1 gave the maximum AGRin the 2nd experiment (0.54 g plant^{-1} day^{-1}) but in the 3rd experiment the maximum AGR (0.52 g plant^{-1} day^{-1}) was found from T_5S_1.The lowest AGR(0.30 g plant^{-1} day^{-1}) was recorded from T_6S_4in the 2nd experiment but in the 3rd experiment the lowest AGR(0.29 g plant^{-1} day^{-1}) was recorded from T_8S_1.

4.2.2.2 Crop growth rate (CGR)

Crop growth rate(CGR) was not significantly influenced by different nutrient sources both at March-June 2015 and 2016 i.e. 2nd and 3rd experiment respectively (Table 4.15 and Appendix XLVII). In the 2nd experiment, T_3 (75% RDF through vermicomost + 25 % as chemical fertilizer) gave the highest CGR (1.71) and in the 3rd experiment T_5 (25% RDF through vermicompost + 75% as chemical fertilizer) gave the highest CGR (1.39 g cm^{-2} day^{-1}). Again, both in the 2nd and 3rd experiment T_6 (100% RDF through FYM) gave the lowest CGR (1.38 and 1.15 g cm^{-2} day^{-1}, respectively).

Significant influence was found for crop growth rate(CGR)as influenced by different plant spacings both at March-June 2015 and 2016, respectively (Table 4.16 and Appendix XLVII). Among the different plant spacing treatment, the maximum CGR both in the 2nd and 3rd experiment (3.12 and 2.13 g cm^{-2} day^{-1} respectively) was obtained from S_1 (30 cm × 5 cm (400 plants $plot^{-1}$) where the lowest CGR both in the 2nd and 3rd experiment (0.58 and 0.73 g cm^{-2} day^{-1}, respectively) was observed from S_4 (30 cm × 20 cm (100 plants $plot^{-1}$). The results obtained from the present findings were supported by Ghosh and Patra (1993). Ghosh and Patra (1993) indicated that increasing plant density was correlated with increases in crop growth rate. Buttery (1970) and Kokilavani (2006) observed higher CGR due to higher LAI.

Crop growth rate(CGR)was significantly influenced by combined effect of different nutrient sources and plant spacingsboth at March-June 2015 and 2016, respectively (Table 4.17 and Appendix XLVII). Results signified that combination between different nutrient sources and plant spacing, T_3S_1 gave the maximum CGR in the 2nd experiment (3.59 g cm^{-2} day^{-1}) which was statistically identical with T_5S_1. But in the 3rd experiment, T_5S_1 gave the maximum CGR (2.30 g cm^{-2} day^{-1}) which was statistically similar with T_4S_1. In terms of lowest value of CGR both at 2nd and 3rd experiment (0.50 and 0.65 g cm^{-2} day^{-1}, respectively) was recorded from T_6S_4.

4.2.2.3 Relative growth rate (RGR)

Relative growth rate(RGR) was not significantly influenced by different sources of plant nutrients both at 2nd and 3rd experiment (March-June 2015 and 2016, respectively) (Table 4.15 and Appendix XLVII). Results indicated that in the 2nd experiment, T_3 (75% RDF through vermicomost + 25 % as chemical fertilizer) gave the highest RGR (0.0163 g g^{-1} day^{-1}) where T_5 (25% RDF through vermicompost + 75% as chemical fertilizer) in the 3rd experiment gave the highest RGR (0.0157 g g^{-1} day^{-1}). Again, both in the 2nd and 3rd experiment T_6 (100% RDF through FYM) gave the lowest the lowest RGR (0.0157 and 0.0146 g g^{-1} day^{-1} respectively).

Significant influence was not also found for relative growth rate(RGR)as influenced by different plant spacing both at March-June 2015 and March-June, 2016i.e. 2nd and 3rd experiment respectively (Table 4.16 and Appendix XLVII). The maximum RGR in the 2nd and 3rd experiment (0.0164 and 0.0158 g g^{-1} day^{-1}, respectively) was obtained from S_1 (30 cm × 5 cm (400 plants $plot^{-1}$)) where the lowest RGR for both 2nd and 3rd experiment (0.0149 and 0.0145 g g^{-1} day^{-1}, respectively) was observed from S_4 (30 cm × 20 cm (100 plants plot^{-1}). Sarkar and Pal (2005) too reported a positive correlation between RGR and other growth parameters.

Relative growth rate(RGR)was not also significantly influenced by combined effect of different nutrient sources and plant spacings (Table 4.17 and Appendix XLVII). It was observed that the treatment combination of T_3S_1 gave the highest RGR (0.0171 g g^{-1} day^{-1}) in the 2nd experiment where in the 3rd experiment T_5S_1 gave the highest RGR (0.0165 g g^{-1} day^{-1}). It was also found that both in 2nd and 3rd experimentthe lowest RGR (0.014 and 0.014 g g^{-1} day^{-1} respectively) was recorded from the treatment combination of T_6S_4.

Table 4.15 Growth performance of sesame influenced by different sources of plant nutrients during March – June 2015 and 2016

Treatment	Growth parameters					
	2nd Experiment			3rd Experiment		
	AGR	CGR	RGR	AGR	CGR	RGR
T_1	0.40	1.43	0.0155	0.36	1.16	0.0149
T_2	0.39	1.36	0.0155	0.40	1.28	0.0153
T_3	0.46	1.71	0.0163	0.38	1.22	0.0151
T_4	0.42	1.56	0.0159	0.42	1.33	0.0155
T_5	0.43	1.60	0.0162	0.43	1.39	0.0157
T_6	0.38	1.38	0.0153	0.38	1.15	0.0146
T_7	0.39	1.42	0.0155	0.38	1.24	0.0151
T_8	0.39	1.41	0.0155	0.35	1.25	0.0152
T_9	0.41	1.53	0.0154	0.37	1.21	0.0150
$LSD_{0.05}$	NS	NS	NS	NS	NS	NS
CV (%)	35.61	22.52	19.76	27.17	10.76	6.67

T_1= 100% RDF through chemical fertilizer, T_2=100% RDF through vermicomost, T_3=75% RDF through vermicomost + 25 % as chemical fertilizer, T_4=50% RDF through vermicompost + 50% as chemical fertilizer, T_5=25% RDF through vermicompost + 75% as chemical fertilizer, T_6=100% RDF through FYM, T_7=75% RDF through FYM + 25% as chemical fertilizer, T_8=50% RDF through FYM + 50% as chemical fertilizer and T_9=25% RDF through FYM + 75% as chemical fertilizer

Table 4.16 Growth performance of sesame influenced by different spacingduring March – June 2015 and 2016

Treatment	Growth parameters					
	2nd Experiment			3rd Experiment		
	AGR	CGR	RGR	AGR	CGR	RGR
S_1	0.47	3.12	0.0164	0.43	2.13	0.0158
S_2	0.42	1.41	0.0159	0.36	1.19	0.0149
S_3	0.39	0.84	0.0155	0.44	0.94	0.0157
S_4	0.35	0.58	0.0149	0.32	0.73	0.0145
$LSD_{0.05}$	NS	0.021	NS	NS	0.114	NS
CV (%)	38.06	2.13	6.25	27.17	2.53	6.67

S_1=30 cm × 5 cm (400 plants plot^{-1}), S_2=30 cm × 10 cm (200 plants plot^{-1}), S_3=30 cm × 15 cm (130 plants plot^{-1}) and S_4=30 cm × 20 cm (100 plants plot^{-1})

Table 4.17 Combined effect of different sources of plant nutrients and spacings on growth performance of sesame during March – June , 2015 and 2016

Treatment	Growth performance					
	2[nd] Experiment			3[rd] Experiment		
	AGR	CGR	RGR	AGR	CGR	RGR
T_1S_1	0.44	2.91	0.0159	0.39	1.96	0.0159
T_1S_2	0.41	1.37	0.0157	0.34	1.15	0.0147
T_1S_3	0.41	0.88	0.0158	0.39	0.84	0.0153
T_1S_4	0.34	0.56	0.0146	0.42	0.70	0.0156
T_2S_1	0.41	2.74	0.0162	0.33	2.22	0.0146
T_2S_2	0.38	1.27	0.0154	0.36	1.20	0.0149
T_2S_3	0.34	0.74	0.0144	0.42	0.90	0.0156
T_2S_4	0.41	0.69	0.0158	0.47	0.79	0.0162
T_3S_1	0.54	3.59	0.0171	0.32	2.12	0.0145
T_3S_2	0.51	1.70	0.0170	0.36	1.19	0.0148
T_3S_3	0.44	0.96	0.0161	0.39	0.85	0.0153
T_3S_4	0.36	0.59	0.0149	0.44	0.73	0.0158
T_4S_1	0.47	3.17	0.0164	0.34	2.25	0.0147
T_4S_2	0.50	1.66	0.0169	0.37	1.22	0.0149
T_4S_3	0.41	0.89	0.0158	0.34	1.05	0.0162
T_4S_4	0.31	0.52	0.0144	0.48	0.80	0.0162
T_5S_1	0.51	3.42	0.0170	0.52	2.30	0.0165
T_5S_2	0.46	1.54	0.0163	0.38	1.28	0.0152
T_5S_3	0.37	0.80	0.0158	0.49	1.12	0.0164
T_5S_4	0.39	0.65	0.0159	0.49	0.82	0.0148
T_6S_1	0.46	3.08	0.0168	0.32	2.17	0.0145
T_6S_2	0.37	1.22	0.0154	0.36	1.20	0.0149
T_6S_3	0.41	0.89	0.0158	0.40	0.87	0.0154
T_6S_4	0.30	0.50	0.0141	0.45	0.65	0.0140
T_7S_1	0.44	2.91	0.0159	0.32	2.14	0.0145
T_7S_2	0.36	1.21	0.0151	0.36	1.20	0.0149
T_7S_3	0.37	0.79	0.0155	0.44	0.96	0.0158
T_7S_4	0.35	0.59	0.0153	0.39	0.66	0.0152
T_8S_1	0.44	2.95	0.0158	0.28	1.89	0.0139
T_8S_2	0.38	1.27	0.0153	0.34	1.15	0.0147
T_8S_3	0.38	0.83	0.0153	0.42	0.91	0.0156
T_8S_4	0.34	0.57	0.0149	0.29	0.76	0.0153
T_9S_1	0.50	3.33	0.0165	0.32	2.11	0.0145
T_9S_2	0.42	1.41	0.0155	0.35	1.16	0.0147
T_9S_3	0.38	0.82	0.0153	0.42	0.92	0.0156
T_9S_4	0.33	0.56	0.0144	0.39	0.66	0.0153
$LSD_{0.05}$	0.0183	0.127	NS	0.048	0.127	NS
CV (%)	4.661	6.334	4.229	5.821	6.583	4.568

T_1= 100% RDF through chemical fertilizer, T_2=100% RDF through vermicomost, T_3=75% RDF through vermicomost + 25 % as chemical fertilizer, T_4=50% RDF through vermicompost + 50% as chemical fertilizer, T_5=25% RDF through vermicompost + 75% as chemical fertilizer, T_6=100% RDF through FYM, T_7=75% RDF through FYM + 25% as chemical fertilizer, T_8=50% RDF through FYM + 50% as chemical fertilizer and T_9=25% RDF through FYM + 75% as chemical fertilizer, S_1=30 cm × 5 cm (400 plants plot^{-1}), S_2=30 cm × 10 cm (200 plants plot^{-1}), S_3=30 cm × 15 cm (130 plants plot^{-1}) and S_4=30 cm × 20 cm (100 plants plot^{-1})

4.2.3 Yield contributing parameters

4.2.3.1 Number of capsule plant^{-1}

Number of capsule plant^{-1} both at 2nd and 3rd experiment (March-June 2015 and 2016, respectively) was significantly influenced due to different sources of plant nutrients (Fig. 4.33 and Appendix XXXI and XLVIII). In the 2nd experiment, the highest number of capsules plant^{-1} (63.25) was found from T_5 (25% RDF through vermicompost + 75% as chemical fertilizer) which was statistically similar with T_1 (100% RDF through chemical fertilizer). The lowest number of capsule plant^{-1} (56.92) in the 2nd experiment was recorded from T_6 (100% RDF through FYM). In the 3rd experiment, the highest number of capsules plant^{-1} (67.68) was also obtained from T_5 (25% RDF through vermicompost + 75% as chemical fertilizer) where the lowest number of capsule plant^{-1} (58.73) was also recorded from T_6 (100% RDF through FYM). Supported results were also obtained from the several findings. El-Habbasha *et al.* (2007) opined that application of 75 percent as chemical fertilizer + 25 percent as FYM recorded the highest number of capsules plant^{-1}. Deshmukh *et al.* (2002) reported that application of 50 percent N through urea + 50 percent N through FYM + 50 percent P and 100 percent K through fertilizer produced the highest capsules plant^{-1}. Thanunathan *et al.* (2001) found that combined application of FYM @ 12.5 t ha^{-1} and 100 percent chemical fertilizer (35:23:23 kg N, P_2O_5 and K_2O ha^{-1}) registered the largest number of capsules plant^{-1}.

Number of capsule plant^{-1} of sesame was also influenced significantly by different plant spacing both at March-June, 2015 and 2016, respectively (Fig. 4.34 and Appendix XXXII and XLVIII). In the 2nd experiment, the highest number of capsule plant^{-1} (66.33) was obtained from S_3 (30 cm × 15 cm; 130 plants plot^{-1}) where the lowest number of capsule plant^{-1} (54.30) was observed from S_1 (30 cm × 5 cm; 400 plants plot^{-1}) followed by S_2 (30 cm × 15 cm; 130 plants plot^{-1}). The equivalent result was also found in the 3rd experiment; the highest number of capsule plant^{-1} (66.05) was also obtained from S_3 (30 cm × 15 cm; 130 plants plot^{-1}) and the lowest number of capsule plant^{-1} (55.90) was observed from S_1 (30 cm × 5 cm; 400 plants plot^{-1}). Similar results were found from several research works. Fard and Bahrani (2005), BINA (1993), Channabasavanna and Setty (1992), Ghungrade *et al*. (1992) and Ghosh and Patra (1993) observed that plant density exhibited significant.

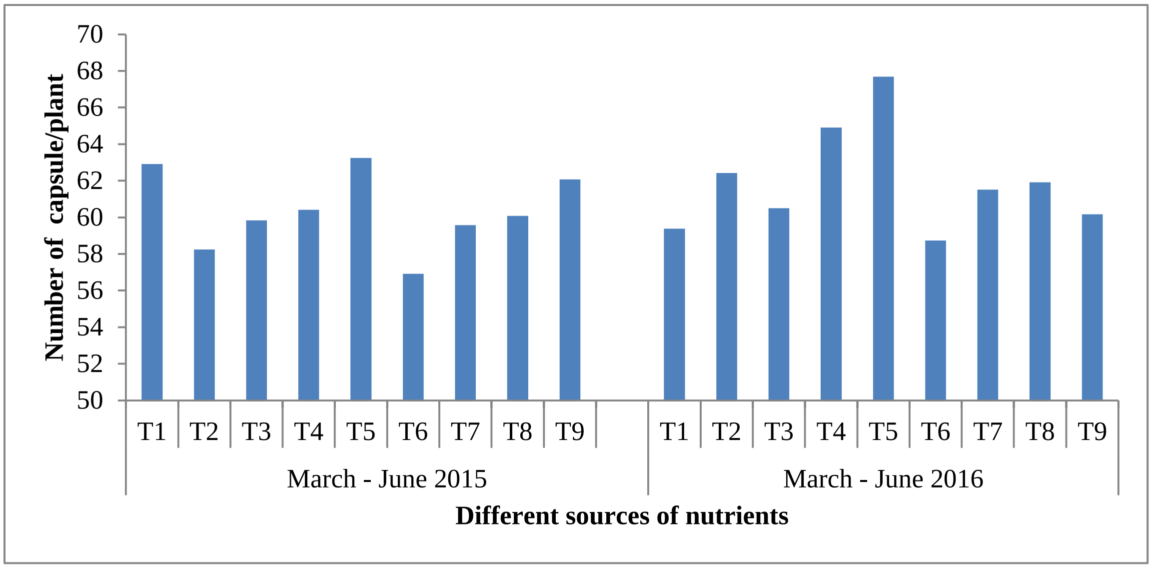

Fig. 4.33 Number of capsule plant^{-1}of sesame as influenced by different sources of plant nutrients during 2015 and 2016 ($LSD_{0.05}$ = 0.854 and 2.334 in 2015 and 2016, respectively)

T_1= 100% RDF through chemical fertilizer, T_2=100% RDF through vermicomost, T_3=75% RDF through vermicomost + 25 % as chemical fertilizer, T_4=50% RDF through vermicompost + 50% as chemical fertilizer, T_5=25% RDF through vermicompost + 75% as chemical fertilizer, T_6=100% RDF through FYM, T_7=75% RDF through FYM + 25% as chemical fertilizer, T_8=50% RDF through FYM + 50% as chemical fertilizer and T_9=25% RDF through FYM + 75% as chemical fertilizer

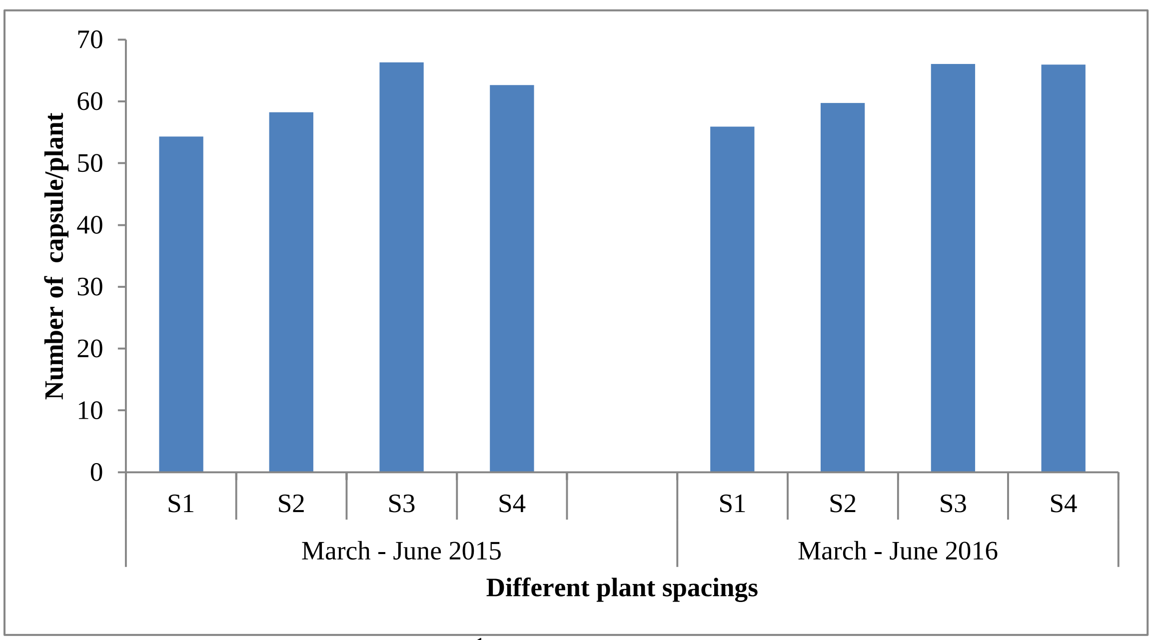

Fig. 4.34 Number of capsule plant^{-1}of sesame as influenced by plant spacings during 2015 and 2016 ($LSD_{0.05}$ = 0.769 and 2.114 in 2015 and 2016, respectively)

S_1=30 cm × 5 cm (400 plants plot^{-1}), S_2=30 cm × 10 cm (200 plants plot^{-1}), S_3=30 cm × 15 cm (130 plants plot^{-1}) and S_4=30 cm × 20 cm (100 plants plot^{-1})

effects on number of capsules plant^{-1}. It was also observed that wider spacing produced maximum number of capsules plant^{-1} than narrower row spacing. Caliskan *et al*. (2004) also revealed that capsule number decreased with increasing plant population. Adeyemo *et al*., (2005) reported decreased in number and weight of capsules plant^{-1} with increased population density. Jakusko *et al*. (2013) revealed that there was significant effect of spacing on the number of capsule plant^{-1}.

Significant influence was found both at March-June, 2015 and 2016, respectively for number of capsule plant^{-1} affected by combined effect of different sources of nutrients and spacing (Table 4.18 and Appendix XLVIII). Results signified that in the 2nd experiment, treatment combination of T_5S_3 listed the maximum number of capsule plant^{-1} (74.33) which was statistically similar with T_1S_3 where the lowest number of capsule plant^{-1} (47.67) was recorded from T_6S_1followed by T_8S_1. In the 3rd experiment, treatment combination ofT_5S_3 also gave the maximum number of capsule plant^{-1} (75.88) which was statistically identical with T_5S_4 but the lowest number of capsule plant^{-1} (50.11) was recorded from T_6S_1 followed by T_8S_1.

4.2.3.2 Number of seeds capsule^{-1}

Number of seeds capsule^{-1} influenced significantly by different nutrient sources both at March-June, 2015and 2016, respectively (Fig. 4.35 and Appendix XXXI and XLVIII). Regarding different nutrient sources in the 2nd experiment, the highest number of seeds capsule^{-1} (77.25) was obtained from T_5 (25% RDF through vermicompost + 75% as chemical fertilizer) which was statistically similar with T_9 (25% RDF through FYM + 75% as chemical fertilizer) followed by T_4(50% RDF through vermicompost + 50% as chemical fertilizer) and T_8 (50% RDF through FYM + 50% as chemical fertilizer). Again, in the 3rd experiment, the highest number of seeds capsule^{-1} (79.83) was also obtained from T_5 (25% RDF through vermicompost + 75% as chemical fertilizer) followed by T_4 (50% RDF through vermicompost + 50% as chemical fertilizer). In the 2nd experiment, the lowest number of seeds capsule^{-1} (71.42) was recorded from T_6 (100% RDF through FYM) followed by T_2 (100% RDF through vermicomost) and T_7 (75% RDF through FYM + 25% as chemical fertilizer). But in the 3rd experiment, the lowest number of seeds capsule^{-1} (72.75) was recorded from T_8 (50% RDF through FYM + 50% as chemical fertilizer) which was statistically identical with T_1 (100% RDF through chemical fertilizer) followed by T_9 (25% RDF through FYM + 75% as chemical fertilizer). El-Habbasha *et al.* (2007) opined that significantly superior number of seeds capsule^{-1} was recorded with 25 percent N through FYM + 75% N through urea than 50% N as FYM + 50% N as urea.

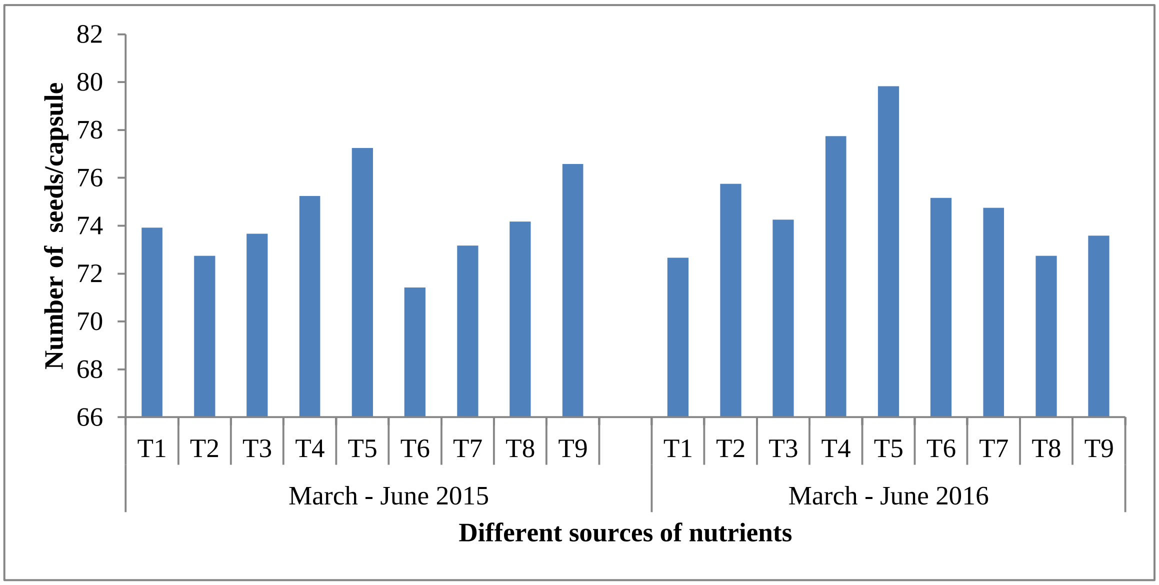

Fig. 4.35 Number of seeds capsule^{-1}of sesame as influenced by different sources of plant nutrientsduring 2015 and 2016 ($LSD_{0.05}$ = 0.841 and 1.137 in 2015 and 2016, respectively)

T_1= 100% RDF through chemical fertilizer, T_2=100% RDF through vermicomost, T_3=75% RDF through vermicomost + 25 % as chemical fertilizer, T_4=50% RDF through vermicompost + 50% as chemical fertilizer, T_5=25% RDF through vermicompost + 75% as chemical fertilizer, T_6=100% RDF through FYM, T_7=75% RDF through FYM + 25% as chemical fertilizer, T_8=50% RDF through FYM + 50% as chemical fertilizer and T_9=25% RDF through FYM + 75% as chemical fertilizer

Significant influence was found for number of seeds capsule^{-1} of sesame affected by different plant spacings in the 2nd and 3rd experiment (Fig. 4.36 and Appendix XXXII and XLVIII). Among the different plant spacings in the 2nd and 3rd experiments, the maximum number of seeds capsule^{-1} (82.52 and 80.48, respectively) was obtained from S_3 (30 cm × 15 cm; 130 plants plot^{-1}) and S_4 (30 cm × 20 cm; 100 plants plot^{-1}). The lowest number of seeds capsule^{-1} in the 2nd and 3rd experiment (66.56 and 67.33 respectively) was observed from S_1 (30 cm × 5 cm; 400 plants plot^{-1}) and S_2 (30 cm × 15 cm; 130 plants plot^{-1}). Similar results were found by Caliskan *et al*. (2004) who observed that number of seeds capsule^{-1} decreased with increasing plant population. Ghosh and Patra (1993) also indicated that number of seeds capsule^{-1}

decreased with increasing plant density. Jakusko *et al*. (2013) revealed that there was significant effect of spacing on the number of seeds capsule^{-1}.

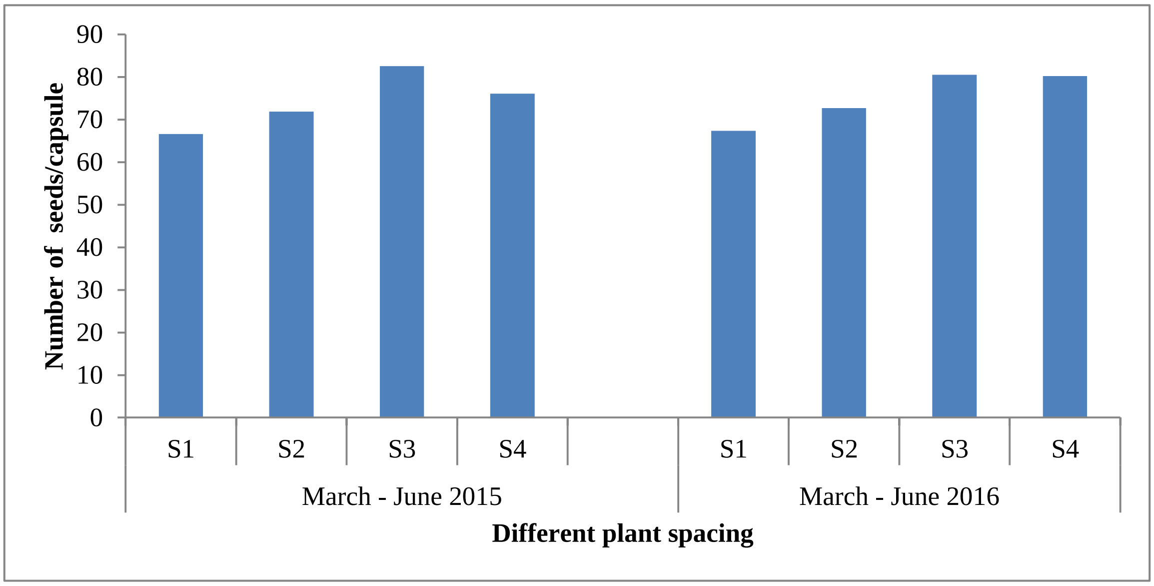

Fig. 4.36 Number of seeds capsule^{-1}of sesame as influenced by plant spacingduring 2015 and 2016 ($LSD_{0.05}$ = 0.587 and 1.356 in 2015 and 2016, respectively)

S_1=30 cm × 5 cm (400 plants plot^{-1}), S_2=30 cm × 10 cm (200 plants plot^{-1}), S_3=30 cm × 15 cm (130 plants plot^{-1}) and S_4=30 cm × 20 cm (100 plants plot^{-1})

Significant influence was found for number of seeds capsule^{-1} affected by combined effect of different sources of nutrients and different plant spacingsboth at March-June, 2015 and 2016, respectively (Table 4.18 and Appendix XLVIII). Results signified that T_5S_3 listed the maximum number of seeds capsule^{-1} both in the 2nd and 3rd experiment (86.67 and 88.00, respectively). The lowest number of seeds capsule^{-1} in the 2nd experiment (63.00) was recorded from T_6S_1 but in the 3rd experiment the lowest number of seeds capsule^{-1} (64.00) was recorded from T_8S_1.

4.2.3.3 Capsule length

Capsule length was influenced significantly by different nutrient sources both in the 2nd and 3rd experiments (Fig. 4.37 and Appendix XXXI and XLVIII). In the 2nd experiment, the highest capsule length (2.35 cm) was obtained from T_5 (25% RDF through vermicompost + 75% as chemical fertilizer) which was statistically smilar with T_9 (25% RDF through FYM + 75% as chemical fertilizer) followed by T_4 (50% RDF through vermicompost + 50% as chemical fertilizer) and T_8 (50% RDF through FYM + 50% as chemical fertilizer). The lowest capsule length in the 2nd experiment (2.24 cm) was recorded from T_6 (100% RDF through FYM) followed by T_2 (100% RDF through vermicomost) and T_7 (75% RDF through FYM + 25% as chemical fertilizer). In the 3rd experiment, the highest capsule length (2.33 cm) was also obtained from T_5 (25% RDF through vermicompost + 75% as chemical fertilizer) followed by T_4 (50% RDF through vermicompost + 50% as chemical fertilizer) and T_2 (100% RDF through vermicomost). The lowest capsule lengthin the 3rd experiment (2.19 cm) was recorded from T_8 (50% RDF through FYM + 50% as chemical fertilizer) which was statistically identical with T_1 (100% RDF through chemical fertilizer) and T_9 (25% RDF through FYM + 75% as chemical fertilizer). Ghosh *et al*. (2013) also found similar findings and observed that the number of seeds capsule^{-1} of sesame increased significantly due to integrated application of 50% RDF+50% N through FYM in sesame and the treatment was at par with those of 75% RDF+25% N through FYM or VC and 50% RDF+50% N through VC.

Significant influence was found for capsule length of sesame affected by different plant spacings both in the 2nd and 3rd experiments (Fig. 4.38 and Appendix XXXII and XLVIII). Among the different plant spacing in the 2nd experiment, the highest capsule length (2.44 cm) was obtained from S_3 (30 cm × 15 cm; 130 plants plot^{-1}) followed by S_4 (30 cm × 20 cm; 100 plants plot^{-1}) where the lowest capsule length (2.16 cm) was observed from S_1 (30 cm × 5 cm; 400 plants plot^{-1}) followed by S_2 (30 cm × 15 cm; 130 plants plot^{-1}). Significant influence was found for capsule length affected by different plant spacing. Among the different plant spacing in the 3rd experiment, the maximum capsule length (2.33 cm) was also obtained from S_3 (30 cm × 15 cm; 130 plants plot^{-1})which was statistically similar with S_4 (30 cm × 20 cm; 100 plants plot^{-1}) where the lowest capsule length (2.10 cm) was observed from S_1 (30 cm × 5 cm; 400 plants plot^{-1}) followed by S_2 (30 cm × 15 cm; 130 plants plot^{-1}). Caliskan *et al*. (2004) supported the present findings. They found that capsule length decreased with increasing plant population. Jakusko *et al*. (2013) also found that there was significant effect of spacing on length of capsule.

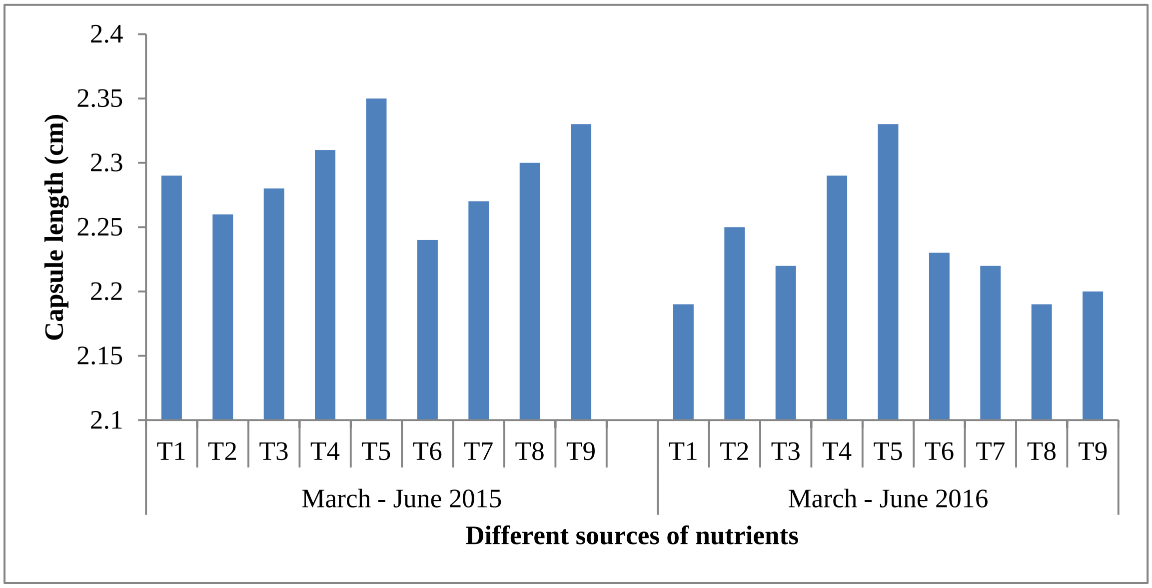

Fig. 4.37 Capsule length of sesame as influenced by different sources of plant nutrients during 2015 and 2016 ($LSD_{0.05}$ = 0.017 and 0.016 in 2015 and 2016, respectively)

T_1= 100% RDF through chemical fertilizer, T_2=100% RDF through vermicomost, T_3=75% RDF through vermicomost + 25 % as chemical fertilizer, T_4=50% RDF through vermicompost + 50% as chemical fertilizer, T_5=25% RDF through vermicompost + 75% as chemical fertilizer, T_6=100% RDF through FYM, T_7=75% RDF through FYM + 25% as chemical fertilizer, T_8=50% RDF through FYM + 50% as chemical fertilizer and T_9=25% RDF through FYM + 75% as chemical fertilizer

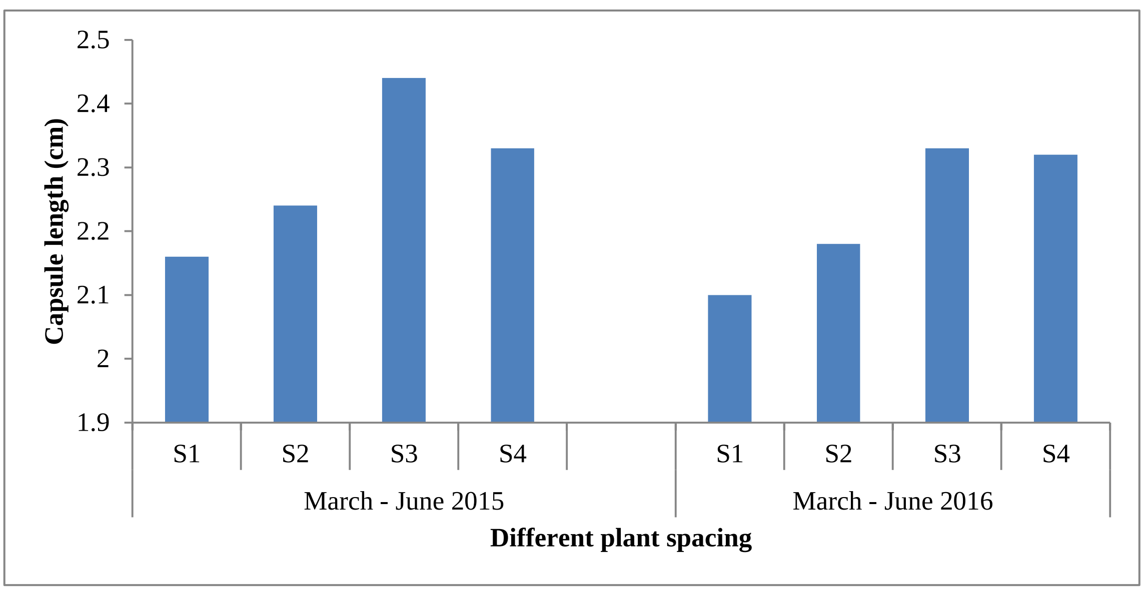

Fig. 4.38 Capsule length of sesame as influenced by plant spacingduring 2015 and 2016 ($LSD_{0.05}$ = 0.098 and 0.021 in 2015 and 2016, respectively)

S_1=30 cm × 5 cm (400 plants $plot^{-1}$), S_2=30 cm × 10 cm (200 plants $plot^{-1}$), S_3=30 cm × 15 cm (130 plants $plot^{-1}$) and S_4=30 cm × 20 cm (100 plants $plot^{-1}$)

Significant influence was found for capsule length affected by combined effect of different sources of nutrients and different plant spacings both in the 2nd and 3rd experiments (Table 4.18 and Appendix XLVIII). In the 2nd experiment, the treatment combination of T_5S_3 listed the highest capsule length (2.54 cm) which was statistically similar with T_9S_4 followed by T_1S_3, T_4S_3, T_7S_3 and T_8S_3. The lowest capsule length in the 2nd experiment (2.09 cm) was recorded from T_6S_1 followed by T_1S_1, T_2S_1, T_3S_1, T_7S_1, T_8S_1 and T_9S_1. In the 3rd experiment the treatment combination of T_5S_3 also listed the maximum capsule length (2.48 cm) which was statistically identical with T_5S_4 followed by T_4S_3, T_4S_4, T_2S_4, T_6S_4 and T_7S_3. The lowest capsule length in the 3rd experiment (2.03 cm) was recorded from T_8S_1which was statistically similar with T_9S_1 followed by T_3S_1 and T_7S_1.

4.2.3.4 Weight of 1000 seeds

Weight of 1000 seeds influenced significantly by different nutrient sources both at March-June 2015 and 2016, respectively (Fig. 4.39 and Appendix XXXI and XLVIII). In the 2nd experiment, the highest 1000 seed weight (2.32 g) was obtained from T_5 (25% RDF through vermicompost + 75% as chemical fertilizer) which was statistically similar with T_4 (50% RDF through vermicompost + 50% as chemical fertilizer) and T_9 (25% RDF through FYM + 75% as chemical fertilizer). In the 3rd experiment, T_5 (25% RDF through vermicompost + 75% as chemical fertilizer) also gave highest 1000 seed weright (2.59 g) followed by T_4 (50% RDF through vermicompost + 50% as chemical fertilizer). The lowest 1000 seed weightin the 2nd experiment (2.08 g) was recorded from T_6 (100% RDF through FYM) followed by T_8 (50% RDF through FYM + 50% as chemical fertilizer) and T_2 (100% RDF through vermicomost). In the 3rd experiment, the lowest 1000 seed weight (2.20 g) was also recorded from T_6 (100% RDF through FYM) which was statistically similar with T_8 (50% RDF through FYM + 50% as chemical fertilizer). Deshmukh *et al.* (2002) reported that application of 50 percent N through urea + 50 percent N through FYM + 50 percent P and 100 percent K through fertilizer produced the highest test weight of seeds. Barik and Fulmali (2011) indicated that combined use of FYM at 10 t ha^{-1} along with 75% recommended dose of NPK fertilizers registered the highest 1000 seed weight of sesame.

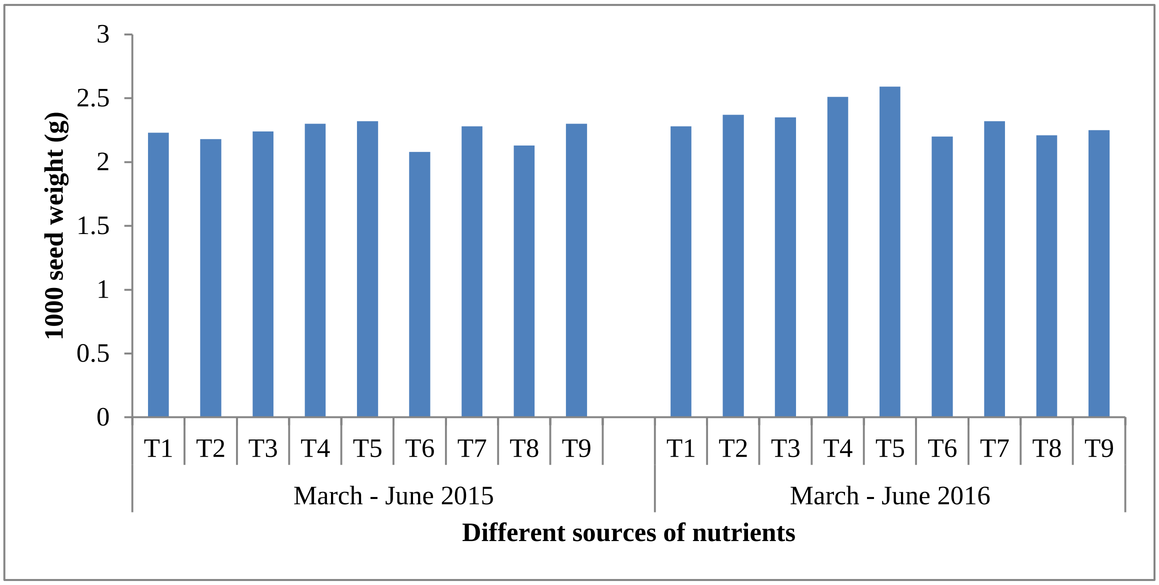

Fig. 4.39 Weight of 1000 seeds of sesame as influenced by different sources of plant nutrients during 2015 and 2016 ($LSD_{0.05}$ = 0.045 and 0.034 in 2015 and 2016, respectively)

T_1= 100% RDF through chemical fertilizer, T_2=100% RDF through vermicomost, T_3=75% RDF through vermicomost + 25 % as chemical fertilizer, T_4=50% RDF through vermicompost + 50% as chemical fertilizer, T_5=25% RDF through vermicompost + 75% as chemical fertilizer, T_6=100% RDF through FYM, T_7=75% RDF through FYM + 25% as chemical fertilizer, T_8=50% RDF through FYM + 50% as chemical fertilizer and T_9=25% RDF through FYM + 75% as chemical fertilizer

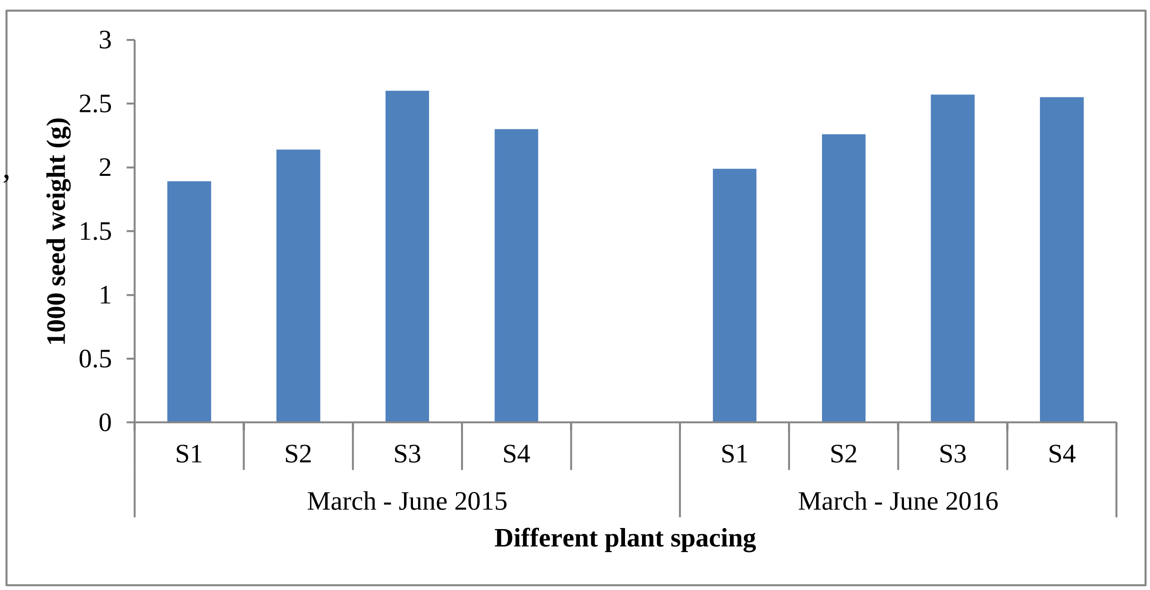

Fig. 4.40 Weight of 1000 seeds of sesame influenced by plant spacingduring 2015 and 2016 ($LSD_{0.05}$ = 0.085 and 0.026 in 2015 and 2016, respectively)

S_1=30 cm × 5 cm (400 plants plot^{-1}), S_2=30 cm × 10 cm (200 plants plot^{-1}), S_3=30 cm × 15 cm (130 plants plot^{-1}) and S_4=30 cm × 20 cm (100 plants plot^{-1})

Significant influence was found for 1000 seed weight of sesame by different plant spacings both in the 2nd and 3rd experiments (Fig. 4.40 and Appendix XXXII and XLVIII). Among the different plant spacings both in the 2nd and 3rd experiments, the maximum 1000 seed weight (2.60 and 2.57 g respectively) was obtained from S_3 (30 cm × 15 cm; 130 plants plot^{-1}) followed by S_4 (30 cm × 20 cm; 100 plants plot^{-1}) at all the situations. The lowest 1000 seed weight both in the 2nd and 3rd experiments (1.89 and 1.99 g, respectively) was observed from S_1 (30 cm × 5 cm; 400 plants plot^{-1}) followed by S_2 (30 cm × 15 cm; 130 plants plot^{-1}) at all the situations. The results on 1000 seed weight found from the present study were conformity with the findings of Majumdar and Roy (1992) and Singh *et al*. (1988). They examined that the 1000-seed weight was marginally improved by increasing spacing. Jakusko *et al*. (2013) and Adeyemo *et al*., (2005) reported decreased in 1000 seed weight was found with increased population density.

Cultivation of sesame in both the year (2nd and 3rd experiments) had significant effect on 1000 seed weight affected by combined effect of different sources of nutrient and different plant spacings (Table 4.18 and Appendix XLVIII). Results signified that in the 2nd experiment, T_5S_3 listed the maximum 1000 seed weight (2.97 g) followed by T_5S_4, T_7S_3 and T_9S_4 wherethe lowest 1000 seed weight (1.73 g) was recorded from T_6S_1which was statistically similar with T_8S_1 and T_7S_1. In the 3rd experiment, T_5S_3 combination also listed the maximum 1000 seed weight (3.02 g) followed by T_5S_4 where the lowest 1000 seed weight (1.81 g) was also recorded from T_6S_1 followed by T_8S_1, T_9S_1 and T_3S_1.

Table 4.18 Combined effect of different sources of plant nutrients and spacings on Yield contributing parameters of sesame during March – June 2015 and 2016

Treatment	Yield contributing parameters							
	2nd Experiment				3rd Experiment			
	Number of capsule $plant^{-1}$	Number of seeds $capsule^{-1}$	Capsule length (cm)	1000 seed weight (g)	Number of capsule $plant^{-1}$	Number of seeds $capsule^{-1}$	Capsule length (cm)	1000 seed weight (g)
T_1S_1	56.33	66.67	2.17	1.93	55.83	66.00	2.07	2.05
T_1S_2	59.33	71.33	2.24	2.13	59.10	70.33	2.15	2.12
T_1S_3	74.00	82.00	2.42	2.30	61.50	75.33	2.24	2.35
T_1S_4	62.00	75.67	2.33	2.53	63.50	79.00	2.29	2.45
T_2S_1	55.33	65.33	2.13	1.93	57.80	68.33	2.12	2.06
T_2S_2	57.67	70.67	2.22	2.07	60.50	74.00	2.20	2.32
T_2S_3	60.00	74.33	2.31	2.43	63.17	77.67	2.28	2.42
T_2S_4	63.33	80.67	2.38	2.27	68.19	83.00	2.38	2.68
T_3S_1	54.33	66.00	2.16	1.83	57.17	67.00	2.10	1.95
T_3S_2	57.67	71.33	2.24	2.13	59.25	72.00	2.18	2.24
T_3S_3	66.67	81.67	2.40	2.47	62.10	76.33	2.26	2.39
T_3S_4	60.67	75.67	2.32	2.27	64.83	81.67	2.32	2.55
T_4S_1	55.67	67.33	2.18	1.97	57.83	68.67	2.14	2.09
T_4S_2	58.00	73.67	2.26	2.20	60.73	74.67	2.20	2.33
T_4S_3	61.33	83.33	2.47	2.37	72.80	84.33	2.41	2.82
T_4S_4	66.67	76.67	2.34	2.33	68.22	83.33	2.40	2.80
T_5S_1	57.00	69.33	2.20	2.00	58.50	70.00	2.14	2.10
T_5S_2	59.33	74.00	2.28	2.23	60.83	75.00	2.22	2.34
T_5S_3	74.33	86.67	2.54	2.97	75.88	88.00	2.48	3.04
T_5S_4	62.33	79.00	2.37	2.73	75.50	86.33	2.46	2.86
T_6S_1	47.67	63.00	2.09	1.73	50.11	68.00	2.11	1.81
T_6S_2	57.67	69.33	2.21	1.97	59.50	72.67	2.19	2.30
T_6S_3	62.33	74.33	2.31	2.37	62.83	77.33	2.27	2.40
T_6S_4	60.00	79.00	2.37	2.23	68.17	82.67	2.34	2.65
T_7S_1	54.00	65.33	2.14	1.80	56.83	67.67	2.11	2.02
T_7S_2	57.67	71.00	2.22	2.10	59.28	72.33	2.18	2.25
T_7S_3	66.33	81.67	2.39	2.70	67.75	82.33	2.33	2.59
T_7S_4	60.33	74.67	2.31	2.27	62.17	76.67	2.27	2.40
T_8S_1	52.00	67.00	2.17	1.77	53.44	64.00	2.03	1.89
T_8S_2	57.67	71.67	2.25	2.20	59.16	71.33	2.16	2.19
T_8S_3	60.67	82.00	2.46	2.53	63.80	80.00	2.31	2.48
T_8S_4	66.67	76.00	2.33	2.30	61.83	75.67	2.25	2.36
T_9S_1	56.33	69.00	2.20	2.00	55.60	66.33	2.08	1.92
T_9S_2	59.00	73.67	2.26	2.23	59.20	71.67	2.16	2.22
T_9S_3	71.33	78.00	2.35	2.33	63.83	80.33	2.31	2.49
T_9S_4	61.67	85.67	2.52	2.70	62.00	76.00	2.25	2.37
$LSD_{0.05}$	1.358	1.761	0.033	0.104	1.246	1.759	0.019	0.021
CV (%)	9.346	11.275	7.651	5.384	8.961	10.759	7.224	6.348

T_1= 100% RDF through chemical fertilizer, T_2=100% RDF through vermicomost, T_3=75% RDF through vermicomost + 25 % as chemical fertilizer, T_4=50% RDF through vermicompost + 50% as chemical fertilizer, T_5=25% RDF through vermicompost + 75% as chemical fertilizer, T_6=100% RDF through FYM, T_7=75% RDF through FYM + 25% as chemical fertilizer, T_8=50% RDF through FYM + 50% as chemical fertilizer and T_9=25% RDF through FYM + 75% as chemical fertilizer, S_1=30 cm × 5 cm (400 plants $plot^{-1}$), S_2=30 cm × 10 cm (200 plants $plot^{-1}$), S_3=30 cm × 15 cm (130 plants $plot^{-1}$) and S_4=30 cm × 20 cm (100 plants $plot^{-1}$)

4.2.4 Yield parameters

4.2.4.1 Seed yield and pooled yield ha^{-1}

Seed yield was affected significantly by different nutrient sources both in March-June 2015 and 2016, respectively (Fig. 4.41 and Appendix XXXIII and XLIX). It was found both in the 2nd and 3rd experiment that the highest seed yield (1326 and 1345 kg ha^{-1}, respectively) and pooled yield (1335.50 kg ha^{-1}) was obtained from T_5 (25% RDF through vermicompost + 75% as chemical fertilizer) followed by T_9 (25% RDF through FYM + 75% as chemical fertilizer) and T_4 (50% RDF through vermicompost + 50% as chemical fertilizer) at all the situations. The lowest seed yield both in the 2nd and 3rd experiment (1204 and 1206.25 kg ha^{-1}, respectively) and pooled yield (1205.13 kg ha^{-1}) was recorded from T_6 (100% RDF through FYM) followed by T_2 (100% RDF through vermicomost) and T_7 (75% RDF through FYM + 25% as chemical fertilizer) at all the situations. Here, it can be mentioned that the yield contributing parameters *viz.* number of capsules $plant^{-1}$, number of seeds $capsule^{-1}$, capsule length and weight of 1000 seeds were found highest with treatment of T_5 (25% RDF through vermicompost + 75% as chemical fertilizer) and resulted best seed yield. Meena *et al.* (2009) reported that application of 20 kg N and 5 t FYM ha^{-1} registered the highest seed yield from higher production of capsules $plant^{-1}$ and capsule length than application of 40 kg N alone. Application of 25:25 kg N and P_2O_5 ha^{-1} + 5 t FYM ha^{-1} registered significantly higher seed yield of sesame over chemical fertilizer alone (Javia *et al*., 2010). Thanunathan *et al.* (2001) found that combined application of FYM @ 12.5 t ha^{-1} and 100 percent chemical fertilizer (35:23:23 kg N, P_2O_5 and K_2O ha^{-1}) registered the highest seed yield.

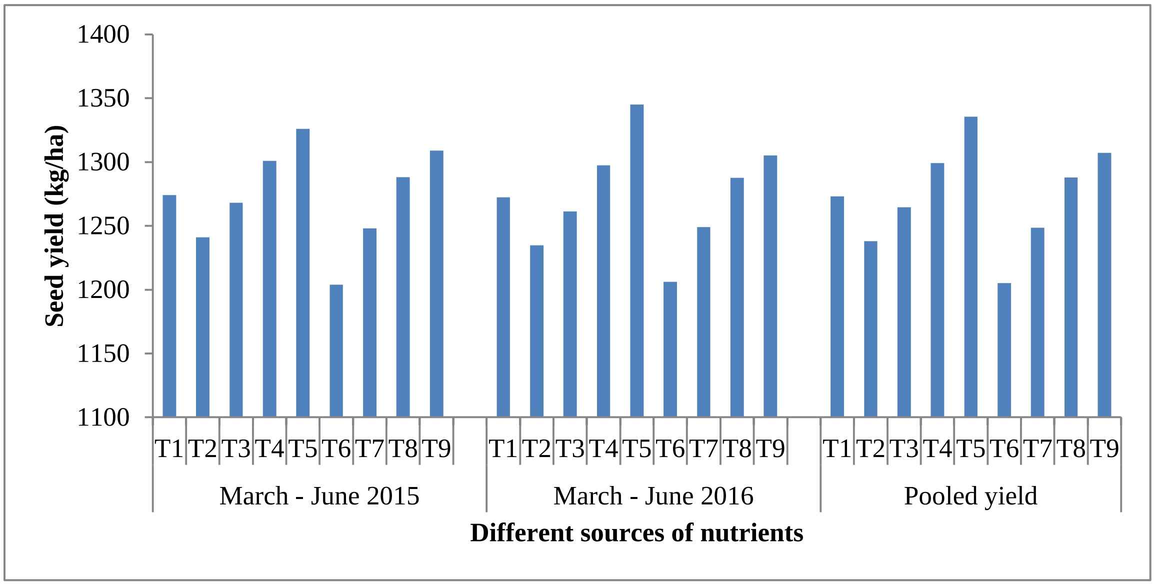

Fig. 4.41 Seed yield and pooled yield ha^{-1} of sesame as influenced by different sources of plant nutrients during 2015 and 2016 ($LSD_{0.05}$ = 4.576, 6.559 and 5.317 in 2015, 2016 and pooled yield, respectively)

T_1= 100% RDF through chemical fertilizer, T_2=100% RDF through vermicomost, T_3=75% RDF through vermicomost + 25 % as chemical fertilizer, T_4=50% RDF through vermicompost + 50% as chemical fertilizer, T_5=25% RDF through vermicompost + 75% as chemical fertilizer, T_6=100% RDF through FYM, T_7=75% RDF through FYM + 25% as chemical fertilizer, T_8=50% RDF through FYM + 50% as chemical fertilizer and T_9=25% RDF through FYM + 75% as chemical fertilizer

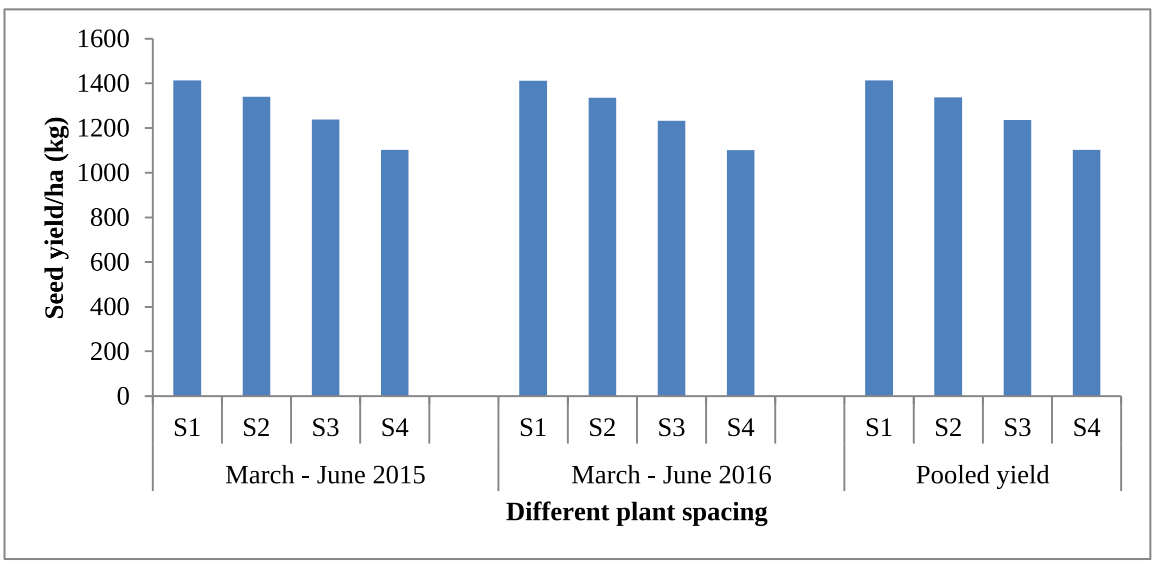

Fig. 4.42 Seed yield pooled yield ha^{-1} of sesame as influenced by plant spacins during 2015 and 2016 ($LSD_{0.05}$ = 13.016, 12.569 and 10.537 in 2015, 2016 and pooled yield, respectively)

S_1=30 cm × 5 cm (400 plants $plot^{-1}$), S_2=30 cm × 10 cm (200 plants $plot^{-1}$), S_3=30 cm × 15 cm (130 plants $plot^{-1}$) and S_4=30 cm × 20 cm (100 plants $plot^{-1}$)

Both in 2^{nd} and 3^{rd} experiments, significant influence was found for seed yield of sesame by different plant spacings both in the 2^{nd} and 3^{rd} experiments (Fig. 4.42 and Appendix XXXIV and XLIX). Among the different plant spacings the maximum seed yield (1413 and 1412 kg ha^{-1} at 2^{nd} and 3^{rd} experiments, respectively) and pooled yield (1412.56 kg ha^{-1}) was obtained from S_1 (30 cm × 5 cm; 400 plants $plot^{-1}$) followed by S_2 (30 cm × 15 cm; 130 plants $plot^{-1}$) where the lowest seed yield (1102 and 1100.89 kg ha^{-1} at 2^{nd} and 3^{rd} experiment, respectively) and pooled yield (1101.45 kg ha^{-1}) was observed from S_4 (30 cm × 20 cm; 100 plants $plot^{-1}$) followed by S_3 (30 cm × 15 cm; 130 plants $plot^{-1}$) at all the situations. Main reason of the best yield from S_1 (30 cm × 5 cm; 400 plants $plot^{-1}$) might be due to cause of higher per unit area production of number of capsules $plant^{-1}$ and number of seeds $capsule^{-1}$. Kalaiselvan *et al*. (2001) also stated that adoption of suitable and optimum spacing would fulfill the objective of maximizing the yield of sesame. Rahnama and Bakhshandeh (2006), Fard and Bahrani (2005) and Caliskan *et al*. (2004) found that increasing the plant density increased the seed yield. Umar *et al*. (2012) found that Narrow intra row spacing of 5 cm between plants significantly decreases grain yield per plant (GYP) but showed increased grain yield per hectare (GY ha^{-1}).

Significant influence was found for seed yield affected by combined effect of different sources of nutrients and different plant spacings both in the 2^{nd} and 3^{rd} experiments (Table 4.19 and Appendix XLIX). Results signified that in the 2^{nd} experiment T_5S_1 gave the maximum seed yield (1437 kg ha^{-1}) and pooled yield (1439.50 kg ha^{-1}) which was statistically similar with T_4S_1 (1430 kg ha^{-1}) followed by T_1S_1, T_3S_1 and T_8S_1 where the lowest seed yield (933.30 kg ha^{-1}) was recorded from T_6S_4 followed by T_1S_4, T_2S_4, T_3S_4 and T_7S_4. In the 3^{rd} experiment T_5S_1treatment combination also gave the maximum seed yield (1442 kg ha^{-1}) which was statistically similar with T_9S_1 (1430 kg ha^{-1}) followed by T_4S_1, T_8S_1, T_1S_1, T_3S_1 and T_7S_1 where the lowest seed yield (962 kg ha^{-1}) and pooled yield (947.65 kg ha^{-1}) was also recorded from T_6S_4 followed by T_2S_4, T_7S_4, T_3S_4, T_1S_4, T_8S_4 and T_4S_4.

4.2.4.2 Stover yield ha^{-1}

Both at March-June 2015 and 2016, respectively stover yield was affected significantly by different nutrient sources (Fig. 4.43 and Appendix XXXIII and XLIX). It was found that in the 2^{nd} and 3^{rd} experiments the highest stover yield (1619 and 1592 kg ha^{-1}, respectively) was obtained from T_5 (25% RDF through vermicompost + 75% as chemical fertilizer). The lowest stover yield (1464 kg ha^{-1}) in the 2nd experiment was recorded from T_8 (50% RDF through FYM + 50% as chemical fertilizer) followed by T_2 (100% RDF through vermicomost) and T_6 (100% RDF through FYM). But in the 3rd experiment, the lowest stover yield (1491.75 kg ha^{-1}) was recorded from T_6(100% RDF through FYM) followed by T_2 (100% RDF through vermicomost), T_7 (75% RDF through FYM + 25% as chemical fertilizer) and T_8 (50% RDF through FYM + 50% as chemical fertilizer). Mandal *et al.* (1990) reported good response in stover yield of sesame through balanced fertilizer management in conjunction with adequate amount of FYM. Stover yield was the highest with integrated application of poultry manure (15 t ha^{-1}), N (120 kg ha^{-1}) and P_2O_5 (13.2 kg ha^{-1}) (Haruna *et al.*, 2010). Barik and Fulmali (2011) indicated that combined use of FYM at 10 t ha^{-1} along with 75% recommended dose of NPK fertilizers registered the highest stover yield of sesame.

Significant influence was found for stover yield of sesame by different plant spacings both in the 2nd and 3rd experiments (Fig. 4.44 and Appendix XXXIV and XLIX). Among the different plant spacing, the maximum stover yield (1715 and 1707.11 kg ha^{-1} at 2nd and 3rd experiment, respectively) was obtained from S_1 (30 cm × 5 cm; 400 plants plot^{-1}) followed by S_2 (30 cm × 15 cm; 130 plants plot^{-1}) at all the situations where the lowest stover yield (1392 and 1363 kg ha^{-1} at 2nd and 3rd experiment, respectively) was observed from S_4 (30 cm × 20 cm; 100 plants plot^{-1}) followed by S_3 (30 cm × 15 cm; 130 plants plot^{-1}). Fard and Bahrani (2005) studied that plant density exhibited significant effects on biological yield (seed yield + stover yield). Increasing the plant density increased the stover yield.

Significant influence was found for stover yield by combined effect of different sources of nutrients and different plant spacings both in 2nd and 3rd experiment (Table 4.19 and Appendix XLIX). In the 2nd experiment T_5S_1 treatment combination gave the maximum stover yield (1708.00 kg ha^{-1}) where the lowest stover yield (1277.00 kg ha^{-1}) was recorded from T_6S_4 followed by T_6S_4, T_2S_4 and T_3S_4. In the 3rd experiment T_5S_1 treatment combination also gave the maximum stover yield (1701 kg ha^{-1}) where the lowest stover yield (1260 kg ha^{-1}) was recorded from T_6S_4 followed by T_2S_4, T_7S_4 and T_3S_4.

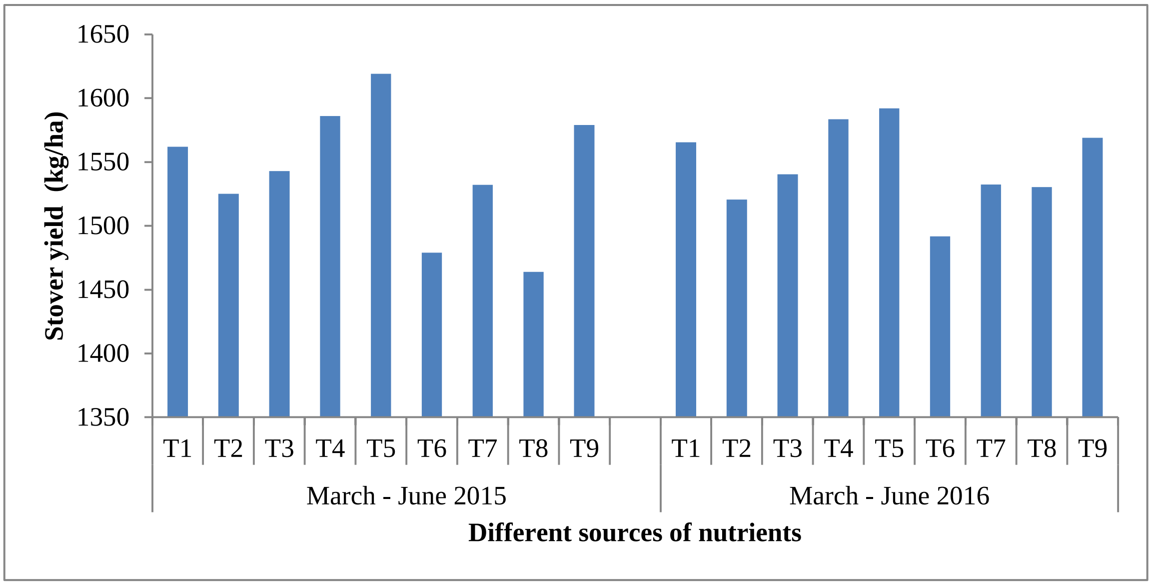

Fig. 4.43 Stover yield ha^{-1} of sesame as influenced by different sources of plant nutrientsduring 2015 and 2016 ($LSD_{0.05}$ = 4.996 and 10.378 in 2015 and 2016, respectively)

T_1= 100% RDF through chemical fertilizer, T_2=100% RDF through vermicomost, T_3=75% RDF through vermicomost + 25 % as chemical fertilizer, T_4=50% RDF through vermicompost + 50% as chemical fertilizer, T_5=25% RDF through vermicompost + 75% as chemical fertilizer, T_6=100% RDF through FYM, T_7=75% RDF through FYM + 25% as chemical fertilizer, T_8=50% RDF through FYM + 50% as chemical fertilizer and T_9=25% RDF through FYM + 75% as chemical fertilizer

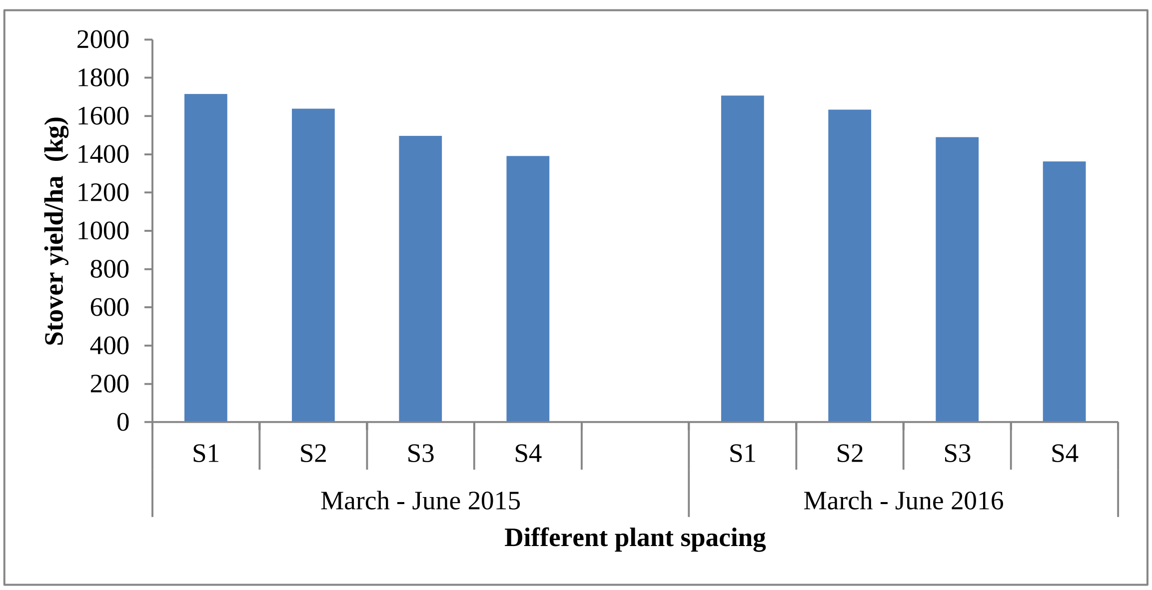

Fig. 4.44 Stover yield ha^{-1} of sesame as influenced by plant spacingduring 2015 and 2016 ($LSD_{0.05}$ = 13.239 and 13.557 in 2015 and 2016, respectively)

S_1=30 cm × 5 cm (400 plants plot^{-1}), S_2=30 cm × 10 cm (200 plants plot^{-1}), S_3=30 cm × 15 cm (130 plants plot^{-1}) and S_4=30 cm × 20 cm (100 plants plot^{-1})

4.2.4.3 Harvest index

Both in March-June, 2015and 2016, harvest index was affected significantly by different nutrient sources (Fig. 4.45 and Appendix XXXIII and XLIX). It was found that the highest harvest index (45.47 and 45.80%in 2^{nd} and 3^{rd} experiments, respectively) was obtained from T_5 (25% RDF through vermicompost + 75% as chemical fertilizer) where the lowest harvest index (42.87 and 44.64% at 2^{nd} and 3^{rd} experiment, respectively) was recorded from T_6 (100% RDF through FYM). Significantly superior harvest index of sesame were recorded with 25 percent N through FYM + 75% N through urea than 50% N as FYM + 50% N as urea in clay soil of Dharwad (Purushottam and Hiremath, 2008). Application of 25:25 kg N and P_2O_5 ha^{-1} + 5 t FYM ha^{-1} registered significantly higher harvest index of sesame over chemical fertilizer alone (Javia *et al*., 2010).

Significant influence was found for harvest index of sesame both in 2^{nd} and 3^{rd} experiments by different plant spacings (Fig. 4.46 and Appendix XXXIV and XLIX). In the 2^{nd} experiment, the highestharvest index (45.17%) was obtained from S_1 (30 cm × 5 cm; 400 plants $plot^{-1}$) which was statistically similar with S_2 (30 cm × 15 cm; 130 plants $plot^{-1}$) where the lowest harvest index (44.19%) was observed from S_4 (30 cm × 20 cm; 100 plants $plot^{-1}$).In the 3^{rd} experiment, the highest harvest index (45.27%) was also obtained from S_1 (30 cm × 5 cm; 400 plants $plot^{-1}$) which was statistically identical with S_3 (30 cm × 15 cm; 130 plants $plot^{-1}$) where the lowest harvest index (44.65%) was observed from S_4 (30 cm × 20 cm; 100 plants $plot^{-1}$). Caliskan *et al*. (2004) supported the present findings and observed that harvest index increased with increasing plant population. Fard and Bahrani (2005) found that plant density exhibited significant effects on harvest index. Increasing the plant density increased the harvest index.

Significant influence was found for harvest index by combined effect of different sources of nutrients and different plant spacings (Table 4.19 and Appendix XLIX). Results signified that in the 2^{nd} experiment, T_5S_1 treatment combination gave the highest harvest index (45.69%) where the lowest harvest index (42.23%) was recorded from T_6S_4. In the 3^{rd} experiment, T_5S_1 also gave the highest harvest index (45.88%) where the lowest harvest index (43.29%) was recorded from T_6S_4.

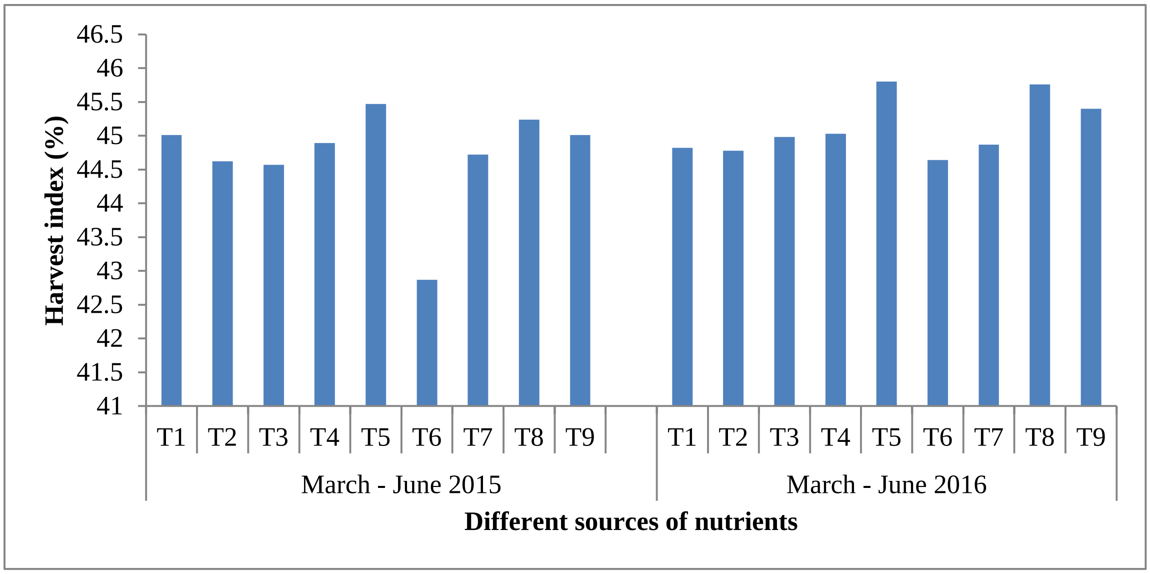

Fig. 4.45 Harvest index of sesame as influenced by different sources of plant nutrientsduring 2015 and 2016 ($LSD_{0.05}$ = 0.227 and 0.105 in 2015 and 2016, respectively)

T_1= 100% RDF through chemical fertilizer, T_2=100% RDF through vermicomost, T_3=75% RDF through vermicomost + 25 % as chemical fertilizer, T_4=50% RDF through vermicompost + 50% as chemical fertilizer, T_5=25% RDF through vermicompost + 75% as chemical fertilizer, T_6=100% RDF through FYM, T_7=75% RDF through FYM + 25% as chemical fertilizer, T_8=50% RDF through FYM + 50% as chemical fertilizer and T_9=25% RDF through FYM + 75% as chemical fertilizer

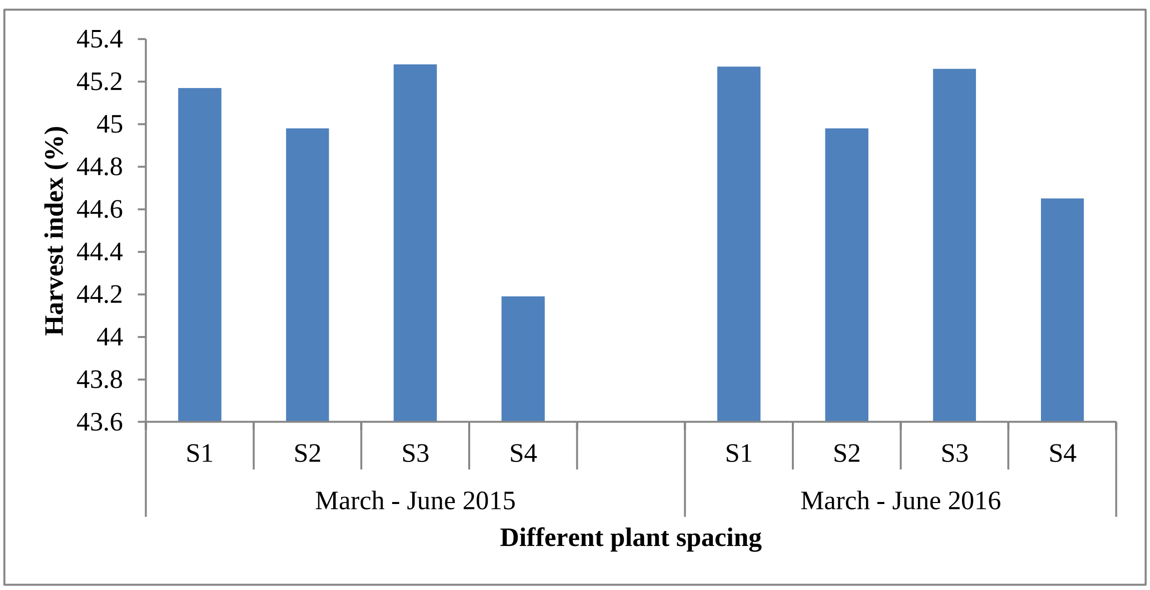

Fig. 4.46 Harvest index of sesame as influenced by plant spacingduring 2015 and 2016 ($LSD_{0.05}$ = 0.407 and 0.124 in 2015 and 2016, respectively)

S_1=30 cm × 5 cm (400 plants plot^{-1}), S_2=30 cm × 10 cm (200 plants plot^{-1}), S_3=30 cm × 15 cm (130 plants plot^{-1}) and S_4=30 cm × 20 cm (100 plants plot^{-1})

Table 4.19 Combined effect of different sources of plant nutrients and spacing on yield parameters of sesame during 2015 and 2016

Treatment	Yield parameters						Pooled yield (kg ha^{-1})
	2^{nd} Experiment			3^{rd} Experiment			
	Seed yield ha^{-1} (kg)	Stover yield ha^{-1} (kg)	Harvest index (%)	Seed yield ha^{-1} (kg)	Stover yield ha^{-1} (kg)	Harvest index (%)	
T_1S_1	1390.00	1692.00	45.10	1398.00	1696.00	45.18	1394.00
T_1S_2	1347.00	1647.00	44.99	1342.00	1640.00	45.00	1344.50
T_1S_3	1240.00	1507.00	45.14	1230.00	1518.00	44.76	1235.00
T_1S_4	1093.00	1373.00	44.32	1105.00	1376.00	44.54	1099.00
T_2S_1	1387.00	1687.00	45.12	1390.00	1688.00	45.16	1388.50
T_2S_2	1310. 00	1607.00	44.91	1297.00	1618.00	44.49	1303.50
T_2S_3	1207.00	1462.00	45.22	1210.00	1444.00	45.59	1208.50
T_2S_4	1053.00	1337.00	44.06	1042.00	1332.00	43.89	1047.50
T_3S_1	1413.00	1688.00	45.57	1410.00	1693.00	45.44	1411.50
T_3S_2	1340.00	1607.00	45.47	1336.00	1610.00	45.35	1338.00
T_3S_3	1233.00	1488.00	45.31	1222.00	1472.00	45.36	1227.50
T_3S_4	1087.00	1362.00	44.39	1077.00	1365.00	44.10	1082.00
T_4S_1	1430.00	1702.00	45.66	1427.00	1698.00	45.66	1428.50
T_4S_2	1353.00	1663.00	44.86	1360.00	1652.00	45.15	1356.50
T_4S_3	1247.00	1517.00	45.12	1240.00	1522.00	44.90	1243.50
T_4S_4	1173.00	1430.00	45.06	1163.00	1422.00	44.99	1168.00
T_5S_1	1437.00	1708.00	45.69	1442.00	1701.00	45.88	1439.50
T_5S_2	1373.00	1692.00	44.80	1366.00	1670.00	44.99	1369.50
T_5S_3	1300.00	1563.00	45.41	1277.00	1570.00	44.85	1288.50
T_5S_4	1193.00	1440.00	45.31	1187.00	1442.00	45.15	1190.00
T_6S_1	1380.00	1685.00	45.02	1375.00	1667.00	45.20	1377.50
T_6S_2	1303.00	1605.00	44.81	1290.00	1602.00	44.61	1296.50
T_6S_3	1200.00	1440.00	45.45	1198.00	1438.00	45.45	1199.00
T_6S_4	933.30	1277.00	42.23	962.00	1260.00	43.29	947.65
T_7S_1	1397.00	1681.00	45.39	1401.00	1690.00	45.33	1399.00
T_7S_2	1323.00	1607.00	45.15	1325.00	1612.00	45.11	1324.00
T_7S_3	1213.00	1480.00	45.04	1215.00	1466.00	45.32	1214.00
T_7S_4	1060.00	1340.00	44.17	1055.00	1346.00	43.94	1057.50
T_8S_1	1418.00	1696.00	45.54	1422.00	1695.00	45.62	1420.00
T_8S_2	1347.00	1653.00	44.90	1350.00	1644.00	45.09	1348.50
T_8S_3	1245.00	1473.00	45.81	1233.00	1456.00	45.85	1239.00
T_8S_4	1140.00	1408.00	44.74	1145.00	1384.00	45.27	1142.50
T_9S_1	1433.00	1706.00	45.65	1430.00	1691.00	45.82	1431.50
T_9S_2	1360.00	1673.00	44.84	1355.00	1657.00	44.99	1357.50
T_9S_3	1260.00	1535.00	45.08	1264.00	1529.00	45.26	1262.00
T_9S_4	1183.00	1434.00	45.20	1172.00	1428.00	45.08	1177.50
$LSD_{0.05}$	8.986	10.17	1.444	8.679	12.554	0.116	7.493
CV (%)	13.52	15.39	6.59	11.40	12.48	6.55	12.17

T_1= 100% RDF through chemical fertilizer, T_2=100% RDF through vermicomost, T_3=75% RDF through vermicomost + 25 % as chemical fertilizer, T_4=50% RDF through vermicompost + 50% as chemical fertilizer, T_5=25% RDF through vermicompost + 75% as chemical fertilizer, T_6=100% RDF through FYM, T_7=75% RDF through FYM + 25% as chemical fertilizer, T_8=50% RDF through FYM + 50% as chemical fertilizer and T_9=25% RDF through FYM + 75% as chemical fertilizer, S_1=30 cm × 5 cm (400 plants $plot^{-1}$), S_2=30 cm × 10 cm (200 plants $plot^{-1}$), S_3=30 cm × 15 cm (130 plants $plot^{-1}$) and S_4=30 cm × 20 cm (100 plants $plot^{-1}$)

4.2.5 Correlation between seed yield with growth and yield characters regarding treatment of different nutrient sources and plant spacings and their combinations during March – June 2015 and 2016

The correlation between different growth charaters, yield components and grain yield of sesame as influenced by different sources of plant nutrients both in March-June 2015 and 2016, respectively are presented in Table 4.21 and 4.21respectively. The seed yield significantly and positively correlated with dry weight plant^{-1} (g), number of capsules plant^{-1}, number of seeds capsule^{-1}, capsule length (cm) and 1000 seed weight (g), stover yield (kg ha^{-1}) and harvest index (%) both in2nd and 3rd experiments but number of leaves plant^{-1} and number of branches plant^{-1} were non-significant and positively correlated with seed yield of sesame both at 2nd and 3rd experiment.

The correlation between different growth charaters, yield components and grain yield of sesame as influenced by different plant spacing both in March-June 2015 and 2016, i.e. 2nd and 3rd experiments are presented in Table 4.22 and 4.23 respectively. The seed yield significantly and positively correlated with plant height (cm), stover yield (kg ha^{-1}) and harvest index (%) both at 2nd and 3rd experiment.but number of branches plant^{-1}, dry weight plant^{-1} (g) and number of capsule plant^{-1} were significant and negatively correlated with seed yield of sesame both at 2nd and 3rd experiments.

The correlation between different growth charaters, yield components and grain yield of sesame as influenced by combined effect of different sources of plant nutrientsand plant spacings both in March-June 2015 and 2016, respectively are presented in Table 4.24 and 4.25, respectively. The seed yield significantly and positively correlated with plant height (cm), stover yield (kg ha^{-1}) and harvest index (%) both at 2nd and 3rd experimentsbut number of leaves plant^{-1}, number of branches plant^{-1}, dry weight plant^{-1} (g), 1000 seed weight (g) were significant and negatively correlated with seed yield of sesame both at 2nd and 3rd experiments.

Table 4.20 Correlation between grain yield (kg ha $^{-1}$) and growth and yield characters regarding different sources of plant nutrients during March-June 2015

	PH	NLP	NBP	DWP	NCP	NSC	CL	1000 SW	StY	HI	SY
PH	1										
NLP	0.058^{NS}	1									
NBP	0.00 ^{NS}	0.686**	1								
DWP	0.002^{NS}	-0.17 ^{NS}	0.201*	1							
NCP	0.521**	0.261*	-0.087 ^{NS}	0.377**	1						
NSC	0.421**	-0.109^{NS}	-0.154*	0.483**	0.838**	1					
CL	0.451**	-0.009^{NS}	-0.061 ^{NS}	0.461**	0.857**	0.991**	1				
1000 SW	0.071^{NS}	-0.245*	-0.423**	0.507**	0.709**	0.772**	0.718**	1			
StY	0.361**	0.098^{NS}	0.059^{NS}	0.505**	0.851**	0.966**	0.979**	0.727**	1		
HI	0.371**	-0.360**	-0.444**	0.571**	0.741**	0.777**	0.724**	0.906**	0.698**	1	
SY	0.056^{NS}	0.119^{NS}	0.023^{NS}	0.276*	0.791**	0.762**	0.784**	0.659**	0.855**	0.531**	1

NS: Non Significant at 5%, * : Significant at 5%, **: Highly Significant at 1%

Table 4.21 Correlation between grain yield ((kg ha $^{-1}$) and growth and yield characters regarding different nutrient sources during March-June 2016

	PH	NLP	NBP	DWP	NCP	NSC	CL	1000 SW	StY	HI	SY
PH	1										
NLP	-0.005^{NS}	1									
NBP	0.044^{NS}	0.742**	1								
DWP	0.185^{NS}	-0.680**	-0.407**	1							
NCP	0.111^{NS}	-0.303**	-0.201*	0.845**	1						
NSC	0.171^{NS}	-0.673**	-0.421**	0.996**	0.851**	1					
CL	0.186^{NS}	-0.630**	-0.368**	0.996**	0.872**	0.996**	1				
1000 SW	0.108^{NS}	-0.431**	-0.295*	0.895**	0.902**	0.891**	0.914**	1			
StY	0.422**	0.065^{NS}	0.016^{NS}	0.386**	0.698**	0.402**	0.429**	0.592**	1		
HI	0.460**	-0.006^{NS}	-0.071^{NS}	0.426**	0.625**	0.424**	0.455**	0.686**	0.903**	1	
SY	0.239*	0.174^{NS}	0.176^{NS}	0.218*	0.573**	0.214*	0.231*	0.274*	0.830**	0.512**	1

NS: Non Significant at 5%, *: Significant at 5%, **: Highly Significant at 1%

PH = Plant height (cm), NLP = Number of leavesplant $^{-1}$, NBP = Number of branches plant $^{-1}$, DWP = Dry weightplant^{-1}, NCP = Number of capsule plant $^{-1}$, NSC = Number of seeds capsule^{-1}, CL = Capsule length (cm), 1000 SW = 1000 seed weight (g), StY = Stover yield ha^{-1} (kg), HI = Harvest index (%) and SY = Seed yield ha^{-1} (kg)

Table 4.22 Correlation between grain yield (kg ha $^{-1}$) and growth and yield characters regarding different plant spacings during March-June 2015

	PH	NLP	NBP	DWP	NCP	NSC	CL	1000 SW	StY	HI	SY
PH	1										
NLP	-0.441**	1									
NBP	-0.856**	0.479**	1								
DWP	0.991**	-0.485**	-0.915**	1							
NCP	-0.729**	0.750**	0.926**	-0.807**	1						
NSC	-0.650**	0.740**	0.900**	-0.739**	0.994**	1					
CL	-0.663**	0.275*	0.892**	-0.749**	0.996**	0.998**	1				
1000 SW	-0.634**	0.722**	0.899**	-0.726**	0.990**	0.999**	0.996**	1			
StY	0.993**	-0.535**	-0.836**	0.284*	-0.751**	-0.672**	-0.691**	-0.653**	1		
HI	0.978**	-0.616**	-0.875**	0.984**	-0.826**	-0.757**	-0.775**	-0.739**	0.992**	1	
SY	0.785**	0.017^{NS}	-0.389**	-0.700**	-0.249*	-0.040^{NS}	-0.059^{NS}	-0.019^{NS}	0.759**	0.671**	1

NS: Non Significant at 5%, *: Significant at 5%, **: Highly Significant at 1%

Table 4.23 Correlation between grain yield (kg ha $^{-1}$) and growth and yield characters regarding different plant spacings during March-June 2016

	PH	NLP	NBP	DWP	NCP	NSC	CL	1000 SW	StY	HI	SY
PH	1										
NLP	-0.723**	1									
NBP	-0.849**	0.949**	1								
DWP	-0.904**	0.939**	0.945**	1							
NCP	-0.890**	0.954**	0.958**	0.999**	1						
NSC	-0.885**	0.960**	0.967**	0.997**	0.999**	1					
CL	-0.875**	0.960**	0.952**	0.998**	0.999**	0.998**	1				
1000 SW	-0.879**	0.965**	0.981**	0.990**	0.995**	0.998**	0.993**	1			
StY	0.993**	-0.751**	-0.844**	-0.929**	-0.913**	-0.906**	-0.902**	-0.894**	1		
HI	0.983**	-0.781**	-0.852**	-0.948**	-0.932**	-0.924**	-0.924**	-0.910**	0.997**	1	
SY	0.791**	-0.201*	-0.472**	-0.461**	-0.439**	-0.437*	-0.408**	-0.444**	0.729**	0.677**	1

NS: Non Significant at 5%, *: Significant at 5%, **: Highly Significant at 1%

PH = Plant height (cm), NLP = Number of leaves plant $^{-1}$**,** NBP = Number of branches plant $^{-1}$, DWP = Dry weight plant $^{-1}$, NCP = Number of capsule plant $^{-1}$, NSC = Number of seeds capsule $^{-1}$, CL = Capsule length (cm), 1000 SW = 1000 seed weight (g), StY = Stover yield ha $^{-1}$ (kg), HI = Harvest index (%) and SY = Seed yield ha $^{-1}$(kg)

Table 4.24 Correlation between grain yield (kg ha^{-1}) and growth and yield characters regarding treatment combination of different nutrient sources and plant spacings during March-June 2015

	PH	NLP	NBP	DWP	NCP	NSC	CL	1000 SW	StY	HI	SY
PH	1										
NLP	-0.370**	1									
NBP	-0.385**	0.763**	1								
DWP	-0.497**	0.497**	0.581**	1							
NCP	-0.243*	0.662**	0.650**	0.726**	1						
NSC	-0.248*	0.644**	0.597**	0.742**	0.814**	1					
CL	-0.606**	0.654**	0.612**	0.748**	0.795**	0.991**	1				
1000 SW	-0.522**	0.619**	0.594**	0.710**	0.763**	0.899**	0.901**	1			
StY	0.910**	-0.492**	-0.478**	-0.241*	-0.534**	-0.676**	-0.676**	-0.615**	1		
HI	0.680**	-0.005^{NS}	-0.056^{NS}	-0.109^{NS}	-0.089^{NS}	-0.197^{NS}	-0.159^{NS}	-0.075^{NS}	0.580**	1	
SY	0.930**	-0.427**	-0.425**	-0.533**	-0.480**	-0.624**	-0.615**	-0.547**	0.983**	0.718**	1

NS: Non Significant at 5%, *: Significant at 5%, **: Highly Significant at 1%

Table 4.25 Correlation between grain yield (kg ha^{-1}) and growth and yield characters regarding treatment combination of different nutrient sources and plant spacingsduring March-June, 2016

	PH	NLP	NBP	DWP	NCP	NSC	CL	1000 SW	StY	HI	SY
PH	1										
NLP	-0.243*	1									
NBP	-0.372**	0.680**	1								
DWP	-0.704**	0.435**	0.503**	1							
NCP	-0.616**	0.498**	0.557**	0.955**	1						
NSC	-0.233*	0.461**	0.528**	0.990**	0.946**	1					
CL	-0.711**	0.244*	0.535**	0.995**	0.958**	0.992**	1				
1000 SW	-0.689**	0.455**	0.567**	0.979**	0.969**	0.981**	0.985**	1			
StY	0.916**	-0.240*	-0.438**	-0.738**	-0.634**	-0.762**	-0.743**	-0.695**	1		
HI	0.759**	-0.206*	-0.177^{NS}	-0.417**	-0.370**	-0.439**	-0.407**	-0.439**	0.576**	1	
SY	0.951**	-0.346**	-0.424**	-0.730**	-0.630**	-0.756**	-0.733**	-0.699**	0.985**	0.709**	1

NS: Non Significant at 5%, *: Significant at 5%, **: Highly Significant at 1%

PH = Plant height (cm), NLP = Number of leaves plant $^{-1}$**,** NBP = Number of branches plant $^{-1}$, DWP = Dry weight plant^{-1}, NCP = Number of capsule plant^{-1}, NSC = Number of seeds capsule^{-1}, CL = Capsule length (cm), 1000 SW = 1000 seed weight (g), StY = Stover yield ha^{-1} (kg), HI = Harvest index (%) and SY = Seed yield ha $^{-1}$(kg)

4.2.6 Regression analysis of grain yield against different nutrient sources and plant spacing and their combination during March – June 2015 and 2016

The regression analysis of grain yield against different sources of nutrient for the year 2015 and 2016 (2nd and 3rd experiments, respectively) was carried out and the result is presented in Fig. 4.47 and 4.48. The response of sesame grain yield against different sources of nutrients in both years was linear and positively significant. This showed that increasing different sources of nutrients significantly increased grain yield of sesame. The linear models had an R^2 value of 0.029 and 0.037 for March – June 2015 and 2016 respectively. The linear equations were y=2.4x+1261 and y=2.908x+1258 for March – June 2015 and 2016, respectively.

The regression analysis of grain yield against different plant spacings for the year 2015 and 2016 (2nd and 3rd experiments, respectively) was examined and the result is presented in Fig.4.49 and 4.50. The response of sesame grain yield against different plant spacing in both years was linear and negatively significant. This showed that increasing plant spacings significantly decreased grain yield of sesame. The linear models had an R^2 value of 0.981 and 0.986 for March–June 2015 and 2016 respectively. The linear equations were y = -103.5x + 1532 and y = -103.7x + 1529 for March–June 2015 and 2016, respectively.

The regression analysis of grain yield against combination of different sources of nutrient and plant spacings for the year 2015 and 2016 (2nd and 3rd experiments respectively) was exposed and the result is presented in Fig.4.51 and 4.52. The response of sesame grain yield combination of different sources of nutrient and plant spacings in both years was linear and negatively significant. This showed that increasing both plant spacing and nutrient sources significantly decreased grain yield of sesame. The linear models had an R^2 value of 0.001 and 0.001 for March–June 2015 and 2016, respectively. The linear equations were y = -0.469x + 1280 and y = -0.419x + 1277 for March–June 2015 and 2016, respectively.

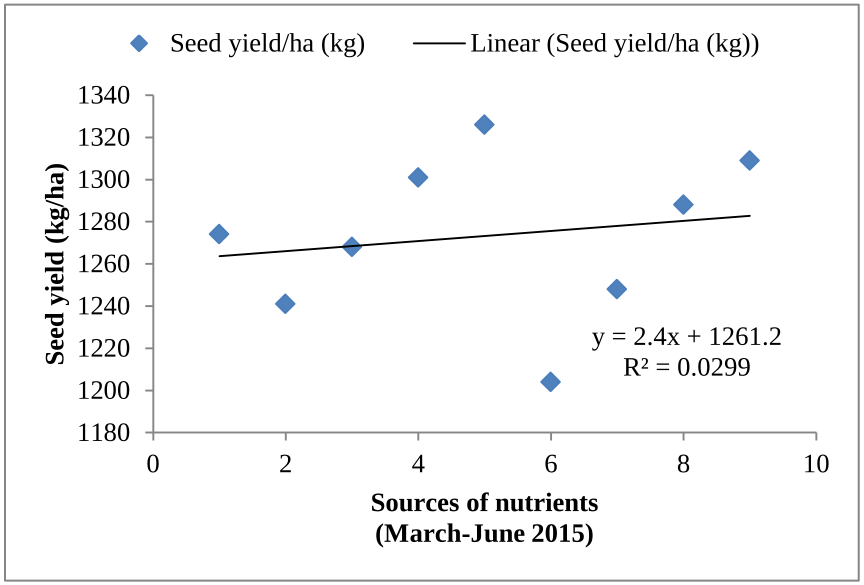

Fig. 4.47 Response of sesame grain yield against different sources of nutrientin 2nd experiment (March-June)

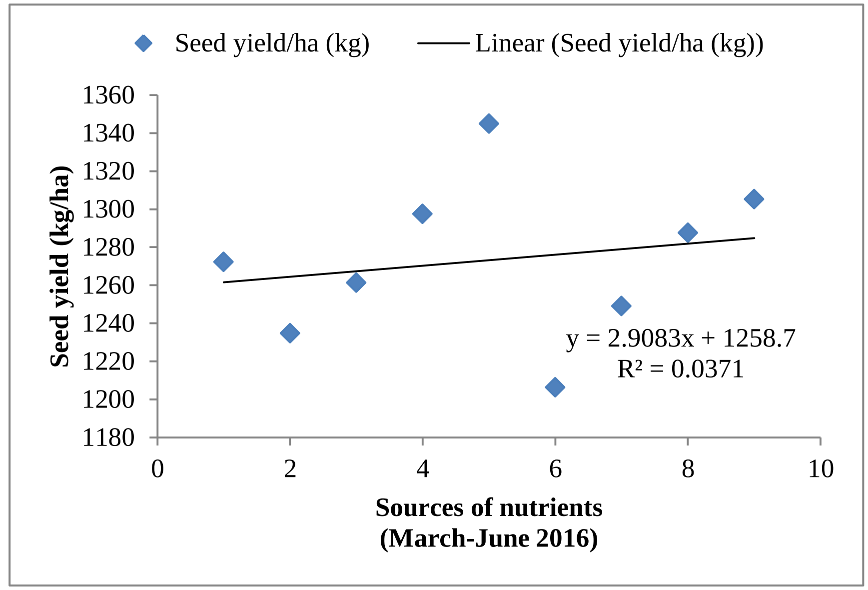

Fig. 4.48 Response of sesame grain yield against different sources of nutrient in 3rd experiment (March-June)

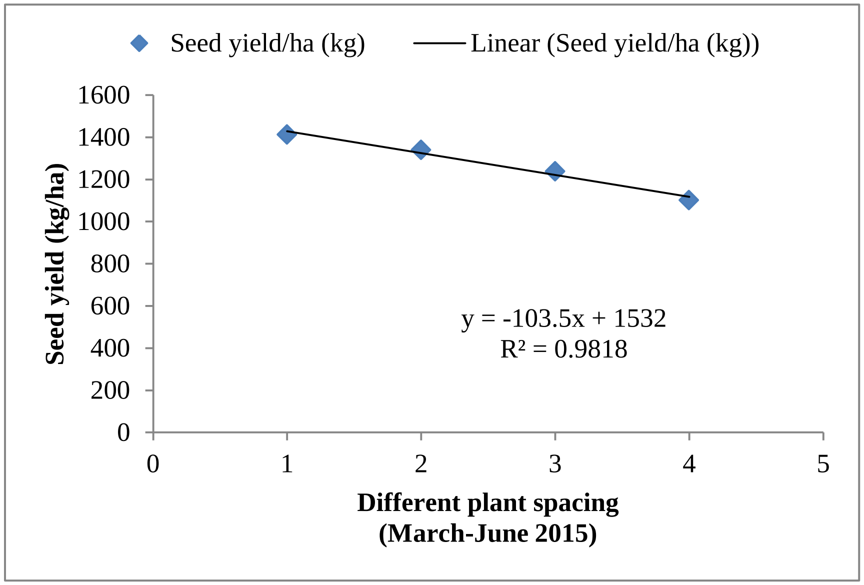

Fig. 4.49 Response of sesame grain yield against different plant spacings in 2nd experiment (March-June 2015)

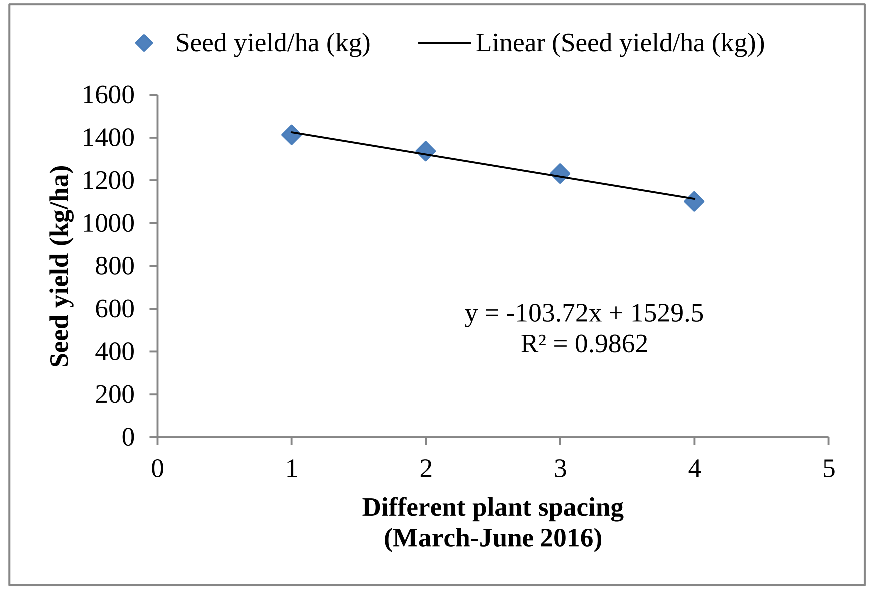

Fig. 4.50 Response of sesame grain yield against different plant spacings in 3rd experiment (March-June 2016)

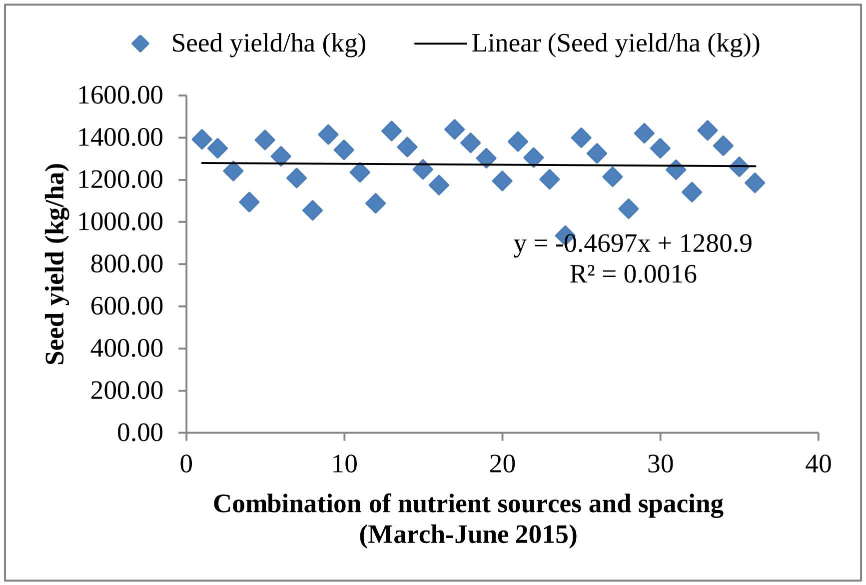

Fig. 4.51 Response of sesame grain yield against combination of different sources of nutrient and plant spacings in 2nd experiment (March-June 2015)

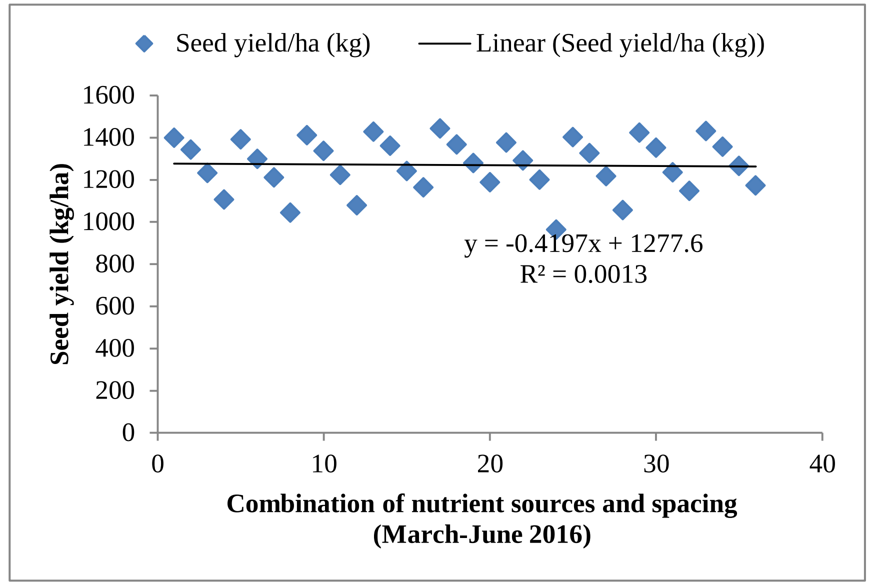

Fig. 4.52 Response of sesame grain yield against combination of different sources of nutrient and plant spacingsat 3rd experiment (March-June 2016)

4.2.7 Quality performance

4.2.7.1 Oil content and yield

Percent (%) oil content and oil yield $ha^{-1}$was apparently influenced due to different nutrient sources to soil for sesame both at March-June 2015 and March-June, 2016, respectively (Table 4.26 and Appendix L). Regarding this situation, in the 2^{nd} and 3^{rd} experiment respectively, % oil content was highest (43.90% and 43.76%) from T_5 (25% RDF through vermicompost + 75% as chemical fertilizer) which was statistically similar with T_4 (50% RDF through vermicompost + 50% as chemical fertilizer) where the lowest % oil content (42.47% and 42.84%) was obtained from T_1 (100% RDF through chemical fertilizer). Similarly, in the 2^{nd} and 3^{rd} experiment, respectively, the highest oil yield ha^{-1} (581.07 and 575.77 kg) was achieved from T_5 (25% RDF through vermicompost + 75% as chemical fertilizer) where the lowest oil yield ha^{-1} (518.57 and 520.22 kg) was recorded from T_6 (100% RDF through FYM).

Significant influence was found for percent oil content and oil yield ha^{-1} as influenced by different plant spacing both in the 2^{nd} and 3^{rd} experiment (Table 4.27 and Appendix L). In the 2^{nd} and 3^{rd} experiment, respectively the highest percent oil content (44.10% and 44.11%) was obtained from S_3 (30 cm × 15 cm; 130 plants $plot^{-1}$) which was statistically similar with S_4 (30 cm × 20 cm; 100 plants $plot^{-1}$) where the lowest percent oil content (41.34% and 41.56%) was observed from S_1 (30 cm × 5 cm; 400 plants $plot^{-1}$) which was closely followed by S_2 (30 cm × 10 cm; 200 plants $plot^{-1}$). Again, in the 2^{nd} and 3^{rd} experiment, respectively in terms of oil yield ha^{-1}, the highest (584.11 and 586.90 kg) was obtained from S_1 (30 cm × 5 cm; 400 plants $plot^{-1}$) and the lowest oil yield ha^{-1} (484.19 and 543.45 kg) was found from S_4 (30 cm × 20 cm; 100 plants $plot^{-1}$). Rahnama and Bakhshandeh (2006) and Caliskan *et al*. (2004) supported the present findings and observed that oil content increased with increasing plant population.

Oil content (%) and oil yield ha^{-1} was significantly influenced by combined effect of different nutrient sources and plant spacing both in the 2^{nd} and 3^{rd} experiment (Table 4.28 and Appendix L). In the 2^{nd} and 3^{rd} experiment, respectively, T_5S_3 listed the maximum percent oil content (45.38% and 44.88%) where the lowest percent oil content (40.10% and 40.87%) was recorded from T_8S_1. Likewise, in the 2^{nd} and 3^{rd} experiment, respectively, the highest oil yield ha^{-1} (608.14 and 609.39 kg) was found from T_5S_1 which was statistically similar with T_4S_1 where the lowest oil yield ha^{-1} (412.05 and 424.43 kg) was recorded from T_6S_4.

4.2.7.2 Protein content and yield

Percent (%) protein content and protein yield $ha^{-1}$was apparently influenced due to different nutrient sources for sesame both at March-June 2015 and March-June, 2016 i.e. 2nd and 3rd experiment, respectively (Table 4.26 and Appendix L). In the 2nd and 3rd experiment, respectively, the highest percent protein content (19.39% and 19.78%) was found from T_5 (25% RDF through vermicompost + 75% as chemical fertilizer) which was closely followed by T_4 (50% RDF through vermicompost + 50% as chemical fertilizer) where the lowest % protein content (18.18% and 18.44%) was obtained from T_8 (0% RDF through FYM + 50% as chemical fertilizer) which was statistically similar with T_1 (100% RDF through chemical fertilizer). Similarly, in the 2nd and 3rd experiment respectively, the highest protein yield ha^{-1} (256.09 and 259.52 kg) was also achieved from T_5 (25% RDF through vermicompost + 75% as chemical fertilizer) and the lowest protein yield ha^{-1} (226.55 and 226.75 kg) was recorded from T_6 (100% RDF through FYM).

Significant influence was found for % protein content and protein yield ha^{-1} as influenced by different plant spacing both in the 2nd and 3rd experiment (Table 4.27 and Appendix L). In the 2nd and 3rd experiment, respectively, the highest% protein content (19.64% and 19.72%) was obtained from S_3 (30 cm × 15 cm; 130 plants $plot^{-1}$) which was statistically similar with S_4 (30 cm × 20 cm; 100 plants $plot^{-1}$) where the lowest % protein content (17.75% and 17.81%) was observed from S_1 (30 cm × 5 cm; 400 plants $plot^{-1}$). Again in the 2nd and 3rd experiment, respectively the highest protein yield ha^{-1} (250.82 and 251.48 kg) was obtained from S_1 (30 cm × 5 cm; 400 plants $plot^{-1}$) which was statistically similar with S_2 (30 cm × 10 cm; 200 plants $plot^{-1}$) but the lowest protein yield ha^{-1} (216.09 and 217.14 kg) was found from S_4 (30 cm × 20 cm; 100 plants $plot^{-1}$). Caliskan *et al*. (2004) observed that the protein content decreased, with increasing plant population which was supported by the present findings.

Protein content (%) and protein yield ha^{-1} was significantly influenced by combined effect of different nutrient sources and plant spacing (Table 4.28 and Appendix L). In the 2nd and 3rd experiments, respectively T_5S_3 listed the highest percent protein content (20.72% and 21.18%, respectively) which was statistically similar with T_5S_4 where the lowest percent protein content (17.23% and 17.34%) was recorded from T_8S_1. Likewise, in the 2nd and 3rd experiments the maximum protein yield ha^{-1} (269.58 and 271.38 kg, respectively) was found from T_5S_1 which was statistically identical with T_5S_3 where the lowest protein yield ha^{-1} (186.29 and 191.44 kg) was recorded from T_6S_4.

Table 4.26 Oil and protein content, and yield of sesame influenced by different sources of plant nutrients during March – June, 2015 and 2016

Treatment	2nd Experiment				3rd Experiment			
	Oil yield		Protein yield		Oil yield		Protein yield	
	% oil content	Oil yield (kg ha^{-1})	% protein content	Protein yield (kg ha^{-1})	% oil content	Oil yield (kg ha^{-1})	% protein content	Protein yield (kg ha^{-1})
T_1	42.47	540.29	18.43	233.77	42.84	543.70	18.50	233.68
T_2	43.21	535.06	18.95	234.10	43.31	533.70	19.00	233.62
T_3	42.94	543.30	18.68	235.87	43.05	541.79	18.67	234.45
T_4	43.46	564.39	19.18	248.57	43.42	562.49	19.19	247.88
T_5	43.90	581.07	19.39	256.09	43.76	575.77	19.78	259.52
T_6	43.18	518.57	18.92	226.55	43.23	520.22	18.89	226.75
T_7	43.02	535.80	18.79	233.86	43.17	538.09	18.83	234.51
T_8	42.63	547.52	18.42	236.60	42.94	551.65	18.44	237.45
T_9	42.86	559.90	18.59	242.73	43.01	560.34	18.67	243.12
$LSD_{0.05}$	0.545	7.395	0.316	5.459	0.435	8.331	0.281	6.337
CV (%)	13.11	17.45	6.16	7.41	7.45	8.65	3.64	5.40

T_1= 100% RDF through chemical fertilizer, T_2=100% RDF through vermicomost, T_3=75% RDF through vermicomost + 25 % as chemical fertilizer, T_4=50% RDF through vermicompost + 50% as chemical fertilizer, T_5=25% RDF through vermicompost + 75% as chemical fertilizer, T_6=100% RDF through FYM, T_7=75% RDF through FYM + 25% as chemical fertilizer, T_8=50% RDF through FYM + 50% as chemical fertilizer and T_9=25% RDF through FYM + 75% as chemical fertilizer

Table 4.27 Oil and protein content, and yield of sesame influenced by plant spacings during March – June, 2015 and 2016

Treatment	2nd Experiment				3rd Experiment			
	Oil yield		Protein yield		Oil yield		Protein yield	
	% oil content	Oil yield (kg ha^{-1})	% protein content	Protein yield (kg ha^{-1})	% oil content	Oil yield (kg ha^{-1})	% protein content	Protein yield (kg ha^{-1})
S_1	41.34	584.11	17.75	250.82	41.56	586.90	17.81	251.48
S_2	42.90	574.66	18.25	244.47	42.98	485.66	18.29	244.27
S_3	44.10	546.33	19.64	243.35	44.11	574.08	19.72	243.10
S_4	43.95	484.19	19.62	216.09	44.10	543.45	19.71	217.14
$LSD_{0.05}$	0.561	6.389	0.327	5.886	0.469	8.339	0.298	7.312
CV (%)	13.43	16.50	6.16	5.40	6.20	5.65	3.48	5.40

S_1=30 cm × 5 cm (400 plants $plot^{-1}$), S_2=30 cm × 10 cm (200 plants $plot^{-1}$), S_3=30 cm × 15 cm (130 plants $plot^{-1}$) and S_4=30 cm × 20 cm (100 plants $plot^{-1}$)

Table 4.28 Combined effect of different sources of plant nutrients and spacings on oil and protein content and yield of sesame during March – June 2015 and 2016

Treatment	2nd Experiment				3rd Experiment			
	Oil yield		Protein yield		Oil yield		Protein yield	
	% oil content	Oil yield (kg ha^{-1})	% protein content	Protein yield (kg ha^{-1})	% oil content	Oil yield (kg ha^{-1})	% protein content	Protein yield (kg ha^{-1})
T_1S_1	40.67	576.29	17.44	247.12	41.05	579.63	17.40	245.69
T_1S_2	42.60	573.82	18.00	242.46	42.45	569.68	18.10	242.90
T_1S_3	43.72	542.13	18.72	232.13	43.88	539.72	18.75	230.63
T_1S_4	42.90	468.90	19.52	213.35	43.96	485.76	19.50	215.48
T_2S_1	41.94	584.22	18.00	250.74	42.00	583.80	18.12	251.87
T_2S_2	43.00	563.30	18.32	239.99	43.07	558.62	18.37	238.26
T_2S_3	43.72	527.70	19.44	234.64	43.95	531.80	19.50	235.95
T_2S_4	44.16	465.00	20.04	211.02	44.20	460.56	20.00	208.40
T_3S_1	41.03	579.75	17.66	249.54	41.28	582.05	17.60	248.16
T_3S_2	42.92	575.13	18.20	243.88	43.00	574.48	18.26	243.95
T_3S_3	43.80	540.05	19.00	234.27	43.87	536.09	19.04	232.67
T_3S_4	44.00	478.28	19.85	215.77	44.06	474.53	19.78	213.03
T_4S_1	42.12	602.32	18.00	257.40	42.06	600.20	17.92	255.72
T_4S_2	43.06	582.60	18.40	248.95	43.10	586.16	18.36	249.70
T_4S_3	44.44	554.17	20.24	252.39	44.27	548.95	20.20	250.48
T_4S_4	44.20	518.47	20.08	235.54	44.25	514.63	20.26	235.62
T_5S_1	42.32	608.14	18.76	269.58	42.26	609.39	18.82	271.38
T_5S_2	43.22	593.41	18.39	252.49	43.12	589.02	18.52	252.98
T_5S_3	45.38	589.94	20.72	269.36	44.88	573.12	21.18	270.47
T_5S_4	44.66	532.79	20.44	243.85	44.78	531.54	21.10	250.46
T_6S_1	41.82	577.12	17.95	247.71	41.84	575.30	17.98	247.23
T_6S_2	42.92	559.25	18.30	238.45	43.04	555.22	18.25	235.43
T_6S_3	43.82	525.84	19.48	233.76	43.90	525.92	19.44	232.89
T_6S_4	44.15	412.05	19.96	186.29	44.12	424.43	19.90	191.44
T_7S_1	41.24	576.12	17.85	249.36	41.56	582.26	17.92	251.06
T_7S_2	42.90	567.57	18.33	242.51	43.12	571.34	18.35	243.14
T_7S_3	44.08	534.69	19.86	240.90	44.10	535.82	19.90	241.79
T_7S_4	43.85	464.81	19.12	202.67	43.88	462.93	19.15	202.03
T_8S_1	40.10	568.62	17.23	244.32	40.87	581.17	17.34	246.57
T_8S_2	42.70	575.17	18.16	244.62	42.95	579.83	18.10	244.35
T_8S_3	43.98	547.55	19.62	244.27	44.08	543.51	19.74	243.39
T_8S_4	43.75	498.75	18.70	213.18	43.85	502.08	18.82	215.49
T_9S_1	40.78	584.38	17.62	252.49	41.14	588.30	17.68	252.82
T_9S_2	42.77	581.67	18.15	246.84	42.98	582.38	18.28	247.69
T_9S_3	44.04	554.90	19.72	248.47	44.00	556.16	19.75	249.64
T_9S_4	43.84	518.63	18.86	223.11	43.90	514.51	18.97	222.33
$LSD_{0.05}$	0.416	6.643	0.318	4.227	0.389	7.992	0.279	6.114
CV (%)	8.34	7.45	6.15	8.39	6.21	9.47	5.25	8.40

T_1= 100% RDF through chemical fertilizer, T_2=100% RDF through vermicomost, T_3=75% RDF through vermicomost + 25 % as chemical fertilizer, T_4=50% RDF through vermicompost + 50% as chemical fertilizer, T_5=25% RDF through vermicompost + 75% as chemical fertilizer, T_6=100% RDF through FYM, T_7=75% RDF through FYM + 25% as chemical fertilizer, T_8=50% RDF through FYM + 50% as chemical fertilizer and T_9=25% RDF through FYM + 75% as chemical fertilizer, S_1=30 cm × 5 cm (400plants plot^{-1}), S_2=30 cm × 10 cm (200 plants plot^{-1}), S_3=30 cm × 15 cm (130 plants plot^{-1}) and S_4=30 cm × 20 cm (100 plants plot^{-1})

4.2.8 Nutrient uptake of sesame

Significant variation was found for nutrient uptake by sesame plant affected by different sources of nutrients both at March-June 2015 and March-June 2016 (Table 4.29 and Appendix LI and LII). Results revealed that in the 2nd and 3rd experiment respectively, T_5 (25% RDF through vermicompost + 75% as chemical fertilizer) gave highest N uptake (37.15 and 37.41kg ha^{-1}, respectively), P_2O_5 uptake (29.18 and 29.58 kg ha^{-1}) and K_2O uptake (12.56 and 14.14 kg ha^{-1}, respectively) followed by T_9 (% RDF through FYM + 75% as chemical fertilizer),T_4 (50% RDF through vermicompost + 50% as chemical fertilizer) and T_8 (50% RDF through FYM + 50% as chemical fertilizer). The lowest N uptake (30.58 and 30.49 kg ha^{-1}), P_2O_5 uptake (27.66 and 27.97 kg ha^{-1}) and K_2O uptake (10.55 and 11.98 kg ha^{-1}) were achieved with T_6 (100% RDF through FYM) which was in close proximity to T_2 (100% RDF through vermicomost).

Significant variation was also found for nutrient uptake by sesame plant affected by different plant spacing both in the 2nd and 3rd experiments (Table 4.30 and Appendix LI and LII). In the 2nd and 3rd experiment, respectively the highest N uptake (43.91 and 44.07 kg ha^{-1}), P_2O_5 uptake (31.29 and 31.55 kg ha^{-1}) and K_2O uptake (15.35 and 16.47 kg ha^{-1}) were from S_1 (30 cm × 5 cm; 400 plants $plot^{-1}$) followed by S_2 (30 cm × 10 cm; 200 plants $plot^{-1}$). The lowest N uptake (23.53 and 23.65 kg ha^{-1}), P_2O_5 uptake (25.47 and 25.60 kg ha^{-1}) and K_2O uptake (7.57 and 8.31 kg ha^{-1}) were obtained from S_4 (30 cm × 20 cm; 100 plants $plot^{-1}$) which was close to S_3 (30 cm × 15 cm; 130 plants $plot^{-1}$).

Significant variation was also found for nutrient uptake by sesame plant affected by combined effect of different nutrient sources and plant spacing both in the 2nd and 3rd experiment (Table 4.31 and Appendix LI and LII). Results signififiend that in the 2nd and 3rd experiment, respectively the highest N uptake (45.88 and 47.32 kg ha^{-1}), P_2O_5 uptake (32.18 and 33.26 kg ha^{-1}) and K_2O uptake (16.78 and 18.11 kg ha^{-1}) were obtained from T_5S_1 and followed by T_4S_1 and T_9S_1. The lowest N uptake (17.36 and 18.65 kg ha^{-1}), P_2O_5 uptake (24.72 and 25.18 kg ha^{-1}, respectively) and K_2O uptake (5.72 and 6.18 kg ha^{-1}) were obtained from T_6S_4 which was preceeded by T_2S_4 and T_7S_4.

Table 4.29 Nutrient uptake of sesame influenced by different sources of plant nutrientsduring, March – June 2015 and 2016

Treatment	Nutrient uptake (kg ha^{-1})					
	2nd Experiment			3rd Experiment		
	N (Nitrogen)	P_2O_5 (Phosphoros)	K_2O (Potassium)	N (Nitrogen)	P_2O_5 (Phosphoros)	K_2O (Potassium)
T_1	34.37	28.39	11.46	34.40	28.43	12.74
T_2	31.67	27.86	10.73	31.65	28.13	12.19
T_3	33.65	28.30	11.50	33.50	28.30	12.63
T_4	35.93	28.73	11.98	35.59	28.91	13.47
T_5	37.15	29.18	12.56	37.41	29.58	14.14
T_6	30.58	27.66	10.55	30.49	27.97	11.98
T_7	32.61	28.03	11.34	32.52	28.20	12.50
T_8	35.19	28.56	11.82	34.88	28.66	13.04
T_9	36.44	28.89	12.39	36.85	29.28	13.68
$LSD_{0.05}$	1.314	0.637	0.572	1.149	0.627	0.486
CV (%)	16.60	11.54	8.14	10.40	10.40	9.40

T_1= 100% RDF through chemical fertilizer, T_2=100% RDF through vermicomost, T_3=75% RDF through vermicomost + 25 % as chemical fertilizer, T_4=50% RDF through vermicompost + 50% as chemical fertilizer, T_5=25% RDF through vermicompost + 75% as chemical fertilizer, T_6=100% RDF through FYM, T_7=75% RDF through FYM + 25% as chemical fertilizer, T_8=50% RDF through FYM + 50% as chemical fertilizer and T_9=25% RDF through FYM + 75% as chemical fertilizer

Table 4.30 Nutrient uptake of sesame influenced by plant spacing during March – June, 2015 and 2016

Treatment	Nutrient uptake					
	2nd Experiment			3rd Experiment		
	N (Nitrogen)	P_2O_5 (Phosphoros)	K_2O (Potassium)	N (Nitrogen)	P_2O_5 (Phosphoros)	K_2O (Potassium)
S_1	43.91	31.29	15.35	44.07	31.55	16.47
S_2	38.00	29.43	12.88	38.11	29.60	14.44
S_3	31.27	27.41	10.57	30.74	27.66	12.50
S_4	23.53	25.47	7.57	23.65	25.60	8.31
$LSD_{0.05}$	2.448	2.167	1.389	2.359	1.144	2.371
CV (%)	18.90	13.64	10.46	12.68	15.45	10.31

S_1=30 cm × 5 cm (400 plants plot^{-1}), S_2=30 cm × 10 cm (200 plants plot^{-1}), S_3=30 cm × 15 cm (130 plants plot^{-1}) and S_4=30 cm × 20 cm (100 plants plot^{-1})

Table 4.31 Combined effects of different sources of plant nutrients and spacing on nutrient uptake of sesame during March – June 2015 and 2016

Treatment	Nutrient uptake (kg ha^{-1})					
	2nd Experiment			3rd Experiment		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
T_1S_1	43.99	31.04	15.00	44.22	31.12	16.17
T_1S_2	38.10	29.44	12.44	37.60	29.60	14.44
T_1S_3	30.84	27.54	11.04	31.06	27.50	12.20
T_1S_4	24.55	25.54	7.34	24.73	25.48	8.16
T_2S_1	42.08	30.77	14.57	42.20	31.00	16.05
T_2S_2	36.00	28.48	12.41	37.14	29.00	13.88
T_2S_3	28.76	27.00	9.00	28.14	27.20	11.95
T_2S_4	19.85	25.20	6.20	19.12	25.32	6.88
T_3S_1	43.12	31.00	15.02	42.89	31.10	16.14
T_3S_2	37.36	29.40	13.10	36.88	29.36	14.17
T_3S_3	30.58	27.38	10.38	30.14	27.22	12.22
T_3S_4	23.54	25.41	7.49	24.10	25.50	8.00
T_4S_1	45.11	31.64	15.44	45.38	31.89	16.75
T_4S_2	39.72	30.00	13.00	40.44	29.88	14.65
T_4S_3	33.12	27.62	11.12	32.10	28.00	13.02
T_4S_4	25.78	25.66	8.36	24.44	25.87	9.44
T_5S_1	45.88	32.18	16.78	47.32	33.26	18.11
T_5S_2	40.94	30.70	13.70	41.18	30.44	15.24
T_5S_3	33.79	27.87	10.87	32.94	28.73	13.43
T_5S_4	28.00	25.98	8.90	28.19	25.90	9.78
T_6S_1	42.18	30.64	14.60	41.76	30.60	15.52
T_6S_2	34.59	28.40	11.80	33.31	29.00	14.08
T_6S_3	28.18	26.88	10.81	28.22	27.10	12.14
T_6S_4	17.36	24.72	5.72	18.65	25.18	6.18
T_7S_1	42.56	31.06	15.36	42.25	31.00	16.06
T_7S_2	36.48	28.66	12.69	36.62	29.14	14.00
T_7S_3	30.20	27.12	10.12	29.36	27.20	12.10
T_7S_4	21.19	25.28	7.20	21.84	25.44	7.84
T_8S_1	44.65	31.33	15.39	45.10	31.26	16.26
T_8S_2	38.56	29.67	13.67	39.15	29.75	14.48
T_8S_3	32.44	27.60	10.60	31.11	27.78	12.48
T_8S_4	25.10	25.62	7.60	24.16	25.85	8.94
T_9S_1	45.64	31.98	15.98	45.53	32.76	17.18
T_9S_2	40.26	30.12	13.10	40.67	30.26	15.04
T_9S_3	33.48	27.66	11.16	33.60	28.18	12.94
T_9S_4	26.39	25.80	9.30	27.58	25.90	9.56
$LSD_{0.05}$	1.123	1.327	0.628	1.214	0.897	0.588
CV (%)	8.56	7.36	9.15	7.49	8.47	8.40

T_1= 100% RDF through chemical fertilizer, T_2=100% RDF through vermicomost, T_3=75% RDF through vermicomost + 25 % as chemical fertilizer, T_4=50% RDF through vermicompost + 50% as chemical fertilizer, T_5=25% RDF through vermicompost + 75% as chemical fertilizer, T_6=100% RDF through FYM, T_7=75% RDF through FYM + 25% as chemical fertilizer, T_8=50% RDF through FYM + 50% as chemical fertilizer and T_9=25% RDF through FYM + 75% as chemical fertilizer, S_1=30 cm × 5 cm (400 plants $plot^{-1}$), S_2=30 cm × 10 cm (200 plants $plot^{-1}$), S_3=30 cm × 15 cm (130 plants $plot^{-1}$) and S_4=30 cm × 20 cm (100 plants $plot^{-1}$)

4.2.9 Economic performance

The cost and return analysis were done and have been presented in Table 4.32. Material cost, non-material cost and overhead cost were recorded for all the treatments of unit plot and calculated on per hectare basis (yield ha^{-1}), the price of sesame at the local market rates were considered (Appendix LIII and LIV).

4.2.9.1 Total cost of production

In the 2nd experiment, the total cost of production ranges between Tk 37,029 and 45,939 ha^{-1} among the different treatment combinations. The variation was due to different sources of plant nutrients and plant specings. The highest cost of production in the 2nd experiment was Tk45,939 ha^{-1} involved in the treatment combinations of T_6S_1 followed by T_6S_2 (Tk 45,577 ha^{-1}). The lowest cost of production (Tk 37,029 ha^{-1}) was involved in the treatment combinations of T_1S_4 followed by T_1S_3 (Tk 37,090 ha^{-1}) (Table 4.32).In the 3rd experiment, the highest cost of production was Tk 45,939 ha^{-1} involved in the treatment combination of T_6S_1 followed by T_6S_2(Tk 45,577 ha^{-1}) while the lowest cost of production (Tk 37,029 ha^{-1}) was involved in the treatment combination of T_1S_4 followed by T_1S_3 (Tk 37,090 ha^{-1}) (Table 4.32).

4.2.9.2 Gross return

In the 2nd experiment, the highest gross return was Tk 64665 ha^{-1} obtained from the treatment combinations of T_5S_1followed by T_9S_1 (Tk 64485 ha^{-1}) and T_4S_1 (Tk 64350 ha^{-1}) where the lowest gross return was (Tk 41999 ha^{-1}) found from the treatment combination of T_6S_4 followed by T_2S_4 (Tk 47385 ha^{-1}) and T_7S_4 (Tk 47700 ha^{-1}) (Table 4.32). In the 3rd experiment, the highest gross return was Tk64890 ha^{-1} obtained from the treatment combination of T_5S_1 followed by T_9S_1 (Tk 64350 ha^{-1}) and T_4S_1 (Tk 64215 ha^{-1}) where the lowest gross return (Tk 43290 ha^{-1}) was found from the treatment combinations of T_6S_4 followed by T_2S_4 (Tk 46890 ha^{-1}) (Table 4.32).

4.2.9.3 Net return

In the 2nd experiment, among the different treatment combinations, T_5S_1 gave the highest net return (Tk 25,952 ha^{-1}) followed by T_1S_1(Tk 24,976 ha^{-1}), T_4S_1 (Tk 24,497 ha^{-1}) and T_9S_1(Tk 24,820 ha^{-1})while the lowest positive net return (Tk 4,397 $ha^{-1)}$ was obtained from the treatment combinations of T_7S_4 followed by T_2S_4 (Tk 5,798 ha^{-1}) where only one negative net return (cost of production is higher than gross return) was found from T_6S_4 (Tk-3,396 ha^{-1}) (Table 4.32). In the 3rd experiment, T_5S_1 gave the highest net return (Tk 26,177ha^{-1}) followed by T_1S_1 (Tk 25,336 ha^{-1}), T_4S_1 (Tk 24,362ha^{-1}) and T_9S_1 (Tk 24,685 ha^{-1}) while the lowest positive net return (Tk 4,172 $ha^{-1)}$ was obtained from the treatment combination of T_7S_4 followed by T_2S_4(Tk 5,303 ha^{-1}). Only one negative net return (cost of production is higher than gross return) was found from T_6S_4 (Tk -2,105 ha^{-1}) (Table 4.32).

4.2.9.4 Benefit cost ratio (BCR)

In the 2nd experiment, the highest benefit cost ratio (1.67) was found from the treatment combination of T_5S_1 followed by T_1S_1 (1.66), T_1S_2 (1.63), T_9S_1 (1.63) and T_5S_2 (1.61). The lowest BCR (0.93) was recorded from the treatment combinations of T_6S_4 followed by T_7S_4 (1.10) (Table 4.32). In the 3rd experiment, the highest benefit cost ratio (1.68) was recorded from the treatment combinations of T_5S_1 followed by T_1S_1 (1.67), T_1S_2 (1.62), T_9S_1 (1.62) and T_5S_2 (1.60). The lowest BCR (0.95) was recorded from the treatment combination of T_6S_4 followed by T_7S_4 (1.10) (Table 4.32).

Table 4.32 Economic performance of sesame regarding different varieties along with different nutrient levels

Treatments	2nd Experiment					3rd Experiment				
	Yield ha^{-1} (kg)	Total cost of production (Tk. ha^{-1})	Gross return (Tk. ha^{-1})	Net return (Tk. ha^{-1})	BCR	Yield ha^{-1} (kg)	Total cost of production (Tk. ha^{-1})	Gross return (Tk. ha^{-1})	Net return (Tk. ha^{-1})	BCR
T_1S_1	1390.00	37,574	62550	24,976	1.66	1398	37,574	62910	25,336	1.67
T_1S_2	1347.00	37,211	60615	23,404	1.63	1342	37,211	60390	23,179	1.62
T_1S_3	1240.00	37,090	55800	18,710	1.50	1230	37,090	55350	18,260	1.49
T_1S_4	1093.00	37,029	49185	12,156	1.33	1105	37,029	49725	12,696	1.34
T_2S_1	1387.00	42,131	62415	20,284	1.48	1390	42,131	62550	20,419	1.48
T_2S_2	1310.00	41,769	58950	17,181	1.41	1297	41,769	58365	16,596	1.40
T_2S_3	1207.00	41,647	54315	12,668	1.30	1210	41,647	54450	12,803	1.31
T_2S_4	1053.00	41,587	47385	5,798	1.14	1042	41,587	46890	5,303	1.13
T_3S_1	1413.00	40,992	63585	22,593	1.55	1410	40,992	63450	22,458	1.55
T_3S_2	1340.00	40,629	60300	19,671	1.48	1336	40,629	60120	19,491	1.48
T_3S_3	1233.00	40,508	55485	14,977	1.37	1222	40,508	54990	14,482	1.36
T_3S_4	1087.00	40,447	48915	8,468	1.21	1077	40,447	48465	8,018	1.20
T_4S_1	1430.00	39,853	64350	24,497	1.61	1427	39,853	64215	24,362	1.61
T_4S_2	1353.00	39,490	60885	21,395	1.54	1360	39,490	61200	21,710	1.55
T_4S_3	1247.00	39,368	56115	16,747	1.43	1240	39,368	55800	16,432	1.42
T_4S_4	1173.00	39,308	52785	13,477	1.34	1163	39,308	52335	13,027	1.33
T_5S_1	1437.00	38,713	64665	25,952	1.67	1442	38,713	64890	26,177	1.68
T_5S_2	1373.00	38,351	61785	23,434	1.61	1366	38,351	61470	23,119	1.60
T_5S_3	1300.00	38,229	58500	20,271	1.53	1277	38,229	57465	19,236	1.50
T_5S_4	1193.00	38,169	53685	15,516	1.41	1187	38,169	53415	15,246	1.40
T_6S_1	1380.00	45,939	62100	16,161	1.35	1375	45,939	61875	15,936	1.35
T_6S_2	1303.00	45,577	58635	13,058	1.29	1290	45,577	58050	12,473	1.27
T_6S_3	1200.00	45,455	54000	8,545	1.19	1198	45,455	53910	8,455	1.19
T_6S_4	933.30	45,395	41999	-3,396	0.93	962	45,395	43290	-2,105	0.95
T_7S_1	1397.00	43,848	62865	19,017	1.43	1401	43,848	63045	19,197	1.44
T_7S_2	1323.00	43,485	59535	16,050	1.37	1325	43,485	59625	16,140	1.37
T_7S_3	1213.00	43,364	54585	11,221	1.26	1215	43,364	54675	11,311	1.26
T_7S_4	1060.00	43,303	47700	4,397	1.10	1055	43,303	47475	4,172	1.10
T_8S_1	1418.00	41,757	63810	22,053	1.53	1422	41,757	63990	22,233	1.53
T_8S_2	1347.00	41,394	60615	19,221	1.46	1350	41,394	60750	19,356	1.47
T_8S_3	1245.00	41,272	56025	14,753	1.36	1233	41,272	55485	14,213	1.34
T_8S_4	1140.00	41,212	51300	10,088	1.24	1145	41,212	51525	10,313	1.25
T_9S_1	1433.00	39,665	64485	24,820	1.63	1430	39,665	64350	24,685	1.62
T_9S_2	1360.00	39,303	61200	21,897	1.56	1355	39,303	60975	21,672	1.55
T_9S_3	1260.00	39,181	56700	17,519	1.45	1264	39,181	56880	17,699	1.45
T_9S_4	1183.00	39,121	53235	14,114	1.36	1172	39,121	52740	13,619	1.35
Selling price of sesame seed = Tk.45 kg^{-1}										

T_1= 100% RDF through chemical fertilizer, T_2=100% RDF through vermicomost, T_3=75% RDF through vermicomost + 25 % as chemical fertilizer, T_4=50% RDF through vermicompost + 50% as chemical fertilizer, T_5=25% RDF through vermicompost + 75% as chemical fertilizer, T_6=100% RDF through FYM, T_7=75% RDF through FYM + 25% as chemical fertilizer, T_8=50% RDF through FYM + 50% as chemical fertilizer and T_9=25% RDF through FYM + 75% as chemical fertilizer, S_1=30 cm × 5 cm (400 plants $plot^{-1}$), S_2=30 cm × 10 cm (200 plants $plot^{-1}$), S_3=30 cm × 15 cm (130 plants $plot^{-1}$) and S_4=30 cm × 20 cm (100 plants $plot^{-1}$)

CHAPTER 5

SUMMARY AND CONCLUSION

Field experiments were conducted during 2014-2016 to screen out a suitable sesame variety and its yield under certain nutrient management practices. The experiment was conducted for the evaluation of different agro-techniques on the productivity of sesame.

The experiments were conducted in three consecutive years. The 1st year experiment consisted of screening a suitable sesame variety under different nutrient level carried out during March-June 2014. From this trial, the best nutrient level and variety were short listed based upon the yield performance and take over to the next year. In the 2nd year experiment; trial varieties and nutrient levels were picked from 1st year, were tried with population densities and different organic and inorganic sources of nutrient. The experiment was carried out during March-June, 2015. In the 3rd year; repeat of the 2nd year experiment and was carried out during March-June, 2016.

5.1 Summary

5.1.1 1st Year experiment, March-June 2014

Data were recorded on different parameters such as plant height, number of leaves plant^{-1} number of branches plant^{-1}, LAI, DMP, AGR, CGR, RGR, number of capsule plant^{-1}, number of seeds capsule^{-1}, weight of 1000 seeds, seed weight ha^{-1}, stover yield ha^{-1}, harvest index.

Different levels of nutrients had significant effect on all the growth parameters. Results revealed that, the highest plant height (29.93, 84.55, 106.00, 118.00 and 133.00 cm at 30, 45, 60, 75 DAS and at harvest respectively), number of leaves plant^{-1} (11.44, 52.67, 73.50, 96.33 and 81.33 at 30, 45, 60, 75 DAS and at harvest, respectively) and LAI (1.57, 2.24, 3.58, 4.92 and 3.43 at 30, 45, 60, 75 DAS and at harvest respectively) were recorded from 150% of RDF (N_4). But the highest branches plant^{-1} (0.611, 3.11, 3.50, 4.11 and 5.39 at 30, 45, 60, 75 DAS and at harvest, respectively) and dry weight plant^{-1} (1.86, 3.56, 18.13, 28.85 and 54.83 at 30, 45, 60, 75 DAS and at harvest, respectively) were signed up with N_2 (100% of RDF). Again, the lowest plant height (26.27, 76.54, 99.27, 107.20 and 124.40 cm at 30, 45, 60, 75 DAS and at harvest respectively), number of leaves plant^{-1} (10.17, 44.83, 67.39, 84.61 and 62.22 at 30, 45, 60, 75 DAS and at harvest respectively), number of branches plant^{-1} (0.00, 2.61, 3.00, 3.00 and 4.28 at 30, 45, 60, 75 DAS and at harvest respectively), dry weight plant^{-1} (1.37, 2.86, 13.09, 26.52 and 47.00 at 30, 45, 60, 75 DAS and at harvest respectively) and LAI (0.94, 1.87, 2.52, 3.58 and 2.45 at 30, 45, 60, 75 DAS and at harvest respectively) were recorded from 75% of RDF (N_1). Growth performance of the studied crops was also influenced by different nutrient levels. The highest AGR and CGR (0.815 and 5.436 respectively) were observed from N_2 (100% of RDF) where the lowest (0.681 and 4.540 respectively) were found from 75% of RDF (N_1). The RGR was not significant with different nutrietnt levels.

Considerable variation was found on different growth parameters with varietal performance. Considering varietal feat, V_5 (BARI til-4) gave the maximum plant height (31.00, 86.44, 106.90, 117.90 and 134.70 cm at 30, 45, 60, 75 DAS and at harvest respectively), number of leaves plant^{-1} (12.50, 58.58, 78.50, 103.90 and 95.57 at 30, 45, 60, 75 DAS and at harvest respectively), number of branches plant^{-1} (1.10, 3.42, 4.00, 4.67 and 5.83 at 30, 45, 60, 75 DAS and at harvest respectively), dry weigh plant^{-1} (1.91, 3.94, 18.66, 28.67 and 55.71 g at 30, 45, 60, 75 DAS and at harvest respectively) and LAI (1.57, 2.44, 3.63, 5.00 and 3.49 at 30, 45, 60, 75 DAS and at harvest respectively) where the lowest plant height (24.92, 73.82, 96.97, 105.60 and 121.40 cm at 30, 45, 60, 75 DAS and at harvest respectively) was observed with local variety V_2 (Atshira) but the lowest number of leaves plant^{-1} (9.67, 42.42, 64.08, 79.92 and 53.83 at 30, 45, 60, 75 DAS and at harvest respectively), number of branches plant^{-1} (0.00, 2.58, 2.75, 2.75 and 3.91 at 30, 45, 60, 75 DAS and at harvest respectively), dry weigh plant^{-1} (1.15, 2.45, 9.90, 26.36 and 43.84 g at 30, 45, 60, 75 DAS and at harvest respectively) and LAI (0.76, 1.70, 2.37, 3.25 and 2.35 at 30, 45, 60, 75 DAS and at harvest respectively) were observed with local variety V_1 (Laltil). In terms of growth performance, the highest AGR and CGR (0.816 and 5.442, respectively) were observed from V_5 (BARI til-4) where the lowest (0.637 and 4.248, respectively) were found from V_1 (Laltil). The RGR was not significant with different variety.

Different growth parameters were significantly influenced by combined effect of different nutrient levels and variety. Results verified that N_4V_5 registered the maximum plant height (33.97, 93.49, 113.80, 129.20 and 139.10 cm at 30, 45, 60, 75 DAS and at harvest respectively) and maximum number of leaves plant^{-1} (13.67, 65.00, 82.00, 111.30 and 109.00 at 30, 45, 60, 75 DAS and at harvest respectively) and maximum LAI (2.96, 4.63, 6.32 and 4.18 at 45, 60, 75 DAS and at harvest, respectively) but the maximum number of branches plant^{-1} (2.00, 3.67, 4.33, 5.33 and 6.67

at 30, 45, 60, 75 DAS and at harvest, respectively), dry weigh plant^{-1} (2.31, 4.50, 22.45, 35.48 and 63.13 g at 30, 45, 60, 75 DAS and at harvest, respectively) were recorded from N_2V_5. Again, the shortest plant (23.15, 70.90, 93.69, 102.80 and 112.90 cm at 30, 45, 60, 75 DAS and at harvest, respectively) was recorded from N_1V_2 but the lowest number of leaves plant^{-1} (9.00, 38.00, 60.67, 70.00 and 41.33 at 30, 45, 60, 75 DAS and at harvest respectively), number of branches plant^{-1} (0.00, 2.33, 2.33,2.33 and 3.00 at 30, 45, 60, 75 DAS and at harvest respectively), dry weight plant^{-1} (0.87, 2.11, 8.75, 21.42 and 40.43 g at 30, 45, 60, 75 DAS and at harvest respectively) and LAI (1.12, 1.67, 2.88 and 1.60 at 45, 60, 75 DAS and at harvest respectively) were recorded from N_1V_1. In case of growth performance, N_2V_5 listed the maximum AGR (0.910) and CGR (6.067) where the lowest AGR (0.590) and CGR (6.067) were recorded from N_2V_5. The RGR was not significantly influenced by the combination of nutrient levels and varieties.

Different yield contributing parameters was influenced significantly due to the effect of different nutrient levels. Results indicated that the highest number of capsules plant^{-1} (77.28), number of seeds capsule^{-1} (79.53), weight of 1000 seeds (2.78 g) and capsule length (3.19 cm) were from 100% of RDF (N_2) where the lowest number of capsule plant^{-1} (63.83) and lowest weight of 1000 seeds (2.60 g) were recorded from 75% of RDF (N_1) but the lowest number of seeds capsule^{-1} (72.76) and lowest capsule length (2.13 cm) were recorded from 150% of RDF (N_4).

Different test varieties had also significant influence on different yield contributing parameters. It was found that the maximum number of capsule plant^{-1} (77.33), number of seeds capsule^{-1} (80.76), weight of 1000 seeds (2.81 g) and capsule length (2.31 cm) were obtained from V_5 (BARI til-4) where the lowest number of capsule plant^{-1} (56.58), number of seeds capsule^{-1} (65.82), lowestcapsule length (2.05 cm) were observed from local variety V_1 (Laltil) but the lowest weight of 1000 seeds (2.45 g) was observed from local variety V_2 (Atshira).

Different yield contributing parameters was influenced significantly by the combined effect of different nutrient levels and variety. Results showed that N_2V_5 listed the maximum number of capsule plant^{-1} (94.67), number of seeds capsule^{-1} (88.13), weight of 1000 seeds (3.00 g) and capsule length (2.43cm) where N_4V_1 recorded the lowest number of capsule plant^{-1} (55.33), number of seeds capsule^{-1} (61.53), weight of 1000 seeds (2.47 g) and capsule length (1.82 cm).

In terms of seed and stover yield different nutrient levels showed significant influence. Results verified that the highest seed yield ha^{-1} (1223 kg ha^{-1}), highest stover yield ha^{-1} (1473 kg ha^{-1})and highest harvest index (45.36%) were achieved from N_2 (100% of RDF).The lowest seed yield ha^{-1} (924kg ha^{-1}) andlowest harvest index (41.23%)were recorded from N_4 (150% of RDF) but the lowest stover yield ha^{-1} (1274 kg ha^{-1}) was recorded from 75% of RDF (N_1).

Different test varieties had also significant influence on different yield parameters. Results also specified that the maximum seed yield ha^{-1} (1170kg ha^{-1}), maximum stover yield ha^{-1} (1476kg ha^{-1}) and maximum harvest index (44.22%)were obtained from V_5 (BARI til-4) where the lowest seed yield ha^{-1} (811.30kg ha^{-1}), lowest stover yield ha^{-1} (1139 kg ha^{-1}) and lowest harvest index (41.60%)were observed from local variety V_1 (Laltil).

In terms of combined effect of different nutrient levels and variety, the maximum seed yield ha^{-1} (1481 kg ha^{-1}), maximum stover yield ha^{-1} (1715 kg ha^{-1}) and highest harvest index (46.34%) were achieved from N_2V_5. Again, the lowest seed yield ha^{-1}(670 kg ha^{-1}) and lowest stover yield ha^{-1}(1043 kg ha^{-1}) were recorded from N_4V_1 but the lowest harvest index (35.87%) was recorded from N_4V_2.

5.1.2 2nd year Experiment March – June, 2015 and 3rd year experiment March to June, 2016

In terms of growth parameters affected by different sources of plant nutrients, T_1 (100% RDF through chemical fertilizer) showed the tallest plants both in 2015 and 2016 (29.68, 83.29, 104.80, 103.90 and 99.97 cm in 2015 and 30.03, 83.50, 104.95, 104.28 and 100.07 cm in 2016 at 30, 45, 60, 75 DAS and at harvest, respectively) but T_5 (25% RDF through vermicompost + 75% as chemical fertilizer) showed the highest number of leaves $plant^{-1}$ (9.33, 20.75, 36.42, 41.17 and 34.75 in 2015 and 9.34, 20.76, 36.31, 41.32 and 35.71 in 2016 at 30, 45, 60, 75 DAS and at harvest, respectively), highest number of branches $plant^{-1}$ (6.33, 6.50, 7.00 and 7.58 in 2015 and 6.48, 7.11, 7.67 and 8.14 in 2016 at 45, 60, 75 DAS and at harvest, respectively), highest dry weight $plant^{-1}$ (6.10.74 and 32.84 g in 2015 and 12.43 and 31.15 g in 2016 at 75 DAS and at harvest, respectively) where T_6 (100% RDF through FYM) gave the shortest plant (26.66, 71.94, 98.38, 97.54 and 93.05 cm in 2015 and 27.35, 72.32, 98.57, 98.04 and 93.36 cm in 2016 at 30, 45, 60, 75 DAS and at harvest respectively), lowest number of leaves $plant^{-1}$ (8.58, 18.67, 34.33, 39.75 and 33.00 in 2015 and 8.56, 18.79, 34.34, 39.85 and 34.16 in 2016 at 30, 45, 60, 75 DAS and at harvest respectively), lowest number of branches $plant^{-1}$ (5.67, 6.00, 6.33 and 6.75 in 2015 and 5.87, 6.78, 7.01 and 7.34 in 2016 at 45, 60, 75 DAS and at harvest respectively) but the lowest dry weight $plant^{-1}$ (9.44 and 27.47 g in 2015 and 11.74 and 26.17 g in 2016 at 75 DAS and at harvest, respectively) was recorded with T_8 (50% RDF through FYM + 50% as chemical fertilizer). Considering growth performance, absolute growth rate (AGR), crop growth rate (CGR) and relative growth rate (RGR) was non-significant with different sources of plant nutrients both in 2015 and 2016.

Considerable influence was found for yield and yield attributes and quality parameters of sesame affected by different sources of plant nutrients. Both in 2015 and 2016 respectively, the highest number of capsules plant^{-1} (63.25 and 67.68), seeds capsule^{-1} (77.25 and 79.83), capsule length (2.35 and 2.33 cm), 1000 seed weight (2.32 and 2.59 g), seed yield (1326.00 and 1318 kg ha^{-1}), stover yield (1619 and 1604.50 kg ha^{-1}), harvest index(45.47% and 45.80%), oil yield (581.07 and 575.77 kgha^{-1}), protein yield (256.09 and 259.52 kgha^{-1}) were obtained from T_5 (25% RDF through vermicompost + 75% as chemical fertilizer) but the lowest number of capsule plant^{-1} (56.92 and 58.73), 1000 seed weight (2.08 and 2.20 g), seed yield (1204 and 1206.25 kg ha^{-1}) and harvest index (42.87% and 44.64%), oil yield (518.57 and 520.22 kg ha^{-1}) and protein yield (226.55 and 226.75 kg ha^{-1}) were recorded from T_6 (100% RDF through FYM). The lowest number of seeds capsule^{-1} (71.42) and lowest capsule length (2.24 cm) in 2015 and lowest stover yield (1491.75 kg ha^{-1}) in 2016 was recorded from T_6(100% RDF through FYM) but the lowest stover yield (1464 kg ha^{-1}) in 2015 and lowest number of seeds capsule^{-1} (72.75) and lowest capsule length (2.19 cm) in 2016 was recorded from T_8 (50% RDF through FYM + 50% as chemical fertilizer).

Considering growth parameters affected by different plant spacings, the tallest plant (31.97, 90.20, 108.30, 110.40 and 106.40 cm in 2015 and 32.32, 90.48, 108.42, 110.69 and 106.43 cm in 2016 at 30, 45, 60, 75 DAS and at harvest, respectively) was obtained from S_1 (30 cm × 5 cm; 400 plants plot^{-1}) but the highest number of leaves plant^{-1} (9.33, 20.83, 37.26, 42.00 and 34.96 in 2015 and 9.29, 20.91, 37.22, 42.09 and 34.89 in 2016 at 30, 45, 60, 75 DAS and at harvest, respectively), highest number of branches plant^{-1} (6.44, 6.56, 7.00 and 7.44 in 2015 and 6.64, 6.17, 7.69 and 8.03 in 2016 at 45, 60, 75 DAS and at harvest, respectively) and highest dry weight plant^{-1} (10.76 and 33.30 g in 2015 and 12.33 and 31.30 g in 2016 at 75 DAS and at harvest, respectively) were obtained from S_3 (30 cm × 15 cm; 130 plants plot^{-1}). The lowest plant height (23.94, 62.57, 93.9992.54 and 85.93 cm in 2015 and 24.62, 62.82, 94.19, 92.93 and 86.21 cm in 2016 at 30, 45, 60, 75 DAS and at harvest, respectively) was observed from S_4 (30 cm × 20 cm; 100 plants plot^{-1}) but the lowest number of leaves plant^{-1} (8.56, 18.07, 32.74, 38.59 and 32.33 in 2015 and

8.63, 18.10, 32.68, 38.72 and 33.33 in 2016 at 30, 45, 60, 75 DAS and at harvest, respectively), lowest number of branches plant^{-1} (5.33, 5.70, 6.11 and 6.37 in 2015 and 5.54, 6.34, 6.79 and 6.93 in 2016 at 45, 60, 75 DAS and at harvest, respectively) and lowest dry weight plant^{-1} (9.20 and 25.40 g in 2015 and 10.83 and 23.43 g in 2016 at 75 DAS and at harvest, respectively) was recorded from S_1 (30 cm × 5 cm; 400 plants plot^{-1}). Regarding growth performance, absolute growth rate (AGR) and relative growth rate (RGR) were non significant with different plant spacings except crop growth rate (CGR) during both the crop duration in 2015 and 2016. The highest CGR (3.12 and 2.13 in 2015 and 2016 respectively) was found from S_1 (30 cm × 5 cm; 400 plants plot^{-1}) where the lowest (0.58 and 0.73, respectively in 2015 and 2016) was from S_4 (30 cm × 20 cm; 100 plants plot^{-1}).

Yield and yield attributes and quality parameters were also affected by different plant spacings. In 2015 and 2016 respectively, S_3 (30 cm × 15 cm; 130 plants plot^{-1}) gave the highest number of capsule plant^{-1} (66.33 and 66.05), number of seeds capsule^{-1} (82.52 and 80.48), capsule length (2.44 and 2.33 cm) and 1000 seed weight (2.60 and 2.57 g) but the highest seed yield (1413 and 1412 kg ha^{-1}), stover yield (1715 and 1707.11 kg ha^{-1}), oil yield (584.11 and 586.90 kg ha^{-1}) and protein yield (250.82 and 251.48 kg ha^{-1}) was obtained from S_1 (30 cm × 5 cm; 400 plants plot^{-1}). The highest harvest index (45.28% and 45.27% in 2015 and 2016, respectively) was achieved from S_3 (30 cm × 15 cm; 130 plants plot^{-1}) and S_1 (30 cm × 5 cm; 400 plants plot^{-1}), respectively. The lowest number of capsule plant^{-1} (54.30 and 55.90), number of seeds capsule^{-1} (66.56 and 67.33), capsule length (2.16 and 2.10 cm) and 1000 seed weight (1.89 and 1.99 g) was observed from S_1 (30 cm × 5 cm; 400 plants plot^{-1}) in 2015 and 2016, respectively but the lowest seed yield (1102 and 1100.89 kg ha^{-1}), stover yield (1322 and 1363 kg ha^{-1}), harvest index (44.19% and 44.65%), oil yield (484.19 and 543.45 kg ha^{-1}) and protein yield (216.09 and 217.14 kg ha^{-1}) was obtained from S_4 (30 cm × 20 cm; 100 plants plot^{-1}) in 2015 and 2016, respectively.

In respect of combination effect of different plant nutrient sources and plant spacings, significant influence was found for growth, yield contributing parameters, yield and quality parameters.

In case of growth parameters , the highest plant height (34.50, 100.50, 112.80, 115.50 and 108.00 cm in 2015 and 34.82, 100.79, 112.71, 115.84 and 108.23 cm in 2016 at 30, 45, 60, 75 DAS and at harvest, respectively) were obtained from the treatment combinations of T_1S_1 but the highest number of leaves plant^{-1} (10.00, 24.33, 40.00, 43.67 and 36.67 in 2015 and 10.03, 24.26, 39.98, 43.77 and 37.44 in 2016 at 30, 45, 60, 75 DAS and at harvest, respectively), highest number of branches plant^{-1} (7.00, 7.33, 7.67 and 8.33 in 2015 and 7.39, 7.97, 8.43 and 8.87 in 2016 at 45, 60, 75 DAS and at harvest, respectively) and the highest dry weight plant^{-1} (7.04, 11.89 and 38.00 g in 2015 and 7.81, 13.73 and 36.73 g in 2016 at 60, 75 DAS and at harvest, respectively) was found from the treatment combinations of T_5S_3. The shortest plant (21.77, 52.39, 85.35, 87.55 and 74.85 cm in 2015 and 23.02, 52.68, 85.55, 88.06 and 75.22 cm in 2016 at 30, 45, 60, 75 DAS and at harvest, respectively) were recorded from the treatment combinations of T_6S_4 and lowest dry weight plant^{-1} (5.76, 8.33 and 22.33 g in 2015 and 6.53, 10.13 and 21.03 g in 2016 at 60, 75 DAS and at harvest, respectively) were recorded from the treatment combinations of T_8S_1. But the lowest number of leaves plant^{-1} (7.67, 16.33, 30.67, 37.67 and 30.00 in 2015 and 8.26, 16.37, 30.42, 37.88 and 30.89 in 2016 at 30, 45, 60, 75 DAS and at harvest, respectively) and the lowest number of branches plant^{-1} (4.67, 4.67, 5.33 and 5.00 in 2015 and 4.84, 5.25, 6.04 and 5.53 in 2016 at 45, 60, 75 DAS and at harvest, respectively) were recorded from T_6S_1. Regarding growth performance, T_3S_1 gave the maximum AGR and CGR (0.54 and 3.59, respectively) in 2015 and in 2016, maximum AGR and CGR (0.52 and 2.30, respectively) was achieved from T_5S_1 where the lowest AGR and CGR (0.50 and 0.014 respectively in 2015 and 0.65 and 0.014, respectively in 2016) was found from T_6S_4.

Again, in terms of yield and yield attributes and quality parameters affected by combined effect of different plant nutrient sources and plant spacings, in 2015 and 2016, respectively, T_5S_3 listed the maximum number of capsule plant^{-1} (74.33 and 75.88), number of seeds capsule^{-1} (86.67 and 88.00), capsule length (2.54 and 2.48 cm) and the 1000 seed weight (2.97 and 3.02 g). Again, T_5S_1 gave the maximum seed yield (1437 and 1442 kg ha^{-1}), stover yield (1708 and 1701 kg ha^{-1}), harvest index (45.69% and 45.88%), Maximum oil yield (608.14 and 609.39 kg ha^{-1}) and protein yield (269.58 and 271.38 kg ha^{-1}) in 2015 and 2016, respectively. Both in 2015 and 2016 respectively, the lowest number of capsule plant^{-1} (47.67 and 50.11) and lowest 1000 seed weight (1.73 and 1.81 g) were recorded from $T_6S_{1.}$ But in 2015, the lowest number of seeds capsule^{-1} (63.00) and lowest capsule length (2.09 cm) were recorded from T_6S_1 where in 2016, the lowest number of seeds capsule^{-1} (64.00) and lowest capsule length (2.03 cm) were recorded from $T_8S_{1.}$ The lowest seed yield (933.30 and 962 kg ha^{-1}, respectively), the lowest stover yield (1277 and 1260 kg ha^{-1}), harvest index (42.23% and 43.29%), oil yield (412.05 and 424.43 kg ha^{-1}) and lowest protein yield (186.29 and 191.44 kg ha^{-1}) was recorded from T_6S_4 both in 2015 and 2016, respectively.

In terms of economic analysis, both in 2015 and 2016, respectively, the highest cost of production was Tk 45,939 ha^{-1}achieved from T_6S_1 where the highest gross return (Tk64665 and 64890 ha^{-1}), net return (Tk 25,952 and 26,177 $ha^{-1,}$ respectively) and BCR (1.67 and 1.68 respectively) were found from the treatment combination of T_5S_1. Again, both in 2015 and 2016, respectively, the lowest cost of production was Tk 37,029 ha^{-1} found from the treatment combination of T_1S_4 where the lowest gross return (Tk41999 and 43290 Tk. ha^{-1}), net return (-3,396 and -2,105 Tk. ha^{-1}) and BCR (0.93 and 0.95 respectively) were recorded from the treatment combination of T_6S_4.

5.2 Conclusion

From the above findings, from 1st year, it is concluded that considering nutrient levels, N_2 (100% of RDF) gave the best performance in respect of growth, yield, yield contributing parameters and also quality parameters. It was also found that N_2 (100% of RDF) gave the highest seed yield (1223 kg ha^{-1}) and oil yield (530.40 kg ha^{-1}). Again, in consideration of variety, the highest seed yield (1170kg ha^{-1}) and oil yield (510.40 kg ha^{-1}) were found from V_5 (BARI til-4). Combined effect of nutrient levels, N_2 (100% of RDF) and variety, V_5 (BARI til-4); N_2V_5 produced the highest seed yield (1481 kg ha^{-1}) and oil yield (670 kg ha^{-1}). The highest net return (Tk. 33,514 ha^{-1}) and BCR (1.89) was also achieved by the treatment combinations of N_2V_5. So, the treatment combination of N_2 (100% of RDF) × V_5 (BARI til-4) can be considered as the best treatment from 1st year experiment.

From 2nd year experiment (March-June, 2015) and 3rd year experiment (March-June, 2016), it can be concluded that regarding different nutrient sources, the highest seed yield (1326.00 and 1318 kg ha^{-1}) and highest oil yield (581.07 and 575.77 kg ha^{-1}) were recorded from T_5 (25% RDF through vermicompost + 75% as chemical fertilizer). Again, in consideration of plant spacing, in both the season, the highest seed yield (1413 and 1412 kg ha^{-1}) and highest oil yield (584.11 and 586.90 kg ha^{-1}) were obtained from S_1 (30 cm × 5 cm; 400 plants $plot^{-1}$). Combined effect of different nutrient sources and plant spacing in March-June, 2015 and March-June, 2016, T_5 (25% RDF through vermicompost + 75% as chemical fertilizer) × S_1 (30 cm × 5 cm; 400 plants $plot^{-1}$) gave the highest seed yield (1437 and 1442 kg ha^{-1}) and oil yield (608.14 and 609.39 kg ha^{-1}).

The highest net return (Tk. 25,952 and Tk. 26,177 ha^{-1}) and BCR (1.67 and 1.68) were also achieved by the treatment combinations of T_5S_1. So, it can be concluded that from 2nd year experiment (March-June 2015) and 3rd year experiment (March-June 2016), the treatment, T_5 (25% RDF through vermicompost + 75% as chemical fertilizer) as sources of plant nutrients and S_1 (30 cm × 5 cm; 400 plants plot^{-1}) as plant specing along with their combination (T_5S_1) were the best practices with variety BARI til-4 under the present study in Sher-e-Bangla Agricultural University condition. Therefore,

1. Among the different variety of sesame, V_5 (BARI til-4) may be considered the best variety for better yield return and this variety may be used commercially for higher production of sesame.
2. In respect of required nutrients, 58, 72 and 30 kg N, P_2O_5 and K_2O ha^{-1}, respectively may be considered as recommended nutrients for sesame production.
3. In terms of nutrient supply system, 25% vermicompost with 75% chemical fertilizer may be considered as the best nutrient supply system for successful cultivation of sesame for maximum return among the different sources of nutrients applied.
4. Plant material V_5 (BARI til-4) and population density/spacing of 30 cm × 5 cm i.e. 66 plants m^{-2} may be considered the best spacing/population density for better yield per unit area as well as to increase the productivity of sesame.
5. Treatment combination of 25% recommended nutrients through vermicompost and 75% recommended nutrients through chemical fertilizer with plant spacing of 30 cm × 5 cm may be considered as the best treatment combination for successful sesame production.
6. Proper agronomic practices like application of chemical fertilizer along with organic manure and with optimum population density should be maintained for maximum return from sesame cultivation.

However, to reach a specific recommendation the experiment may be repeated at different AEZs of Bangladesh considering soil, weather and climatic condition, variety and with optimum plant spacing/population density.

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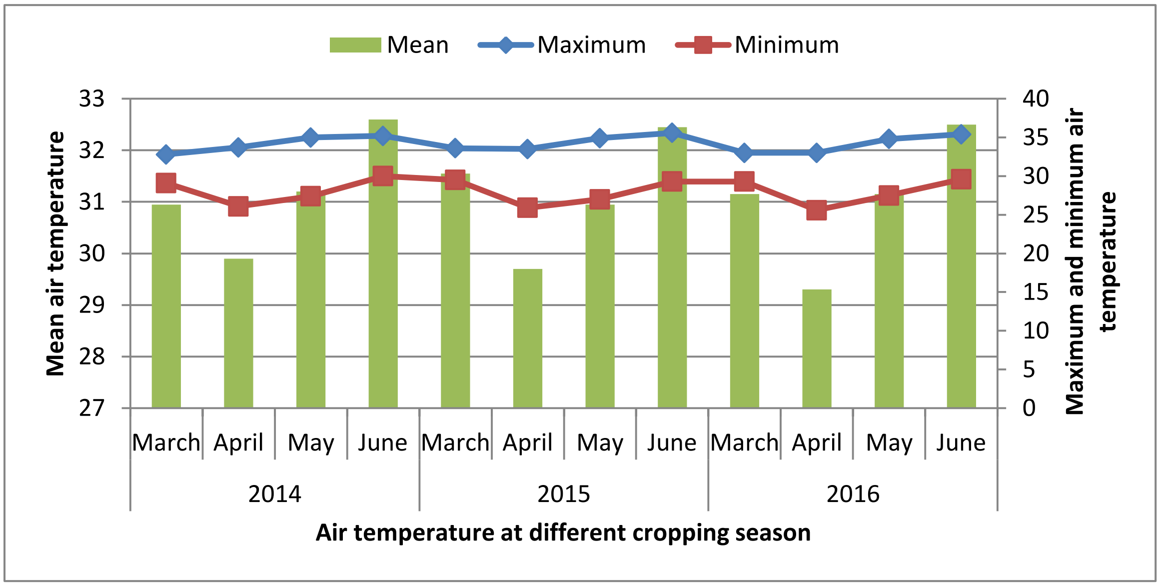
APPENDICES

Appendix I. Experimental site showing in the map

Fig. 7.1 Map of Bangladesh presenting experimental site

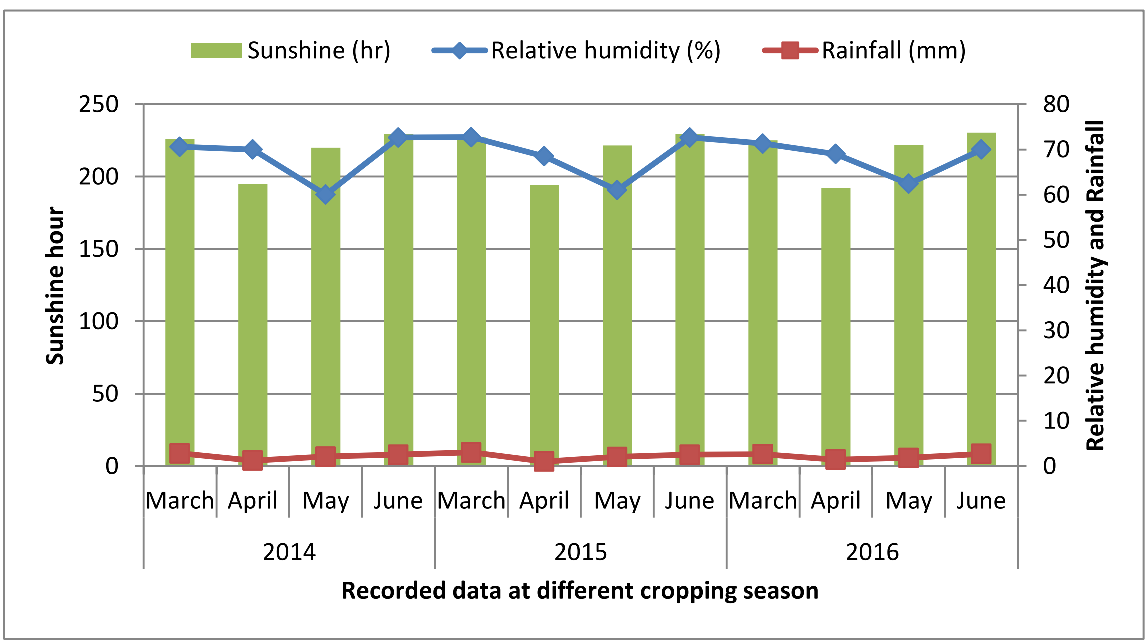
Appendix II (a). Monthly records of air temperature during the study period (2014 – 2016)



Source: Bangladesh Meteorological Department (Climate division), Dhaka-1212

Fig. 7.2. Monthly records of air temperature during the experimental period from March to June 2014 – March to June 2016

Appendix II (b). Monthly records of relative humidity, rainfall and sunshine hours during the study from March to June, 2014 –2016



Source: Bangladesh Meteorological Department (Climate division), Dhaka-1212

Fig. 7.3. Monthly records of relative humidity, rainfall and sunshine hours during the experimental period from March to June, 2014 –2016

Appendix III. Physical characteristics of soil of the experimental field

Soil Characteristics	Analytical results
Agro-Ecological Zone	Madhupur Tract
pH	5.45 – 5.61
Organic matter	0.83%
Sand	40%
Silt	40%
Clay	20%
Texture	Loamy

Source: Soil Resources Development Institute (SRDI), Khamarbari Sorok, Dhaka-1215

Appendix IV. The chemical characteristics of the experiment field of soil (0 - 15 cm depth)

Soil characters	Value
Organic matter	1.44 %
Potassium	0.15 meq/100 g soil
Calcium	3.60 meq/100 g soil
Magnesium	1.00 meq/100 g soil
Total nitrogen	0.072%
Phosphorus	22.08 µg/g soil
Sulphur	25.98 µg/g soil
Boron	0.48 µg/g soil
Copper	3.54 µg/g soil
Iron	262.6 µg/g soil
Manganese	164 µg/g soil
Zinc	3.32 µg/g soil

Source: Soil Resources Development Institute (SRDI), Khamarbari, Dhaka-1215

Appendix V. Nutrient content of Farm yard manure and Vermicompost used for the experiment

Nutrients	Farm yard manure (FYM)	Vermicompost
Nitrogen (N)	1.30%	2.67%
Phosphorus (P)	0.85%	1.72%
Potssium (K)	1.00%	1.05%

Source: BARC, 2012

Appendix VI. Layout of the experiment field – 1st Year Experiment

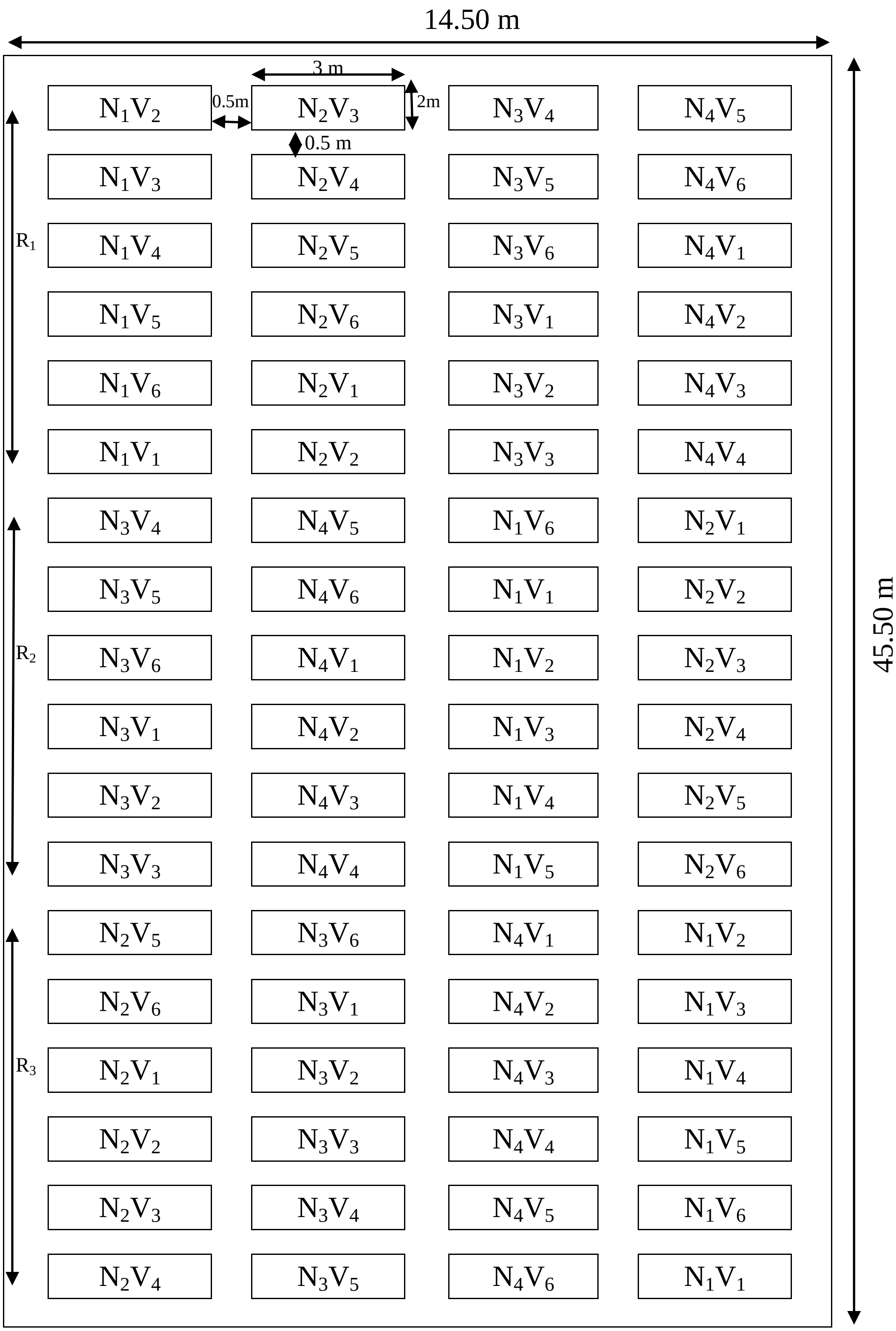


Fig. 7.4 Layout of the experiment field – 1st Year Experiment

Appendix VII. Layout of the experiment field – 2nd Year Experiment

Plot size: 3m × 2m

T_8S_3	T_8S_1	T_8S_4	T_8S_2	T_4S_2	T_4S_3	T_4S_1	T_4S_4	T_8S_4	T_8S_2	T_8S_3	T_8S_1
T_3S_3	T_3S_1	T_3S_4	T_3S_2	T_7S_4	T_7S_2	T_7S_1	T_7S_3	T_9S_3	T_9S_2	T_9S_1	T_9S_4
T_7S_4	T_7S_3	T_7S_2	T_7S_1	T_5S_2	T_5S_1	T_5S_4	T_5S_3	T_7S_2	T_7S_3	T_7S_1	T_7S_4
T_9S_1	T_9S_2	T_9S_4	T_9S_3	T_1S_1	T_1S_4	T_1S_2	T_1S_3	T_3S_2	T_3S_4	T_3S_3	T_3S_1
T_6S_3	T_6S_4	T_6S_1	T_6S_2	T_3S_4	T_3S_3	T_3S_1	T_3S_2	T_6S_1	T_6S_2	T_6S_4	T_6S_3
T_4S_3	T_4S_1	T_4S_4	T_4S_2	T_6S_2	T_6S_1	T_6S_3	T_6S_4	T_4S_1	T_4S_3	T_4S_2	T_4S_4
T_5S_4	T_5S_2	T_5S_1	T_5S_3	T_2S_3	T_2S_4	T_2S_2	T_2S_1	T_5S_3	T_5S_1	T_5S_4	T_5S_2
T_1S_2	T_1S_4	T_1S_1	T_1S_3	T_9S_4	T_9S_2	T_9S_1	T_9S_3	T_1S_1	T_1S_3	T_1S_2	T_1S_4
T_2S_4	T_2S_2	T_2S_3	T_2S_1	T_8S_1	T_8S_3	T_8S_2	T_8S_4	T_2S_4	T_2S_1	T_2S_3	T_2S_2
R_1				R_2				R_3			

Fig. 7.5 Layout of the field experiment field – 2nd Year Experiment

Appendix VIII. Layout of the experiment field – 3rd Year Experiment

3m

2m

T_1S_2	T_1S_4	T_1S_1	T_1S_3	T_9S_4	T_9S_2	T_9S_1	T_9S_3	T_1S_1	T_1S_3	T_1S_2	T_1S_4
T_2S_4	T_2S_2	T_2S_3	T_2S_1	T_8S_1	T_8S_3	T_8S_2	T_8S_4	T_2S_4	T_2S_1	T_2S_3	T_2S_2
T_3S_3	T_3S_1	T_3S_4	T_3S_2	T_7S_4	T_7S_2	T_7S_1	T_7S_3	T_9S_3	T_9S_2	T_9S_1	T_9S_4
T_4S_3	T_4S_1	T_4S_4	T_4S_2	T_6S_2	T_6S_1	T_6S_3	T_6S_4	T_4S_1	T_4S_3	T_4S_2	T_4S_4
T_5S_4	T_5S_2	T_5S_1	T_5S_3	T_2S_3	T_2S_4	T_2S_2	T_2S_1	T_5S_3	T_5S_1	T_5S_4	T_5S_2
T_6S_3	T_6S_4	T_6S_1	T_6S_2	T_3S_4	T_3S_3	T_3S_1	T_3S_2	T_6S_1	T_6S_2	T_6S_4	T_6S_3
T_7S_4	T_7S_3	T_7S_2	T_7S_1	T_5S_2	T_5S_1	T_5S_4	T_5S_3	T_7S_2	T_7S_3	T_7S_1	T_7S_4
T_8S_3	T_8S_1	T_8S_4	T_8S_2	T_4S_2	T_4S_3	T_4S_1	T_4S_4	T_8S_4	T_8S_2	T_8S_3	T_8S_1
T_9S_1	T_9S_2	T_9S_4	T_9S_3	T_1S_1	T_1S_4	T_1S_2	T_1S_3	T_3S_2	T_3S_4	T_3S_3	T_3S_1
R_1				R_2				R_3			

Fig. 7.6 Layout of the experiment field – 3rd Year Experiment

Appendix IX. Plant height of sesame at different days after sowing as influenced by different levels of plant nutrients during March-June, 2014

Treatment	Plant height (cm)				
	30 DAS	45 DAS	60 DAS	75 DAS	At harvest
N_1	26.27	76.54	99.27	107.2	124.4
N_2	27.34	78.61	100.3	108.6	127.8
N_3	28.61	81.32	102.7	112.3	131.1
N_4	29.93	84.55	106	118	133
$LSD_{0.05}$	0.720	0.866	0.873	1.014	1.175

N_1 = 75% of RDF (43:54:23 kg N, P_2O_5 and K_2O ha^{-1}), N_2 = 100% of RDF (58:72:30 kg N, P_2O_5 and K_2O ha^{-1}), N_3 = 125% of RDF (72:90:38 kg N, P_2O_5 and K_2O ha^{-1}), N_4 = 150% of RDF (86:108:45 kg N, P_2O_5 and K_2O ha^{-1})

Appendix X. Plant height of sesame at different days after sowing as influenced by different variety during March-June, 2014

Treatment	Plant height (cm)				
	30 DAS	45 DAS	60 DAS	75 DAS	At harvest
V_1	24.58	74.20	96.34	106.2	123.3
V_2	24.92	73.82	96.97	105.6	121.4
V_3	28.57	80.9	103.20	111.6	130.6
V_4	29.93	84.01	104.70	114.7	133.3
V_5	31.00	86.44	106.90	117.9	134.7
V_6	29.21	82.16	104.30	113.2	131.2
$LSD_{0.05}$	1.056	1.209	0.777	1.242	1.439

V_1 = Lal til (Local), V_2 = Atshira (Local), V_3 = T-6, V_4 = BARI til-3, V_5 = BARI til-4, V_6 = Bina til 2

Appendix XI. Number of leaves $plant^{-1}$ of sesame at different days after sowing as influenced by different levels of plant nutrients during March-June, 2014

Treatment	Number of leaves $plant^{-1}$				
	30 DAS	45 DAS	60 DAS	75 DAS	At harvest
N_1	10.17	44.83	67.39	84.61	62.22
N_2	11.33	51.72	73.06	95.17	81.83
N_3	11.28	50.78	72.11	93.78	77.78
N_4	11.44	52.67	73.5	96.33	81.33
$LSD_{0.05}$	0.227	0.675	0.769	0.966	1.137

N_1 = 75% of RDF (43:54:23 kg N, P_2O_5 and K_2O ha^{-1}), N_2 = 100% of RDF (58:72:30 kg N, P_2O_5 and K_2O ha^{-1}), N_3 = 125% of RDF (72:90:38 kg N, P_2O_5 and K_2O ha^{-1}), N_4 = 150% of RDF (86:108:45 kg N, P_2O_5 and K_2O ha^{-1})

Appendix XII. Number of leaves plant^{-1} of sesame at different days after sowing as influenced by different variety during March-June, 2014

Treatment	Number of leaves plant^{-1}				
	30 DAS	45 DAS	60 DAS	75 DAS	At harvest
V_1	9.67	42.42	64.08	79.92	55.83
V_2	9.83	43.33	63.83	81.92	56.75
V_3	11.17	50.00	72.17	93.92	78.25
V_4	12.00	55.50	77.67	101.40	88.00
V_5	12.50	58.58	78.50	103.90	96.75
V_6	11.17	50.17	72.83	93.75	79.17
$LSD_{0.05}$	0.419	0.883	1.496	1.441	1.617

V_1 = Lal til (Local), V_2 = Atshira (Local), V_3 = T-6, V_4 = BARI til-3, V_5 = BARI til-4, V_6 = Bina til 2

Appendix XIII. Number of branches plant^{-1} of sesame at different days after sowing as influenced by different levels of plant nutrients during March-June, 2014

Treatment	Number of branches plant^{-1}				
	30 DAS	45 DAS	60 DAS	75 DAS	At harvest
N_1	0.00	2.61	3.00	3.00	4.28
N_2	0.61	3.11	3.50	4.11	5.39
N_3	0.22	3.06	3.44	3.78	5.06
N_4	0.33	3.06	3.56	3.72	5.22
$LSD_{0.05}$	0.104	0.146	0.127	0.254	0.227

N_1 = 75% of RDF (43:54:23 kg N, P_2O_5 and K_2O ha^{-1}), N_2 = 100% of RDF (58:72:30 kg N, P_2O_5 and K_2O ha^{-1}), N_3 = 125% of RDF (72:90:38 kg N, P_2O_5 and K_2O ha^{-1}), N_4 = 150% of RDF (86:108:45 kg N, P_2O_5 and K_2O ha^{-1})

Appendix XIV. Number of branches plant^{-1} of sesame at different days after sowing as influenced by different variety during March-June, 2014

Treatment	Number of branches plant^{-1}				
	30 DAS	45 DAS	60 DAS	75 DAS	At harvest
V_1	0.00	2.58	2.75	2.75	3.92
V_2	0.00	2.58	2.83	2.92	4.17
V_3	0.00	3.00	3.33	3.58	5.08
V_4	0.50	3.17	3.75	4.08	5.58
V_5	1.08	3.42	4.00	4.67	5.83
V_6	0.17	3.00	3.58	3.92	5.33
$LSD_{0.05}$	0.097	0.228	0.280	0.241	0.252

V_1 = Lal til (Local), V_2 = Atshira (Local), V_3 = T-6, V_4 = BARI til-3, V_5 = BARI til-4, V_6 = Bina til 2

Appendix XV. Dry weight plant^{-1} of sesame at different days after sowing as influenced by different levels of plant nutrients during March-June, 2014

Treatment	Dry Dry weight plant^{-1} (g)				
	30 DAS	45 DAS	60 DAS	75 DAS	At harvest
N_1	1.37	2.86	13.09	26.52	47.00
N_2	1.86	3.76	18.13	28.85	54.83
N_3	1.70	3.58	15.45	27.99	52.47
N_4	1.62	3.40	15.37	26.77	51.37
$LSD_{0.05}$	0.209	0.160	0.302	0.325	0.605

N_1 = 75% of RDF (43:54:23 kg N, P_2O_5 and K_2O ha^{-1}), N_2 = 100% of RDF (58:72:30 kg N, P_2O_5 and K_2O ha^{-1}), N_3 = 125% of RDF (72:90:38 kg N, P_2O_5 and K_2O ha^{-1}), N_4 = 150% of RDF (86:108:45 kg N, P_2O_5 and K_2O ha^{-1})

Appendix XVI. Dry weight plant^{-1} of sesame at different days after sowing as influenced by different variety during March-June, 2014

Treatment	Dry weight plant^{-1} (g)				
	30 DAS	45 DAS	60 DAS	75 DAS	At harvest
V_1	1.15	2.45	9.90	26.36	43.84
V_2	1.33	2.75	11.91	27.39	46.78
V_3	1.78	3.65	16.84	27.29	53.76
V_4	1.86	3.83	18.02	27.84	54.10
V_5	1.91	3.94	18.66	28.67	55.71
V_6	1.81	3.77	17.72	27.65	54.31
$LSD_{0.05}$	0.078	0.104	0.369	0.369	0.275

V_1 = Lal til (Local), V_2 = Atshira (Local), V_3 = T-6, V_4 = BARI til-3, V_5 = BARI til-4, V_6 = Bina til 2

Appendix XVII. LAI of sesame at different days after sowing as influenced by different levels of plant nutrients during March-June, 2014

Treatment	Leaf area index (LAI)				
	30 DAS	45 DAS	60 DAS	75 DAS	At harvest
N_1	2.25	12.11	17.45	22.27	15.65
N_2	2.36	11.71	17.97	22.96	17.25
N_3	2.60	11.14	19.10	24.47	19.60
N_4	2.87	13.01	20.49	26.65	23.22
$LSD_{0.05}$	0.453	0.458	0.715	0.894	0.834

N_1 = 75% of RDF (43:54:23 kg N, P_2O_5 and K_2O ha^{-1}), N_2 = 100% of RDF (58:72:30 kg N, P_2O_5 and K_2O ha^{-1}), N_3 = 125% of RDF (72:90:38 kg N, P_2O_5 and K_2O ha^{-1}), N_4 = 150% of RDF (86:108:45 kg N, P_2O_5 and K_2O ha^{-1})

Appendix XVIII. LAI of sesame at different days after sowing as influenced by different variety during March-June, 2014

Treatment	Leaf area index (LAI)				
	30 DAS	45 DAS	60 DAS	75 DAS	At harvest
V_1	2.12	11.98	16.34	21.22	13.99
V_2	2.10	11.56	16.67	21.29	13.77
V_3	2.54	11.52	19.14	24.35	19.44
V_4	2.81	12.58	20.03	25.66	21.69
V_5	2.87	12.66	20.54	26.93	23.94
V_6	2.68	11.65	19.81	25.08	20.73
$LSD_{0.05}$	0.637	0.566	1.229	0.723	0.624

V_1 = Lal til (Local), V_2 = Atshira (Local), V_3 = T-6, V_4 = BARI til-3, V_5 = BARI til-4, V_6 = Bina til 2

Appendix XIX. Yield contributing parameters of sesame as influenced by different levels of plant nutrients during March-June, 2014

Treatment	Yield contributing parameters			
	Number of capsule plant^{-1}	Number of seeds capsule^{-1}	1000 seed weight (g)	Capsule length (cm)
N_1	63.83	73.05	2.60	2.18
N_2	77.28	79.53	2.78	2.32
N_3	69.11	75.69	2.70	2.24
N_4	64.28	72.76	2.62	2.13
$LSD_{0.05}$	1.214	1.406	0.037	0.060

N_1 = 75% of RDF (43:54:23 kg N, P_2O_5 and K_2O ha^{-1}), N_2 = 100% of RDF (58:72:30 kg N, P_2O_5 and K_2O ha^{-1}), N_3 = 125% of RDF (72:90:38 kg N, P_2O_5 and K_2O ha^{-1}), N_4 = 150% of RDF (86:108:45 kg N, P_2O_5 and K_2O ha^{-1})

Appendix XX. Yield contributing parameters of sesame as influenced by different varieties during March-June, 2014

Treatment	Yield contributing parameters			
	Number of capsule plant^{-1}	Number of seeds capsule^{-1}	1000 seed weight (g)	Capsule length (cm)
V_1	56.58	65.82	2.45	2.05
V_2	59.17	69.03	2.52	2.12
V_3	70.25	77.66	2.73	2.26
V_4	76.08	79.67	2.79	2.30
V_5	77.33	80.76	2.81	2.31
V_6	72.33	78.62	2.75	2.28
$LSD_{0.05}$	0.9286	0.969	0.069	0.052

V_1 = Lal til (Local), V_2 = Atshira (Local), V_3 = T-6, V_4 = BARI til-3, V_5 = BARI til-4, V_6 = Bina til 2

Appendix XXI. Yield parameters of sesame as influenced by different levels of plant nutrients during March-June, 2014

Treatment	Yield parameters		
	Seed yield ha^{-1} (kg)	Stover yield ha^{-1} (kg)	Harvest index (%)
N_1	971.30	1274.00	43.26
N_2	1223.00	1473.00	45.36
N_3	1042.00	1425.00	42.24
N_4	924.00	1317.00	41.23
$LSD_{0.05}$	13.43	16.45	0.679

N_1 = 75% of RDF (43:54:23 kg N, P_2O_5 and K_2O ha^{-1}), N_2 = 100% of RDF (58:72:30 kg N, P_2O_5 and K_2O ha^{-1}), N_3 = 125% of RDF (72:90:38 kg N, P_2O_5 and K_2O ha^{-1}), N_4 = 150% of RDF (86:108:45 kg N, P_2O_5 and K_2O ha^{-1})

Appendix XXII. Yield parameters of sesame as influenced by different variety during March-June, 2014

Treatment	Yield parameters		
	Seed yield ha^{-1} (kg)	Stover yield ha^{-1} (kg)	Harvest index (%)
V_1	811.30	1139.00	41.60
V_2	910.30	1208.00	42.97
V_3	1063.00	1435.00	42.55
V_4	1152.00	1470.00	43.94
V_5	1170.00	1476.00	44.22
V_6	1133.00	1468.00	43.56
$LSD_{0.05}$	16.44	14.82	0.7125

V_1 = Lal til (Local), V_2 = Atshira (Local), V_3 = T-6, V_4 = BARI til-3, V_5 = BARI til-4, V_6 = Bina til 2

Appendix XXIII. Plant height of sesame at different days after sowing as influenced by different sources of plant nutrients during March – June, 2015 and 2016

Treatment	Plant height									
	March-June, 2015					March-June, 2016				
	30 DAT	45 DAT	60 DAT	75 DAT	At harvest	30 DAT	45 DAT	60 DAT	75 DAT	At harvest
T_1	29.68	83.29	104.8	103.9	99.97	30.03	83.5	104.95	104.28	100.07
T_2	26.99	73.55	99.	98.45	94.73	27.77	74.49	99.27	98.93	95.15
T_3	27.51	75.56	101.6	100.5	98.29	27.86	75.93	101.79	100.88	93.94
T_4	28.10	78.4	102.8	101.9	97.66	28.45	78.61	102.99	102.4	98.07
T_5	29.11	80.94	103.8	103.7	99.08	29.47	81.28	103.89	104.04	99.38
T_6	26.66	71.94	98.38	97.54	93.05	27.35	72.32	98.57	98.04	93.36
T_7	27.24	74.24	101.2	98.92	93.69	27.58	73.93	101.44	99.44	98.47
T_8	27.99	76.25	102.3	100.8	96.11	28.33	76.49	102.4	101.19	96.44
T_9	28.50	80.15	103.3	103.5	98.55	28.86	80.3	103.33	104.01	98.83
$LSD_{0.05}$	0.598	0.984	0.857	0.854	0.857	0.584	0.871	0.883	0.868	0.796

T_1 = 100% RDF through chemical fertilizer, T_2 = 100% RDF through vermicomost, T_3 = 75% RDF through vermicomost + 25 % as chemical fertilizer, T_4 = 50% RDF through vermicompost + 50% as chemical fertilizer, T_5 = 25% RDF through vermicompost + 75% as chemical fertilizer, T_6 = 100% RDF through FYM, T_7 = 75% RDF through FYM + 25% as chemical fertilizer, T_8 = 50% RDF through FYM + 50% as chemical fertilizer and T_9 = 25% RDF through FYM + 75% as chemical fertilizer

Appendix XIV. Plant height of sesame at different days after sowing as influenced by different plant spacing during March – June, 2015 and 2016

Treatment	Plant height									
	March-June, 2015					March-June, 2016				
	30 DAT	45 DAT	60 DAT	75 DAT	At harvest	30 DAT	45 DAT	60 DAT	75 DAT	At harvest
S_1	31.97	90.20	108.3	110.4	106.4	32.32	90.48	108.42	110.69	106.63
S_2	29.28	81.33	104.7	103.9	99.57	29.63	81.63	104.91	104.39	99.89
S_3	26.71	74.48	100.6	97.29	95.25	27.06	74.77	100.75	97.85	95.6
S_4	23.94	62.57	93.99	92.54	85.93	24.62	62.82	94.19	92.93	86.21
$LSD_{0.05}$	0.434	0.656	0.667	0.789	0.711	0.448	0.576	0.659	0.714	0.723

S_1 = 30 cm × 5 cm (400 plants $plot^{-1}$), S_2 = 30 cm × 10 cm (200 plants $plot^{-1}$), S_3 = 30 cm × 15 cm (130 plants $plot^{-1}$) and S_4 = 30 cm × 20 cm (100 plants $plot^{-1}$)

Appendix XV. Number of leaves plant^{-1} of sesame at different days after sowing as influenced by different sources of plant nutrients during M March – June, 2015 and 2016

Treatment	Number of leaves plant^{-1}									
	March-June, 2015					March-June, 2016				
	30 DAT	45 DAT	60 DAT	75 DAT	At harvest	30 DAT	45 DAT	60 DAT	75 DAT	At harvest
T_1	9	19.77	36.08	40.92	34.67	8.95	19.75	36.14	41	35.52
T_2	9.08	19.75	34.75	40.33	33.25	9.12	19.8	34.76	40.07	34.22
T_3	8.83	19.42	34.92	40.42	33.5	8.84	19.26	34.56	40.6	34.8
T_4	9.08	20.33	35.67	40.5	33.75	9.17	20.46	35.62	40.53	34.44
T_5	9.33	20.75	36.42	41.17	34.75	9.34	20.76	36.31	41.32	35.71
T_6	8.58	18.67	34.33	39.75	33	8.56	18.79	34.34	39.85	34.16
T_7	8.67	19.25	34.58	39.92	33.17	8.7	19.51	34.87	40.46	34.67
T_8	9.33	20.17	35.5	40.42	33.67	9.34	20.15	35.51	40.6	34.2
T_9	8.83	19.58	35.67	40.67	33.33	8.82	19.68	35.62	40.79	34.34
$LSD_{0.05}$	0.212	0.342	0.372	0.403	0.455	0.207	0.335	0.381	0.426	0.461

T_1 = 100% RDF through chemical fertilizer, T_2 = 100% RDF through vermicomost, T_3 = 75% RDF through vermicomost + 25 % as chemical fertilizer, T_4 = 50% RDF through vermicompost + 50% as chemical fertilizer, T_5 = 25% RDF through vermicompost + 75% as chemical fertilizer, T_6 = 100% RDF through FYM, T_7 = 75% RDF through FYM + 25% as chemical fertilizer, T_8 = 50% RDF through FYM + 50% as chemical fertilizer and T_9 = 25% RDF through FYM + 75% as chemical fertilizer

Appendix XXVI. Number of leaves plant^{-1} of sesame at different days after sowing as influenced by different plant spacing during March – June, 2015 and 2016

Treatment	Number of leaves plant^{-1}									
	March-June, 2015					March-June, 2016				
	30 DAT	45 DAT	60 DAT	75 DAT	At harvest	30 DAT	45 DAT	60 DAT	75 DAT	At harvest
S_1	8.56	18.07	32.74	38.59	32.33	8.63	18.1	32.68	38.72	33.33
S_2	8.78	20.15	34.63	39.93	33.41	8.81	20.21	34.66	40.17	34.36
S_3	9.33	20.83	37.26	42	34.96	9.29	20.91	37.22	42.09	35.89
S_4	9.22	19.93	36.67	41.3	34.07	9.19	19.96	36.65	41.34	35.11
$LSD_{0.05}$	0.286	0.228	0.281	0.206	0.239	0.206	0.235	0.291	0.216	0.229

S_1 = 30 cm × 5 cm (400 plants plot^{-1}), S_2 = 30 cm × 10 cm (200 plants plot^{-1}), S_3 = 30 cm × 15 cm (130 plants plot^{-1}) and S_4 = 30 cm × 20 cm (100 plants plot^{-1})

Appendix XXVII. Number of branches plant^{-1} of sesame at different days after sowing as influenced by different sources of plant nutrients during March – June, 2015 and 2016

Treatment	Number of branches plant^{-1}							
	March-June, 2015				March-June, 2016			
	45 DAT	60 DAT	75 DAT	At harvest	45 DAT	60 DAT	75 DAT	At harvest
T_1	6.17	6.5	6.83	7.33	6.34	7.15	7.49	7.79
T_2	5.75	6.25	6.33	6.83	5.95	6.9	7.01	7.39
T_3	5.92	6.08	6.58	7.17	6.12	6.69	7.36	7.88
T_4	6.09	6.25	6.67	7.25	6.31	6.85	7.26	7.81
T_5	6.33	6.5	7	7.58	6.48	7.11	7.67	8.14
T_6	5.67	6	6.33	6.75	5.87	6.78	7.01	7.34
T_7	5.75	6.17	6.58	7.08	5.97	6.61	7.27	7.64
T_8	6	6.33	6.42	6.83	6.21	6.97	7.08	7.4
T_9	6.17	6.17	6.75	6.83	6.41	6.83	7.58	7.44
$LSD_{0.05}$	0.121	0.137	0.146	0.190	0.116	0.135	0.149	0.187

T_1 = 100% RDF through chemical fertilizer, T_2 = 100% RDF through vermicomost, T_3 = 75% RDF through vermicomost + 25 % as chemical fertilizer, T_4 = 50% RDF through vermicompost + 50% as chemical fertilizer, T_5 = 25% RDF through vermicompost + 75% as chemical fertilizer, T_6 = 100% RDF through FYM, T_7 = 75% RDF through FYM + 25% as chemical fertilizer, T_8 = 50% RDF through FYM + 50% as chemical fertilizer and T_9 = 25% RDF through FYM + 75% as chemical fertilizer

Appendix XXVIII. Number of branches plant^{-1} of sesame at different days after sowing as influenced by different plant spacing during March – June, 2015 and 2016

Treatment	Number of branches plant^{-1}							
	March-June, 2015				March-June, 2016			
	45 DAT	60 DAT	75 DAT	At harvest	45 DAT	60 DAT	75 DAT	At harvest
S_1	5.33	5.7	6.11	6.37	5.54	6.34	6.79	6.93
S_2	5.85	6.37	6.41	7.07	6.06	6.99	7.1	7.64
S_3	6.44	6.56	7.00	7.44	6.64	7.17	7.69	8.03
S_4	6.30	6.37	6.93	7.41	6.49	6.99	7.62	7.98
$LSD_{0.05}$	0.104	0.118	0.120	0.140	0.124	0.127	0.108	0.151

S_1 = 30 cm × 5 cm (400 plants plot^{-1}), S_2 = 30 cm × 10 cm (200 plants plot^{-1}), S_3 = 30 cm × 15 cm (130 plants plot^{-1}) and S_4 = 30 cm × 20 cm (100 plants plot^{-1})

Appendix XXIX. Dry weight plant^{-1} of sesame at different days after sowing as influenced by different sources of plant nutrients during March – June, 2015 and 2016

Treatment	Dry weight plant^{-1}									
	March-June, 2015					March-June, 2016				
	30 DAT	45 DAT	60 DAT	75 DAT	At harvest	30 DAT	45 DAT	60 DAT	75 DAT	At harvest
T_1	2.8	3.2	6.31	9.97	28.63	2.8	3.37	7.02	11.28	26.24
T_2	2.75	3.13	6.3	9.6	27.92	2.87	3.45	7.16	11.79	28.6
T_3	2.82	3.12	6.48	9.85	30.95	2.83	3.39	7.08	11.65	27.25
T_4	2.77	3.22	6.3	9.89	30.37	2.92	3.51	7.3	12.08	30.02
T_5	2.89	3.29	6.53	10.47	32.84	2.95	3.58	7.38	12.43	31.15
T_6	2.69	3.23	6.19	9.94	27.75	2.8	3.14	6.99	11.32	27.93
T_7	2.72	3.2	6.5	10.37	27.92	2.85	3.41	7.12	11.7	27.47
T_8	2.71	2.91	6.18	9.44	27.47	2.86	3.43	7.15	11.74	26.17
T_9	2.86	3.26	6.49	9.57	29.4	2.82	3.38	7.07	11.47	26.82
$LSD_{0.05}$	NS	0.302	0.151	0.197	0.172	NS	0.316	0.148	0.188	0.169

T_1 = 100% RDF through chemical fertilizer, T_2 = 100% RDF through vermicomost, T_3 = 75% RDF through vermicomost + 25 % as chemical fertilizer, T_4 = 50% RDF through vermicompost + 50% as chemical fertilizer, T_5 = 25% RDF through vermicompost + 75% as chemical fertilizer, T_6 = 100% RDF through FYM, T_7 = 75% RDF through FYM + 25% as chemical fertilizer, T_8 = 50% RDF through FYM + 50% as chemical fertilizer and T_9 = 25% RDF through FYM + 75% as chemical fertilizer

Appendix XXX. Dry weight plant^{-1} of sesame at different days after sowing as influenced by different plant spacing during March – June, 2015 and 2016

Treatment	Dry weight plant^{-1}									
	March-June, 2015					March-June, 2016				
	30 DAT	45 DAT	60 DAT	75 DAT	At harvest	30 DAT	45 DAT	60 DAT	75 DAT	At harvest
S_1	2.71	3.02	6.21	9.2	25.4	2.69	3.15	6.81	10.83	23.43
S_2	2.75	3.09	6.29	9.78	28.08	2.82	3.36	7.02	11.41	26.08
S_3	2.86	3.3	6.6	10.76	33.3	2.95	3.56	7.37	12.33	31.3
S_4	2.79	3.28	6.37	9.86	30.21	2.95	3.55	7.37	12.28	31.01
$LSD_{0.05}$	NS	0.060	0.101	0.113	0.131	NS	0.056	0.113	0.124	0.145

S_1 = 30 cm × 5 cm (400 plants plot^{-1}), S_2 = 30 cm × 10 cm (200 plants plot^{-1}), S_3 = 30 cm × 15 cm (130 plants plot^{-1}) and S_4 = 30 cm × 20 cm (100 plants plot^{-1})

Appendix XXXI. Yield contributing parameters of sesame as influenced by different sources of plant nutrients during March – June, 2015 and 2016

Treatment	Yield contributing parameters							
	2nd Year Experiment				3rd Year Experiment			
	Number of capsule plant^{-1}	Number of seeds capsule^{-1}	Capsule length (cm)	1000 seed weight (g)	Number of capsule plant^{-1}	Number of seeds capsule^{-1}	Capsule length (cm)	1000 seed weight (g)
T_1	62.92	73.92	2.29	2.23	59.39	72.67	2.19	2.28
T_2	58.25	72.75	2.26	2.18	62.42	75.75	2.25	2.37
T_3	59.83	73.67	2.28	2.24	60.50	74.25	2.22	2.35
T_4	60.42	75.25	2.31	2.30	64.90	77.75	2.29	2.51
T_5	63.25	77.25	2.35	2.32	67.68	79.83	2.33	2.59
T_6	56.92	71.42	2.24	2.08	58.73	75.17	2.23	2.20
T_7	59.58	73.17	2.27	2.28	61.51	74.75	2.22	2.32
T_8	60.08	74.17	2.30	2.13	61.92	72.75	2.19	2.21
T_9	62.08	76.58	2.33	2.30	60.16	73.58	2.20	2.25
$LSD_{0.05}$	0.854	0.841	0.017	0.045	2.334	1.137	0.016	0.034

T_1 = 100% RDF through chemical fertilizer, T_2 = 100% RDF through vermicomost, T_3 = 75% RDF through vermicomost + 25 % as chemical fertilizer, T_4 = 50% RDF through vermicompost + 50% as chemical fertilizer, T_5 = 25% RDF through vermicompost + 75% as chemical fertilizer, T_6 = 100% RDF through FYM, T_7 = 75% RDF through FYM + 25% as chemical fertilizer, T_8 = 50% RDF through FYM + 50% as chemical fertilizer and T_9 = 25% RDF through FYM + 75% as chemical fertilizer

Appendix XXXII. Yield contributing parameters of sesame as influenced by plant spacing during March – June, 2015 and 2016

Treatment	Yield contributing parameters							
	2nd Year Experiment				3rd Year Experiment			
	Number of capsule plant^{-1}	Number of seeds capsule^{-1}	Capsule length (cm)	1000 seed weight (g)	Number of capsule plant^{-1}	Number of seeds capsule^{-1}	Capsule length (cm)	1000 seed weight (g)
S_1	54.30	66.56	2.16	1.89	55.90	67.33	2.10	1.99
S_2	58.22	71.85	2.24	2.14	59.73	72.67	2.18	2.26
S_3	66.33	82.52	2.44	2.60	66.05	80.48	2.33	2.57
S_4	62.63	76.04	2.33	2.30	65.96	80.18	2.32	2.55
$LSD_{0.05}$	0.769	0.587	0.098	0.085	2.114	1.356	0.021	0.026

S_1 = 30 cm × 5 cm (400 plants plot^{-1}), S_2 = 30 cm × 10 cm (200 plants plot^{-1}), S_3 = 30 cm × 15 cm (130 plants plot^{-1}) and S_4 = 30 cm × 20 cm (100 plants plot^{-1})

Appendix XXXIII. Yield parameters of sesame as influenced by different sources of plant nutrients during March – June, 2015 and 2016

Treatment	Yield parameters						Pooled yield (kg ha^{-1})
	2nd Year Experiment			3rd Year Experiment			
	Seed yield ha^{-1} (kg)	Stover yield ha^{-1} (kg)	Harvest index (%)	Seed yield ha^{-1} (kg)	Stover yield ha^{-1} (kg)	Harvest index (%)	
T_1	1274.00	1562.00	45.01	1272.25	1565.50	44.82	1273.13
T_2	1241.00	1525.00	44.62	1234.75	1520.50	44.78	1237.88
T_3	1268.00	1543.00	44.57	1261.25	1540.50	44.98	1264.63
T_4	1301.00	1586.00	44.89	1297.50	1583.50	45.03	1299.25
T_5	1326.00	1619.00	45.47	1345.00	1592.00	45.80	1335.50
T_6	1204.00	1479.00	42.87	1206.25	1491.75	44.64	1205.13
T_7	1248.00	1532.00	44.72	1249.00	1532.25	44.87	1248.50
T_8	1288.00	1464.00	45.24	1287.50	1530.25	45.76	1287.75
T_9	1309.00	1579.00	45.01	1305.25	1569.00	45.40	1307.13
$LSD_{0.05}$	4.576	4.996	0.227	6.559	10.378	0.105	5.317

T_1 = 100% RDF through chemical fertilizer, T_2 = 100% RDF through vermicomost, T_3 = 75% RDF through vermicomost + 25 % as chemical fertilizer, T_4 = 50% RDF through vermicompost + 50% as chemical fertilizer, T_5 = 25% RDF through vermicompost + 75% as chemical fertilizer, T_6 = 100% RDF through FYM, T_7 = 75% RDF through FYM + 25% as chemical fertilizer, T_8 = 50% RDF through FYM + 50% as chemical fertilizer and T_9 = 25% RDF through FYM + 75% as chemical fertilize

Appendix XXXIV. Yield parameters of sesame as influenced by plant spacing during March – June, 2015 and 2016

Treatment	Yield parameters						Pooled yield (kg ha^{-1})
	2nd Year Experiment			3rd Year Experiment			
	Seed yield ha^{-1} (kg)	Stover yield ha^{-1} (kg)	Harvest index (%)	Seed yield ha^{-1} (kg)	Stover yield ha^{-1} (kg)	Harvest index (%)	
S_1	1413.00	1715.00	45.17	1412.11	1707.11	45.27	1412.56
S_2	1340.00	1639.00	44.98	1335.67	1633.89	44.98	1337.84
S_3	1238.00	1496.00	45.28	1232.11	1490.56	45.26	1235.06
S_4	1102.00	1392.00	44.19	1100.89	1363.00	44.65	1101.45
$LSD_{0.05}$	13.016	13.239	0.407	12.569	13.557	0.124	10.537

S_1 = 30 cm × 5 cm (400 plants $plot^{-1}$), S_2 = 30 cm × 10 cm (200 plants $plot^{-1}$), S_3 = 30 cm × 15 cm (130 plants $plot^{-1}$) and S_4 = 30 cm × 20 cm (100 plants $plot^{-1}$)

Appendix XXXV. Mean square of plant height of sesame as influenced by different levels of plant nutrients and varieties in 2014

Source of variation	Degrees of freedom	Mean square of plant height (cm)				
		30 DAS	45 DAS	60 DAS	75 DAS	At harvest
Replication	2	3.507	4.477	7.090	4.458	7.149
Factor A	3	5.258*	6.796*	6.290*	9.217*	10.588*
Error	6	3.739	31.459	8.413	17.582	61.245
Factor B	5	5.687*	22.518*	28.012*	28.138*	35.896*
AB	15	0.759**	9.150*	4.064*	3.909**	9.739*
Error	40	2.249	2.845	3.475	5.488	7.621

* = Significant at 5%   ** = Significant at 1%   NS = Non-Significant

Appendix XXXVI. Mean square of number of leaves plant^{-1} of sesame as influenced by different levels of plant nutrients and varieties in 2014

Source of variation	Degrees of freedom	Mean square of number of leaves plant^{-1}				
		30 DAS	45 DAS	60 DAS	75 DAS	At harvest
Replication	2	4.01	8.875	3.097	6.597	9.292
Factor A	3	6.407*	24.259*	14.162*	14.019*	15.718*
Error	6	10.366	22.968	15.356	22.782	34.106
Factor B	5	15.422*	49.167*	48.281**	16.022*	32.958*
AB	15	0.763*	23.581**	18.695*	5.474*	7.751*
Error	40	4.494	3.228	4.508	4.519	4.936

* = Significant at 5%   ** = Significant at 1%   NS = Non-Significant

Appendix XXXVII. Mean square of number of branches plant^{-1} of sesame as influenced by different levels of plant nutrients and varieties in 2014

Source of variation	Degrees of freedom	Mean square of number of branches plant^{-1}				
		30 DAS	45 DAS	60 DAS	75 DAS	At harvest
Replication	2	0.154	0.310	0.375	0.500	0.531
Factor A	3	1.162*	4.347**	0.977*	1.162*	3.940**
Error	6	0.190	1.986	2.449	0.593	0.856
Factor B	5	2.258*	7.247*	1.292*	3.025*	6.347*
AB	15	0.451*	0.425*	0.055**	0.195*	0.451**
Error	40	0.011	0.489	0.481	0.619	1.025

* = Significant at 5%   ** = Significant at 1%   NS = Non-Significant

Appendix XXXVIII. Mean square of dry weight plant^{-1} of sesame as influenced by different levels of plant nutrients and varieties in 2014

Source of variation	Degrees of freedom	Mean square of dry weight plant^{-1} (g)				
		30 DAS	45 DAS	60 DAS	75 DAS	At harvest
Replication	2	0.110	0.273	0.595	0.652	1.542
Factor A	3	0.760**	2.676**	7.610*	21.219*	19.585*
Error	6	1.154	0.345	3.842	9.672	34.811
Factor B	5	1.222*	4.805**	11.629*	6.841*	24.289*
AB	15	0.051*	0.102*	2.558*	32.469**	7.923*
Error	40	0.443	0.548	1.907	2.559	3.862

* = Significant at 5% ** = Significant at 1% NS = Non-Significant

Appendix XXXIX. Mean square of LAI of sesame as influenced by different levels of plant nutrients and varieties in 2014

Source of variation	Degrees of freedom	Mean square of LAI				
		30 DAS	45 DAS	60 DAS	75 DAS	At harvest
Replication	2	0.362	0.401	1.564	1.245	3.390
Factor A	3	1.333*	11.186*	12.822*	17.778*	19.845*
Error	6	0.271	4.358	25.078	33.348	15.668
Factor B	5	1.373*	3.173*	19.031*	16.477*	9.703*
AB	15	0.045*	1.669*	0.635**	2.420*	3.822*
Error	40	0.650	2.591	2.059	3.386	2.061

* = Significant at 5% ** = Significant at 1% NS = Non-Significant

Appendix XL. Mean square of growth performance of sesame as influenced by different levels of plant nutrients and varieties in 2014

Source of variation	Degrees of freedom	Mean square of growth performance		
		AGR	CGR	RGR
Replication	2	0.006	0.046	0.00
Factor A	3	0.055**	2.438*	NS
Error	6	0.094	4.178	0.002
Factor B	5	0.065**	2.876*	NS
AB	15	0.003**	0.116**	NS
Error	40	0.030	0.551	0.0001

* = Significant at 5% ** = Significant at 1% NS = Non-Significant

Appendix XLI. Mean square of yield contributing parameters of sesame as influenced by different levels of plant nutrients and varieties in 2014

Source of variation	Degrees of freedom	Mean square of yield contributing parameters			
		No. of capsule/plant	No. of seeds/capsule	1000 SW	Capsule length (cm)
Replication	2	3.625	41.718	0.095	0.059
Factor A	3	12.792**	17.443*	0.128**	0.117**
Error	6	34.125	9.697	0.038	0.047
Factor B	5	17.558*	47.082*	0.279**	0.139*
AB	15	10.381*	2.862**	0.018**	0.014**
Error	40	3.200	6.744	0.163	0.037

* = Significant at 5% ** = Significant at 1% NS = Non-Significant

Appendix XLII. Mean square of yield parameters of sesame as influenced by different levels of plant nutrients and varieties in 2014

Source of variation	Degrees of freedom	Mean square of yield parameters		
		Seed yield/ha (kg)	Stover yield/ha (kg)	HI
Replication	2	20.556	21.380	3.051
Factor A	3	309.185**	490.195*	24.665*
Error	6	103.630	516.897	37.347
Factor B	5	258.422*	510.445*	29.219*
AB	15	32.385**	74.258**	10.686*
Error	40	26.911	29.553	5.560

* = Significant at 5% ** = Significant at 1% NS = Non-Significant

Appendix XLIII. Mean square of plant height of sesame as influenced by different sources of plant nutrients and plant spacings in 2015 and 2016

Source of variation	Degrees of freedom	Mean square of plant height (cm) durning March-June, 2015 (2nd Year Experiment)					Mean square of plant height (cm) durning March-June 2016, (3rd Year Experiment)				
		30 DAS	45 DAS	60 DAS	75 DAS	At harvest	30 DAS	45 DAS	60 DAS	75 DAS	At harvest
Replication	2	2.596	0.907	2.994	0.544	1.024	2.007	1.389	2.116	1.627	2.331
Factor A	8	7.985*	7.855*	9.412*	8.808*	7.608*	9.317*	10.26*	14.24*	13.67*	10.28*
Error	16	1.836	2.246	0.693	1.387	2.732	1.814	3.216	3.517	2.314	2.618
Factor B	3	3.115*	6.158*	7.461*	6.162*	6.847*	5.219*	8.314*	6.117*	9.316*	7.119*
AB	24	0.562**	16.84*	11.812*	8.365*	9.379*	6.211**	10.84*	14.63*	10.76*	8.352*
Error	54	1.633	1.444	1.496	2.088	1.697	2.012	2.317	1.883	1.569	1.381

* = Significant at 5%   ** = Significant at 1%   NS = Non-Significant

Appendix XLIV. Mean square of number of leaves plant^{-1} of sesame as influenced by different sources of plant nutrients and plant spacings in 2015 and 2016

Source of variation	Degrees of freedom	Mean square of number of leaves plant^{-1} durning March-June, 2016 (2nd Year Experiment)					Mean square of number of leaves plant^{-1} durning March-June, 2016 (3rd Year Experiment)				
		30 DAS	45 DAS	60 DAS	75 DAS	At harvest	30 DAS	45 DAS	60 DAS	75 DAS	At harvest
Replication	2	2.031	3.224	2.044	2.037	2.561	1.367	2.138	3.144	2.196	1.511
Factor A	8	8.431*	11.366*	9.126*	12.324*	10.628*	7.386*	12.81*	14.62*	12.52*	11.36*
Error	16	9.623	6.529	15.322	18.701	3.128	5.366	7.148	9.319	7.814	6.134
Factor B	3	5.426*	9.144*	8.257**	8.369*	12.934*	9.322*	11.46*	10.59**	7.293*	11.85*
AB	24	1.763*	6.579**	10.695*	4.425*	9.722*	6.442*	13.27**	9.229*	14.56*	7.525*
Error	54	3.279	2.119	3.119	3.221	3.853	2.778	3.217	3.634	3.511	2.924

* = Significant at 5%   ** = Significant at 1%   NS = Non-Significant

Appendix XLV. Mean square of number of branches plant^{-1} of sesame as influenced by different sources of plant nutrients and plant spacings in 2015 and 2016

Source of variation	Degrees of freedom	Mean square of number of branches plant^{-1} durning March-June, 2015 (2nd Year Experiment)				Mean square of number of branches plant^{-1} durning March-June, 2016 (3rd Year Experiment)			
		45 DAS	60 DAS	75 DAS	At harvest	45 DAS	60 DAS	75 DAS	At harvest
Replication	2	0.136	0.115	0.284	0.389	0.107	0.128	0.174	0.186
Factor A	8	1.149*	5.361**	6.014*	5.349*	3.184*	6.618**	5.349*	6.221*
Error	16	0.184	2.388	1.596	1.544	0.212	0.536	1.728	1.637
Factor B	3	3.018*	8.544*	3.714*	4.219**	4.237*	5.311*	4.538*	5.229**
AB	24	4.196**	6.574*	4.216**	5.348*	6.114**	5.312*	6.389**	4.109*
Error	54	0.011	0.489	0.481	0.619	1.028	0.517	0.466	0.389

* = Significant at 5%   ** = Significant at 1%   NS = Non-Significant

Appendix XLVI. Mean square of dry weight plant^{-1} of sesame as influenced by different sources of plant nutrients and plant spacings in 2015 and 2016

Source of variation	Degrees of freedom	Mean square of dry weight plant^{-1} durning March-June, 2015 (2nd Year Experiment)					Mean square of dry weight plant^{-1} durning March-June, 2016 (3rd Year Experiment)				
		30 DAS	45 DAS	60 DAS	75 DAS	At harvest	30 DAS	45 DAS	60 DAS	75 DAS	At harvest
Replication	2	0.014	0.036	0.068	0.712	1.039	0.004	0.008	0.016	0.112	0.164
Factor A	8	NS	NS	NS	6.542*	9.566*	NS	NS	3.139	5.116*	8.389*
Error	16	0.068	0.083	0.075	1.537	2.399	0.031	0.042	0.113	0.849	1.386
Factor B	3	NS	NS	NS	6.875*	7.311*	NS	NS	2.536	5.229*	8.314*
AB	24	NS	NS	2.564*	8..419**	5.931*	NS	NS	3.389*	7.711**	6.044*
Error	54	0.418	0.488	1.238	1.597	2.566	0.048	0.056	0.834	1.039	1.112

* = Significant at 5%   ** = Significant at 1%   NS = Non-Significant

Appendix XLVII. Mean square of growth performance of sesame as influenced by different sources of plant nutrients and plant spacings in 2015 and 2016

Source of variation	Degrees of freedom	Mean square of growth performance durning March-June, 2015 (2nd Year Experiment)			Mean square of growth performance durning March-June, 2016 (3rd Year Experiment)		
		AGR	CGR	RGR	AGR	CGR	RGR
Replication	2	0.003	0.006	0.00	0.002	0.004	0.001
Factor A	8	NS	NS	NS	NS	0.127	NS
Error	16	0.001	0.002	0.002	0.003	0.012	0.003
Factor B	3	NS	0.103*	NS	NS	0.118*	NS
AB	24	0.102**	0.106**	NS	0.089**	0.114**	NS
Error	54	0.004	0.051	0.002	0.005	0.048	0.003

* = Significant at 5% ** = Significant at 1% NS = Non-Significant

Appendix XLVIII. Mean square of yield contributing parameters of sesame as influenced by different sources of plant nutrients and plant spacings in 2015 and 2016

Source of variation	Degrees of freedom	Mean square of yield contributing parameters durning March-June, 2015 (2nd Year Experiment)				Mean square of yield contributing parameters durning March-June, 2016 (3rd Year Experiment)			
		Number of capsule plant^{-1}	Number of seedscapsule^{-1}	Capsule length (cm)	1000 seed weight (g)	Number of capsule plant^{-1}	Number of seedscapsule^{-1}	Capsule length (cm)	1000 seed weight (g)
Replication	2	2.312	4.583	0.076	0.044	3.114	2.368	0.028	0.052
Factor A	8	13.02*	16.35*	0.109*	0.214*	10.56*	14.39*	0.094*	0.326*
Error	16	4.126	3.604	0.107	0.058	3.527	5.229	0.143	0.076
Factor B	3	7.536**	8.319*	0.288*	0.124**	6.311**	9.525*	0.316*	0.108**
AB	24	9.428*	5.904*	0.032**	0.024**	10.81*	11.38*	0.024**	0.031**
Error	54	2.539	2.637	0.048	0.022	1.836	2.314	0.065	0.016

* = Significant at 5% ** = Significant at 1% NS = Non-Significant

Appendix XLIX. Mean square of yield parameters of sesame as influenced by different sources of plant nutrients and plant spacings in 2015 and 2016

Source of variation	Degrees of freedom	Mean square of yield parameters durning March-June, 2015 (2nd Year Experiment)			Mean square of yield parameters durning March-June, 2016 (3rd Year Experiment)		
		Seed yield ha^{-1} (kg)	Stover yield ha^{-1} (kg)	Harvest index (%)	Seed yield ha^{-1} (kg)	Stover yield ha^{-1} (kg)	Harvest index (%)
Replication	2	18.398	20.744	1.534	22.442	26.349	2.314
Factor A	8	168.24*	289.95*	8.622*	201.67*	354.831*	10.36*
Error	16	13.244	16.836	3.311	18.545	26.341	2.117
Factor B	3	118.83*	140.67*	9.263**	110.529*	165.37*	8.314**
AB	24	28.614*	64.329*	4.237*	46.853*	71.319*	5.714*
Error	54	20.361	32.529	2.209	22.366	37.249	1.381

* = Significant at 5% ** = Significant at 1% NS = Non-Significant

Appendix L. Mean square of quality parameters (oil and protein yield) of sesame as influenced by different sources of plant nutrients and plant spacings in 2015 and 2016

Source of variation	Degrees of freedom	Mean square of quality parameters durning March-June, 2015 (2nd Year Experiment)				Mean square of quality parameters durning March-June, 2016 (3rd Year Experiment)			
		% oil content	Oil yield (kg ha^{-1})	% protein content	Protein yield (kg ha^{-1})	% oil content	Oil yield (kg ha^{-1})	% protein content	Protein yield (kg ha^{-1})
Replication	2	1.529	5.366	1.044	3.627	1.044	3.249	2.314	2.863
Factor A	8	16.52*	26.35*	12.53*	18.36*	18.65*	28.39*	16.86*	23.22*
Error	16	4.266	6.289	3.214	5.112	3.291	7.563	2.714	4.389
Factor B	3	8.339**	10.26*	7.381*	11.26**	11.83**	13.96*	6.414*	12.37**
AB	24	10.54*	13.27*	11.36**	12.29**	14.27*	18.56*	9.539**	10.38**
Error	54	1.386	2.517	1.072	2.114	2.334	3.112	1.278	2.514

* = Significant at 5% ** = Significant at 1% NS = Non-Significant

Appendix LI. Mean square of nutrient uptake of sesame as influenced by different sources of plant nutrients and plant spacings in 2015 and 2016

Source of variation	Degrees of freedom	Mean square (Nutrient uptake) durning March-June, 2015 (2nd Year Experiment)			Mean square (Nutrient uptake) durning March-June, 2016 (3rd Year Experiment)		
		N	P	K	N	P	K
Replication	2	1.628	1.059	0.831	2.314	1.127	1.112
Factor A	8	9.553*	8.361*	8.224*	8.554*	9.286*	6.442*
Error	16	2.311	1.389	1.027	3.217	2.546	2.118
Factor B	3	4.316*	5.247*	4.22*	5.517*	6.312*	4.015*
AB	24	5.389**	4.056*	6.459*	6.386**	7.118*	7.312*
Error	54	2.347	2.048	1.346	2.047	1.756	1.218

* = Significant at 5%   ** = Significant at 1%   NS = Non-Significant

Appendix LII. Postharvest analysis of soil (2nd year experiment and 3rd year experiment)

Treatment	Post harvest soil analysis (kg ha^{-1})					
	2nd year			3rd year		
	N	P	K	N	P	K
T_1S_1	185.10	10.52	7.75	187.31	10.60	8.10
T_1S_2	175.63	12.50	10.20	173.38	12.50	10.36
T_1S_3	162.89	14.62	12.00	163.11	14.44	12.14
T_1S_4	145.84	16.10	13.88	144.37	16.06	14.00
T_2S_1	184.17	10.90	8.60	185.22	10.80	8.67
T_2S_2	174.38	13.21	10.66	175.34	12.77	10.80
T_2S_3	160.48	15.24	12.26	160.60	15.12	12.44
T_2S_4	143.18	17.80	14.62	144.36	16.98	14.70
T_3S_1	184.26	10.80	8.24	187.00	10.65	8.30
T_3S_2	175.39	12.75	10.22	175.89	12.60	10.30
T_3S_3	162.22	14.72	12.08	160.86	14.67	12.24
T_3S_4	144.78	16.30	14.20	144.80	16.36	14.06
T_4S_1	188.67	10.45	7.38	193.88	10.28	7.48
T_4S_2	177.48	12.23	9.88	175.39	12.12	9.90
T_4S_3	165.82	14.10	12.70	166.10	13.60	12.94
T_4S_4	147.92	16.06	13.48	148.29	16.00	13.55
T_5S_1	190.66	10.20	7.00	195.14	9.80	7.22
T_5S_2	178.36	12.15	9.54	176.88	11.80	9.42
T_5S_3	168.74	14.06	12.50	166.87	13.42	12.38
T_5S_4	152.37	15.63	13.20	150.76	15.74	12.90
T_6S_1	183.00	10.90	8.68	185.34	11.00	8.72
T_6S_2	173.26	13.75	10.74	174.50	12.80	11.10
T_6S_3	160.00	15.50	12.78	158.54	15.70	12.60
T_6S_4	139.71	18.30	14.86	140.78	17.20	14.94
T_7S_1	183.96	10.90	8.53	187.18	10.70	8.40
T_7S_2	176.11	13.00	10.48	174.52	12.60	10.50
T_7S_3	160.58	14.80	12.18	160.74	15.00	12.32
T_7S_4	143.75	16.90	14.42	144.80	16.60	14.12
T_8S_1	185.33	10.50	7.66	188.34	10.38	7.80
T_8S_2	177.12	12.20	10.12	174.58	12.40	9.98
T_8S_3	165.14	14.40	11.78	164.32	14.40	12.00
T_8S_4	147.28	16.18	13.67	147.67	16.00	13.55
T_9S_1	188.54	10.30	7.22	192.54	10.28	7.36
T_9S_2	177.87	12.26	9.72	176.10	12.00	9.60
T_9S_3	167.55	14.09	12.57	166.24	13.50	12.50
T_9S_4	150.27	16.05	13.25	150.44	15.75	12.87

Appendix LIII. Cost of production during the cropping period from March-June, 2015

A. Input cost

Treatment combination	Labour cost (Tk. ha^{-1})	Ploughing cost (Tk. ha^{-1})	Cost of seeds (Tk. ha^{-1})	Irrigation cost (Tk. ha^{-1})	Cost of fertilizer and manure (Tk. ha^{-1})	Insecticide/ Pesticides cost (Tk. ha^{-1})	Sub-total (A)
T_1S_1	7,000	7,000	675	2,000	8800	2,000	27,475
T_1S_2	7,000	7,000	338	2,000	8800	2,000	27,138
T_1S_3	7,000	7,000	225	2,000	8800	2,000	27,025
T_1S_4	7,000	7,000	169	2,000	8800	2,000	26,969
T_2S_1	7,000	7,000	675	2,000	13034	2,000	31,709
T_2S_2	7,000	7,000	338	2,000	13034	2,000	31,372
T_2S_3	7,000	7,000	225	2,000	13034	2,000	31,259
T_2S_4	7,000	7,000	169	2,000	13034	2,000	31,203
T_3S_1	7,000	7,000	675	2,000	11975	2,000	30,650
T_3S_2	7,000	7,000	338	2,000	11975	2,000	30,313
T_3S_3	7,000	7,000	225	2,000	11975	2,000	30,200
T_3S_4	7,000	7,000	169	2,000	11975	2,000	30,144
T_4S_1	7,000	7,000	675	2,000	10917	2,000	29,592
T_4S_2	7,000	7,000	338	2,000	10917	2,000	29,255
T_4S_3	7,000	7,000	225	2,000	10917	2,000	29,142
T_4S_4	7,000	7,000	169	2,000	10917	2,000	29,086
T_5S_1	7,000	7,000	675	2,000	9858	2,000	28,533
T_5S_2	7,000	7,000	338	2,000	9858	2,000	28,196
T_5S_3	7,000	7,000	225	2,000	9858	2,000	28,083
T_5S_4	7,000	7,000	169	2,000	9858	2,000	28,027
T_6S_1	7,000	7,000	675	2,000	16571	2,000	35,246
T_6S_2	7,000	7,000	338	2,000	16571	2,000	34,909
T_6S_3	7,000	7,000	225	2,000	16571	2,000	34,796
T_6S_4	7,000	7,000	169	2,000	16571	2,000	34,740
T_7S_1	7,000	7,000	675	2,000	14629	2,000	33,304
T_7S_2	7,000	7,000	338	2,000	14629	2,000	32,967
T_7S_3	7,000	7,000	225	2,000	14629	2,000	32,854
T_7S_4	7,000	7,000	169	2,000	14629	2,000	32,798
T_8S_1	7,000	7,000	675	2,000	12686	2,000	31,361
T_8S_2	7,000	7,000	338	2,000	12686	2,000	31,024
T_8S_3	7,000	7,000	225	2,000	12686	2,000	30,911
T_8S_4	7,000	7,000	169	2,000	12686	2,000	30,855
T_9S_1	7,000	7,000	675	2,000	10743	2,000	29,418
T_9S_2	7,000	7,000	338	2,000	10743	2,000	29,081
T_9S_3	7,000	7,000	225	2,000	10743	2,000	28,968
T_9S_4	7,000	7,000	169	2,000	10743	2,000	28,912

B. Overhead cost

Treatment	Cost of lease of land (Tk.7% of value of land cost/4 months)	Miscellaneous cost (Tk. 7% of the input cost	Interest on running capital for 3 months (Tk. 14% of cost/year)	Sub-total (Tk.) (B)	Total cost of production (Tk./ha) [Input cost (A) + overhead cost (B)]	Yield ha^{-1} (kg)	Gross return (Tk. ha^{-1})	Net return (Tk. ha^{-1})	BCR
T_1S_1	8,000	1,374	725	10,099	37,574	1390	62550	24,976	1.66
T_1S_2	8,000	1,357	716	10,073	37,211	1347	60615	23,404	1.63
T_1S_3	8,000	1,351	713	10,065	37,090	1240	55800	18,710	1.50
T_1S_4	8,000	1,348	712	10,060	37,029	1093	49185	12,156	1.33
T_2S_1	8,000	1,585	837	10,423	42,131	1393	62685	20,554	1.49
T_2S_2	8,000	1,569	828	10,397	41,769	1310	58950	17,181	1.41
T_2S_3	8,000	1,563	825	10,388	41,647	1207	54315	12,668	1.30
T_2S_4	8,000	1,560	824	10,384	41,587	1053	47385	5,798	1.14
T_3S_1	8,000	1,533	809	10,342	40,992	1413	63585	22,593	1.55
T_3S_2	8,000	1,516	800	10,316	40,629	1340	60300	19,671	1.48
T_3S_3	8,000	1,510	797	10,307	40,508	1233	55485	14,977	1.37
T_3S_4	8,000	1,507	796	10,303	40,447	1087	48915	8,468	1.21
T_4S_1	8,000	1,480	781	10,261	39,853	1430	64350	24,497	1.61
T_4S_2	8,000	1,463	772	10,235	39,490	1353	60885	21,395	1.54
T_4S_3	8,000	1,457	769	10,226	39,368	1247	56115	16,747	1.43
T_4S_4	8,000	1,454	768	10,222	39,308	1173	52785	13,477	1.34
T_5S_1	8,000	1,427	753	10,180	38,713	1437	64665	25,952	1.67
T_5S_2	8,000	1,410	744	10,154	38,351	1373	61785	23,434	1.61
T_5S_3	8,000	1,404	741	10,146	38,229	1300	58500	20,271	1.53
T_5S_4	8,000	1,401	740	10,141	38,169	1193	53685	15,516	1.41
T_6S_1	8,000	1,762	931	10,693	45,939	1380	62100	16,161	1.35
T_6S_2	8,000	1,745	922	10,667	45,577	1303	58635	13,058	1.29
T_6S_3	8,000	1,740	919	10,658	45,455	1200	54000	8,545	1.19
T_6S_4	8,000	1,737	917	10,654	45,395	933	41994	-3,396	0.93
T_7S_1	8,000	1,665	879	10,544	43,848	1397	62865	19,017	1.43
T_7S_2	8,000	1,648	870	10,519	43,485	1323	59535	16,050	1.37
T_7S_3	8,000	1,643	867	10,510	43,364	1213	54585	11,221	1.26
T_7S_4	8,000	1,640	866	10,506	43,303	1060	47700	4,397	1.10
T_8S_1	8,000	1,568	828	10,396	41,757	1418	63810	22,053	1.53
T_8S_2	8,000	1,551	819	10,370	41,394	1347	60615	19,221	1.46
T_8S_3	8,000	1,546	816	10,362	41,272	1245	56025	14,753	1.36
T_8S_4	8,000	1,543	815	10,357	41,212	1140	51300	10,088	1.24
T_9S_1	8,000	1,471	777	10,248	39,665	1433	64485	24,820	1.63
T_9S_2	8,000	1,454	768	10,222	39,303	1360	61200	21,897	1.56
T_9S_3	8,000	1,448	765	10,213	39,181	1260	56700	17,519	1.45
T_9S_4	8,000	1,446	763	10,209	39,121	1183	53235	14,114	1.36

Appendix LIV. Cost of production during the cropping period from March-June, 2016

A. Input cost

Treatment combination	Labour cost (Tk. ha^{-1})	Ploughing cost (Tk. ha^{-1})	Cost of seeds (Tk. ha^{-1})	Irrigation cost (Tk. ha^{-1})	Cost of fertilizer and manure (Tk. ha^{-1})	Insecticide/ Pesticides cost (Tk. ha^{-1})	Sub-total (A)
T_1S_1	7,000	7,000	675	2,000	8800	2,000	27,475
T_1S_2	7,000	7,000	338	2,000	8800	2,000	27,138
T_1S_3	7,000	7,000	225	2,000	8800	2,000	27,025
T_1S_4	7,000	7,000	169	2,000	8800	2,000	26,969
T_2S_1	7,000	7,000	675	2,000	13034	2,000	31,709
T_2S_2	7,000	7,000	338	2,000	13034	2,000	31,372
T_2S_3	7,000	7,000	225	2,000	13034	2,000	31,259
T_2S_4	7,000	7,000	169	2,000	13034	2,000	31,203
T_3S_1	7,000	7,000	675	2,000	11975	2,000	30,650
T_3S_2	7,000	7,000	338	2,000	11975	2,000	30,313
T_3S_3	7,000	7,000	225	2,000	11975	2,000	30,200
T_3S_4	7,000	7,000	169	2,000	11975	2,000	30,144
T_4S_1	7,000	7,000	675	2,000	10917	2,000	29,592
T_4S_2	7,000	7,000	338	2,000	10917	2,000	29,255
T_4S_3	7,000	7,000	225	2,000	10917	2,000	29,142
T_4S_4	7,000	7,000	169	2,000	10917	2,000	29,086
T_5S_1	7,000	7,000	675	2,000	9858	2,000	28,533
T_5S_2	7,000	7,000	338	2,000	9858	2,000	28,196
T_5S_3	7,000	7,000	225	2,000	9858	2,000	28,083
T_5S_4	7,000	7,000	169	2,000	9858	2,000	28,027
T_6S_1	7,000	7,000	675	2,000	16571	2,000	35,246
T_6S_2	7,000	7,000	338	2,000	16571	2,000	34,909
T_6S_3	7,000	7,000	225	2,000	16571	2,000	34,796
T_6S_4	7,000	7,000	169	2,000	16571	2,000	34,740
T_7S_1	7,000	7,000	675	2,000	14629	2,000	33,304
T_7S_2	7,000	7,000	338	2,000	14629	2,000	32,967
T_7S_3	7,000	7,000	225	2,000	14629	2,000	32,854
T_7S_4	7,000	7,000	169	2,000	14629	2,000	32,798
T_8S_1	7,000	7,000	675	2,000	12686	2,000	31,361
T_8S_2	7,000	7,000	338	2,000	12686	2,000	31,024
T_8S_3	7,000	7,000	225	2,000	12686	2,000	30,911
T_8S_4	7,000	7,000	169	2,000	12686	2,000	30,855
T_9S_1	7,000	7,000	675	2,000	10743	2,000	29,418
T_9S_2	7,000	7,000	338	2,000	10743	2,000	29,081
T_9S_3	7,000	7,000	225	2,000	10743	2,000	28,968
T_9S_4	7,000	7,000	169	2,000	10743	2,000	28,912

B. Overhead cost

Treatment	Cost of lease of land (Tk.7% of value of land cost/4 months)	Miscella neous cost (Tk. 7% of the input cost	Interest on running capital for 3 months (Tk. 14% of cost/year)	Sub-total (Tk.) (B)	Total cost of production (Tk./ha) [Input cost (A) + overhead cost (B)]	Yield ha^{-1} (kg)	Gross return (Tk. ha^{-1})	Net return (Tk. ha^{-1})	BCR
T_1S_1	8,000	1,374	725	10,099	37,574	1398	62910	25,336	1.67
T_1S_2	8,000	1,357	716	10,073	37,211	1342	60390	23,179	1.62
T_1S_3	8,000	1,351	713	10,065	37,090	1230	55350	18,260	1.49
T_1S_4	8,000	1,348	712	10,060	37,029	1105	49725	12,696	1.34
T_2S_1	8,000	1,585	837	10,423	42,131	1390	62550	20,419	1.48
T_2S_2	8,000	1,569	828	10,397	41,769	1297	58365	16,596	1.40
T_2S_3	8,000	1,563	825	10,388	41,647	1210	54450	12,803	1.31
T_2S_4	8,000	1,560	824	10,384	41,587	1042	46890	5,303	1.13
T_3S_1	8,000	1,533	809	10,342	40,992	1410	63450	22,458	1.55
T_3S_2	8,000	1,516	800	10,316	40,629	1336	60120	19,491	1.48
T_3S_3	8,000	1,510	797	10,307	40,508	1222	54990	14,482	1.36
T_3S_4	8,000	1,507	796	10,303	40,447	1077	48465	8,018	1.20
T_4S_1	8,000	1,480	781	10,261	39,853	1427	64215	24,362	1.61
T_4S_2	8,000	1,463	772	10,235	39,490	1360	61200	21,710	1.55
T_4S_3	8,000	1,457	769	10,226	39,368	1240	55800	16,432	1.42
T_4S_4	8,000	1,454	768	10,222	39,308	1163	52335	13,027	1.33
T_5S_1	8,000	1,427	753	10,180	38,713	1442	64890	26,177	1.68
T_5S_2	8,000	1,410	744	10,154	38,351	1366	61470	23,119	1.60
T_5S_3	8,000	1,404	741	10,146	38,229	1277	57465	19,236	1.50
T_5S_4	8,000	1,401	740	10,141	38,169	1187	53415	15,246	1.40
T_6S_1	8,000	1,762	931	10,693	45,939	1375	61875	15,936	1.35
T_6S_2	8,000	1,745	922	10,667	45,577	1290	58050	12,473	1.27
T_6S_3	8,000	1,740	919	10,658	45,455	1198	53910	8,455	1.19
T_6S_4	8,000	1,737	917	10,654	45,395	962	43290	-2,105	0.95
T_7S_1	8,000	1,665	879	10,544	43,848	1401	63045	19,197	1.44
T_7S_2	8,000	1,648	870	10,519	43,485	1325	59625	16,140	1.37
T_7S_3	8,000	1,643	867	10,510	43,364	1215	54675	11,311	1.26
T_7S_4	8,000	1,640	866	10,506	43,303	1055	47475	4,172	1.10
T_8S_1	8,000	1,568	828	10,396	41,757	1422	63990	22,233	1.53
T_8S_2	8,000	1,551	819	10,370	41,394	1350	60750	19,356	1.47
T_8S_3	8,000	1,546	816	10,362	41,272	1233	55485	14,213	1.34
T_8S_4	8,000	1,543	815	10,357	41,212	1145	51525	10,313	1.25
T_9S_1	8,000	1,471	777	10,248	39,665	1430	64350	24,685	1.62
T_9S_2	8,000	1,454	768	10,222	39,303	1355	60975	21,672	1.55
T_9S_3	8,000	1,448	765	10,213	39,181	1264	56880	17,699	1.45
T_9S_4	8,000	1,446	763	10,209	39,121	1172	52740	13,619	1.35