EFFECT OF SPACING AND MOTHER PLANT NUTRITION ON CROP GROWTH, SEED YIELD, QUALITY AND STORABILITY OF SESAME (*Sesamum indicum* L.)

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INTRODUCTION

Sesame (*Sesamum indicum* L.), a member of *Pedaliaceae* family with 2n=26, is an important oilseed crop of India. It is commonly called by several names like gingely, til, simsim, gergelim,biniseed and ellu in kannada dilect.. It has earned a poetic label “Queen of oilseeds” due to its high quality and stable poly unsaturated fatty acids in seeds, which offer resistance to rancidity of sesame. Its seeds are rich source of edible oil (48-55%) and protein (20-28%) (Nagaraj, 1995), consisting both methionine and tryptophane, vitamin (niacine) and minerals (Ca and P) and have two principal compounds *viz*. sesamine and sesamolin. Sesamolin on hydrolysis yields sesmol which has pronounced antioxidant activity and offers shelf life and called as “Seeds of immortality”. The expeller cake not only serves as good feed concentrate for livestock and also as organic manure. According to Watt (1893), cultivation of sesame has archeological evidences which dates back to Vedic period (1000-1600 B.C.). Cultivation and domestic utilization of sesame is also mentioned in Vedic literature like Atharwaveda and Ashtadhayhi (Umarao Singh, 1958). Among many oilseed crops, sesame is the only crop having importance in religious rituals. Apart from these, sesame is also a good catch crop and performs well in pure and mixed plant stands, in residual soil moisture.

Sesame is widely cultivated in tropical and sub-tropical regions of the world in countries like India, China, Myanmar, Sudan, Nigeria, Mexico and to a smaller extent in Ethiopia, Uganda, Venezuela, Turkey, *etc*.. India is the major producer of sesame and ranks first both in area and production. It is being grown in an area of 19.42 lakh ha and production of 8.93 lakh tonnes. At present, national average yield of sesame is about 517 kg per ha, which has to be increased to at around 1.2 to 1.5 tonnes per ha by 2020 (Hegde, 2005). In India, major states growing sesame are Rajasthan, Gujarat, Uttar Pradesh, Orissa, Madhya Pradesh, Andra Pradesh, Karnataka, Tamil Nadu and West Bengal. Area and production in Karnataka is 60,000 ha and 31000 tonne respectively in 2011-12.

In Karnataka, sesame is being principally grown as single pure crop or as mixed crop in both rainfed and irrigated conditions in districts like Bidar, Gulbarga, Raichur, Koppal, Bellary, Bagalkot, Gadag, Haveri and Dharwad. The yield of sesame crop is generally low due to cultivation of low yielding local cultivars with lack of improved agronomic practices such as inadequate plant stand, poor nutrient management and inadequate protection against diseases and insect pests.

Among these several factors causing low productivity in sesame, lack of suitable agronomic management technology is considered as the most crucial aspect in ultimate commercial success of sesame crop. Among the several agronomic practices, optimization of plant spacings and mother plant nutrition play a decisive role not only in achieving higher seed yield but also in maintaining healthy seed crop of better quality traits. Under field conditions, maintenance of proper spacing is essential to maintain optimum plant population per unit area for increased seed yield and quality of sesame crop. The optimum density plant population can provide congenial conditions for maximum light interruption right from early growth stage to grain filling stage leading to higher seed yield. By altering the plant spacing to optimum level, it is possible to achieve luxuriant vegetative and reproductive growth to boost up the ultimate seed crop productivity per unit area.

The judicious application of balanced and adequate nutrients play a decisive role in deciding the ultimate success of sesame seed crop by realizing higher yield of good quality seeds. The growth, yield and quality of seed crop are largely influenced by the nutrient fertility status of the soil apart from genetic potential of the variety. Altering the soil nutrients like nitrogen, phosphorus, potassium and sulphur as per crop requirement is one of the easiest ways to boost up seed crop productivity of sesame since any interception in the availability of major nutrients even for a brief period is determined by pattern of crop growth and development which may affect yield potentiality and it cannot be corrected or altered at later stages of the crop growth even by supplying with heavier doses of major and minor nutrients (Dwivedi *et al.,* 2002).

Out of several plants nutrients, nitrogen is a major and essential nutrient for getting luxuriant plant growth and seed yield. It also helps in better translocation and utilization of potassium, phosphorus and other elements when provided to the plants. It is an important constituent of chlorophyll, proteins, enzymes, vitamins, *etc*.. N– deficiency in soils causes serious problems like reduced flowering and yield productivity apart from lowering the protein content. On the contrary, the excess N-availability has a delitarious effect causing secculency in plant, lean and taller plant causing lodging apart from sowing susceptible to pest and diseases.

Phosphorous is also a major essential nutrient which helps in better root growth and development resulting in higher fruit set and seed weight. Further, It helps in early crop maturity and imparts disease resistance. P is involved in energy transfer, photosynthesis, transformation of sugars and starch, nutrient movement within the plant and transfer of genetic characteristics from one generation to next.

Potassium is a unique major element involved in plant metabolism and development in plant metabolism and development. It regulates the opening and closing of the stomata essential for photosynthesis, water and nutrient transport, and plant cooling. It increases the root growth and improves drought tolerance. Potassium is responsible for the activation of protein- forming nitrate reductase enzyme. It enhances the crop quality and high concentration of available K improves physical qualities and shelf-life of fruits and vegetables. It also reduces lodging of the plants and imparts disease resistance to crops.

The oilseed crops like sesame require a higher quantity of sulphur nutrients for their proper growth and development for securing higher yields and better quality seeds (Salwa *et al*., 2010). It plays an important role in primary and secondary plant metabolism as a component of proteins, glucosinolates and other compounds determining the nutritive quality of crops (Ceccotti 1996 and Jamal *et al*., 2010). The response of oilseeds to sulphur is increasing due to increasing of cropping intensity (Ghosh *et al*., 2002). Since, nitrogen and sulphur metabolism are linked to each other. S-application significantly increased the uptake of N in straw and grain (Badruddin, 1999 and Fazli *et al*., 2008) and thereby increased grain yield. But, S-deficiency cause decrease in nitrate reductase activity and in the accumulation of chlorophyll, soluble protein, amino acid and sugar (Tandon 1986, Badruddin, 1999; Jamal *et al*., 2006 and Jamal *et al*. 2009). Thus the synergistic relationship of N and S in plant metabolism and the maximum yield response can be achieved when their balanced supply is achieved in oilseed crops (Jaggi *et al*., 1977; Badruddin 1999 and Fazli *et al*., 2010).

Seed is a living entity and is subjected to various environmental and soil nutritional stresses during different stages of growth, which ultimately affect the yield and quality of the seeds in oilseed crops like sesame. In storage, the viability and vigour of the seeds not only vary from genera to genera and variety to variety, but it is also regulated by many physiological factors like moisture content, atmospheric relative humidity, temperature, initial seed quality, physical and chemical composition of seed, gaseous exchange, storage structure, packaging materials, seed production location and techniques, *etc.*

Sesamum seed being an oilseed crop exhibits rapid loss in viability due to its high poly and saturated fatty acid content which undergoes rapid deterioration due to lipid antioxidation and fungal activity, besides, it is also susceptible to storage insect pests and disease attacks during storage causing rapid loss of seed viability due to fluctuating storage condition. It is also obvious that, storage any deficit or excess of plant nutrients during the crop growth period will effect severely seed yield and quality of seeds in oilseed crops like sesame. Similar line of research to know the effect of plant nutrients on storability of sesame seeds have not been carried out and also is adequate.

With this backdrop in view, the present investigation entitled “Effect of spacing and mother plant nutrition on crop growth, seed yield, quality and storability of sesame (*Sesamum indicum* L.)” is taken up with the following objectives.

i. To find the effect of different spacing levels on crop growth, seed yield and quality.

ii. To find the effect of different fertilizer levels on crop growth, seed yield and quality.

iii. To ascertain the interaction effect of spacing and fertilizer levels on seed yield and quality.

iv. To know the effect of mother plant nutrition on storability of sesame under ambient condition.

REVIEW OF LITERATURE

The review of literature pertaining to the effect of plant spacing and fertilizer levels on crop growth, seed yield and quality and also effect of mother plant nutrition on seed storability is very limited in oil seed crop like sesame. Hence, the review of literature on these aspects in other oil seed crops and related field crops is also presented in this chapter.

2.1 Effect of spacing and fertilizer levels on crop growth, seed yield and quality in sesame

2.1.1 Studies on spacing

2.1.1.1 Effect of spacings on growth parameters

Mohammed (1990) noticed increase in number of branches with increase in spacings from 10 to 30 cm but plant height was unaffected in fenugreek.

Ramachandra (1990) observed more number of branches plant^{-1} in the widely spaced plants compared to the closely spaced plants in grain amaranth.

Sharma and Gulshanlal (1991) noticed the highest plant height (156.7 cm) in 60x30cm spacing and number of primary branches (11.87) plant^{-1} in 60x60 cm spacing compared to other spacings in radish. Similarly, the highest plant height (127.87 cm) and number of primary branches by Srivastava *et al*. (1992).

Basavaraj (1994) reported that number of branches were decreased from 3.21 to 1.91 with increase in plant density from 3.33 lakh plants ha^{-1} to 6.66 lakh plants ha^{-1}. On the contrary, Channabasavanna and Setty (1992) opined that increase in plant density from 2.22 lakh plants ha^{-1} to 6.66 lakh plants ha^{-1} did not affect the number of branches in sesame.

Dry matter production and its distribution to different plant parts is very important in regulating crop yield. The observations made by Basavaraj (1994) revealed that dry matter accumulation in leaf varied significantly due to plant densities at all the growth stages. Plant density of 3.33 lakh plants ha^{-1} produced higher dry matter accumulation in leaves (0.91 g) as compared to a plant density of 6.66 lakh plants ha^{-1} (0.75 g). Dry matter accumulation in stem and reproductive parts of sesame also followed similar trend as that of dry matter accumulation in leaf. Plant density of 6.66 lakh plants ha^{-1} recorded lower dry matter accumulation in stem and reproductive parts (6.19 g and 9.3 g, respectively)as compared to plant density of 3.33 lakh plants ha^{-1} (7.62 g and 11.79 g, respectively).

Basavaraj (1994) reported that plant density of 3.33 lakh plants ha^{-1} produced higher dry matter plant^{-1} (20.32 g) as compared to plant density of 6.66 lakh plants ha^{-1} (16.24 g).

Pandita and Randhawa (1994) reported that row to row spacings significantly affected the plant height in fenugreek. With increase in row spacing from 10 to 30 cm, there was significant reduction in plant height. The plant height was maximum (57.7 cm) at 10 cm spacing followed by 20 cm (54.2 cm) and 30 cm (51.4 cm) spacings, respectively.

Pandey *et al*. (1996) observed that a narrow spacing of 60x45 cm in tomato hybrids recorded the highest plant height (108.71 cm) while, wider spacing of 10x45 cm recorded the highest number of primary branches (7.91) plant^{-1}. The highest plant height recorded in narrow spacing was due to its higher plant density which resulted in greater competition for space, moisture and light and there by forced the plants to grow taller.

Plant height of sesame increased linearly with increasing plant density. Tomar (1996) observed that higher plant density (4 lakh plants/ha) produced taller plants (121 cm) compared to lower plant density 2 and 3 lakh plants ha^{-1} (112 cm and 116 cm, respectively). On the contrary, Basavaraj (1994) reported that plant height of sesame cultivars did not increase linearly with increase in plant density from 3.33 lakh plants ha^{-1} to 6.66 lakh plants ha^{-1} and he observed that plant density of 3.33 lakh plants ha^{-1} produced taller plants (121.06 cm) as compared to 6.66 lakh plants ha^{-1} (114.96 cm). However, Channabasavanna and Setty (1992) observed that plant height of sesame was not affected by change in plant density (2.22 lakh plants ha^{-1} to 6.66 lakh plants ha^{-1}).

Malik *et al*. (1999) revealed that the closer spacing of 30x45 cm gave the highest plant height (145.9 cm) while, number of branches plant^{-1} (8.3) were highest in the widest spacing of 60 x 45 cm in radish.

Kanwar *et al.* (2000) conducted field experiment to know the effect of different levels of population density in onion and concluded that population density failed to register any effect on days to flowering and maturity. Out of three row spacings of 20, 30 and 30 cm adopted with a constant plant spacing of 7.5 cm, the closest spacing of 20x7.5 cm recorded highest plant height (82.5 cm) (Sharma, 2002).

According to Sharma (2002), out of the three row spacings of 20, 30 and 40 cm adopted with a constant plant spacing of 7.5 cm in pea, the closest spacing of 20x7.5 cm recorded highest plant height (82.5 cm).

Raut *et al.* (2003) studied the growth and yield attributes of Indian mustard cv. Pusabold in three spacings *viz.*, S_1 (30x15 cm), S_2 (45x15 cm) and S_3 (60x15 cm). The highest plant height and number of branches plant^{-1} were obtained at 45x15 cm spacing compared to other spacings.

Bahadur and Singh (2005) stated that a closer spacing of 60x40 cm recorded the highest plant height of 176.1 cm. Whereas, wider spacing of 60x60 cm recorded the highest number of branches plant^{-1} (13.2) in tomato.

Venkaraddi (2008) reported that the performance of mustard with respect to growth parameters was significantly superior with variety Pusa Agram with II fortnight of September sowing and 30 cm row spacing.

Adam *et al.* (2013) reported that plant height was significantly decreased with increase in inter-row spacing. The tallest plants were recorded for 25 cm at 3 and 6 WAS, but values declined significantly at closer inter rows as the growth period progressed.

2.1.1.2 Effect of spacing on seed yield parameters

Thimmegouda and Krishnamurthy (1977) studied spacing levels in *Dolichos lablab.* The highest seed yield of 1017 kg ha^{-1} was obtained with a row spacing of 60 cm. while it was 880 and 714 kg ha^{-1} for 90 and 45 cm row spacings, respectively.

In a field study conducted in coriander by Baswana *et al.* (1989) to know the effect of plant spacing, it was found that closer spacing 20x20 cm produced the highest seed yield (11.25 q/ha) compared to wider spacing of 40x20 cm (9.50 q/ha).

In multi location AICRIP trials conducted at S.K. Nagar (Gujarat) and Delhi, it is revealed that narrow spacing of 30x15 cm resulted in 58 and 25 per cent higher yield, respectively over wider row spacing of 75x15 cm in grain amaranth (Anon., 1990).

Kharodia and Patel (1990) observed seed yield of 1.84 1.90 and 2.04 t ha^{-1} in mustard Cv. 'Varuna' grown in 30, 45 and 60 cm row spacing, respectively.

Singh and Kumar (1990) reported that siliquae plant^{-1} and seeds per siliquae were significantly higher at 45x15 cm spacing than at 20x20 cm spacing. Variety and density interactions were significant for seed weight plant^{-1} and seed yield ha^{-1} in mustard. Chaudhari and Mankar (1991) evaluated mustard crop under the 30x15 cm and 45x15cm spacings. The higher seed yield of 1.27 tonnes ha^{-1} was produced from 30x15 cm spacing. There was significant yield reduction when row spacing increased from 30 to 45 cm.

Mujumdar and Roy (1992) observed a significant variation in number of seedscapsule-1 due to change in plant density from 1.6 lakh plants ha^{-1} to 3.33 lakh plants ha^{-1}.They observed, higher number of seeds capsule-1 at plant density of 1.6 lakh plants ha^{-1}compared to plant density of 3.33 lakh plants ha^{-1}.

Out of the two plant spacings (45 and 50 cm) tried in radish, Srivastava *et al.* (1992) revealed that 60x50 cm spacing gave the highest seed yield plant^{-1} (14.42 g), while seed yield ha^{-1} was the highest (6.2 q) in 60x45 cm spacing.

Pastucha (1992) observed more number of pods plant^{-1}, seeds pod^{-1} and seed yield plant^{-1} at wider spacing (45x15 cm) than narrow spacing (30x15 cm) in fenugreek crop.

Basavaraj (1994) reported that seed weight plant^{-1} increased from 4.56 g to 5.60 g plant^{-1} with decrease in plant density from 6.66 lakh plants ha^{-1} to 3.33 lakh plants ha^{-1}.

Change in plant density in sesame resulted in change in test weight (1000-seed weight). Basavaraj (1994) reported that 1000-seed weight decreased from 3.34 g to 3.30 g with increase in plant density from 3.33 lakh plants ha^{-1} to 6.66 lakh plants ha^{-1}.

Sesame grown at higher plant density (6.66 lakh plants/ha) attained 50 per cent flowering earlier by 3.8 days as compared to those grown at lower plant density (Basavaraj, 1994).

Yadav *et al*. (1994) reported that 45x10 cm spacing registered significantly higher seed yield than 45x20 cm spacing in mustard.

According to Halesh (1996), a spacing of 15 x 15 cm was found ideal for obtaining higher seed yield in fenugreek during *khari* season. Similarly, Randhawa *et al*. (1996) in their three year field trials obtained maximum seed yield of fenugreek crop when sown in 22.5 cm rows apart as against other spacings.

Bhati (1996) obtained higher yield by sowing the fenugreek crop at 30 cm row to row spacing and 10 to 12 cm plant to plant distance as compared to other spacings.

In a study conducted to know the response of rainfed Indian mustard, three cultivars (TM-2, TM4 and Aruna) at two spacings (30 and 45 cm), Thakuria and Gogoi (1996) found that varieties and spacings could not influence seed yield and yield attributes except for variations in siliquae $plant^{-1}$ between the spacings and for 1000 seed weight among the varieties.

Malav and Yadav (1997) reported the highest number of umbels $plant^{-1}$ (25.20) and seed yield $plant^{-1}$ (3.58 g) with 40 cm row spacing in coriander, while 30 cm row spacing registered the highest seed yield ha^{-1} (12.44 q).

Singh *et al*. (1997) reported that plant population of 3.33 lakh plants ha^{-1} at 30 cm spacing gave the highest seed yield of 16.47 q ha^{-1} followed by 16.03 q ha^{-1} with 2.66 lakh plants ha ^{1} in 45 cm spacing. But increasing plant population to 4.44 lakh ha^{-1} in 22.5 cm spacing has recorded significant reduction in seed yield of raya.

Sharma (2000) noticed the highest seed yield $plot^{-1}$ (747.2 g) and ha^{-1} (18.79 kg) at 30x7.5 cm as against 60x7.5 cm spacing in fenugreek.

Sowing of fenugreek in 30 cm row spacing significantly improved the number of pods $plant^{-1}$, seeds pod^{-1} and seed yield $plant^{-1}$ as compared to 45 cm row spacing (Yadav *et al.,* 2000).

Prakash *et al.* (2002) stated that narrow row spacing of 45 cm produced the significantly higher seed yield (758 kg/ha) than wider row spacing of 60 cm (649 kg/ha) in moth bean.

In a field experiment involving row two spacings *viz.,* 30 and 45 cm, Anilkumara (2004) reported significantly higher number of pods $plant^{-1}$, seeds pod^{-1}, seed yield (1179.89 kg/ha), cost benefit ratio and net returns (Rs. 17,513/ha) were recorded in 30 cm spacing compared to 45 cm spacing in fenugreek.

Shaikh and Kumbhar (2005) conducted an experiment to know the effect of plant spacing in soybean. It was found that closer spacing 30x20 cm produced the highest seed yield (28.24 q/ha) as compared to wider spacing of 45x10 cm (23.47 q/ha).

Nandita *et al.* (2009) reported in sesame that the highest seed yield was produced byrow spacing 30 cm while the lowest was at row spacing 45 cm.

Ozturk *et al.* (2012) reported that The highest seed yield, oil yield and protein yield (respectively, 1115.0 kg ha^{-1}, 551.3 kg ha^{-1}, 224.7 kg ha^{-1}) were obtained from 30x5 cm plant density while the lowest seed yield, oil yield and protein yield (respectively, 677.0 kg ha^{-1}, 327.0 kg ha^{-1},130.0 kg ha^{-1}) from 70x30 cm plant density.

2.1.1.3 Effect of spacings on seed quality parameters

Seed quality attributes like test weight, germination percentage and seedling vigour index were found to be better at wider spacing compared to narrower spacings in fennel, according to Ameen Ahmed *et al.* (1988).

In fenugreek, the widest row spacing of 20 cm recorded the highest 1000 seed weight (2.4 g) followed by 15 cm (2.35 g) as against the lowest spacing of 10 cm (2.30 g) as reported by Kanwar and Saimbhi (1989).

Sharma and Gulshanlal (1990) opined that in radish, the widest plant spacing (60x60 cm) produced the highest 1000 seed weight (11.14 g) and closest plant spacing (60x30 cm) produced the lowest 1000 seed weight due to higher plant population pressure. This has led to competition for nutrients and decreased the total nutrient availability plant^{-1}.

Phor and Mangal (1991) recorded the highest 1000 seed weight (8.68 g) in row spacing of 20 cm while, the highest germination (90.14 %) was noticed in the widest row spacing of 40 cm in palak.

Srivastava *et al.* (1992) noticed the highest number of seeds (89) gram^{-1} and seed germination (98.5%) at 60 x 45 cm spacing compared to other spacings in radish.

Change in plant density in sesame did not significantly affect the nutrient uptake (N, P and K kg/ha) (Basavaraj, 1994).

In coriander, the widest row spacing of 40 cm recorded the highest 1000 fruit weight (9.34 g) as compared to other spacings (30 and 20 cm) (Malav and Yadav, 1997).

Malik *et al.* (1999) opined that the widest spacing of 60x45 cm recorded the highest test weight (6.79 g), germination (81.1%) and seedling vigour index (635.8) compared to other two spacings of 45x45 cm and 30x45 cm in radish.

Sharma (2000) reported that the widest spacing of 60x7.5 cm recorded the highest germination rate (93.6%) as against 30x7.5 cm (87.5%) spacing in fenugreek crop.

Anilkumar (2004) recorded significantly higher 1000 seed weight (12.89 g), germination (92.22%), seedling vigour index (2273) and field emergence (87.00%) in 45 cm row spacing compared to 30 cm row spacing in fenugreek.

Ozturk *et al.* (2012) conducted an experiment and reported that the highest seed yield, oil yield and protein yield (respectively, 1115.0 kg ha^{-1}, 551.3 kg ha^{-1}, 224.7 kg ha^{-1}) were obtained from 30x5 cm plant density while the lowest seed yield, oil yield and protein yield (respectively, 677.0 kg ha^{-1}, 327.0 kg ha^{-1}, 130.0 kg ha^{-1}) were recorded from 70x30 cm plant density.

2.1.2 Studies on effect of fertilizer application

The average yield potential of seasme bean under both rainfed and irrigated condition is very low. One of the agronomic approaches followed is the efficient use of fertilizer, particularly N, P and K, and S, which plays an important role in enhancing the production and productivity of the sesame crop by increasing cell division and multiplication.

Nitrogen is a fundamental structural unit of protein, which is required for formation of amides, amino acids and protein (Singh and Singh, 1978 and Nyital and Singh, 1984). Nitrogen nutrition is also required for improvement of growth parameters through efficient metabolic activity and increased rate of photosynthesis. The N deficiencies in plants induce change in carbohydrate synthesis and degradation pathway (Hazra and Som, 1999). Phosphorus is a constituent of nucleoprotein and it helps for increased cell division and expansion of cells resulting into higher dry matter accumulation in reproductive parts. It also stimulates early root growth and development, encourages fruiting, seed setting and hastens maturity of plants. Phosphorus deficiency progressively stops aerial plant growth, decreases P concentration in dry biomass and diminishes photosynthetic activity (Hazra and Som, 1999). Potassium plays a significant role in increasing the crop yield and extra balancing effect on both nitrogen and phosphorus. It is essential for cell organization and structure of cell walls. It enhances plants ability to resist diseases, cold and other adverse conditions (Hazra and Som, 1999). In oilseeds, sulphur plays a significant role in the quality and development of seeds. Therefore, oilseeds crops require a higher quantity of sulphur for proper growth and development of plant for getting higher yields (Salwa *et al*., 2010). It is reported that sulphur plays an important role in the primary and secondary plant metabolism as a component of proteins, glucosinolates and other compounds that related to several parameters determining the nutritive quality of crops (Ceccotti, 1996 amd Jamal *et al*., 2010). Providing optimum nutrition, among other agro-techniques is very important aspect for realizing full yield potential and the role of sulfur is next only to nitrogen in the nutrition of this crop. Little research effort is being made to reclaim optimum S requirement for the good growth and increased seed yield with better quality traits of sesame.

2.1.2.1 Effect of fertilizers on growth parameters

Ameen Ahmed *et al.* (1988) reported that application of nitrogen @ 100 kg ha^{-1} to fennel crop produced the highest plant height (113.97 cm) and number of branches plant^{-1} (8.33). They also noticed the highest plant height (111.02 cm) and number of branches plant^{-1} (8.26) with 50 kg phosphorus ha^{-1} as against control (no fertilizer).

Thakral *et al.* (1991) found that the highest plant height (63.7 cm) at 60 kg nitrogen ha^{-1} while number of branches per plant (6.2) at 90 kg nitrogen ha^{-1} compared to no nitrogen application in coriander.

Singh and Tripathi (1994) noticed significantly the highest plant height (40.65 cm) and number of branches plant^{-1} (14.60) at harvest with application of 75:120:120 kg NPK ha^{-1} over control (no fertilizer) (38.72 cm and 12.15, respectively) in french beans.

Patil *et al.* (1995) conducted a field experiment on lablab bean cv. Konkan Bhushan and which that application of nitrogen at 75 kg and phosphorus at 50 kg ha^{-1} showed significantly higher plant height (60.85 cm), panicles plant^{-1} (9.52), pods plant^{-1} (30.95) over control (no N and P) (53.64 cm, 7.69 and 19.30, respectively).

Detroja *et al.* (1996) noticed significant increase in all growth characters with the combined application of 30 kg nitrogen, 60 kg phosphorus and 30 kg potassium ha^{-1} over control in fenugreek.

Gupta *et al.* (1996) observed significant increase in plant dry matter accumulation plant^{-1} with corresponding increase in fertility levels up to 120:38.7:49.8 kg NPK ha^{-1} in french beans.

Malav and Yadav (1997) observed the highest plant height (90.82 cm) and number of branches plant^{-1} (13.88) with nitrogen of 120 kg ha^{-1}, while the least number of days taken to flowering (68.00) was seen in control (no nitrogen) in coriander.

Sharma (1997) stated that application of phosphorus and potassium at 120 kg ha^{-1} produced the highest plant height (125.7 and 124.6 cm) and number of branches plant^{-1} (9.3 and 9.2) over their corresponding lower doses of phosphorus and potassium in radish seed crop.

Arya *et al.* (1999) conducted a experiment on frenchbean cv. Contender and noticed increase in the days to 50 per cent flowering (50 days) with 50:75:100 kg NPK ha^{-1} whereas early flowering (44 days) with 50:100:50 kg NPK ha^{-1} and less number of days to crop maturity (81.32 days) with 25:75:50 kg NPK ha^{-1}. Similarly, Thakur *et al.* (1999) reported that days to 50 per cent flowering decreased significantly (57, 56 and 54 days) with increasing phosphorus fertilizer levels from 0 to 60 kg ha^{-1}.

Kushwaha (2001) obtained the highest plant dry matter (8.26 and 114.13 g) at 74 and 105 DAS with application of nitrogen @ 90 kg ha^{-1} as against control (7.65 and 11.53 g, respectively) in field pea.

Dwivedi *et al.* (2002) conducted an experiment on dolichos bean and concluded that 40 kg N and K ha^{-1} has significantly increased the days to flower initiation (120 days). While, phosphorus @ 60 kg ha^{-1} recorded less number of days to first flowering (113.5 days).

Patil (2003) noticed more plant height (92.2 cm) and number of branches plant^{-1} (5.70) at a fertilizer application of 25:112:60 kg NPK ha^{-1} over control (no NPK) (84.7 cm and 4.3, respectively) in cluster bean.

Kumar *et al.* (2004) noticed significant increase in growth parameters like plant height (21.68 cm) and number of branches plant^{-1} (7.2) with fertilizer level of 120:60:45 kg NPK ha^{-1} which was followed by 80:40:30 kg NPK ha^{-1} and it was significantly less (17.00 cm and 5.9, respectively) in control (no fertilizer) in french bean crop.

Harura (2011) conducted an experiment on sesame and the results obtained showed that applications of 15 t ha^{-1} of poultry manure, 120 kg N ha^{-1} and 26.4 kg P ha^{-1} partitioned more dry matter to the leaf and stem compared with other levels of applied nutrients while, the dry matter partitioned to the capsule was optimized with the applications of 5 t ha^{-1} of poultry manure, 60 kg N ha^{-1} and 13.2 kg P ha^{-1}.

2.1.2.2 Effect of fertilizers on seed yield parameters

Yaladalli and Jayaram (1975) reported that field bean cv. Hebbal Avare performed better with application of 25 kg N ha^{-1} and 50 kg P_20_5 ha^{-1}, by recording more yield of 729 kg ha^{-1} compared to 351 kg ha^{-1} in control (no N & P).

Application of nitrogen at 20 kg and phosphorus at 50 kg ha^{-1} in fenugreek recorded the highest seed yield under semi-arid region of Rajasthan according to Rathore and Manohar (1989).

Ramachandra (1990) stated that application of 40 kg nitrogen ha^{-1} recorded 58 per cent more yield of amaranthus over no nitrogen (875 kg/ha).

Application of optimum dose of nitrogen at 60 kg ha^{-1} to coriander crop recorded higher number of umbels $plant^{-1}$ (32.7) and seed yield ha^{-1} (15.98 q) over lower (0 and 30 kg/ha) and higher doses (90 kg/ha) (Thakral *et al.,* 1991).

In a study conducted to know the effect of macro nutrients on growth and yield of lablab bean *(Dolichos lablab),* Noor *et al.* (1992) concluded that application of 60 kg P_2O_5 ha^{-1} has yielded significantly higher (21.05 t/ha) pod yield over control (no P_2O_5) (14.0 t/ha).

Application of NPK @ 62.5:100:75 kg ha^{-1} to french bean crop produced the highest number of seeds pod^{-1} (5.15) over control (no fertilizer) (4.63) as reported by Thirumalai and Abdul Khalak (1993).

In a field trial of major nutrient application on fenugreek, Banafar *et al.* (1995) revealed that application of 60 kg nitrogen ha^{-1} along with 40 kg phosphorus ha^{-1} showed significant increase in the vegetable leaf and seed yields, respectively as against control.

Gupta *et al.* (1996) also noticed above similar results and reported that significant increase in seed weight $plant^{-1}$ with increasing fertility levels from 0:0:0 to 120:38.7:49.9 kg ha^{-1}.

Baishva and Thakur (1998) observed that mean seed yield of french bean revealed significant and positive increase with increase in NPK levels up to 60:80:40 kg NPK ha^{-1}.

Arya *et al.* (1999) stated that seed yield of french bean was significantly the highest (13.27 q/ha) with 25:75:100 kg NPK ha^{-1} over control (11.73 q/ha).

Gajendra Singh and Singh (1999) reported that application of 120:90:45 kg NPK ha^{-1} to the bean crop resulted significant increase in seed yield (17.8 kq/ha) compared to control (no NPK) (8.2 q/ha).

Ghosal *et al.* (2000) studied the effect of nitrogen fertilizer applied to soil at different rates *viz.,* 0, 40, 80 and 160 kg ha^{-1} on french bean cv. HUR-15. All the growth attributes and seed yield showed significant increase with increase in the rate of nitrogen as against control. Similarly, Dhanraj *et al.* (2001) reported increase in seed yield (9.49 q/ha) of french bean with increasing nitrogen levels up to 120 kg ha^{-1} as compared to 0 and 60 kg nitrogen (7.02 q/ha and 8.39 q/ha, respectively). Application of NPK @ 62.5:100:75 kg NPK ha^{-1} to french bean crop produced the highest harvest index (39.2) as against control (no fertilizer) (38.1).

Sharma (2000) conducted a field experiment in Himachal Pradesh to know the effect of fertilizer in fenugreek and he recorded the highest number of branches (4.4). pods $plant^{-1}$ (64), seed yield $plot^{-1}$ (725 g) and ha^{-1} (18.2 q) at 60 kg nitrogen ha^{-1} over control.

Dataram *et al.* (2001) studied the effect of different levels of phosphorus on fenugreek cv. Pusa Early Bunching at Agra (Uttar Pradesh). Application of 120 kg phosphorus ha^{-1} showed the maximum seed yield. The yield attributing characters such as seed weight $plant^{-1}$, number of seeds and seed weight pod^{-1} were favorably improved with 120 kg P_2O_5 ha^{-1} as compared to control (no phosphorus).

Kushwaha (2001), in a field experiment conducted at Indian Institute of Pulse Research, Kanpur, revealed that application of 90 kg N ha^{-1} and 60 kg K_2O ha^{-1} could produce significantly higher seed yield (3683 kg/ha) as compared to 0 kg N and K_2O ha^{-1} (3493 kg/ha) in field pea.

Dwivedi *et al.* (2002) found that increased level of nutrition (40:60:40 kg NPK/ha) significantly increased the yield parameters like pod weight $plant^{-1}$, number of pods $plant^{-1}$ and seed yield ha^{-1} as against control (0 kg NPK) in dolichos bean.

In a field experiment conducted during *rabi* season on loamy soils of Jobner in Rajasthan, Nehra *et al.* (2002) studied the response of fenugreek to phosphorus and potassium fertilizers. They found that the increasing levels of P_20_5 up to 40 kg ha^{-1} and K_2O up to 45 kg ha^{-1} have significantly increased pods $plant^{-1}$, seeds pod^{-1}, length of pod and seed yield compared to control.

In a field experiment conducted on garden pea Cv. Bonneville at Dharwad, Amaregouda (2002) reported the significantly highest seed yield (1984 kg/ha) with 37.5:78:50 kg NPK ha^{-1} over 37.5:60:50 kg NPK ha^{-1} (1571 kg/ha).

Kalmani *et al.* (2002) reported that a fertilizer level of 80:75:30 kg NPK ha^{-1} produced significantly higher seed yield (2076 kg/ha) due to significant increase in growth and yield components *viz.,* plant dry matter (16.8 mg/plant), number of pods $plant^{-1}$ (12.38), number of seeds pod^{-1} (5.26) and seed weight $plant^{-1}$ (8.93 g) over control (no NPK) (1368 kg seed/ha) in french bean.

Prakash *et al.* (2002) reported higher seed yield (813 kg/ha) of moth bean by applying P_20_5 at 30 kg ha^{-1} over control (0 kg P_20_5) (613 kg/ha).

Khiriya *et al.* (2003) observed significant increase in seed yield with the increasing levels of phosphorus up to 40 kg ha^{-1} over it's lower doses (10 and 20 kg ha^{-1}) in fenugreek.

Sharma *et al.* (2003) reported about 42 per cent more yield in onion with application of 125:33:50 kg NPK ha^{-1} due to significant increase in growth and yield attributes like plant height, bulb girth and bulb weight over the control (no NPK).

Anilkumar (2004) reported that application of 125:63:25 kg NPK ha^{-1} to fenugreek crop recorded significantly the highest number of pods $plant^{-1}$ (36.11), seeds pod^{-1} (13.12), seed yield $plant^{-1}$ (16.18 g), seed yield (1252 kg/ha), benefit cost ratio (1:2.66) and net returns (Rs. 18,191/ha) over control (100:50:0 kg NPK/ha).

In a field experiment conducted by Kumar *et al.* (2004) marked variation on benefit cost ratio was noticed in different fertilizer levels and it was significantly the highest (1.60:1) in 120:60:45 kg NPK ha^{-1} as against control (no NPK) (1:0.83) in french bean.

Datta *et al.* (2005) reported that seed yield of fenugreek increased significantly by nitrogen application (0, 15, 25 and 45 kg N/ha). Higher seed yield of 1.07 tonnes ha^{-1} was obtained with 45 kg nitrogen ha^{-1} over control (0 kg N) (0.66 t/ha).

Zakaria *et al.* (2006) reported that the higher N-rate as well as the application of potassium at different concentrations and plant growth retardant Pix resulted in an increase in cotton seed yield ha^{-1}, seed index, seed protein content, oil and protein yield/ha, seed oil refractive index, unsaponifiable matter and total unsaturated fatty acids (oleic and linoleic).

In an experiment on sesame, Umar *et al.* (2012) reported that the interactive effects of nitrogen level and intra row spacing produced highest values for capsule yield and grain yield $plant^{-1}$ at 80 kg N/ha and 15cm intra row spacing, while the least values were obtained at 20 kg N/ha and 5cm intra rows pacing. leaf area index, crop growth rate and grain yield ha^{-1} recorded highest values at 80 kg N/ha and 5 cm and the least values at 20 kg N/ha and 15 cm.

2.1.2.3 Effect of fertilizers on seed quality parameters

Elbehri *et al.* (1993) observed that 1000-seed weight of amaranthus increased significantly at higher nitrogen rates as against control (no nitrogen).

Detroja *et al.* (1996) stated that application of 30 kg nitrogen ha^{-1} significantly influenced the 1000-seed weight (14.32 g) over control (no nitrogen) (11.38 g) in fenugreek.

Halesh (1996) recorded significantly the highest 1000-seed weight (13.21 g) when nitrogen was applied to fenugreek crop at 60 kg ha^{-1} along with 90 kg phosphorus ha^{-1} whereas, it was (9.72 g) in control (0 kg N and 0 kg P_20_5/ha).

Malav and Yadav (1997) reported that application of 120 kg nitrogen ha^{-1} to coriander crop recorded the highest 1000 seed weight (9.36 g) as against no nitrogen treatment.

Chaudhary (1999) reported that application of 40 kg each of nitrogen and phosphorus ha^{-1} depicted the highest 1000-seed weight (12.11 g) over control (0 kg N and 0 kg P_2 CV ha) (11.76 g) in fenugreek.

Jadhao *et al.* (1999) observed that application of NPK @ 100:50:25 kg ha^{-1} to radish crop recorded the highest test weight (11.57 g) and germination (97.0%) compared to control (no NPK).

Sharma (2000) noticed the highest seed germination (90.3%) and 1000 seed weight (13.1 g) with nitrogen applied at 90 kg ha^{-1} over control in fenugreek.

Dataram *et al.* (2001) reported that application of 120 kg phosphorus ha^{-1} favourably affected 1000-seed weight compared to control in fenugreek.

Kumar *et al.* (2004) reported that application of 120:60:45 kg NPK ha^{-1} gave significantly the highest 100 seed weight (42.43 g) as against control (no fertilizer) (38.32 g) in french bean.

Zakaria *et al.* (2006) reported that the higher N-rate, as well as the application of potassium at different concentrations and plant growth retardant Pix resulted in an increase in cotton seed yield ha^{-1}, seed index, seed protein content, oil and protein yield ha^{-1}, seed oil refractive index, unsaponifiable matter and total unsaturated fatty acids (oleic and linoleic).

Mondal *et al.* (2012) reported that the biochemical parameters such as chlorophyll, nitrate reductase, amino acid and total sugar in leaves, total dry mass production, total nitrogen accumulation in seeds and seed yield increased with sulphur application up to 20 kg S ha^{-1}. Application of 40 kg S ha^{-1} had no significant benefit on biochemical parameters, dry matter and seed yield of sesame though ^{35}S uptake in seeds increased with increasing sulphur levels till 40 kg ha^{-1}. The biochemical traits and nutrients uptake were superior in SM4 than in other genotypes which resulted in the highest seed yield of SM4. Among the sulphur levels, 20 kg S/ha showed the maximum seed yield in all the genotypes.

Mahsa Salar *et al.* (2013) indicated that there were significant differences in the seed germination speed and seed germination percentage ($p \leq 0.05$) by nitrogen rates due to fertilizers. The highest of the seed germination speed and seed germination percentage were obtained by N_{104} with 9.07 and 95.17 %, respectively and the lowest were obtained in seed germination speed by N_{35} with 8.07 and the seed germination percentage by N_{69} with 88.33 %. Also, there was significant difference in the seed germination speed ($p \leq 0.01$) by potassium rates. K_{100} and K_0 had shown the highest and the lowest of the seed germination speed with 9.15 and 8.21, respectively.

2.2 Effect of mother plant nutrition on seed storability of sesame under ambient condition

A number of separate, but interacting factors like genetic, biotic and abiotic factors like seed moisture content, relative humidity, temperature, pest and disease affect the viability of seeds during storage. Besides these, mother plant nutrition is observed as one of the factor which influence storability of seeds. The available literature on storability of oilseeds with respect to plant nutrition is presented in this chapter. In the absence of sufficient literature on oilseeds, the reviews on storability studies in related crops have also been included.

Kharb *et al*. (1998) reported that the soybean genotypes F-49, MO-40, PK-262 and Durga deteriorated at faster rates and considered them as poor storers where as Kalithur, JS-8021, JS-8759, JS-8918, Punjab-1, KB-92, NRC-2, MACS-335 and Pusa-20 as good storers as there genotypes maintained the germination percentage above the certification standards (70%) after nine months of storage.

Krishna *et al*. (2009) reported that seeds harvested from RDF treatment maintained significantly higher germination throughout the storage compared to without fertilizers.

Raikar *et al*. (2011) studied the effect of organic and integrated management practices of seed production and storage containers along with organic (insecticide and fungicide) and organic (botanicals) as seed treatments on seed viability of scented rice cv. Mugad sugandha and revealed that though organically grown seeds maintained significantly higher germination at the end of storage, but failed to maintain the seedling vigour. Seeds produced with INM recorded the significantly high seedling vigour index and lower electrical conductivity.

Morsy *et al.* (2012) during the storage of onion stated that increasing the level of the combination between phosphorus and potassium fertilization up to 30 kg P_2O_5 + 48 kg K_2O/fed significantly decreased bulbs weight loss percentage after six months of storage, in both seasons.

Oyekale *et al*. (2012) reported that Neem leaf powder (NLP) and Dress force powder (DFP) treatments had better mean seed germination of 89.53% and 82.35% respectively compared to Dry paper powder (DFP) (46.47%)and control (80.76). NLP also enhanced better seedling vigour index (339.24) throughout the storage time compared to DFP (99.74). It is therefore recommended that natural botanicals like NLP could be adopted for short and medium term storage of sesame seeds; as it maintained seed viability and seedling vigour optimally among other treatments.

Sreedhar *et al*. (2014) revealed in their study on storage of sweet corn that the superior combinations for yield and yield components also performed desirably for seed quality attributes indicating better storage potential under ambient conditions. In this context, treatment combinations *viz*., 45 x 20 cm /120:60:45 NPK kg ha^{-1}, 60 x 15 cm / 150:75:45 NPK kg ha^{-1}, 60 x 20 cm / 120:60:45 NPK kg ha^{-1}, 60 x20 cm / 150:75:45 NPK kg ha^{-1} performed better at the end of six months of storage in terms germination and seedling parameters.

MATERIAL AND METHODS

The field experiment was conducted during *khari* 2013-14 in the Main Agricultural Research Station, University of Agricultural Sciences, Dharwad to study the effect of spacing and fertilizer levels on crop growth, seed yield and quality and a laboratory experiment was also conducted to study the effect of mother plant nutrition on storability of sesame seeds under ambient conditions. The details of the material used and methods employed are presented in this chapter.

3.1 General description

3.1.1 Location

The field experiment was conducted under the rainfed conditions during *khari* 2013-14 at the Main Agricultural Research Station Farm, University of Agricultural Sciences, Dharwad which is situated at 15° 26^1 North latitude, 75° 0^1 East longitude and altitude of 678 m above Mean Sea Level. It comes under the Northern Transitional Tract (Zone-VIII) of the Karnataka State lying in between the western heavy rainfall and eastern low rainfall areas.

3.1.2 Soil characteristics

The soil of the selected experimental site was well fertile and deep black clay in nature with a neutral pH of 6.7. The composite soil sample taken from upper 30 cm layer was analysed for physico-chemical properties which are presented in Appendix I.

3.1.3 Climatic conditions

Dharwad has the benefit of receiving both South West and North East monsoon rains. The rainfall is confined to the monsoon period ranging from May to November with occasional showers in the pre- monsoon months during April and May. During the period of experimentation, the total rainfall received was 489.0 mm from June to September, 2013 with highest rainfall during July (177.8 mm) (Appendix II). The mean maximum temperature during the period of experimentation ranged between 25.4℃ (July) to 28.0℃ (June) and the mean minimum temperature between 19.9℃ (August) to 20.8℃ (June). The mean relative humidity ranged between 89 per cent (July) and 81 percent (September).

3.2 Experimental details

3.2.1 Experiment – I : Effect of spacings and fertilizer levels on growth, seed yield and quality of sesame cv. DS-5

A field experiment was conducted on two spacings and eight fertilizer levels on crop growth, seed yield and quality parameters of sesame cv. DS-5 during *khari* season of 2013-14 at Main Agricultural Research Station farm, University of Agricultural Sciences, Dharwad. The details of the experiment are as below.

3.2.1.1 Treatments details

The field experiment consisted of 16 treatment combinations involving two factors as detailed below.

I) Spacings (S)

S_1 = 30 x 15 cm (Rd)

S_2 = 45 x 15 cm

II) Fertilizer levels (F)

F_1 : 40 : 20 : 20 NPK kg/ha

F_2 : 50 : 20 : 20 NPK kg/ha

F_3 : 50 : 25 : 25 NPK kg/ha (Rd)

F_4 : 50 : 30 : 30 NPK kg/ha

F_5 : 60 : 30 : 30 NPK kg/ha

F_6 : 50 : 25 : 25 NPK kg/ha + sulphur @ 5 kg/ha

F_7 : 60 : 20 : 30 NPK kg/ha + sulphur @ 10 kg/ha

F_8 : 40 : 10 : 20 NPK kg/ha + sulphur @ 15 kg/ha

Treatment combinations

S_1xF_1	S_1xF_2	S_1xF_3	S_1xF_4	S_1xF_5	S_1xF_6	S_1xF_7	S_1xF_8
S_2xF_1	S_2xF_2	S_2xF_3	S_2xF_4	S_2xF_5	S_2xF_6	S_2xF_7	S_2xF_8

3.2.1.2 Design and plan of layout

The experiment was laid out in the Randamised Block Design (RBD) in Factorial concept with three replications. The plan of layout of the experiment is given in Fig. 1 and general view of the experimental plot is presented in Plate 1.

3.2.1.2.1 Plot size

Gross plot size : 3.6 x 1.8 m

Net plot size : 3.0 x 1.5 m (30 x 15 cm)

2.7 x 1.5 m (45 x 15 cm)

3.2.1.3 Land preparation

Prior to sowing, the selected experimental land was brought to fine tilth by one deep ploughing, 3 harrowings and leveling. Totally, 48 plots of 7.2 m^2 gross plot were laid out by leaving the small bunds and irrigation channels on either side of the each plots and the inter plant rows were marked according to the treatment schedule as detailed in 3.2.1.1

3.2.1.4 Fertilizer application

A day prior to sowing, the pre-calculated quantities of fertilizers in the form of urea, diammonium phosphate and muriate of potash and sulphur in the form of single super phosphate were applied as single basal dose to each of the plots at two to three inches deep and two to three inches away from the plant rows as per the treatment schedule listed in 3.2.1.1 and were incorporated well in to the soil.

3.2.1.5 Method of sowing

Seeds of the sesame cv.DS-5 mixed with the sand in the ratio of 1:3 were sown by hand dibbling at 2-3 cm below the soil in the specified row spacings as listed. The crop was sown on 28^{lh} June 2013 and was irrigated with light water immediately after sowing to get good germination and uniform plant population in each plots. Thinning was done at fifteen days after sowing by retaining one healthy seedling per hill to maintain the optimum plant population per unit area.

3.2.1.6 After care operations

The necessary aftercare operations such as hand weeding and inter culturing operations were carried out timely as and when required to maintain a good and healthy crop throughout the cropping period. The necessary irrigation was also given to the experimental crop depending upon the soil moisture and atmospheric conditions at vegetative growth, flowering and capsule initiation stages. Foliar spray with carbendezim @ 1 g/lit at 30 days after sowing and monocrotophos @ 2 ml/lit of water at 80 days after sowing for the control of pest and disease incidences.

3.2.1.7 Harvesting, drying, threshing and cleaning

The crop was harvested treatment and replication wise at physiological maturity when the leaves turn yellow and start dropping, while the capsules were still greenish. The plants were cut with sickles and the harvested plants of each treatment were carried to threshing yard and stacked for a week. During this period, the capsule burst open and leaves were shed almost completely. Plants were dried in the open sun and threshed manually simply by turning plant upright down and shaking. Seeds were cleaned with help of special type of sieve meant for the cleaning of sesame seed and then cleaned by winnowing.

LEGEND

I) Spacings (S)

S_1 = 30 x 15 cm (RPP)

S_2 = 45 x 15 cm

II) Fertilizer levels (F)

F_1 : 40 : 20 : 20 NPK kg/ha

F_2 : 50 : 20 : 20 NPK kg/ha

F_3 : 50 : 25 : 25 NPK kg/ha (RDF)

F_4 : 50 : 30 : 30 NPK kg/ha

F_5 : 60 : 30 : 30 NPK kg/ha

F_6 : 50 : 25 : 25 NPK kg/ha + sulphur @ 5 kg/ha

F_7 : 60 : 20 : 30 NPK kg/ha + sulphur @ 10 kg/ha

F_8 : 40 : 10 : 20 NPK kg/ha + sulphur @ 15 kg/ha

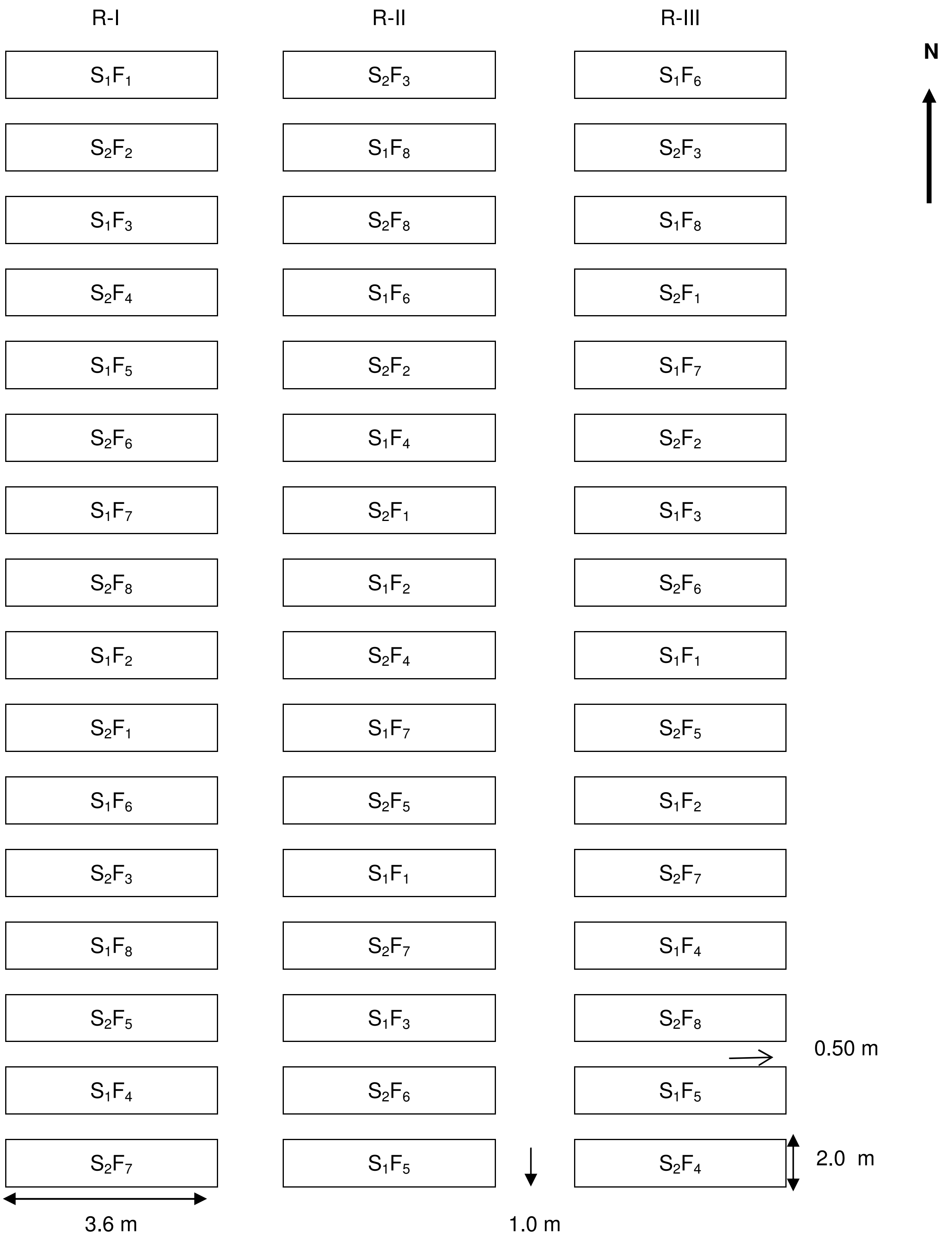

Fig 1 : Plan of layout of field experiment

Plate 1. General view of experimental plot

3.2.2 Record of biometric observations

Ten normal and healthy plants were tagged randomly in each treatments as per treatment schedule 3.2.1.1 and various biometric observations were recorded on crop growth, physiological, seed yield and seed quality as detailed below.

3.2.2.1 Growth parameters

3.2.2.1.1 Plant height (cm)

The height of ten plants randomly tagged were measured on a metric scale from the ground level to the tip of the plant at 30 DAS and to the base of the capsule at 60 DAS and at the time of harvest in all treatments and replications. The average height of the plant was worked out and expressed in centimeters.

3.2.2.1.2 Number of primary branches per plant

The number of primary branches per plant recorded from the earlier tagged plants at 30 and 60 days after sowing and at harvest stages for each treatments. The average number was computed and expressed as number of primary branches per plant for the respective stages of crop growth.

3.2.2.1.3 Days to flower initiation

The number of days taken from the date of sowing to date of initiation of first flower was counted manually on individual plant basis for all the earlier tagged plants for each treatments.The date when first flower was initiated on individual plant basis was recorded, computed and expressed in whole number as days to flower initiation.

3.2.2.1.4 Days to 50 per cent flowering

From the date of sowing , the day on which first flowering was initiated in atleast five plants of the earlier tagged plants in each of the plots was recorded and expressed in whole number as days taken to 50 percent flowering (Plate 2).

3.2.2.2 Seed yield parameters

3.2.2.2.1 Number of capsules per plant

The number of fully developed and matured capsules was counted manually from the ten randomly tagged plants on individual plant basis at harvest stage. The average was worked out and expressed as number of capsules per plant at harvest for each treatment and replication.

3.2.2.2.2 Capsule weight per plant (g)

The well matured capsules obtained from each of the five tagged plants were dried in the sun for 48 hours and their weight was recorded on analytical balance on individual plant basis. The average was expressed as capsule weight per plant in grams.

3.2.2.2.3 Number of seeds per capsule

The ten well matured, fully dried and normal size capsules were selected randomly from each of the ten tagged plants for recording number of seeds per capsule. The seeds were separated manually from each capsule and their number was counted on individual capsule basis and average was expressed as number of seeds per capsule.

3.2.2.2.4 Capsule length (cm)

The length of ten well matured and normal size capsules obtained as above listed in 3.2.2.2.3 was recorded on metric scale on individual capsule basis and was expressed as capsule length in centimeters.

3.2.2.2.5 Seed yield per plant (g)

The seed yield obtained from each of the ten tagged plants were dried in the sun to around 8.0 per cent moisture content and weighed on an analytical precision balance. Their average weight was expressed in grams per plant for each treatment and replication.

Plate 2. Sesame Cv. DS-5 at 50 per cent flowering stage

3.2.2.2.6 Seed yield per hectare (kg)

Seeds obtained from the corresponding net plot area of each treatments were cleaned manually, dried to around 8.0 per cent moisture and weighed on an analytical precision balance. Seed yield per hectare was computed from net plot seed yield data and recorded as average seed yield per hectare in kilograms.

3.2.2.2.7 Seed Multiplication Ratio

Seed Multiplication Ratio was calculated for each treatment and replication and expressed in whole number by using the following formula.

$$\text{SMR} = \frac{\text{Seed yield (Kg/ha)}}{\text{Seed rate (Kg/ha)}}$$

3.2.2.2.8 Net returns (Rs.)

For the purpose of seed production, net returns of lablab bean experimental plot is estimated by using following arithmetic formula and expressed in Rupees (Rs.). The estimated gross returns and cost of cultivation are presented in Appendix III and IV.

Net returns = Gross returns (Rs.) - Cost of Cultivation (Rs.)

3.2.2.2.9 Benefit cost ratio

To know the net returns per rupee invested, the benefit cost ratio (B:C ratio) was worked out by using following arithmetical formula by considering the prices of inputs and produce used for calculating total cost of cultivation as presented in Appendix III and IV.

$$\text{B:C ratio} = \frac{\text{Net returns (Rs./ha)}}{\text{Cost of cultivation (Rs./ha)}}$$

3.2.2.2.10 Seed oil content (%)

The oil content on dry seed weight basis was estimated by using the Nuclear Magnetic Resonance (NMR) spectrophotometer installed at Regional Research Station, Raichur and was expressed as percentage of seed oil content.

3.2.2.3 Seed quality parameters

3.2.2.3.1 1000 seed weight (g)

About 1,000 seeds were chosen randomly from each treatments in four replications and their weight was measured on an analytical precision balance as per the procedure given in the ISTA Rules, (Anon., 1996) and the average weight was expressed in grams.

3.2.2.3.2 Seed germination (%)

The standard germination test was carried out in the laboratory in four replications by adopting the 'Between Paper' method as per the procedure given by ISTA Rules (Anon., 1996). The number of normal seedlings was counted on 6^{th} day of germination testing (final count) for all the treatments. The average was expressed as germination percentage of seeds.

3.2.2.3.3 Shoot length of seedling (cm)

On the day of final count (6^{th} day), ten randomly selected normal seedlings were measured on metric scale for shoot length in each treatments replication wise. It was measured from collar region to the point of attachment of cotyledons and was expressed as average shoot length in centimeter.

3.2.2.3.4 Root length of seedling (cm)

The same seedlings used for shoot measurement were also used for measuring the root length. The length of root was measured from collar region to the tip of the main root and expressed as average root length in centimeter.

3.2.2.3.5 Seedling dry weight (mg)

The ten normal seedlings used for measurement of root and shoot lengths were used for recording seedling dry weight and were kept the in hot air oven for at 70º +1º C for 24 hours. The completely dried seedlings were cooled in dessicator for 30 minutes and their weight was recorded. Their average weight was expressed in milligrams per seedling.

3.2.2.3.6 Seedling vigour index

Seedling vigour index was computed by using the following formula as given by Abdul-Baki and Anderson (1973) and expressed in whole number.

Seedling vigour index (SVI) = Germination percentage x Total seedling length (SL+RL) (cm)

3.2.2.3.7 Seed moisture content (%)

Moisture content of seed was estimated by using the Low Constant Temperature Hot Air Oven method in two replications as per the ISTA procedure (Anon., 1999). Five grams of seeds were weighed accurately on precision electronic balance and the finely ground seed material was kept in snug fitted aluminium containers and was dried in the hot air oven at 103±1℃ for 17±1 hours. After drying period, the dried seed material was cooled in desiccator for 30 minutes and was weighed along with cups. Moisture content of seeds was estimated on wet weight basis by using the following formula and average was expressed as moisture content of seeds in percentage for each treatments.

$$\text{Seed moisture (\%)} = \frac{W_2 - W_3}{W_2 - W_1} \times 100$$

Where,

W_1 = Weight of empty aluminium cup along with lid (g)

W_2 = Weight of aluminium cup + grounded seed sample before drying (g)

W_3 = Weight of aluminium cup + grounded seed sample after drying (g)

3.2.2.3.8 Electrical conductivity of seed leachate (dSm^{-1})

Five grams of seeds were weighed accurately, surface sterilized with 0.5 per cent mercuric chloride for several times and washed sufficiently with distilled water. Subsequently, these were soaked in 25 ml distilled water for 24 hours. The leachate was decanted and its volume was made up to 25 ml by adding distilled water and the electrical conductivity of seed leachate (EC) was measured by using the Electrical Conductivity Bridge (Systronics, type 305 with cell constant of 0.5 Siemens per cm) and expressed as dSm^{1} (Presley, 1958).

3.2.3 Experiment – II : Effect of mother plant nutrition on seed storability of sesame under ambient condition

This experiment was conducted in the laboratory of Department of Seed Science & Technology, Agriculture college, Dharwad under ambient condition from month of November,2013 to April,2014 to study the storability of sesame seeds. For this storage experiment, the seeds harvested from the wider spacing (45 x 15 cm) as per the nutrient treatment schedule of the experiment – I were only utilized as listed below.

3.2.3.1 Treatments details

F_1: 40:20:20 NPK kg/ha

F_2: 50:20:20 NPK kg/ha

F_3: 50:25:25 NPK kg/ha (Rd)

F_4: 50:30:30 NPK kg/ha

F_5: 60:30:30 NPK kg/ha

F_6: 50:25:25 NPK kg/ha + sulphur @ 5 kg/ha

F_7: 60:20:30 NPK kg/ha + sulphur @ 10 kg/ha

$F_{8:}$ 40:10:20 NPK kg/ha + sulphur @ 15 kg/ha

3.2.3.2 Design and layout

The storage experiment was laid out in three replication by adopting the Completely Randomised Design.

3.2.3.3 Storage condition

About 500 g of cleaned and dried (8% MC) seeds were packed in the fresh and sterilized cloth bags as per the treatment schedule 3.2.3.1 and were kept in the laboratory of Seed Science and Technology, University of Agricultural Sciences Dharwad under ambient condition for the period of 6 months from November,2013 to April,2014 and observations on seed quality parameters were recorded on monthly basis upto 6 months as listed below.

3.2.3.4 Seed quality parameters

3.2.3.4.1 Seed germination

The seed germination (%) test procedure followed as detailed in 3.2.2.3.2

Shoot length of seedling (cm)	As detailed in 3.2.2.3.3
Root length of seedling (cm)	As detailed in 3.2.2.3.4
Seedling dry weight (mg)	As detailed in 3.2.2.3.5
Seedling vigour index	As detailed in 3.2.2.3.6
Seed moisture content (%)	As detailed in 3.2.2.3.7
Electrical conductivity of seed leachate (dSm'^{1})	As detailed in 3.2.2.3.8

3.3 Statistical analysis

The mean data obtained from the experimentation were statistically analysed and subjected to the Analysis of variance by adopting the appropriate statistical methods as outlined by Panse and Sukhatme (1978) and Sundararaj *et al.* (1972). The critical differences were calculated at five per cent level of probability wherever 'F' test was significant. The percentage data were transformed into arc sine root transformation before analysis.

EXPERIMENTAL RESULTS

The field experiment was conducted during the *khari* season, 2013 to know the effect of spacing and fertilizer levels on crop growth, seed yield and quality in sesame (*Sesamum indicum* L.) Cv. DS-5. A laboratory experiment was also carried out to know the effect of mother plant nutrition on storability of sesame seeds under ambient condition for period of six months from November 2013 to April 2014. The laboratory experiment was conducted in the Department of Seed Science and Technology, College of Agriculture, UAS, Dharwad. The results obtained from field and laboratory experiments are presented in this chapter.

4.1 Experiment I: Effect of plant spacings and fertilizer levels on crop growth, seed yield and quality in sesame (*Sesamum indicum* L.) Cv. DS-5

4.1.1 Growth parameters

4.1.1.1 Plant height at 30 days after sowing (DAS)

The data on plant height at 30 days after sowing (DAS) as influenced by spacings, fertilizer levels and their interaction effects are presented in Table 1.

Spacings (S)

Plant height at 30 DAS showed non-significant differences between the spacings irrespective of fertilizer levels. Numerically more (44.55 cm) plant height was recorded in the narrow spacing of 30 x 15 cm (S_1) over wider spacing of 45 x 15 cm (S_2) (41.76 cm).

Fertilizer levels (F)

Plant height at 30 DAS varied significantly due to fertilizer levels over spacings used. Significantly taller plants (49.00 cm) were recorded at 30 DAS in a fertilizer level of 60:20:30 NPK per ha + sulphur @ 10 kg per ha (F_7) which was on par with F_8 (44.80 cm), F_6 (44.15 cm) and F_5 (43.30 cm), F_4 (41.50 cm), F_3 (43.00 cm) and F_2 (41.00 cm) levels. While, significantly shorter plants (39.80 cm) were seen in 40:20:20 kg NPK per ha (F_1) fertilizer level.

Interaction (SxF)

The statistical variations on plant height at 30 DAS due to interaction between spacings and fertilizer levels (SxF) were found to be non-significant. Plant height was numerically higher (50.50 cm) in interaction of S_1 (30x15 cm) and F_7 (60:20:30 NPK kg/ha + sulphur @ 10 kg/ha (S_1xF_7) and lower (38.30 cm) in S_2 (45 x 15 cm) and F_1 (40 : 20 : 20 NPK kg/ha) treatment combination (S_2F_1).

4.1.1.2 Plant height at 60 DAS

The data on plant height at 60 DAS due to spacings, fertilizer levels and their interactions are presented in Table 1. The statistical difference on plant height at 60 DAS was significant only due to fertilizer levels except for spacings and their interaction effects.

Spacings (S)

At 60 DAS, plant height was non-significant due to spacings over fertilizer levels. Numerically more plant height (113.00 cm) was recorded in 30x15 cm (S_1) as against 45x15 cm (S_2) spacing (109.96 cm).

Fertilizer levels (F)

The marked variations amongst the different fertilizer levels were noticed for plant height with 60 DAS irrespective of spacings. Significantly taller plants (121.00 cm) were observed in 60:20:30 NPK per ha + sulphur @ 10 kg per ha (F_7) level which was on par at F_8 (115.65 cm), F_6 (113.80 cm) and F_5 (109.80 cm), F_4 (108.80 cm), F_3 (110.80 cm),and F_2 (108.50 cm) levels as against fertilizer level of 40:20:20 kg NPK per ha (F_1) (103.50 cm).

Interaction (SxF)

Non-significant differences on plant height at 60 DAS due to interaction of spacings and fertilizer levels are recorded. It was numerically higher (122.50 cm) and lower (102.00 cm) plant height in S_1xF_7 and S_2xF_1 interaction levels, respectively.

Table 1. Effect of spacing and fertilizer levels on plant height at different growth stages in sesame Cv. DS-5

Fertilizer levels	Plant height (cm)								
	30 DAS			60 DAS			At harvest		
	Spacing (cm) (S)			Spacing (cm) (S)			Spacing (cm) (S)		
	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean
F_1	41.30	38.30	**39.80**	105.00	102.00	**103.50**	134.70	127.70	**131.20**
F_2	42.30	39.70	**41.00**	110.00	107.00	**108.50**	135.00	130.00	**132.50**
F_3	44.00	42.00	**43.00**	112.30	109.30	**110.80**	138.00	131.70	**134.85**
F_4	42.70	40.30	**41.50**	110.30	107.30	**108.80**	136.70	130.00	**133.35**
F_5	43.30	40.70	**42.00**	111.30	108.30	**109.80**	138.00	131.30	**134.65**
F_6	46.00	42.30	**44.15**	115.30	112.30	**113.80**	138.30	134.00	**136.15**
F_7	50.50	47.50	**49.00**	122.50	119.50	**121.00**	145.00	137.70	**141.35**
F_8	46.30	43.30	**44.80**	117.30	114.00	**115.65**	140.30	135.70	**138.00**
Mean	**44.55**	**41.76**	**43.20**	**113.00**	**109.96**	**111.48**	**138.30**	**132.30**	**135.30**
For comparing the means of	S.Em±	CD at 5%		S.Em±	CD at 5%		S.Em±	CD at 5%	
S	1.15	NS		3.022	NS		1.86	5.50	
F	3.10	8.95		6.045	17.46		3.30	10.02	
S x F	1.47	NS		2.850	NS		2.70	NS	

DAS- Dyas after sowing NS – Non significant

Spcings (S)
S_1 (30x15 cm)
S_2 (45x 15 cm)

Fertilizer levels (F)
F_1 : 40 : 20 : 20 NPK kg/ha
F_2 : 50 : 20 : 20 NPK kg/ha
F_3 : 50 : 25 : 25 NPK kg/ha (Rd)
F_4 : 50 : 30 : 30 NPK kg/ha
F_5 : 60 : 30 : 30 NPK kg/ha
F_6 : 50 : 25 : 25 NPK kg/ha + sulphur @ 5 kg/ha
F_7 : 60 : 20 : 30 NPK kg/ha + sulphur @ 10 kg/ha
F_8 : 40 : 10 : 20 NPK kg/ha + sulphur @ 15 kg/ha

4.1.1.3 Plant height at harvest

The data on plant height at harvest as influenced by spacings, fertilizer levels and their interaction effects are presented in Table 1. The marked differences on plant height were seen at harvest due to spacings and fertilizer levels except their interaction effects.

Spacings (S)

Between the two spacings adopted, 30x15 cm (S_1) recorded significantly taller plants (138.30 cm) at harvest as against 45x 15 cm (S_2) spacing (132.30 cm).

Fertilizer levels (F)

The marked differences on plant height at harvest were seen due to fertilizer levels over spacings. At harvest, plant height was significantly the highest (141.35 cm) in 60:20:30 NPK per ha + sulphur @ 10 kg per ha (F_7) level and it was at par with F_8 (138.00 cm), F_6 (136.15 cm) and F_5 (134.65 cm), F_4 (133.35 cm), F_3 (134.85 cm),and F_2 (132.50 cm) levels. Whereas, it was significantly the lowest (131.20 cm) in 40:20:20 kg NPK per ha (F_1) fertilizer level.

Interaction (SxF)

Interaction effect of spacings and fertilizer levels on plant height at harvest was found to be non-significant. However, it was numerically more (145.00 cm) in S_1xF_7 and less (127.70 cm) in S_2xF_1 level.

4.1.1.4Number of primary branches per plant at 30 DAS

The statistical variations on number of primary branches per plant at 30 DAS as influenced by spacings, fertilizer levels and their interaction effects are presented in Table 2.

Spacings (S)

Number of primary branches per plant did not differ significantly at 30 DAS due to spacings over fertilizer levels. At 30 DAS, it was numerically more (3.77) in S_2 than S_1 (3.41 cm).

Fertilizer levels (F)

Number of branches per plant at 30 DAS varied significantly between the different fertilizer levels irrespective of spacings. Number of primary branches per plant were significantly more (5.10) in 60:20:30 NPK per ha + sulphur @ 10 kg per ha (F_7) level and less (2.90) in 40:20:20 kg NPK per ha (F_1) level respectively.

Interaction (SxF)

Interaction effect between spacings and fertilizer levels were non significant for number of primary branches per plant at 30 DAS. It was numerically higher (5.20) in S_2xF_7 and lower (2.80) in S_1xF_1 interaction treatments.

4.1.1.5 Number of primary branches per plant at 60 DAS

The data pertaining to number of primary branches per plant at 60 DAS as influenced by spacings, fertilizer levels and their interaction effects are furnished in Table 2.

Spacings (S)

Number of primary branches per plant at 60 DAS differed non-significantly due to spacings over fertilizer levels. It was numerically more (4.65) and less (4.26) in S_2 and S_1 spacings, respectively.

Fertilizer levels (F)

The marked variations on number of primary branches per plant at 60 DAS were noticed due to fertilizer levels over spacings. It was significantly higher (5.85) at 60:20:30 NPK per ha + sulphur @ 10 kg per ha (F_7) fertilizer level and lower (3.70) in 40:20:20 kg NPK per ha (F_1).

Interaction (SxF)

The statistical differences on number of primary branches per plant at 60 DAS were found to be non-significant due to interaction effect between spacings and fertilizer levels. It recorded numerically higher and lower (6.50 and 3.90) number of primary branches per plant in S_2xF_7 and S_1xF_1 levels, respectively.

Table 2. Effect of spacing and fertilizer levels on number of primary branches at different growth stages in sesame Cv. DS-5

Fertilizer levels	Number of primary branches								
	30 DAS			60 DAS			At harvest		
	Spacing (cm) (S)			Spacing (cm) (S)			Spacing (cm) (S)		
	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean
F_1	2.80	3.00	**2.90**	3.50	3.90	**3.70**	3.90	5.20	**4.55**
F_2	3.10	3.30	**3.20**	3.60	4.20	**3.90**	3.90	5.20	**4.55**
F_3	3.30	3.90	**3.60**	4.30	4.50	**4.40**	4.30	5.50	**4.90**
F_4	3.00	3.50	**3.25**	4.00	4.40	**4.20**	4.10	5.30	**4.70**
F_5	3.00	3.50	**3.25**	4.10	4.40	**4.25**	4.20	5.40	**4.80**
F_6	3.40	3.80	**3.60**	4.40	4.80	**4.60**	4.40	5.60	**5.00**
F_7	5.00	5.20	**5.10**	5.60	6.10	**5.85**	5.90	6.50	**6.20**
F_8	3.70	4.00	**3.85**	4.60	4.90	**4.75**	4.80	5.90	**5.35**
Mean	**3.41**	**3.77**	**3.59**	**4.26**	**4.65**	**4.45**	**4.43**	**5.57**	**5.00**

For comparing the means of	S.Em±	CD at 5%	S.Em±	CD at 5%	S.Em±	CD at 5%
S	0.374	NS	0.35	NS	0.26	0.76
F	0.748	2.16	0.70	2.01	0.53	1.53
S x F	0.353	NS	0.33	NS	0.25	NS

DAS- Dyas after sowing NS – Non significant

Spcings (S)
S_1 (30x15 cm)
S_2 (45x 15 cm)

Fertilizer levels (F)
F_1 : 40 : 20 : 20 NPK kg/ha
F_2 : 50 : 20 : 20 NPK kg/ha
F_3 : 50 : 25 : 25 NPK kg/ha (Rd)
F_4 : 50 : 30 : 30 NPK kg/ha
F_5 : 60 : 30 : 30 NPK kg/ha
F_6 : 50 : 25 : 25 NPK kg/ha + sulphur @ 5 kg/ha
F_7 : 60 : 20 : 30 NPK kg/ha + sulphur @ 10 kg/ha
F_8 : 40 : 10 : 20 NPK kg/ha + sulphur @ 15 kg/ha

4.1.1.6 Number of primary branches per plant at harvest

The data on number of primary branches per plant at harvest as influenced by spacings, fertilizer levels and their interaction effects are presented in Table 2.

Spacings (S)

At harvest, number of primary branches per plant varied significantly between the spacings irrespective of fertilizer levels. It was significantly more (5.57) in S_2 (45x15 cm) than in S_1 (30x15 cm) (4.43).

Fertilizer levels (F)

The marked differences between the fertilizer levels were noticed for number of primary branches per plant at harvest over spacings. It was significantly maximum (6.20) at 60:20:30 NPK per ha + sulphur @ 10 kg per ha (F_7) fertilizer level which was on par with F_8 (40:10:20 kg NPK/ha+ sulphur @ 15 kg/ha) (5.35), F_6 (50:25:25 kg NPK/ha+ sulphur @5 kg/ha) (5.00) and F_5 (60:30:30 kg NPK/ha) (4.80), F_4 (50:30:30 NPK kg/ha) (4.70) and F_3 (50:25:25 NPK kg/ha) (4.90) levels. Whereas, it was significantly minimum (4.55) in 40:20:20 kg NPK per ha (F_1) level.

Interaction (SxF)

Interaction effect on number of primary branches per plant at harvest between spacings and fertilizer levels was found to be non-significant. It was numerically more (6.50) in S_2xF_7 followed by S_2xF_8 (5.90), S_1xF_7 (5.90), S_2xF_6 (5.60) and less in S_1xF_1 (3.90) levels.

4.1.1.7 Days to flower initiation

Data on days to flower initiation showed significant differences only due to fertilizer levels except for spacings and their interactions as depicted in Table 3.

Spacings (S)

Days to flower initiation was found to be non-significant due to spacings over fertilizer levels. It was numerically more and less (41.21 and 39.03 days) at 45 x 15 cm (S_2) and 30x15 cm (S_1) spacings, respectively

Fertilizer levels (F)

A fertilizer level of 60:30:30 NPK kg/ha (F_5) took significantly maximum (42.40 days) number of days to flower initiation, which was at par with F_7 (40.85 days), F_4 (40.70 days) and F_6 (40.50 days), F_3 (40.15 days), F_8 (39.35 days) andF_7 (39.20 days) levels. Whereas, it was minimum (37.85 days) in 40:20:20 kg NPK per ha (F_8) irrespective of spacings.

Interaction (SxF)

Non-significant differences were observed for days to flower initiation due to interaction of spacings and fertilizer levels. It was numerically higher (43.30 days) in S_2xF_5 followed by S_2xF_7 (42.00 days) and lower (37.00 days) in S_1xF_1 level.

4.1.1.8 Days to 50 per cent flowering

The data pertaining to days to 50 per cent flowering as influenced by spacings, fertilizer levels and their interaction effects are presented in Table 3.

Spacings (S)

Days to 50 per cent flowering was found to be statistically non-significant due to spacings over the fertilizer levels. It was numerically more (49.05 days) at 45x15 cm (S_2) than at 30x15 cm (S_1) (46.89 days) spacing..

Fertilizer levels (F)

A fertilizer level of 60:30:30 NPK kg/ha (F_5) took significantly maximum (49.15 days) number of days to flower initiation, which was at par with F_7 (48.70 days), F_4 (48.53 days) and F_6 (48.50 days), F_3 (48.35 days), F_8 (47.85 days) andF_7 (47.20 days) levels. Whereas, it was minimum (46.00 days) in 40:20:20 kg NPK per ha (F_8) irrespective of spacings.

Table 3. Effect of spacing and fertilizer levels on flowering parameters in sesame Cv. DS-5

Fertilizer levels	Days to flower initiation			Days to 50 per cent flowering		
	Spacing (cm) (S)			Spacing (cm) (S)		
	S_1	S_2	Mean	S_1	S_2	Mean
F_1	37.00	38.70	**37.85**	45.30	46.70	**46.00**
F_2	37.70	40.70	**39.20**	45.70	48.70	**47.20**
F_3	39.00	41.30	**40.15**	47.00	49.70	**48.35**
F_4	39.70	41.70	**40.70**	47.77	49.30	**48.50**
F_5	41.50	43.30	**42.40**	48.00	50.30	**49.15**
F_6	39.70	41.30	**40.50**	47.70	49.30	**48.50**
F_7	39.70	42.00	**40.85**	47.70	49.70	**48.70**
F_8	38.00	40.70	**39.35**	47.00	48.70	**47.85**
Mean	**39.03**	**41.21**	**40.12**	**46.89**	**49.05**	**47.97**

For comparing the means of	S.Em±	CD at 5%	S.Em±	CD at 5%
S	0.75	NS	0.74	NS
F	1.51	4.35	1.50	2.35
S x F	0.71	NS	0.71	NS

NS- Non significant

Spcings (S)
S_1 (30x15 cm)
S_2 (45x 15 cm)

Fertilizer levels (F)
F_1 : 40 : 20 : 20 NPK kg/ha
F_2 : 50 : 20 : 20 NPK kg/ha
F_3 : 50 : 25 : 25 NPK kg/ha (Rd)
F_4 : 50 : 30 : 30 NPK kg/ha
F_5 : 60 : 30 : 30 NPK kg/ha
F_6 : 50 : 25 : 25 NPK kg/ha + sulphur @ 5 kg/ha
F_7 : 60 : 20 : 30 NPK kg/ha + sulphur @ 10 kg/ha
F_8 : 40 : 10 : 20 NPK kg/ha + sulphur @ 15 kg/ha

Interaction (SxF)

Non-significant variation for days to 50 per cent flowering was seen due to interaction effect between spacings and fertilizer levels. However, it was numerically more (50.30 days) in S_2xF_4 level, which was followed by S_2xF_3 (49.70 days), S_2xF_6 (49.30 days) and S_2xF_7 (49.30 days) and it was numerically less (45.30 days) in S_1xF_1 level.

4.1.2 Seed yield parameters

4.1.2.1 Number of capsules per plant

The data on number of capsules per plant at harvest due to spacings, fertilizer levels and their interaction effects are presented in Table 4 and depicted in Fig. 2.

Spacings (S)

Number of capsules per plant differed significantly due to spacings irrespective of fertilizer levels. It was significantly more (78.15) in 45x15 cm (S_2) compared to 30x15 cm (S_1) (72.85) spacing.

Fertilizer levels (F)

Irrespective of spacings, the marked differences between the fertilizer levels were recorded for number of capsules per plant. It was significantly the highest (89.40) in 60:20:30 NPK per ha + sulphur @ 10 kg per ha (F_7) fertilizer level, which was at par with F_8 (86.05), F_6 (83.30) and F_5 (72.60), F_4 (69.30), F_3 (68.50) levels. Whereas, 40:20:20 kg NPK per ha (F_1) recorded the lowest capsule number (67.15) per plant.

Interaction (SxF)

The non-significant interaction effect between spacings and fertilizer levels was seen for number of capsules per plant. However, it was numerically more and less number in S_2xF_7 (93.40) and S_1xF_1 (64.30) respectively.

4.1.2.2 Number of seeds per capsule

The data on number of seeds per capsule as influenced by spacings, fertilizer levels and their interaction effects are furnished in Table 4.

Spacings (S)

Irrespective of fertilizer levels, the significant variations on number of seeds per capsule were seen between the spacings. Significantly higher (69.03) number of seeds per capsule were noticed in S_2 (45x15 cm) than S_1 (30x15 cm) (65.75).

Fertilizer levels (F)

The marked differences amongst the fertilizer levels were noticed for number of seeds per capsule over spacings. It was significantly the highest (74.85) in 60:20:30 NPK per ha + sulphur @ 10 kg per ha (F_7), which was on par with F_8 (72.50), F_6 (69.00) and F_5 (68.70), F_4 (64.70) and F_3 (63.70). Whereas, 40:20:20 kg NPK per ha recorded significantly the lowest (62.35) seed number.

Interaction (SxF)

The non-significant interaction effect between spacings and fertilizer levels was seen for number of seeds per capsule. However, it was numerically more and less number in S_2xF_7 (76.70) and S_1xF_1 (60.00) respectively.

4.1.2.3 Weight of capsule (g)

The data on weight of capsule at harvest due to spacings, fertilizer levels and their interaction effects are presented in Table 5.

Spacings (S)

The statistical differences for weight of capsule were found to be non-significant due to spacings over fertilizer levels. It was numerically more (0.392 g) and less (0.384) in 45x15 cm (S_2) and 30x15 cm (S_1) spacings, respectively.

Table 4. Effect of spacing and fertilizer levels on seed yield components in sesame Cv. DS-5

Fertilizer levels	Number of capsules per plant			Number of seeds per capsule		
	Spacing (cm) (S)			Spacing (cm) (S)		
	S_1	S_2	Mean	S_1	S_2	Mean
F_1	64.30	70.00	**67.15**	60.00	64.70	**62.35**
F_2	64.70	70.70	**67.70**	61.30	65.30	**63.30**
F_3	65.20	71.80	**68.50**	61.70	65.70	**63.70**
F_4	65.70	72.90	**69.30**	62.70	66.70	**64.70**
F_5	69.40	75.80	**72.60**	67.70	69.70	**68.70**
F_6	83.70	82.90	**83.30**	68.30	69.70	**69.00**
F_7	85.40	93.40	**89.40**	73.00	76.70	**74.85**
F_8	84.30	87.70	**86.05**	71.30	73.70	**72.50**
Mean	**72.85**	**78.15**	**75.50**	**65.75**	**69.03**	**67.39**

For comparing the means of	S.Em±	CD at 5%	S.Em±	CD at 5%
S	1.55	4.72	1.02	3.10
F	7.10	20.50	4.04	11.67
S x F	3.35	NS	1.91	NS

NS- Non significant

Spcings (S)
S_1 (30x15 cm)
S_2 (45x 15 cm)

Fertilizer levels (F)
F_1 : 40 : 20 : 20 NPK kg/ha
F_2 : 50 : 20 : 20 NPK kg/ha
F_3 : 50 : 25 : 25 NPK kg/ha (Rd)
F_4 : 50 : 30 : 30 NPK kg/ha
F_5 : 60 : 30 : 30 NPK kg/ha
F_6 : 50 : 25 : 25 NPK kg/ha + sulphur @ 5 kg/ha
F_7 : 60 : 20 : 30 NPK kg/ha + sulphur @ 10 kg/ha
F_8 : 40 : 10 : 20 NPK kg/ha + sulphur @ 15 kg/ha

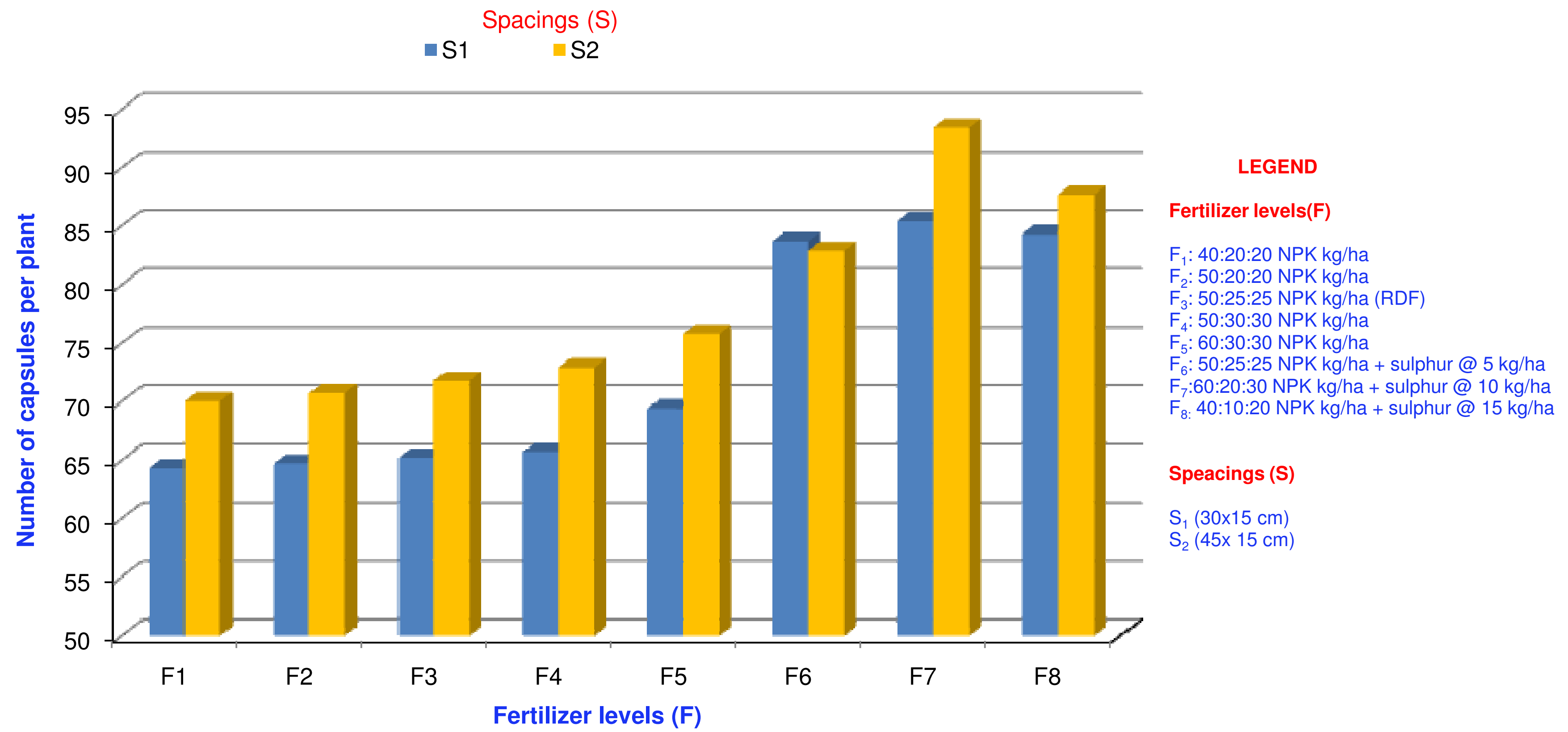

Fig. 2 : Effect of spacing and fertilizer levels on number of capsules per plant in sesame Cv. DS-5

Fertilizer levels (F)

Irrespective of spacings, the marked differences between the fertilizer levels were recorded for weight of capsule. It was significantly the highest (0.404 g) in 60:20:30 NPK per ha + sulphur @ 10 kg per ha (F_7) fertilizer level, which was at par with F_8 (0.397 g), F_6 (0.396 g), F_5 (0.394 g), F_4 (0.393 g), F_3 (0.392 g) levels. Whereas, 40:20:20 kg NPK per ha (F_1) recorded the lowest capsule weight (0.344 g).

Interaction (SxF)

The statistical variations for SxF interaction effect were found to be significant for weight of capsule. Significantly, the highest (0.410 g) weight of capsule was noticed in S_2xF_7, which was on par at S_2xF_8 (0.402 g), S_2xF_6 (0.400 g), S_2xF_5 (0.398 g), S_1xF_7 (0.398 g) levels. While, it was significantly the lowest (0.338 g) in S_1xF_1 level.

4.1.2.4 Length of capsule (cm)

The data on weight of capsule at harvest due to spacings, fertilizer levels and their interaction effects are presented in Table 5.

Spacings (S)

Length of capsule was found to be statistically non-significant due to spacings over the fertilizer levels. It was numerically more (3.15 cm) at 30x15 cm (S_1) than at 45x15 cm (S_2) (3.10) spacing.

Fertilizer levels (F)

Irrespective of spacings, the marked differences between the fertilizer levels were recorded for length of capsule. It was significantly the highest (3.55 cm) in 60:20:30 NPK per ha + sulphur @ 10 kg per ha (F_7) fertilizer level, which was at par with F_8 (3.25 cm), F_6 (3.20 cm), F_5 (3.15), F_4 (3.10), F_3 (3.00 cm) levels. Whereas, 40:20:20 kg NPK per ha (F_1) recorded the lowest length of capsule (2.85 cm).

Interaction (SxF)

The statistical variations for SxF interaction effect were found to be significant for length of capsule. Significantly, the highest (3.60 cm) length of capsule was noticed in S_1xF_7, which was on par at S_1xF_8 (3.30 cm), S_1xF_6 (3.20 cm), S_2xF_8 (3.20cm), S_2xF_6 (3.20 cm), S_2XF_5 (3.20 cm), S_1xF_5 (3.10 cm) levels. While, it was significantly the lowest (2.80 cm) in S_2xF_1 level.

4.1.2.5 Seed weight per capsule (g)

The data on seed weight per capsule at harvest due to spacings, fertilizer levels and their interaction effects are presented in Table 5.

Spacings (S)

Irrespective of fertilizer levels, the significant variations on seed weight per capsule were seen between the spacings. Significantly higher (0.205 g) seed weght per capsule was noticed in S_2 (45x15 cm) than S_1 (30x15 cm) (0.201 g).

Fertilizer levels (F)

The marked differences amongst the fertilizer levels were noticed for seed weight per capsule over spacings. It was significantly the highest (0.208 g) in 60:20:30 NPK per ha + sulphur @ 10 kg per ha (F_7). which was on par with F_8 (0.205 g), F_6 (0.205) and F_5 (0.204 g), F_4 (0.204 g) and F_3 (0.203 g). Whereas, 40:20:20 kg NPK per ha recorded significantly the lowest (0.197 g) seed weight per capsule.

Interaction (SxF)

The statistical variations for SxF interaction effect were found to be significant for seed weight per capsule. Significantly, the highest (0.210 g) seed weight per capsule was noticed in S_2xF_7, which was on par at S_2xF_8 (0.207 g), S_1xF_7 (0.207 g cm), S_2xF_6 (0.207 g), S_2xF_5 (0.205 g), S_2XF_4 (0.205 g), S_1xF_8 (0.204 g) levels. While, it was significantly the lowest (0.197 g) in S_1xF_1 level.

Table 5. Effect of spacing and fertilizer levels on seed yield components in sesame Cv. DS-5

Fertilizer levels	Weight of capsule (g) at harvest			Length of capsules (cm) at harvest			Seed weight (g) per capsule		
	Spacing (cm) (S)			Spacing (cm) (S)			Spacing (cm) (S)		
	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean
F_1	0.338	0.350	**0.344**	2.90	2.80	**2.85**	0.197	0.198	**0.197**
F_2	0.386	0.389	**0.387**	3.00	2.90	**2.95**	0.198	0.200	**0.199**
F_3	0.389	0.396	**0.392**	3.00	3.00	**3.00**	0.203	0.204	**0.203**
F_4	0.389	0.397	**0.393**	3.10	3.10	**3.10**	0.204	0.205	**0.204**
F_5	0.389	0.398	**0.394**	3.10	3.20	**3.15**	0.204	0.205	**0.204**
F_6	0.391	0.400	**0.396**	3.20	3.20	**3.20**	0.204	0.207	**0.205**
F_7	0.398	0.410	**0.404**	3.60	3.50	**3.55**	0.207	0.210	**0.208**
F_8	0.392	0.402	**0.397**	3.30	3.20	**3.25**	0.204	0.207	**0.205**
Mean	**0.384**	**0.392**	**0.388**	**3.15**	**3.10**	**3.13**	**0.201**	**0.205**	**0.203**

For comparing the means of	S.Em±	CD at 5%	S.Em±	CD at 5%	S.Em±	CD at 5%
S	0.008	NS	0.12	NS	0.001	0.003
F	0.016	0.050	0.24	0.68	0.001	0.003
S x F	0.008	0.020	0.11	0.32	0.001	0.003

NS – Non significant

Spcings (S)
S_1 (30x15 cm)
S_2 (45x 15 cm)

Fertilizer levels (F)
F_1 : 40 : 20 : 20 NPK kg/ha
F_2 : 50 : 20 : 20 NPK kg/ha
F_3 : 50 : 25 : 25 NPK kg/ha (Rd)
F_4 : 50 : 30 : 30 NPK kg/ha
F_5 : 60 : 30 : 30 NPK kg/ha
F_6 : 50 : 25 : 25 NPK kg/ha + sulphur @ 5 kg/ha
F_7 : 60 : 20 : 30 NPK kg/ha + sulphur @ 10 kg/ha
F_8 : 40 : 10 : 20 NPK kg/ha + sulphur @ 15 kg/ha

4.1.2.6 Seed yield per plant (g)

The data on seed yield per plant due to spacings, fertilizer levels and their interaction effects are presented in Table 6 and depicted in Fig. 3. An average seed yield of 4.46 g per plant was recorded irrespective of spacing and fertilizer levels.

Spacings (S)

Seed yield per plant showed marked differences between the spacings over fertilizer levels. It was significantly higher (4.50 g) in 45x15 cm (S_2) over 30x15 cm (S_1) (4.41 g) spacing.

Fertilizer levels (F)

The marked differences on seed yield per plant were noticed amongst the fertilizer levels irrespective of spacings. It was significantly maximum (5.40 g) in 60:20:30 NPK per ha + sulphur @ 10 kg per ha (F_7) as against 40:20:20 kg NPK per ha (F_1) (3.70 g) and it was on par with F_6 (4.84 g), F_8 (4.92 g) and F_5 (4.54 g), F_4 (4.20 g) and F_3 (4.28 g) levels.

Interaction (SxF)

Non-significant variations of seed yield per plant were observed due to interaction between spacings and fertilizer levels. However, it was numerically more (5.40 g) in S_2xF_7 level and it was less (3.63 g) in S_1xF_1 interaction.

4.1.2.7 Seed yield per ha (q)

The data on seed yield per ha as influenced by spacings, fertilizer levels and their interaction effects are presented in Table 6 and depicted in Fig. 4. On an average seed yield of 866.10 kg per ha was recorded over spacings and fertilizer levels.

Spacings (S)

Seed yield per ha differed markedly due to spacings over fertilizer levels. Significantly more seed yield (981.2 kg/ha) was recorded in 30x15 cm (S_1) spacing than in 45x15 cm (S_2) (859.3 kg/ha) spacing.

Fertilizer levels (F)

Irrespective of spacings, the fertilizer levels depicted the significant variations on seed yield per ha. It was significantly the highest (1110 kg/ha) in 60:20:30 NPK per ha + sulphur @ 10 kg per ha (F_7). But, it differed significantly with rest of the fertilizer levels. However, the least yield was (769.4 kg/ha) in 40:20:20 kg NPK/ha) (F_1).

Interaction (SxF)

The interaction between spacings and fertilizer levels differed significantly for seed yield per ha. It was significantly maximum (1178 kg/ha) in the S_1xF_7 interaction. But, it also differed significantly with rest of the interactions levels and minimum was (732.7 kg/ha) in S_2xF_1 interaction level.

4.1.2.8 Seed Multiplication Ratio (SMR)

The data on Seed Multiplication Ratio due to spacings, fertilizer levels and their interaction effects are presented in Table 7. An average seed multiplication ratio of 230 was recorded irrespective of spacing and fertilizer levels.

Spacings (S)

Seed Multiplication Ratio showed marked differences between the spacings over fertilizer levels. It was significantly higher (245) in 30x15 cm (S_1) over 45x15 cm (S_2) (215) spacing.

Fertilizer levels (F)

The marked differences on seed multiplication ratio were noticed amongst the fertilizer levels irrespective of spacings. It was significantly maximum (278) in 60:20:30 NPK per ha + sulphur @ 10 kg per ha (F_7) as against 40:20:20 kg NPK per ha (F_1) (192).

Interaction (SxF)

Non-significant variations of seed multiplication ratio were observed due to interaction

Table 6. Effect of spacing and fertilizer levels on seed yield components in sesame Cv. DS-5

Fertilizer levels	Seed yield (g) per plant			Seed yield (kg) per ha		
	Spacing (cm) (S)			Spacing (cm) (S)		
	S_1	S_2	Mean	S_1	S_2	Mean
F_1	3.63	3.74	**3.70**	806.00	732.70	**769.40**
F_2	3.73	3.84	**3.79**	828.00	762.70	**795.40**
F_3	4.17	4.28	**4.23**	926.00	816.70	**871.40**
F_4	4.37	4.46	**4.20**	970.70	844.70	**907.40**
F_5	4.49	4.58	**4.54**	996.70	840.70	**918.40**
F_6	4.78	4.89	**4.84**	1061.30	916.00	**988.70**
F_7	5.30	5.40	**5.40**	1178.00	1042.00	**1110.00**
F_8	4.87	4.96	**4.92**	1083.00	920.70	**1001.00**
Mean	**4.41**	**4.50**	**4.46**	**981.20**	**859.30**	**920.30**

For comparing the means of	S.Em$\pm$	CD at 5%	S.Em$\pm$	CD at 5%
S	0.03	0.08	7.59	21.92
F	0.06	0.16	15.19	43.86
S x F	0.03	NS	7.16	21.50

NS – Non significant

Spcings (S)
S_1 (30x15 cm)
S_2 (45x 15 cm)

Fertilizer levels (F)
F_1 : 40 : 20 : 20 NPK kg/ha
F_2 : 50 : 20 : 20 NPK kg/ha
F_3 : 50 : 25 : 25 NPK kg/ha (Rd)
F_4 : 50 : 30 : 30 NPK kg/ha
F_5 : 60 : 30 : 30 NPK kg/ha
F_6 : 50 : 25 : 25 NPK kg/ha + sulphur @ 5 kg/ha
F_7 : 60 : 20 : 30 NPK kg/ha + sulphur @ 10 kg/ha
F_8 : 40 : 10 : 20 NPK kg/ha + sulphur @ 15 kg/ha

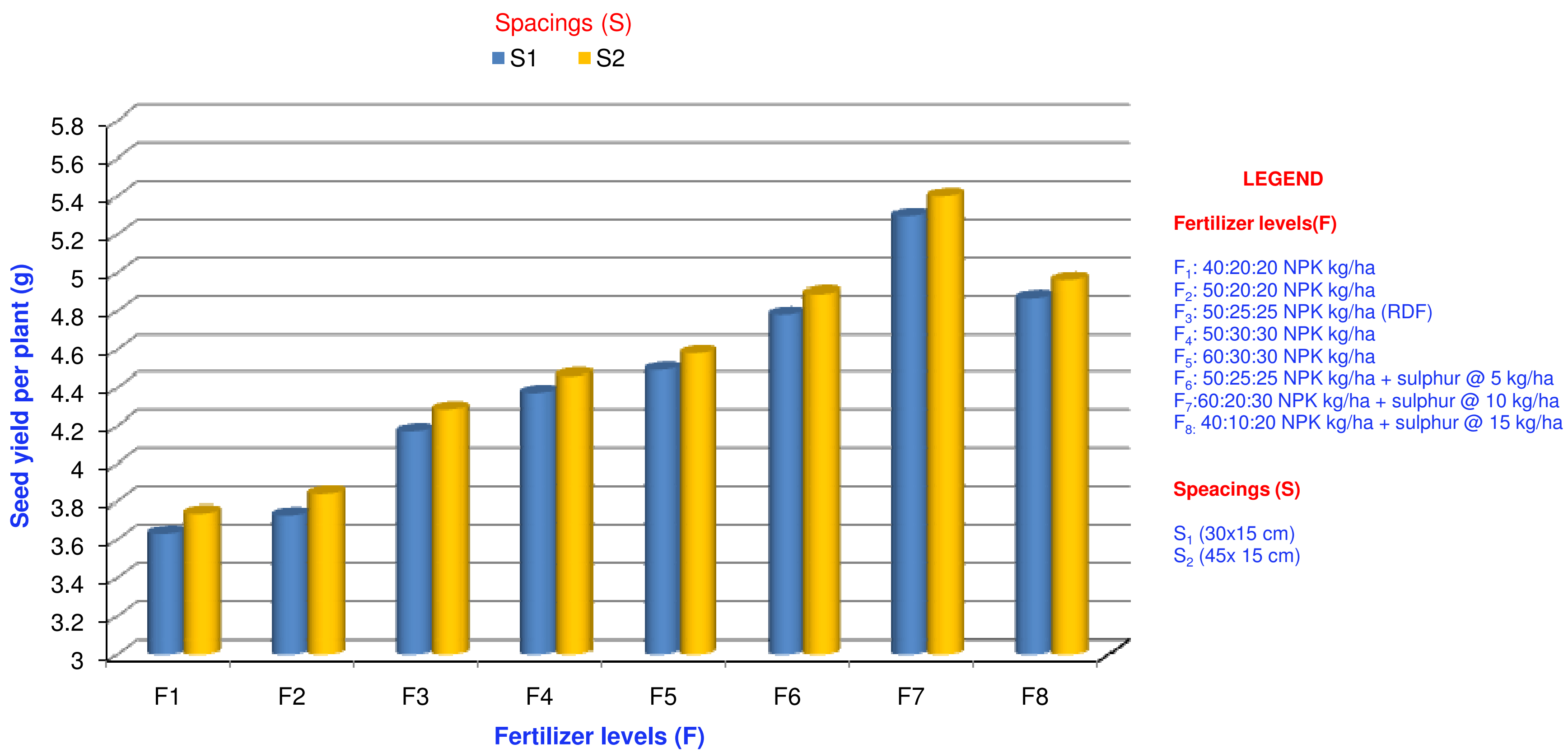

Fig. 3 : Effect of spacing and fertilizer levels on seed yield per plant (g) in sesame Cv. DS-5

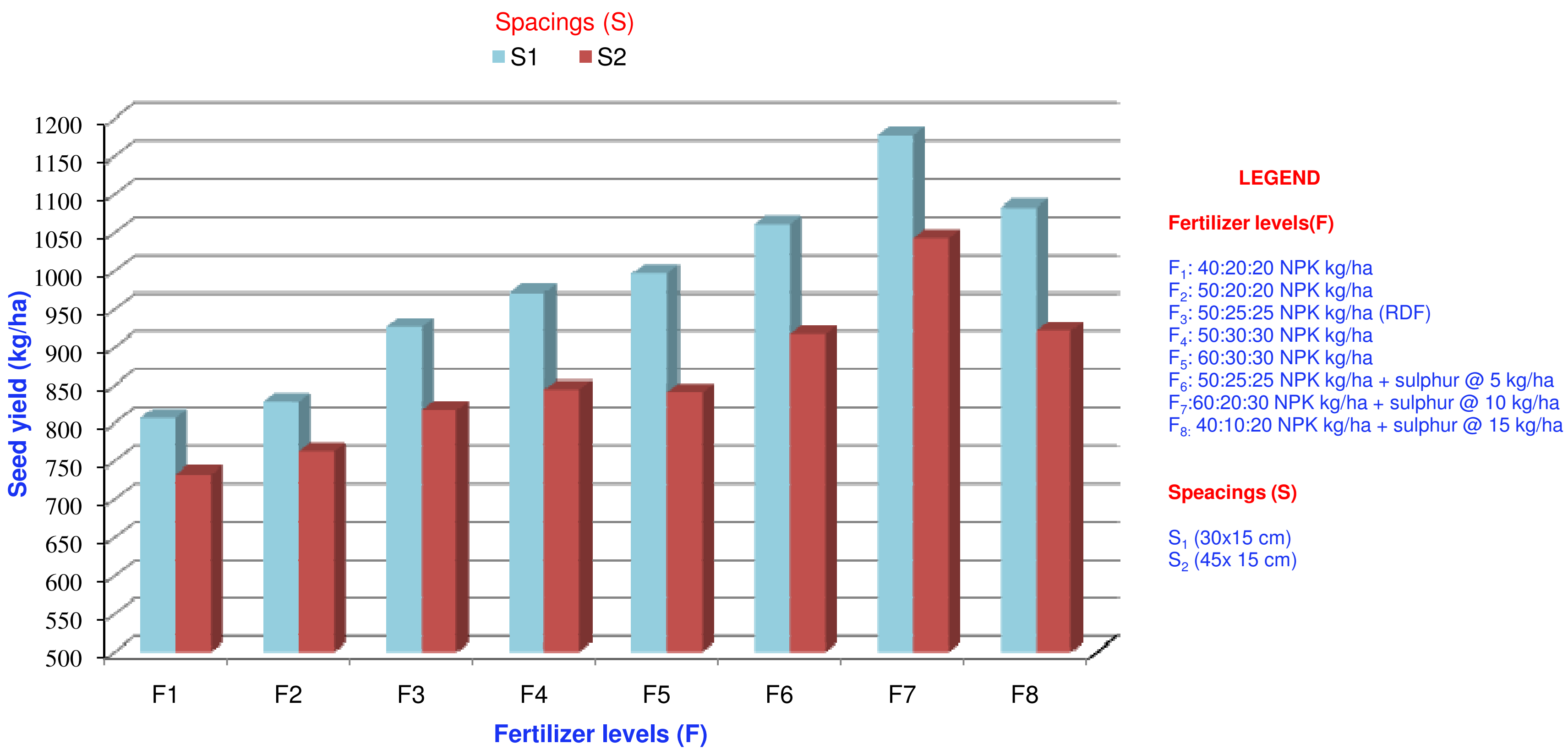

Fig. 4 : Effect of spacing and fertilizer levels on seed yield (kg/ha) in sesame Cv. DS-5

Table 7. Effect of spacing and fertilizer levels on seed multiplication ratio of sesame Cv. DS-5

Fertilizer levels	**Seed multiplication ratio (SMR)**		
	Spacing (cm) (S)		
	S_1	**S_2**	**Mean**
F_1	201.50	183.2	**192.3**
F_2	207.0	190.7	**198.8**
F_3	231.5	204.2	**217.8**
F_4	242.7	211.2	**226.9**
F_5	249.3	210.2	**229.7**
F_6	265.3	228.5	**246.9**
F_7	294.5	260.5	**277.5**
F_8	270.3	230.0	**250.2**
Mean	**245.3**	**214.8**	**230.0**

For comparing the means of	S.Em$\pm$	CD at 5%
S	1.9	5.6
F	3.9	11.2
S x F	1.8	NS

NS – Non significant

Spcings (S)	**Fertilizer levels (F)**	
S_1 (30x15 cm)	F_1 : 40 : 20 : 20 NPK kg/ha	F_5 : 60 : 30 : 30 NPK kg/ha
S_2 (45x 15 cm)	F_2 : 50 : 20 : 20 NPK kg/ha	F_6 : 50 : 25 : 25 NPK kg/ha + sulphur @ 5 kg/ha
	F_3 : 50 : 25 : 25 NPK kg/ha (Rd)	F_7 : 60 : 20 : 30 NPK kg/ha + sulphur @ 10 kg/ha
	F_4 : 50 : 30 : 30 NPK kg/ha	F_8 : 40 : 10 : 20 NPK kg/ha + sulphur @ 15 kg/ha

between spacings and fertilizer levels. However, it was numerically more (295) in S_1xF_7 level and it was less (183) in S_2xF_1 interaction.

4.1.2.9 Net returns (Rs.)

The data on calculated net returns from sesame experimental crop as influenced by spacing, fertilizer levels and their interactions are shown in Table 8.

Spacings (S)

Among the two spacings adopted narrow spacing of 30x15 cm (S_1) recorded the higher net returns of Rs. 64,863 per ha compared to 45x15 cm (S_2) (Rs. 55103) irrespective of fertilizer levels.

Fertilizer levels (F)

Among the different fertilizer levels, the highest net returns of Rs. 74811 per ha was obtained from the 60:20:30 kg NPK per ha + sulphur @ 10 kg/ha (F_7) fertilizer level, followed by F_8 (Rs. 67118/ha), F_6 (Rs. 65256/ha) and F_5 (Rs. 59213/ha) levels and it was the least (Rs. 48529/ha) in 40:20:20 kg NPK per ha irrespective of spacings.

Interaction (SxF)

A treatment combination of S_1xF_7 recorded the highest (Rs. 80,251/ha) net returns followed by S_1xF_8 (Rs. 73,708/ha), S_1xF_6 (Rs. 71,056/ha) interaction while the lowest (45,569/ha) net returns was seen in S_2xF_1 interaction.

4.1.2.10 Benefit cost ratio (B:C)

The data on estimated benefit cost ratio due to spacings, fertilizer levels and their interactions are shown in Table 8 (Fig. 5). An average of 4.40 cost benefit ratio was recorded over spacings and fertilizer levels.

Spacings (S)

Between two spacings adopted more (4.80) cost benefit ratio was registered in narrow spacing of 30x15 cm (S_1) as against wider spacing of 45x15 cm (S_2) (4.00).

Fertilizer levels (F)

Irrespective of spacings, variations of cost benefit ratio were recorded due to different fertilizer levels. It was higher (5.35) ratio in a fertilizer level of 60:20:30 kg NPK per ha + sulphur @ 10 kg/ha (F_7) and it was the lowest (3.70) in 40:20:20 kg NPK per ha (F,) level.

Interaction (SxF)

A treatment combination of S_1xF_7 recorded the highest benefit : cost ratio (5.74) Whereas, the lowest benefit: cost ratio was seen in S_2XF_1 (3.50) interaction treatment.

4.1.2.10 Seed oil content (%)

The data on seed oil content as influenced by spacings, fertilizer levels and their interaction effects are presented in Table 9. On an average seed oil content of 45.38 % was recorded over spacings and fertilizer levels.

Spacings (S)

Seed oil content differed markedly due to spacings over fertilizer levels. Significantly more seed oil content (45.68 %) was recorded in 45x15 cm (S_2) spacing than in 30x15 cm (S_1) (45.07 %) spacing.

Fertilizer levels (F)

Irrespective of spacings, the fertilizer levels depicted the significant variations on seed oil content. It was significantly the highest (46.33 %) in 60:20:30 NPK per ha + sulphur @ 10 kg per ha (F_7) and was on par with F_8 and F_6 (46.30 % and 46.20 %, respectively) However, the least yield was (44.10 %) in 40:20:20 kg NPK/ha) (F_1).

Table 8. Effect of spacing and fertilizer levels on benefit cost ratio in sesame Cv DS-5

Fertilizer levels	Net returns (Rs. /ha)			B:C ratio		
	Spacing (cm) (S)			Spacing (cm) (S)		
	S_1	S_2	Mean	S_1	S_2	Mean
F_1	51489	45569	**48529**	3.96	3.50	**3.70**
F_2	53015	47735	**50375**	4.01	3.60	**3.81**
F_3	60415	51615	**56015**	4.42	3.77	**4.10**
F_4	63514	53434	**58475**	4.50	3.80	**4.20**
F_5	65453	52973	**59213**	4.60	3.72	**4.20**
F_6	71056	59456	**65256**	5.07	4.30	**4.70**
F_7	80251	69371	**74811**	5.74	4.95	**5.35**
F_8	73708	60668	**67188**	5.70	4.70	**5.20**
Mean	**64863**	**55103**	**59983**	**4.80**	**4.00**	**4.40**

For comparing the means of	S.Em±	CD at 5%	S.Em±	CD at 5%
S	NA	NA	NA	NA
F	NA	NA	NA	NA
S x F	NA	NA	NA	NA

NA- Not subjected to statistical analysis

Spcings (S)
S_1 (30x15 cm)
S_2 (45x 15 cm)

Fertilizer levels (F)
F_1 : 40 : 20 : 20 NPK kg/ha
F_2 : 50 : 20 : 20 NPK kg/ha
F_3 : 50 : 25 : 25 NPK kg/ha (Rd)
F_4 : 50 : 30 : 30 NPK kg/ha
F_5 : 60 : 30 : 30 NPK kg/ha
F_6 : 50 : 25 : 25 NPK kg/ha + sulphur @ 5 kg/ha
F_7 : 60 : 20 : 30 NPK kg/ha + sulphur @ 10 kg/ha
F_8 : 40 : 10 : 20 NPK kg/ha + sulphur @ 15 kg/ha

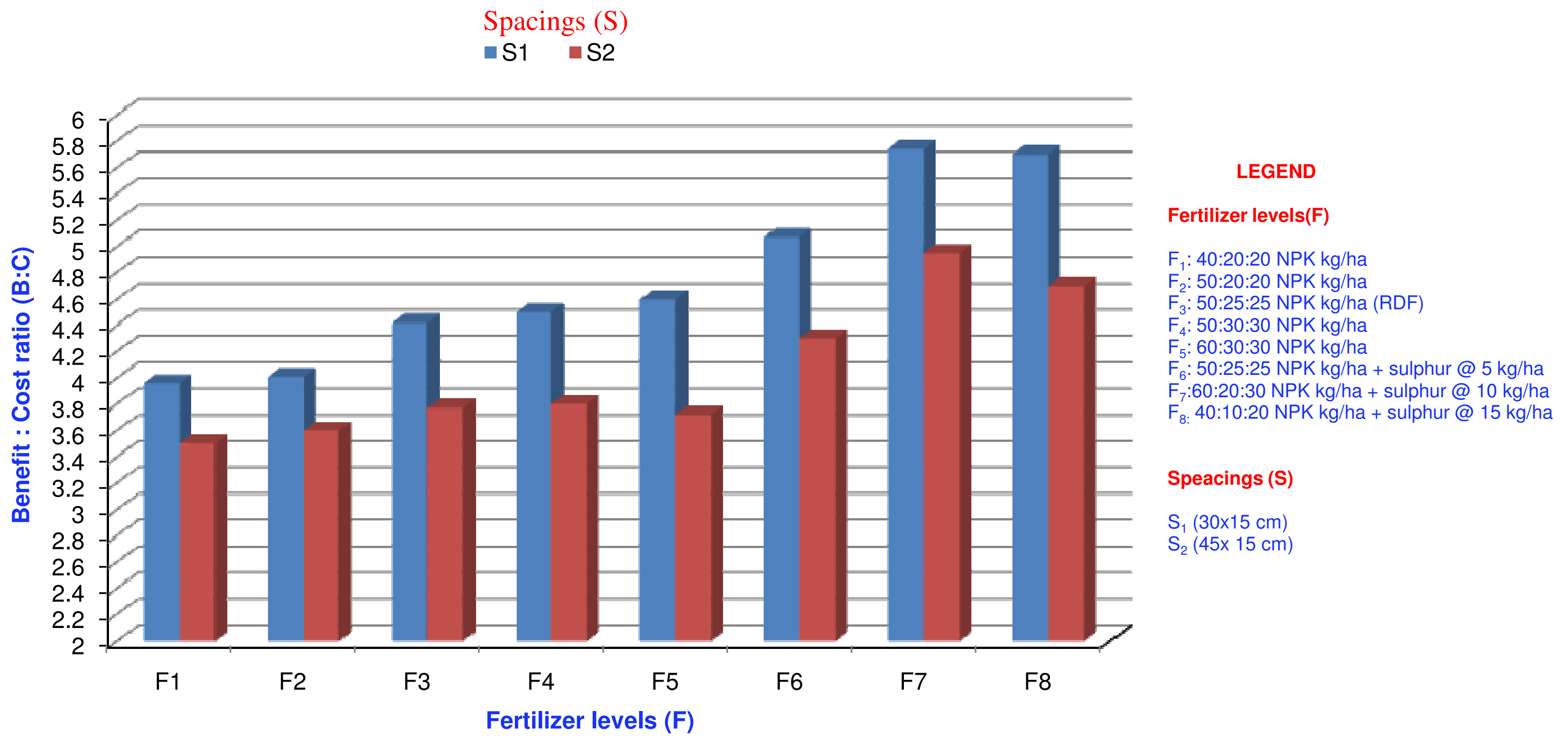

Fig. 5 : Effect of spacing and fertilizer levels on benefit : cost ratio (B:C) in sesame Cv. DS-5

Table 9. Effect of spacing and fertilizer levels on seed oil content (%) in sesame Cv. DS-5

Fertilizer levels	**Oil content (%)**		
	Spacing (cm) (S)		
	S_1	**S_2**	**Mean**
F_1	43.38	44.31	**44.10**
F_2	44.22	44.74	**44.48**
F_3	44.60	45.13	**44.86**
F_4	44.80	45.38	**45.09**
F_5	44.95	46.38	**45.67**
F_6	45.95	46.46	**46.20**
F_7	46.15	46.57	**46.33**
F_8	46.03	46.51	**46.30**
Mean	**45.07**	**45.68**	**45.38**

For comparing the means of	S.Em±	CD at 5%
S	1.9	5.6
F	3.9	11.2
S x F	1.8	NS

NS – Non significant

Spcings (S)
S_1 (30x15 cm)
S_2 (45x 15 cm)

Fertilizer levels (F)
F_1 : 40 : 20 : 20 NPK kg/ha
F_2 : 50 : 20 : 20 NPK kg/ha
F_3 : 50 : 25 : 25 NPK kg/ha (Rd)
F_4 : 50 : 30 : 30 NPK kg/ha
F_5 : 60 : 30 : 30 NPK kg/ha
F_6 : 50 : 25 : 25 NPK kg/ha + sulphur @ 5 kg/ha
F_7 : 60 : 20 : 30 NPK kg/ha + sulphur @ 10 kg/ha
F_8 : 40 : 10 : 20 NPK kg/ha + sulphur @ 15 kg/ha

Interaction (SxF)

The interaction between spacings and fertilizer levels differed significantly for seed oil content. It was significantly maximum (46.57 %) in the S_2xF_7 interaction and minimum was (43.38 %) in S_1xF_1 interaction level.

4.1.3 Seed quality parameters

4.1.3.1 1000 seed weight (g)

The data on 1000 seed weight as influenced by spacings, fertilizer levels and their interaction effects are depicted in Table 10 and depicted in Fig. 6.

Spacings (S)

1000 seed weight differed markedly between the two spacings adopted irrespective of fertilizer levels. Significantly higher 1000 seed weight (3.75 g) was recorded in S_2 (45x15 cm) as against S_1 (30x15 cm) (3.70 g) spacing.

Fertilizer levels (F)

The marked variations on 1000 seed weight were recorded due to the fertilizer levels irrespective of spacings. It was significantly maximum (3.95 g) in a fertilizer level of 60:20:30 NPK per ha + sulphur @ 10 kg per ha (F_7) which was on par with F_8 (40:10:20 kg NPK/ha+ sulphur @ 15 kg/ha) (3.91 g), F_6 (50:25:25 kg NPK/ha+ sulphur @5 kg/ha) (3.91 g) levels while, it was minimum (3.31 g) in 40:20:20 kg NPK per ha (F_1) level.

Interaction (SxF)

Non-significant variations of 1000 seed weight were observed due to interaction between spacings and fertilizer levels. However, it was numerically more (3.97 g) in S_2xF_7 level and it was less (3.29 g) in S_1xF_1 interaction.

4.1.3.2 Germination (%)

The data on germination percentage due to spacings, fertilizer levels and interactions are furnished in Table 10 (Fig. 7). On an average, 91.13 per cent of germination was recorded irrespective of spacings and fertilizer levels

Spacings (S)

Marked variations on germination percentage were noticed due to spacings irrespective of fertilizer levels. Significantly higher (91.63 %) germination was noticed in 45x15 cm (S_2) as against 30x15 cm (S_1) (90.63%) spacing.

Fertilizer levels (F)

Germination percentage revealed marked differences due to fertilizer levels over spacings. It was significantly the highest (92.50 %) in a fertilizer level of 60:20:30 NPK per ha + sulphur @ 10 kg per ha (F_7) which was on par with F_6 (50:25:25 kg NPK/ha+ sulphur @5 kg/ha) (91.50%), F_8 (40:10:20 kg NPK/ha+ sulphur @ 15 kg/ha) (92.00%), F_5 (60:30:30 kg NPK/ha) (91.00%) levels. Whereas, the lowest germination (89.50%) was seen in 40:20:20 kg NPK per ha (F_1) level.

Interaction (SxF)

The statistical differences on germination percentage were non-significant due to SxF interaction effects. It was numerically more (93.50%) in S_2xF_7 and less (89.00 %) in S_1xF_1 interactions.

4.1.3.3 Shoot length (cm)

The data pertaining to shoot length due to the effect of spacings, fertilizer levels and their interactions are revealed in Table 11.

Spacings (S)

Irrespective of fertilizer levels, shoot length differed significantly due to spacings. A wider spacing 45x15 cm (S_2) recorded significantly more root length (9.30 cm) than narrow spacing of 30x15 cm (S_1) (9.28 cm).

Table 10. Effect of spacing and fertilizer levels on 1000 seed weight (g) and seed germination percentage in sesame Cv. DS-5

Fertilizer levels	1000 seed weight (g)			Seed germination (%)		
	Spacing (cm) (S)			Spacing (cm) (S)		
	S_1	S_2	Mean	S_1	S_2	Mean
F_1	3.29	3.32	**3.31**	89.00 (70.68)*	90.00 (71.62)	**89.50 (71.15)**
F_2	3.34	3.43	**3.39**	90.00 (71.62)	91.00 (72.60)	**90.50 (72.11)**
F_3	3.71	3.76	**3.74**	90.75 (72.35)	91.75 (73.37)	**91.25 (72.86)**
F_4	3.79	3.84	**3.82**	90.25 (71.86)	91.25 (72.85)	**90.75 72.35**
F_5	3.81	3.88	**3.85**	90.50 (72.10)	91.50 (73.10)	**91.00 (72.60)**
F_6	3.90	3.92	**3.91**	91.00 (72.60)	92.00 (73.61)	**91.50 (73.10)**
F_7	3.93	3.97	**3.95**	92.00 (73.63)	93.00 (74.72)	**92.50 (74.17)**
F_8	3.91	3.91	**3.91**	91.50 (73.10)	92.50 (74.17)	**92.00 73.63**
Mean	**3.70**	**3.75**	**3.73**	**90.63 (72.24)**	**91.63 (73.25)**	**91.13 (72.74)**

For comparing the means of	S.Em±	CD at 5%	S.Em±	CD at 5%
S	0.01	0.04	0.21	0.80
F	0.02	0.09	0.42	1.61
S x F	0.03	0.09	0.59	2.28

* Figures in the parenthesis are arcsine values NS – Non significant

Spcings (S)
S_1 (30x15 cm)
S_2 (45x 15 cm)

Fertilizer levels (F)
F_1 : 40 : 20 : 20 NPK kg/ha
F_2 : 50 : 20 : 20 NPK kg/ha
F_3 : 50 : 25 : 25 NPK kg/ha (Rd)
F_4 : 50 : 30 : 30 NPK kg/ha
F_5 : 60 : 30 : 30 NPK kg/ha
F_6 : 50 : 25 : 25 NPK kg/ha + sulphur @ 5 kg/ha
F_7 : 60 : 20 : 30 NPK kg/ha + sulphur @ 10 kg/ha
F_8 : 40 : 10 : 20 NPK kg/ha + sulphur @ 15 kg/ha

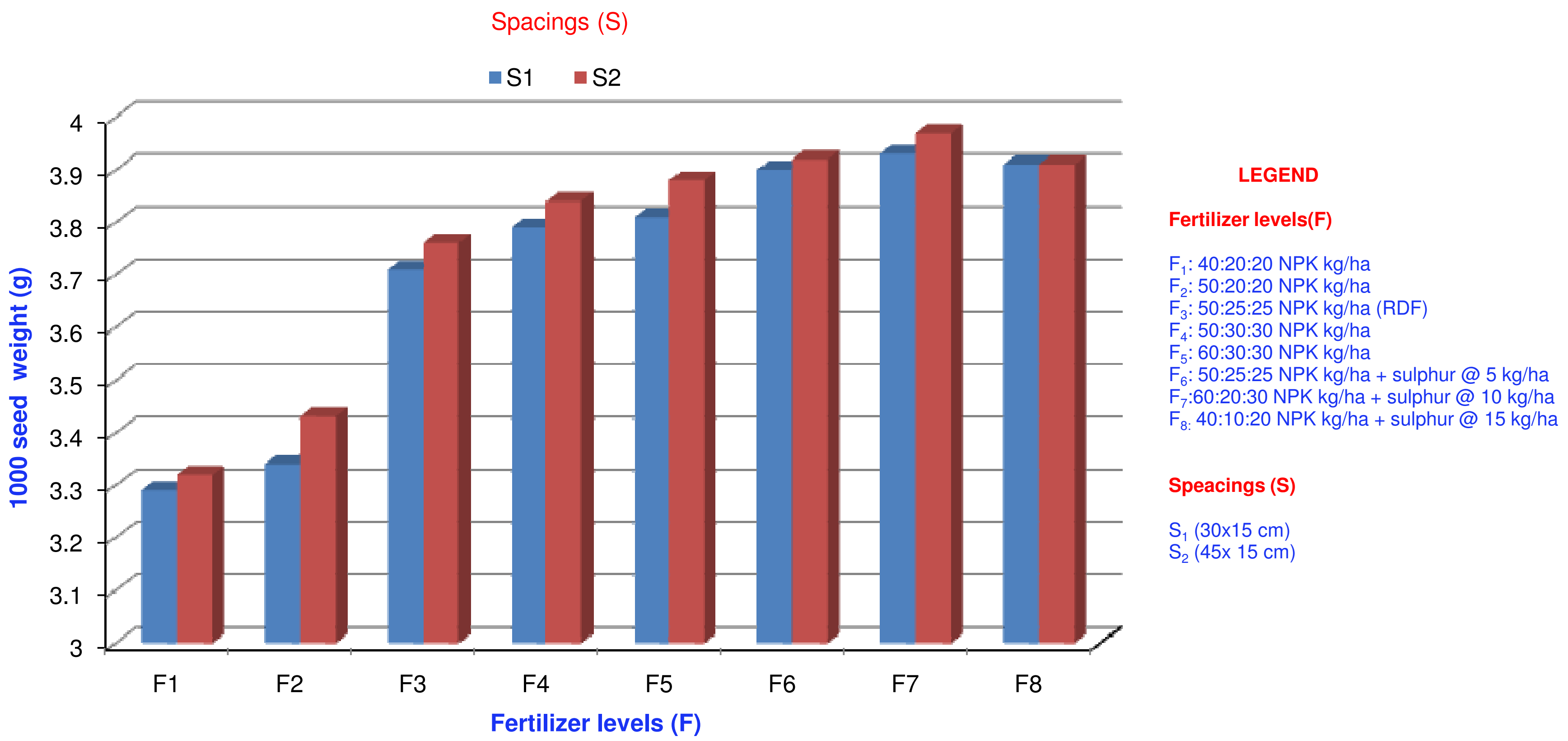

Fig. 6: Effect of spacing and fertilizer levels on 1000 seed weight (g) in sesame Cv. DS-5

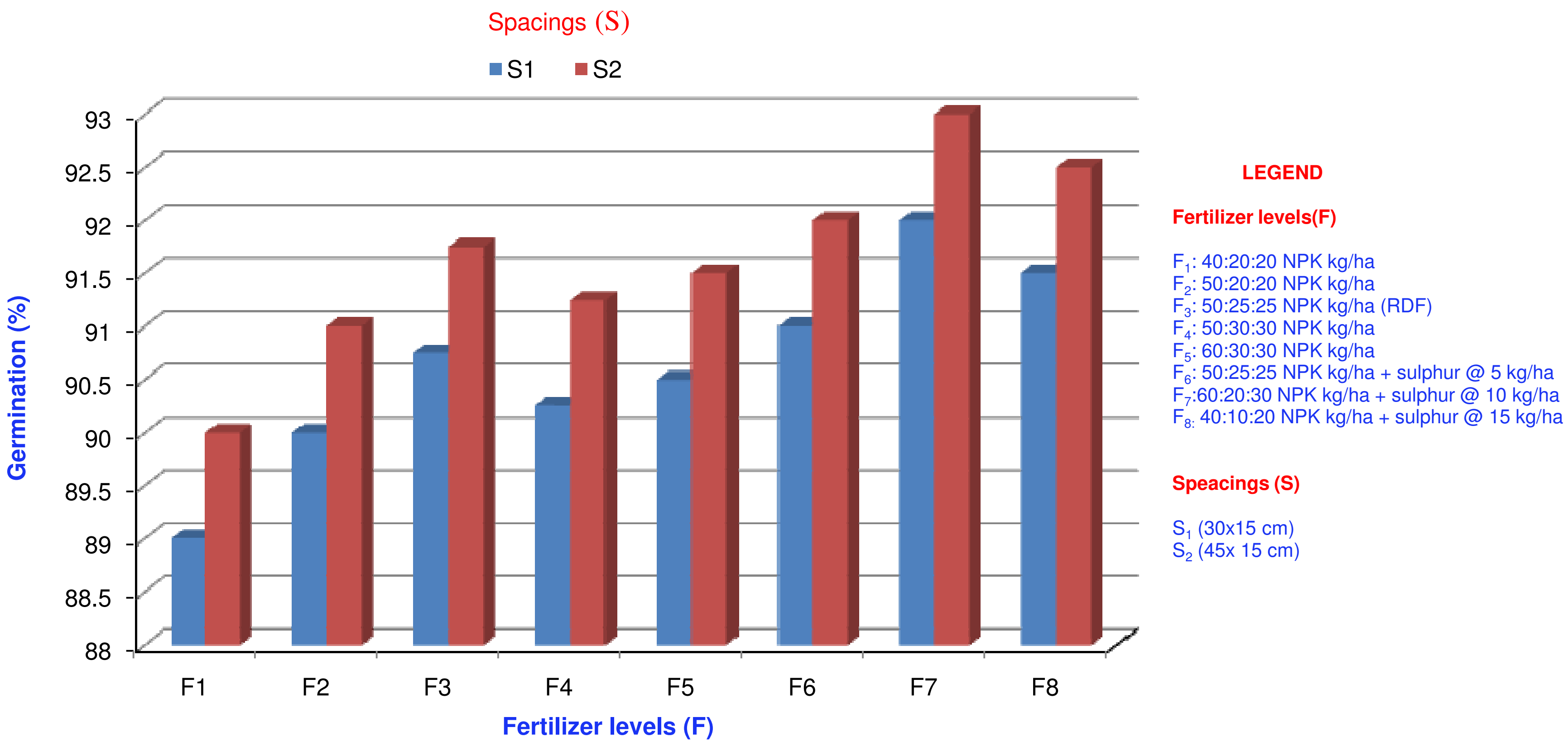

Fig. 7 : Effect of spacing and fertilizer levels on germination (%) in sesame Cv. DS-5

Fertilizer levels (F)

The significant differences on shoot length were seen due to fertilizer levels irrespective of spacings. It was significantly the highest (9.49 cm) in 60:20:30 NPK per ha + sulphur @ 10 kg per ha (F_7). But, it differed significantly with rest of the fertilizer levels. the lowest (9.15 cm) was recorded in 40:20:20 kg NPK per ha (F_1) level.

Interaction (SxF)

The interaction between spacings and fertilizer levels revealed non-significant differences on shoot length. It was numerically more (9.52 cm) and less (9.14 cm) in the treatment combinations of S_2xF_7 and S_1xF_1 levels, respectively.

4.1.3.4 Root length (cm)

The statistical differences on root length due to spacings and fertilizer levels except their interactions were found to be significant, as shown in Table 11.

Spacings (S)

Irrespective of fertilizer levels, root length differed significantly due to spacings. A wider spacing 45x15 cm (S_2) recorded significantly more root length (10.10 cm) than narrow spacing of 30x15 cm (S_1) (10.06 cm).

Fertilizer levels (F)

The significant differences on root length were seen due to fertilizer levels irrespective of spacings. It was significantly the highest (10.33 cm) in 60:20:30 NPK per ha + sulphur @ 10 kg per ha (F_7). But, it differed significantly with rest of the fertilizer levels. The lowest (9.93 cm) was recorded in 40:20:20 kg NPK per ha (F_1) level.

Interaction (SxF)

The interaction between spacings and fertilizer levels revealed non-significant differences on root length. It was numerically more (10.36 cm) and less (9.92 cm) in the treatment combinations of S_2xF_7 and S_1xF_1 levels, respectively.

4.1.3.5 Seedling vigour index (SVI)

The data on seedling vigour index as influenced by spacings, fertilizer levels and interaction effects are presented in Table 11. On an average, 1727 seedling vigour index was recorded over spacings and fertilizer levels.

Spacings (S)

Seedling vigour index varied markedly due to spacings irrespective of fertilizer levels. A wider spacing of 45x15 cm (S_2) recorded significantly more (1776) vigour index than narrow spacing of 30x15 cm(S_1) (1678).

Fertilizer levels (F)

Among the different fertilizer levels irrespective of spacings adopted significantly the highest (1765) vigour index was recorded in 60:20:30 NPK per ha + sulphur @ 10 kg per ha (F_7) But, it differed significantly with rest of the fertilizer levels. The lowest (1687) was recorded in 40:20:20 kg NPK per ha (F_1) level.

Interaction (SxF)

The interaction between spacings and fertilizer levels revealed non-significant differences on seedling vigour index. It was numerically more (1820) and less (1644) in the treatment combinations of S_2xF_7 and S_1xF_1 levels, respectively.

4.1.3.6 Seedling dry weight (mg)

The data on seedling dry weight as influenced by spacings, fertilizer levels and their interaction effects are presented in Table 12.

Table 11. Effect of spacing and fertilizer levels on shoot length (cm), root length (cm) and seedling vigour index in sesame Cv. DS-5

Fertilizer levels	Shoot length (cm)			Root length (cm)			Seedling vigour index		
	Spacing (cm) (S)			Spacing (cm) (S)			Spacing (cm) (S)		
	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean
F_1	9.14	9.16	**9.15**	9.92	9.94	**9.93**	1644	1730	**1687**
F_2	9.20	9.21	**9.21**	9.99	10.00	**9.99**	1653	1749	**1701**
F_3	9.25	9.27	**9.26**	10.03	10.05	**10.04**	1686	1784	**1735**
F_4	9.25	9.25	**9.25**	10.03	10.04	**10.03**	1664	1764	**1714**
F_5	9.25	9.26	**9.26**	10.03	10.05	**10.04**	1670	1770	**1720**
F_6	9.28	9.31	**9.30**	10.04	10.07	**10.06**	1687	1795	**1741**
F_7	9.45	9.52	**9.49**	10.30	10.36	**10.33**	1710	1820	**1765**
F_8	9.42	9.41	**9.42**	10.20	10.22	**10.21**	1711	1800	**1756**
Mean	**9.28**	**9.30**	**9.29**	**10.06**	**10.10**	**10.08**	**1678**	**1776**	**1727**

For comparing the means of	Shoot length S.Em±	Shoot length CD at 5%	Root length S.Em±	Root length CD at 5%	Seedling vigour index S.Em±	Seedling vigour index CD at 5%
S	0.003	0.01	0.003	0.01	0.95	3.70
F	0.005	0.02	0.005	0.02	1.91	7.39
S x F	0.008	NS	0.008	NS	2.70	NS

NS – Non significant

Spcings (S)
S_1 (30x15 cm)
S_2 (45x 15 cm)

Fertilizer levels (F)
F_1 : 40 : 20 : 20 NPK kg/ha
F_2 : 50 : 20 : 20 NPK kg/ha
F_3 : 50 : 25 : 25 NPK kg/ha (Rd)
F_4 : 50 : 30 : 30 NPK kg/ha
F_5 : 60 : 30 : 30 NPK kg/ha
F_6 : 50 : 25 : 25 NPK kg/ha + sulphur @ 5 kg/ha
F_7 : 60 : 20 : 30 NPK kg/ha + sulphur @ 10 kg/ha
F_8 : 40 : 10 : 20 NPK kg/ha + sulphur @ 15 kg/ha

Spacings (S)

Seedling dry weight showed marked variations between the two spacings adopted over fertilizer levels. Significantly higher (21.20 mg) seedling dry weight was noticed in 45x15 cm (S_2) compared to 30x15 cm (S_1) spacing (20.66 mg).

Fertilizer levels (F)

Among the different fertilizer levels followed, significantly maximum (23.40 mg) seedling dry weight was noticed in 60:20:30 NPK per ha + sulphur @ 10 kg per ha (F_7), which was statistically at par with F_8 (23.14 mg). However, it was significantly minimum (17.83 mg) in 40:20:20 kg NPK per ha (F_1) levels.

Interaction (SxF)

The interaction effect between spacings and fertilizer levels did not show significant variations on seedling dry weight. The S_2xF_7 and S_1xF_1 treatment combinations recorded numerically more (23.70 mg) and less (17.75 mg) seedling dry weight, respectively.

4.1.3.8 Electrical conductivity of seed leachate (dSm^{-1})

The data pertaining to electrical conductivity as influenced by spacings, fertilizer levels and their interaction effects are shown in Table 12.

Spacings (S)

Electrical conductivity was found to be non-significant due to spacings over fertilizer levels. It was numerically more (0.670 dSm^{-1}) and less (0.659 dSm^{-1}) in 30x15 cm (S_1) and 45x15 cm (S_2) spacings, respectively.

Fertilizer levels (F)

The statistical variations for electrical conductivity were found to be significant due to fertilizer levels over spacings. A fertilizer level of 40:20:20 kg NPK per ha recorded significantly the highest (0.796 dSm^{-1}) electrical conductivity followed by 50:20:20 kg NPK per ha (F_2) (0.733 dSm^{-1}). Whereas, it was the least (0.518 dSm^{-1}) at 60:20:30 NPK per ha + sulphur @ 10 kg per ha (F_7) fertilizer level.

Interaction (SxF)

Non-significant variations on electrical conductivity were seen for the interaction between spacings and fertilizer levels. Numerically more (0.803 dSm^{-1}) and less (0.513 dSm^{-1}) electrical conductivity were seen in S_1xF_1 and S_2xF_7 interaction levels, respectively.

4.2 Experiment II : Effect of mother plant nutrition on seed storability of sesame Cv. DS-5 under ambient condition

4.2.1 Seed moisture content (%)

The data pertaining to seed moisture content (Table 14 and Fig. 9) due to application of different fertilizer levels in field did not differ significantly during entire storage period of six months from the initial month. In general, seed moisture content (%) increased progressively with the advancement of storage period upto third month and decreased from fourth month to six month. Among the treatments, the seeds produced by the application of a fertilizer level of 60:20:30 NPK per ha + sulphur @ 10 kg per ha (F_7) recorded consistently lower values for seed moisture content (%) from first month upto six month of storage (8.49, 8.65, 9.13, 9.36, 8.82, 8.68 and 8.54 respectively). Further more, higher values for seed moisture content were observed in the fertilizer level of 40;20;20 NPK kg/ha (8.63, 8.91,9.37, 9.68, 9.17, 9.10 and 8.98 respectively) from initial to six months of storage

4.2.2 Germination (%)

The data on effect of mother plant nutrition on germination percentage during storage (six months) period as influenced by mother plant nutrition are presented in Table 15 and depicted in Fig. 10.

Table 12. Effect of spacing and fertilizer levels on seedling dry weight (mg) and electrical conductivity (dSm^{-1}) in sesame Cv. DS-5

Fertilizer levels	Seedling dry weight (mg)			Electrical conductivity (dSm^{-1})		
	Spacing (cm) (S)			Spacing (cm) (S)		
	S_1	**S_2**	**Mean**	**S_1**	**S_2**	**Mean**
F_1	17.75	17.91	17.83	0.803	0.790	**0.796**
F_2	18.56	19.00	18.78	0.740	0.727	**0.733**
F_3	21.12	21.70	21.41	0.657	0.647	**0.652**
F_4	19.10	19.79	19.45	0.707	0.693	**0.700**
F_5	20.86	21.40	21.13	0.670	0.663	**0.667**
F_6	21.97	22.50	22.23	0.633	0.623	**0.628**
F_7	23.11	23.70	23.40	0.523	0.513	**0.518**
F_8	22.88	23.60	23.14	0.617	0.607	**0.612**
Mean	**20.66**	**21.20**	**20.93**	**0.670**	**0.659**	**0.660**

For comparing the means of	S.Em$\pm$	CD at 5%	S.Em$\pm$	CD at 5%
S	0.05	0.17	0.003	NS
F	0.09	0.34	0.005	0.021
S x F	0.13	0.48	0.008	NS

NS – Non significant

Spcings (S)
S_1 (30x15 cm)
S_2 (45x 15 cm)

Fertilizer levels (F)
F_1 : 40 : 20 : 20 NPK kg/ha
F_2 : 50 : 20 : 20 NPK kg/ha
F_3 : 50 : 25 : 25 NPK kg/ha (Rd)
F_4 : 50 : 30 : 30 NPK kg/ha
F_5 : 60 : 30 : 30 NPK kg/ha
F_6 : 50 : 25 : 25 NPK kg/ha + sulphur @ 5 kg/ha
F_7 : 60 : 20 : 30 NPK kg/ha + sulphur @ 10 kg/ha
F_8 : 40 : 10 : 20 NPK kg/ha + sulphur @ 15 kg/ha

Table 13. Effect of mother plant nutrition on seed infestation (%) of sesame Cv. DS-5 under ambient condition of storage

Treatments	Storage period (months)						
	Initial	1	2	3	4	5	6
F_1: 40:20:20 NPK kg/ha	0.00	0.00	1.68	3.19	9.26	15.28	23.08
F_2: 50:20:20 NPK kg/ha	0.00	0.00	1.60	3.04	8.82	14.56	21.98
F_3: 50:25:25 NPK kg/ha (RDF)	0.00	0.00	1.58	3.00	8.71	14.37	21.71
F_4: 50:30:30 NPK kg/ha	0.00	0.00	1.40	2.66	7.72	12.74	19.23
F_5: 60:30:30 NPK kg/ha	0.00	0.00	1.20	2.28	6.62	10.92	16.49
F_6: 50:25:25 NPK kg/ha + sulphur @ 5 kg/ha	0.00	0.00	1.00	1.90	5.51	9.10	13.74
F_7:60:20:30 NPK kg/ha + sulphur @ 10 kg/ha	0.00	0.00	0.60	1.14	3.31	5.46	8.24
$F_{8:}$ 40:10:20 NPK kg/ha + sulphur @ 15 kg/ha	0.00	0.00	0.80	1.52	4.41	7.28	10.99
Mean	**0.00**	**0.00**	**1.23**	**2.34**	**6.80**	**11.21**	**16.93**
S.Em ±	-	-	0.17	0.25	0.41	0.55	0.56
C.D.(0.01)	NA	NA	0.69	1.00	1.66	2.19	2.25

NA- Not statistically analyzed

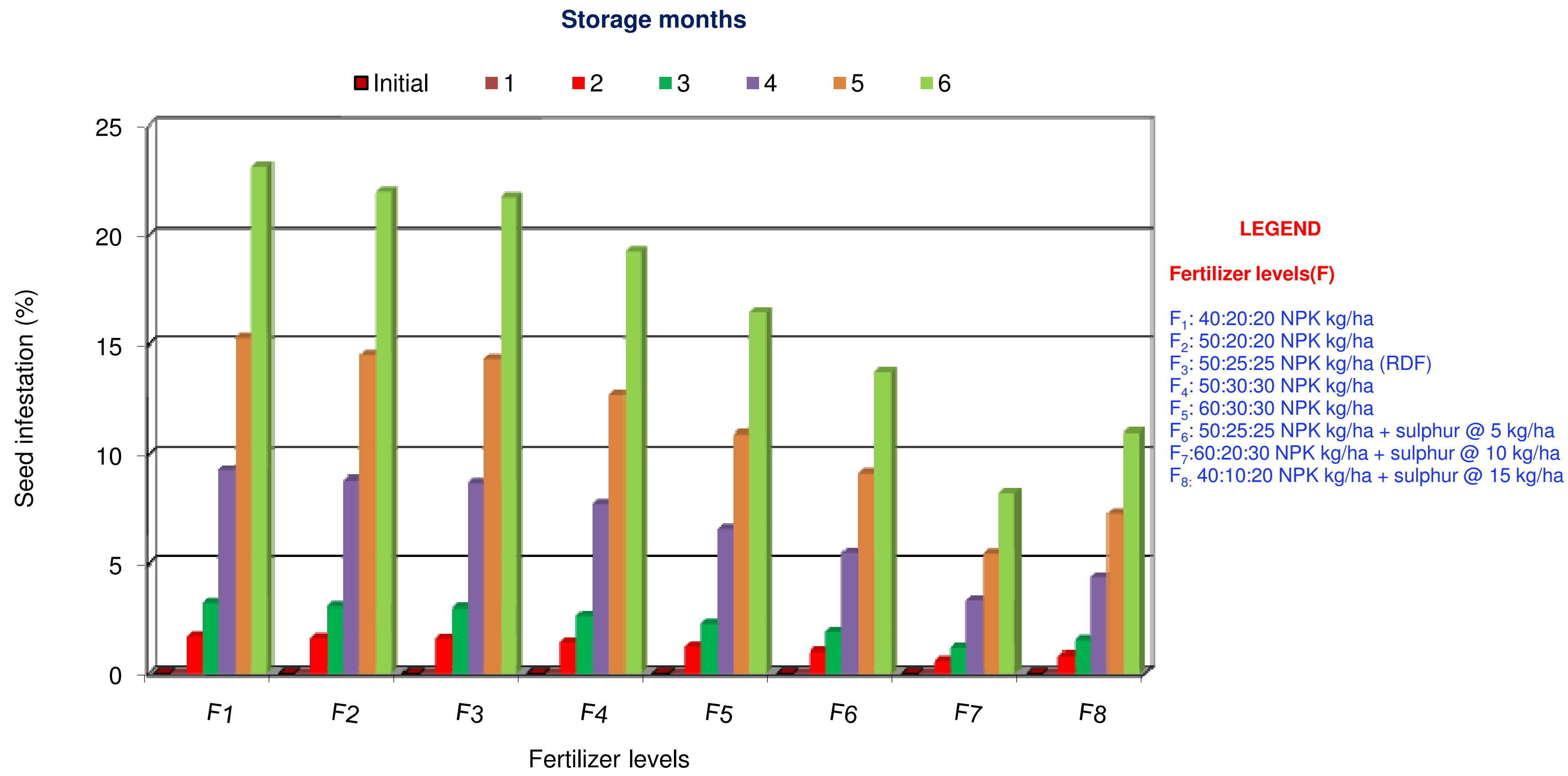

Fig. 8 : Effect of mother plant nutrition on seed infestation (%) of sesame cv. DS-5 under ambient condition of storage

There was gradual loss of germination from first month (91.71%) to six month (71.92%)of storage. Initially, there was no significant difference among the treatments with respect to germination percentage upto second month of storage.

Among the treatments, a fertilizer level of 60:20:30 NPK per ha + sulphur @ 10 kg per ha (F_7) recorded significantly highest germination from third month upto six month of storage (88.25%, 82.50%, 79.25% and 76.50% respectively) which was on par with F_8 (40:10:20 NPK kg/ha + sulphur @ 15 kg/ ha), F_6 (50;25:25 NPK kg/ha + sulphur @ 5 kg/ha), F_4 (50:30:30 NPK Kg/ha), F_5 (60;30:30 NPK Kg/ha) and F_3 (50:25:25 NPK Kg/ha). Significantly lowest germination was observed in the fertilizer level of 40;20;20 NPK Kg/ha (80.25%, 77.25% 68.50% and 64.75%, respectively) from 3, 4, 5 and 6 months of storage.

4.2.3 Shoot length (cm)

The data on effect of mother plant nutrition on shoot length during storage (six months) period as influenced by mother plant nutrition are presented in Table 16.

There was gradual reduction in the shoot length from first month(9.34 cm) to six month (8.16 cm) of storage. Initially, there was no significant difference among the treatments with respect to shoot length. There was significant reduction with respect to shoot length from first month of storage upto six months. Among the treatments, a fertilizer level of 60:20:30 NPK per ha + sulphur @ 10 kg per ha (F_7) recorded significantly highest shoot length from first month upto six month of storage (9.62 cm, 9.14 cm, 9.05 cm, 8.96 cm and 8.79 cm respectively) which was on par with F_8 (40:10:20 NPK kg/ha + sulphur @ 15 kg/ ha), F_6 (50;25:25 NPK kg/ha + sulphur @ 5 kg/ha), F_4 (50:30:30 NPK Kg/ha), F_5 (60;30:30 NPK Kg/ha) and F_3 (50:25:25 NPK Kg/ha). Significantly lowest values for shoot length were observed in the fertilizer level of 40;20;20 NPK Kg/ha (8.91 cm, 8.46 cm, 8.38 cm, 8.30 cm, 8.14 cm and 7.84 cm respectively) from first to six months of storage.

4.2.4 Root length (cm)

The data on effect of mother plant nutrition on root length during storage (six months) period as influenced by mother plant nutrition are presented in Table 17.

There was gradual reduction in the root length from first month to six months of storage. Initially when the seeds were tested, there was no significant difference among the treatments with respect to root length and then there was significant reduction with respect to root length from first month (9.50 cm) of storage upto six months (8.67 cm). Among the treatments, a fertilizer level of 60:20:30 NPK per ha + sulphur @ 10 kg per ha (F_7) recorded significantly highest root length from first month upto six month of storage (9.86 cm, 9.37 cm, 9.27 cm, 9.18 cm, 9.09 cm and 9.00 cm respectively) which was on par with F_8 (40:10:20 NPK kg/ha + sulphur @ 15 kg/ ha), F_6 (50;25:25 NPK kg/ha + sulphur @ 5 kg/ha), F_4 (50:30:30 NPK Kg/ha), F_5 (60;30:30 NPK Kg/ha) and F_3 (50:25:25 NPK Kg/ha). Significantly lowest values for root length were observed in the fertilizer level of 40;20;20 NPK Kg/ha (9.13 cm, 8.67 cm, 8.59 cm, 8.50 cm, 8.42 cm and 8.33 cm, respectively) from first to six months of storage.

4.2.5 Seedling vigour index

The data indicated that the seedling vigour index (Table 18 and Fig. 11) due to foliar mother plant nutrition in the field did differ significantly during storage period of six months except for initial and first month of storage. In general seedling vigour index was declined progressively with the advancement of storage period. Among the treatments, a fertilizer level of 60:20:30 NPK per ha + sulphur @ 10 kg per ha (F_7) recorded significantly highest seedling vigour index from second month upto six month of storage (1675, 1617, 1496, 1417 and 1336 respectively) which was on par with F_8 (40:10:20 NPK kg/ha + sulphur @ 15 kg/ ha), F_6 (50;25:25 NPK kg/ha + sulphur @ 5 kg/ha), F_4 (50:30:30 NPK Kg/ha), F_5 (60;30:30 NPK Kg/ha) and F_3 (50:25:25 NPK Kg/ha). Significantly lowest values for seedling vigour index were observed in the fertilizer level of 40;20;20 NPK Kg/ha (1465, 1362, 1298, 1134 and 1047 respectively) from second to six months of storage.

4.2.6 Seedling dry weight (mg 10^{-1} seedlings)

The data pertaining to seedling dry weight presented in the Table 19 indicated significant differences between the treatments during the storage from the initial month itself. The seeds produced by the application of a fertilizer level of 60:20:30 NPK per ha + sulphur @ 10 kg per ha (F_7) recorded significantly highest seedling dry weight for ten seedlings analysed from initial month upto six month of storage(23.69 mg, 23.23 mg, 22.49 mg, 21.91mg, 20.90 mg, 19.80 mg and 18.37 mg,

Table 14. Effect of mother plant nutrition on seed moisture content (%) of sesame cv.DS-5 under ambient condition of storage

Treatments	Storage period (months)						
	Initial	**1**	**2**	**3**	**4**	**5**	**6**
F_1: 40:20:20 NPK kg/ha	8.63	8.91	9.37	9.68	9.17	9.10	8.98
F_2: 50:20:20 NPK kg/ha	8.59	8.86	9.29	9.58	9.10	9.00	8.81
F_3: 50:25:25 NPK kg/ha (RDF)	8.56	8.73	9.19	9.37	8.91	8.81	8.69
F_4: 50:30:30 NPK kg/ha	8.58	8.82	9.31	9.51	9.07	8.92	8.84
F_5: 60:30:30 NPK kg/ha	8.58	8.78	9.27	9.47	9.00	8.89	8.78
F_6: 50:25:25 NPK kg/ha + sulphur @ 5 kg/ha	8.55	8.75	9.22	9.42	8.99	8.87	8.72
F_7:60:20:30 NPK kg/ha + sulphur @ 10 kg/ha	8.49	8.65	9.13	9.36	8.82	8.68	8.54
$F_{8:}$ 40:10:20 NPK kg/ha + sulphur @ 15 kg/ha	8.54	8.69	9.16	9.32	8.86	8.71	8.63
Mean	**8.56**	**8.77**	**9.24**	**9.46**	**8.99**	**8.87**	**8.75**
S.Em ±	0.13	0.12	0.16	0.18	0.16	0.19	0.15
C.D.(0.01)	NS	NS	NS	NS	NS	NS	NS

NS- Non significant

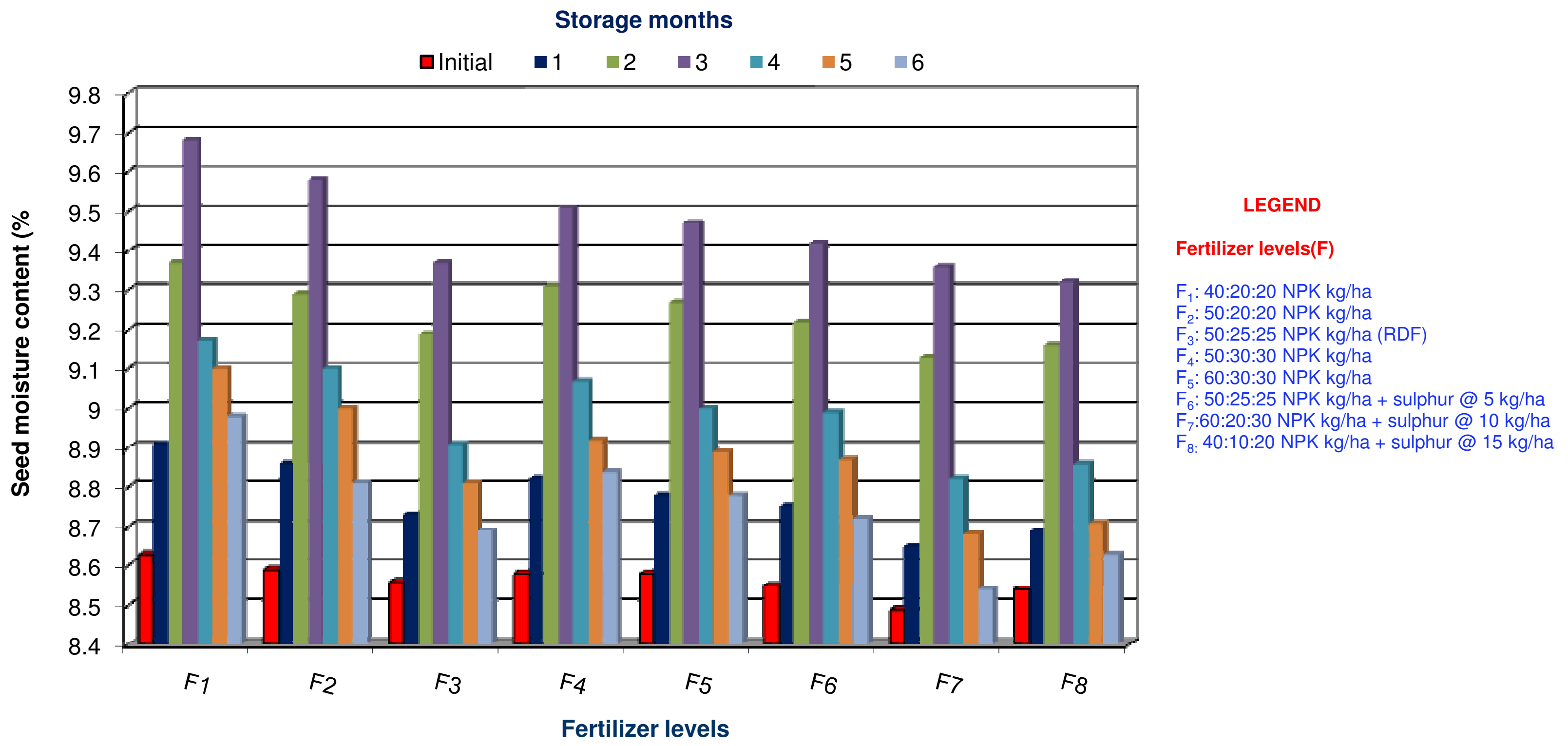

Fig. 9 : Effect of mother plant nutrition on moisture content (%) of sesame cv. DS-5 under ambient condition of storage

Table 15. Effect of mother plant nutrition on seed germination (%) of sesame cv.DS-5 under ambient condition of storage

Treatments	Storage period (months)						
	Initial	**1**	**2**	**3**	**4**	**5**	**6**
F_1: 40:20:20 NPK kg/ha	90.00 (71.55)	88.25 (69.64)	85.50 (67.59)	80.25 (63.59)	77.25 (61.49)	68.50 (55.84)	64.75 (53.56)
F_2: 50:20:20 NPK kg/ha	91.00 (72.54)	89.25 (70.84)	86.25 (68.22)	82.50 (65.25)	78.00 (62.01)	75.25 (60.14)	69.25 (56.30)
F_3: 50:25:25 NPK kg/ha (RDF)	91.75 (73.25)	90.50 (72.05)	88.50 (70.15)	85.50 (67.59)	79.50 (63.05)	76.50 (60.98)	73.25 (58.83)
F_4: 50:30:30 NPK kg/ha	91.25 (72.75)	90.00 (71.55)	89.50 (71.05)	84.50 (66.80)	78.50 (62.35)	75.75 (60.48)	71.50 (57.71)
F_5: 60:30:30 NPK kg/ha	91.50 (73.03)	90.00 (71.55)	86.75 (68.64)	83.25 (65.82)	79.00 (62.70)	76.00 (60.64)	70.25 (56.92)
F_6: 50:25:25 NPK kg/ha + sulphur @ 5 kg/ha	92.00 (73.55)	90.50 (72.02)	89.00 (70.61)	86.25 (68.22)	80.00 (63.41)	77.50 (61.67)	74.50 (59.65)
F_7:60:20:30 NPK kg/ha + sulphur @ 10 kg/ha	93.00 (74.82)	92.25 (73.81)	90.50 (72.02)	88.25 (69.94)	82.50 (65.26)	79.25 (63.25)	76.50 (60.98)
$F_{8:}$ 40:10:20 NPK kg/ha + sulphur @ 15 kg/ha	92.50 (74.10)	91.50 (73.03)	89.75 (71.30)	87.25 (69.06)	81.25 (64.32)	78.25 (62.18)	75.25 (60.14)
Mean	**91.71 (73.25)**	**90.28 (71.85)**	**88.22 (69.95)**	**84.72 (67.03)**	**79.50 (63.07)**	**75.95 (60.64)**	**71.92 (58.01)**
S.Em ±	1.40	1.70	1.25	1.60	1.34	1.39	1.37
C.D.(0.01)	NS	NS	NS	6.50	5.35	5.59	5.49

NS- Non significant *Figures in the parenthesis are arcsine values

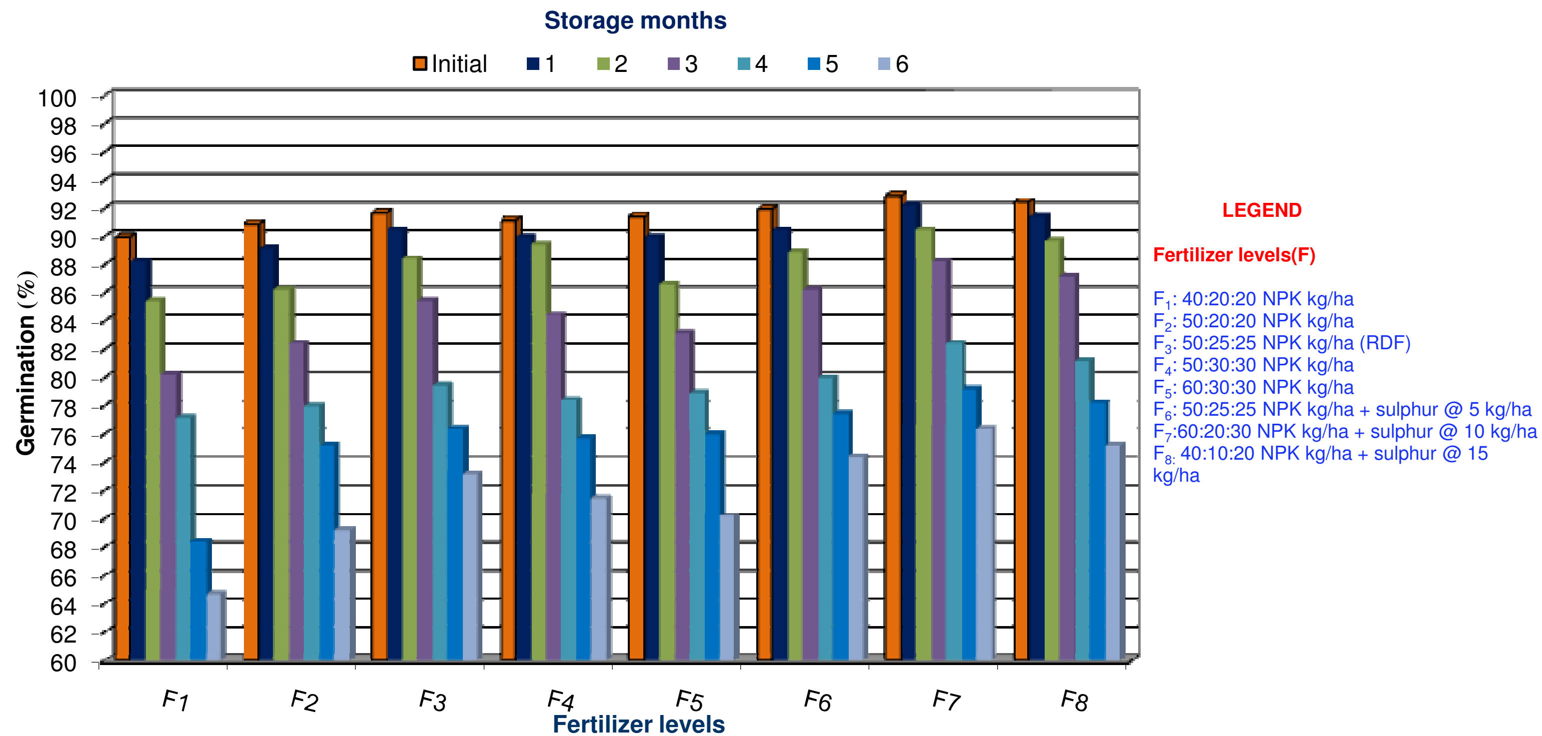

Fig. 10 : Effect of mother plant nutrition on germination (%) of sesame cv. DS-5 under ambient condition of storage

Table 16 Effect of mother plant nutrition on shoot length of seeds sesame cv.DS-5 under ambient condition of storage

Treatments	Storage period (months)						
	Initial	**1**	**2**	**3**	**4**	**5**	**6**
F_1: 40:20:20 NPK kg/ha	9.20	8.91	8.46	8.38	8.30	8.14	7.84
F_2: 50:20:20 NPK kg/ha	9.26	9.02	8.57	8.48	8.40	8.24	7.94
F_3: 50:25:25 NPK kg/ha (RDF)	9.31	9.35	8.88	8.79	8.70	8.54	8.23
F_4: 50:30:30 NPK kg/ha	9.28	9.10	8.65	8.56	8.48	8.32	8.01
F_5: 60:30:30 NPK kg/ha	9.29	9.20	8.74	8.65	8.57	8.41	8.10
F_6: 50:25:25 NPK kg/ha + sulphur @ 5 kg/ha	9.33	9.42	8.95	8.86	8.77	8.60	8.29
F_7:60:20:30 NPK kg/ha + sulphur @ 10 kg/ha	9.61	9.62	9.14	9.05	8.96	8.79	8.47
$F_{8:}$ 40:10:20 NPK kg/ha + sulphur @ 15 kg/ha	9.42	9.52	9.05	8.96	8.87	8.70	8.38
Mean	**9.34**	**9.27**	**8.80**	**8.72**	**8.63**	**8.47**	**8.16**
S.Em ±	0.34	0.22	0.24	0.18	0.22	0.21	0.17
C.D.(0.01)	NS	0.88	0.98	0.72	0.88	0.83	0.66

NS- Non significant

Table 17. Effect of mother plant nutrition on root length of sesame cv.DS-5 seeds under ambient condition of storage

Treatments	Storage period (months)						
	Initial	1	2	3	4	5	6
F_1: 40:20:20 NPK kg/ha	9.94	9.13	8.67	8.59	8.50	8.42	8.33
F_2: 50:20:20 NPK kg/ha	10.00	9.24	8.78	8.69	8.60	8.52	8.43
F_3: 50:25:25 NPK kg/ha (RDF)	10.06	9.58	9.10	9.01	8.92	8.83	8.74
F_4: 50:30:30 NPK kg/ha	10.03	9.33	8.86	8.77	8.69	8.60	8.51
F_5: 60:30:30 NPK kg/ha	10.04	9.43	8.96	8.87	8.78	8.69	8.61
F_6: 50:25:25 NPK kg/ha + sulphur @ 5 kg/ha	10.08	9.65	9.17	9.08	8.99	8.90	8.81
F_7:60:20:30 NPK kg/ha + sulphur @ 10 kg/ha	10.38	9.86	9.37	9.27	9.18	9.09	9.00
$F_{8:}$ 40:10:20 NPK kg/ha + sulphur @ 15 kg/ha	10.18	9.76	9.27	9.18	9.09	9.00	8.91
Mean	**10.09**	**9.50**	**9.02**	**8.93**	**8.84**	**8.75**	**8.67**
S.Em ±	0.33	0.14	0.15	0.19	0.24	0.24	0.18
C.D.(0.01)	NS	0.55	0.58	0.78	0.96	0.98	0.71

NS- Non significant

respectively) which was on par with F_8 (40:10:20 NPK kg/ha + sulphur @ 15 kg/ ha), F_6 (50;25:25 NPK kg/ha + sulphur @ 5 kg/ha), F_4 (50:30:30 NPK Kg/ha), F_5 (60;30:30 NPK Kg/ha) and F_3 (50:25:25 NPK Kg/ha). Significantly lowest values for seedling dry weight were observed in the fertilizer level of 40;20;20 NPK Kg/ha (17.91 mg, 17.17 mg, 16.68 mg, 16.22 mg, 15.25 mg, 14.21 mg and 11.71 mg respectively) from initial to six months of storage.

4.2.7 Electrical conductivity of seed leachate (dSm^{-1})

The data indicated that electrical conductivity of seed leachate (Table 20) due to application of different fertilizer levels in field did differ significantly during storage period of six months except for the initial month. In general, electrical conductivity of seed leachate increased progressively with the advancement of storage period. Among the treatments, the seeds produced by the application of a fertilizer level of 60:20:30 NPK per ha + sulphur @ 10 kg per ha (F_7) recorded consistently and significantly lowest values for electrical conductivity of seed leachate from first month upto six month of storage(0.76, 0.89, 0.99, 1.04, 1.28 and 1.46 dS m^{-1} respectively) which was on par with F_8 (40:10:20 NPK kg/ha + sulphur @ 15 kg/ ha), F_6 (50;25:25 NPK kg/ha + sulphur @ 5 kg/ha), F_4 (50:30:30 NPK Kg/ha), F_5 (60;30:30 NPK Kg/ha) and F_3 (50:25:25 NPK Kg/ha). Significantly highest values for electrical conductivity were observed in the fertilizer level of 40;20;20 NPK Kg/ha (0.88, 0.98, 1.14, 1.34, 1.48 and 1.59 dS m^{-1} respectively) from first to six months of storage.

Table 18 Effect of mother plant nutrition on seedling vigour index of sesame cv.DS-5 under ambient condition of storage

Treatments	Storage period (months)						
	Initial	1	2	3	4	5	6
F_1: 40:20:20 NPK kg/ha	1723	1592	1465	1362	1298	1134	1047
F_2: 50:20:20 NPK kg/ha	1752	1629	1496	1417	1326	1261	1134
F_3: 50:25:25 NPK kg/ha (RDF)	1777	1713	1591	1522	1401	1329	1243
F_4: 50:30:30 NPK kg/ha	1762	1659	1567	1465	1347	1282	1182
F_5: 60:30:30 NPK kg/ha	1769	1677	1536	1459	1370	1300	1174
F_6: 50:25:25 NPK kg/ha + sulphur @ 5 kg/ha	1786	1726	1612	1547	1420	1356	1274
F_7:60:20:30 NPK kg/ha + sulphur @ 10 kg/ha	1859	1797	1675	1617	1496	1417	1336
$F_{8:}$ 40:10:20 NPK kg/ha + sulphur @ 15 kg/ha	1813	1764	1644	1582	1459	1385	1301
Mean	**1780**	**1694**	**1573**	**1495**	**1389**	**1307**	**1210**
S.Em ±	93.18	59.97	45.89	49.70	47.57	42.65	35.05
C.D.(0.01)	NS	NS	183.76	199.02	190.49	170.78	140.35

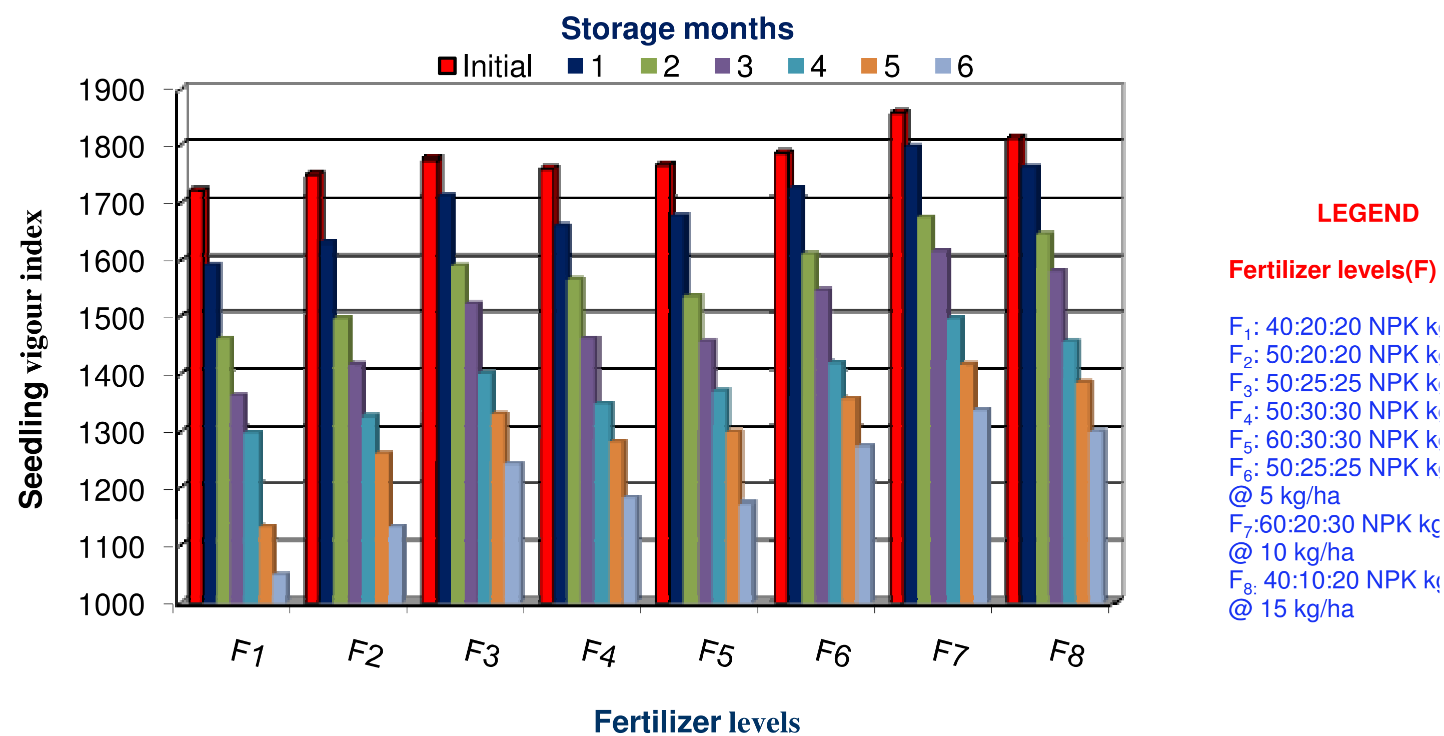

Fig. 11: Effect of mother plant nutrition on seedling vigour index of sesame cv. DS-5 under

Table 19. Effect of mother plant nutrition on seedling dry weight (mg 10^{-1} seedling) of sesame cv.DS-5 under ambient condition of storage

Treatments	Storage period (months)						
	Initial	1	2	3	4	5	6
F_1: 40:20:20 NPK kg/ha	17.91	17.17	16.68	16.22	15.25	14.21	11.71
F_2: 50:20:20 NPK kg/ha	19.00	18.63	17.93	17.36	16.50	15.60	13.06
F_3: 50:25:25 NPK kg/ha (RDF)	21.72	21.26	20.66	19.91	19.05	17.99	16.35
F_4: 50:30:30 NPK kg/ha	19.79	18.35	17.92	17.26	16.48	15.63	13.25
F_5: 60:30:30 NPK kg/ha	21.38	20.91	20.33	19.56	18.76	17.52	15.73
F_6: 50:25:25 NPK kg/ha + sulphur @ 5 kg/ha	22.47	22.04	21.43	20.77	19.74	18.68	16.98
F_7:60:20:30 NPK kg/ha + sulphur @ 10 kg/ha	23.69	23.23	22.49	21.91	20.90	19.80	18.37
$F_{8:}$ 40:10:20 NPK kg/ha + sulphur @ 15 kg/ha	23.55	23.18	22.55	21.86	20.83	19.66	17.96
Mean	**21.18**	**20.59**	**19.99**	**19.35**	**18.43**	**17.38**	**15.42**
S.Em ±	0.11	0.47	0.48	0.39	0.42	0.36	0.27
C.D.(0.01)	0.34	1.88	1.92	1.56	1.68	1.44	0.88

Table 20 Effect of mother plant nutrition on electrical conductivity (ds m^{-1}) of sesame cv.DS-5 under ambient condition of storage

Treatments	Storage period (months)						
	Initial	1	2	3	4	5	6
F_1: 40:20:20 NPK kg/ha	0.72	0.88	0.98	1.14	1.34	1.48	1.59
F_2: 50:20:20 NPK kg/ha	0.71	0.82	0.96	1.12	1.28	1.44	1.58
F_3: 50:25:25 NPK kg/ha (RDF)	0.69	0.79	0.94	1.07	1.23	1.39	1.53
F_4: 50:30:30 NPK kg/ha	0.71	0.81	0.93	1.10	1.23	1.42	1.57
F_5: 60:30:30 NPK kg/ha	0.70	0.80	0.95	1.09	1.25	1.40	1.56
F_6: 50:25:25 NPK kg/ha + sulphur @ 5 kg/ha	0.69	0.78	0.92	1.02	1.14	1.32	1.49
F_7:60:20:30 NPK kg/ha + sulphur @ 10 kg/ha	0.67	0.75	0.89	0.99	1.04	1.28	1.46
$F_{8:}$ 40:10:20 NPK kg/ha + sulphur @ 15 kg/ha	0.68	0.76	0.82	0.93	1.01	1.20	1.42
Mean	**0.69**	**0.80**	**0.92**	**1.06**	**1.19**	**1.37**	**1.54**
S.Em ±	0.04	0.02	0.02	0.02	0.03	0.03	0.03
C.D.(0.01)	NS	0.06	0.08	0.08	0.11	0.12	0.13

NS- Non significant

DISCUSSION

Sesame (*Sesamum indicum* L.)is an important oilseed crop grown in India for its edible oil (48-55%) and protein (20-28%) and for its expeller cake which not only serves as good feed concentrate for livestock but also as organic manure. Presently, sesame crop is being grown annually on 1.942 m ha area in India but average productivity is quite low (517 kg ha^{-1}) due to several constraints like availability of poor quality seeds, lack of improved agronomic packages, inadequate post-harvest handlings *etc.* Among these factors, development of improved agronomic packages is the most important in enhancing the average productivity of sesame. Among the several agronomic packages, the higher yield of best quality seeds could be obtained in sesame by optimizing the spacing and fertilizer levels during its crop growth period. Although, sufficient work is carried out to enhance seed yield and quality by standardizing spacing and fertilizer levels in other oilseed crops, such systematic works are lacking in sesame crop particularly in Karnataka under Dharwad conditions. Therefore, an attempt was made to standardize the different levels of spacings and fertilizer doses for getting higher yield and quality seeds in sesame crop. The field experiment was conducted to know the effect of spacings and fertilizer levels on crop growth, seed yield and quality in sesame at Main Agricultural Research Station farm, University of Agricultural Sciences, Dharwad during *khari* 2013-14 and a laboratory experiment was also carried out to know the effect of mother plant nutrition on storability of sesame seeds for a period of six months and their results are discussed in this chapter.

5.1 Experiment I: Effect of spacing and fertilizer levels on crop growth, seed yield and quality in sesame

The field experiment consisted of totally 16 treatments combinations of two spacings (S_1-30 x 15 cm and S_2-45xl5 cm) and eight fertilizer levels *viz.,* F_1 (40:20:20 kg NPK/ha), F_2 (50:20:20 kg NPK/ha), F_3 (50:25:25 kg NPK/ha), F_4 (50:30:30 kg NPK /ha), F_5 (60:30:30 kg NPK/ha, F_6 (50:25:25 kg NPK/ha+ sulphur @ 5 kg /ha), F_7 (60:20:30 kg NPK /ha + sulphur @ 10 kg /ha) and F_8 (40:10:20 kg NPK /ha + sulphur @ 15 kg /ha). It was laid out in Randomized Block Design with factorial concept in three replications and its results are discussed here.

Due to **spacing** (S)

The present investigation revealed the consistent and significant variations for growth parameters like plant height and number of primary branches at different stages of crop growth (30, 60 DAS and at harvest) due to spacings irrespective of fertilizer levels (Table 1 to 2). Among the growth parameters, plant height at harvest was significantly more (138.30 cm) in narrow spacing of 30x15 cm (S_1) compared to wider spacing of 45x15 cm (S_2) (132.30 cm) at 30 and 60 DAS which indicated that the effect of spacing was more pronounced at later stages of crop growth than at early growth period. The marked increase in plant height was noticed in narrow spacing may be attributed to its increased plant population density (2,22,222 plants/ha) which might have resulted in less plant canopy area and exhibited more vertical growth by producing weak, lanky and taller plants due to stiff competition for space, light, nutrients and moisture (Pandey *et al.,* 1996) in the narrow spacing compared to those in wider spacing (1, 11,111 plants/ha). Similar results were also obtained by Ameen Ahmed *et al.* (1988) in fennel, Patil *et al.* (1995) in lablab bean and Bahadur and Singh (2005) in tomato.

In contrast to plant height, number of primary branches per plant also varied significantly due to spacings at different crop growth stages *i.e.* 30 DAS, 60 DAS and harvest stages irrespective of fertilizer levels. At harvest, number of primary branches per plant was significantly more (5.57) in the broader spacing of 45x15 cm (S_2) than in closer spacing of 30x15 cm (S_1) (4.43) and it may be ascribed to the better growth of plants under broader spacing and it exhibited better vegetative growth due to less plant population density (1,48,148/ha) and competition. It resulted in more horizontal growth and plant canopy area compared to those under narrow spacing (2,22,222 plants/ha). The similar increase in number of primary branches and plant under wider spacing were also confirmed by Kanwar and Saimbhi (1989) and Mohammed (1990) in fenugreek, Patil *et al.* (1995) in lablab bean and Bahadur and Singh (2005) in tomato.

Irrespective of fertilizer levels, effect of spacing was found to be non-significant for flowering parameters like days to flower initiation, 50 per cent flowering, (Table 3). In general, consistently more values for flowering parameters were recorded in the wider spacing (S_2) (41.21, 49.05 days, respectively) over narrow spacing ($S_{1)}$ (39.03, 46.89 days, respectively). It might be related to better due to vegetative growth, plant canopy area and efficient photosynthetic activity which might have enhanced the reproductive phase in wider spacing compared to narrow spacing. These results are in agreement with the findings of Malav and Yadav (1997) in coriander, Kanwar *et al.* (2000) in onion, Gurusharan and Sharma (2004) in mungbean and Mazumder *et al.* (2007) in hyacinth bean.

In a crop like sesame, seed yield is a function of plant growth, number of productive primary branches, number of capsules per plant, seeds per capsule, weight of capsule, seed weight per capsule, seed yield per plant *etc*. Irrespective of fertilizer levels, the marked and consistent variations due to spacing were seen for the seed yield and its components (Table 4, 5 and 6). On an average, plants of wider spacing (45x15 cm) recorded more number of capsules per plant (78.15), seeds per capsule (69.03), weight of capsule (0.392 g), seed weight per capsule (0.205 g), seed yield per plant (4.50 g) over narrow spacing of 30x15 cm (S_1) (72.85, 69.03, 0.384 g, 0.201 g and 4.41 g, respectively). The superior values of seed yield and its components noticed under wider spacing may be attributed to better growth and development of plants under less plant population density and it resulted into better source to sink relationship due to availability of balanced and adequate nutrients and better light, space and moisture unlike in narrow spacing. These results are in conformity with those of Mohammed (1990), Pastucha (1992) and Anilkumar (2004) in fenugreek, Srivastava *et al.* (1992) in radish and Mazumder *et al.* (2007) in hyacinth bean. On the contrary, significant but reciprocal trend was noticed in the closer spacing by registering more seed yield (981.20 kg/ha) over broader spacing (S_2) (859.30 kg/ha). On an average, 14.20 per cent increase in seed yield per ha was recorded in 30x15 cm (S_1) spacing over 45x15 cm (S_2) spacing (859.30 kg/ha). This may be probably attributed to about 50 per cent more plant population density noticed in closer spacing over wider spacing (1,48,148 plants/ha) (Table 6). These results are in corroborative with the findings of Sharma (2000) in fenugreek, Prakash *et al.* (2002) in moth bean and Shaikh and Kumbar (2005) in soybean.

The calculated gross returns (Rs. 78480/ha), net returns (Rs.64863/ha) and B:C ratio (4.76:1) were more in closer spacing (S_1) compared to broader spacing (S_2) which might be due to higher seed yield per ha harvested from closer spacing (Appendix IV and Table 8). These findings are also confirmed by Anilkumar (2004) in fenugreek.

Irrespective of fertilizer levels, the plants in wider spacing recorded significantly higher values for all seed quality parameters except for electrical conductivity of seed leachates (Table 10 to 12). The consistently higher 1000 seed weight (3.75 g), germination percentage (91.63%), shoot length (9.30 cm), root length (10.10 cm), seedling vigour index (1776), seedling dry weight (21.20 mg) and lower electrical conductivity of seed leachate (0.659 dSm"^{1}) were noticed in wider spacing (S_2) compared to narrow spacing (S_1) (3.70 g, 90.63%, 9.28 cm, 10.06 cm, 1678, 20.66 mg and 0.670 dSm^{-1}, respectively). In the present study, superior seed quality parameters with lower electrical conductivity values noticed in wider spacing may be attributed to better source to sink relationship of the plants which resulted in better accumulation and assimilation of photosynthates into sinks as reflected in the present study with higher test weight, germination percentage and seedling vigour index in the seeds obtained from wider spacing compared to narrow spacing. The similar superior trend in seed quality parameters under wider spacing was also confirmed by Phor and Mangal (1991) in palak, Malik *et al.* (1999) in radish, Anilkumar (2004) in fenugreek and Mazumder *et al.* (2007) in hyacinth bean.

Due to fertilizer levels (F)

In the present study, the growth parameters varied markedly due to fertilizer levels irrespective of spacings at different growth stages *viz.,* 30, 60 DAS and at harvest (Table 1 to 2). At harvest, a fertilizer level of 60:20:30 NPK per ha + sulphur @ 10 kg per ha (F_7) recorded significantly the highest plant height (141.35 cm), number of primary branches (6.20) followed by F_8, F_6 as against recommended fertilizer level of 50:25:25 kg NPK per ha (F_3). The significant rise in growth parameters noticed under higher (F_7) fertilizer level may be ascribed to greater uptake of nutrients by the plants favouring better cell division, elongation, amino acid and protein synthesis and it might have produced more plant height, number of primary branches compared to recommended fertilizer level. The similar increase in growth parameters under higher fertilizer levels were also noticed by Thakral *et al.* (1991) in coriander, Banafer *et al*. (1995) in fenugreek and Kumar *et al.* (2004) in french beans.

The significant variations due to fertilizer levels were seen for the flowering parameters irrespective of spacings (Table 3). Days to flower initiation, 50 per cent flowering were consistently more under the higher levels of fertilizer over the recommended fertilizer level and they were significantly maximum (42.40, 49.15 days, respectively) in 60:30:30 kg NPK per ha (F_5) followed by F_7, F_4 and F_6 levels which might be attributed to the increased vegetative growth and plant canopy area noticed at higher fertilizer levels. Furthermore, this study also revealed that the plants fertilized with 40:20:20 kg NPK per ha (F_1) level recorded the significantly least number of days to flower initiation

(37.85 days), 50 per cent flowering (46.00 days) as against F_5 fertilizer level which might be attributed to the decresing level of NPK nutrients and it might have accelerated the reproductive phase. Similar findings were also noticed by Mandal and Maiti (1992) in fenugreek, Arya *et al.* (1999) in frenchbean, Amaregouda (2000) in garden pea and Patil (2003) in cluster bean and Haruna *et al.* (2011) in sesame.

Irrespective of spacings, the significant variations due to fertilizer levels were seen for all seed yield and its components (Table 4, 5 and 6). In the present investigation significantly maximum number of capsules per plant (89.40), seeds per capsule (74.85), weight of capsule (0.404 g), seed weight per capsule (0.208 g), seed yield per plant (5.40 g), seed yield per ha (1110 kg/ha) were noticed at 60:20:30 NPK per ha + sulphur @ 10 kg per ha (F_7) level followed by F_8, F_6 and F_5 levels as against 50:25:25 kg NPK per ha (F_3).

On an average 27.40 per cent increase in seed yield per ha was recorded in 60:20:30 NPK per ha + sulphur @ 10 kg per ha (F_7) level followed by F_8 (14.87%), F_6 (13.40%) levels compared to 50:25:25 kg NPK per ha (F_3) (871.40 kg/ha). These results indicated that 60:20:30 NPK per ha + sulphur @ 10 kg per ha (F_7) fertilizer level was most optimum dose for obtaining higher seed yield per ha as evident by the results of the present study with higher number of primary branches, capsules per plant, seeds per capsules and seed yield per plant. This might be attributed to the enhanced photosynthetic activity, greater accumulation and translocation of photosynthates from source to sink resulting in heavier and bolder seeds. These results are in agreement with those of Raul *et al.*(2003) in mustard, Datta *et al.* (2005) in frenchbean, Jamal (2006) and Harura (2011) in sesame.

Irrespective of spacings, the significant variation due to fertilizer levels were seen for all the seed quality parameters studied (Table 10 to 12). The significantly highest 1000 seed weight (3.95 g), germination (92.50%), shoot length (9.49 cm), root length (10.33 cm), vigour index (1765), seedling dry weight (23.40 mg) and lower electrical conductivity of seed leachates (0.518 dSm^{-1}) were recorded in F_7 fertilizer level followed by F_7, F_6 and F_5 as against F_3 (3.74 g, 91.25%, 9.26 cm, 10.04 cm, 1735, 21.41 mg and 0.652 dSm-1, respectively). This might be ascribed to the efficient amino acid and protein synthesis and better source to sink relationship which resulted in better development of seeds giving rise to higher test weight, germination and vigour index under increasing levels of NPK from 50:25:25 kg per ha (F_3) to 60:20:30 NPK per ha with added sulphur @ 10 kg/ha (F_7). These results are in corroborative with the findings of Dataram *et al.* (2001) in fenugreek, Jamal (2006) and Harura (2011) in sesame.

Due to interaction of spacing and fertilizer levels

The interaction between spacing and fertilizer levels were found to be non-significant for all the growth parameters studied at different stages of crop growth *viz.,* 30, 60 DAS and at harvest (Table 1 to 2). The numerically more plant height (145.00 cm) were seen in S_1xF_7 over S_2xF_1 (127.70 cm) treatment combination. Whereas, more number of primary branches (6.50) were recorded in S_2xF_7 over S_1xF_1 (3.90). These results are in agreement with Ameen Ahmed *et al.* (1988) in fennel, Malav and Yadav (1997) in coriander, Malligawad (1994) in grain amaranthus and Anilkumar (2004) in fenugreek.

All the reproductive parameters under study did not differ significantly due to interaction between spacings and fertilizer levels (Table 3). On an average, relatively more number of days to flower initiation (43.30 days), 50 per cent flowering (50.30 days) were noticed in S_2 xF_5 as against S_1xF_1 treatment combination (37.00, 45.30, respectively). These results are in corroborative with the findings of Malligawad (1994) in grain amaranthus and Patil *et al.* (1995) in dolichos bean.

The interaction between spacings and fertilizer levels did not differ significantly for all seed yield and its components except, weight of capsule, seed weight per capsule, length of capsule and seed yield per ha (Table 4 to 6). In general, the S_2xF_7 treatment combination recorded consistently more number of capsules per plant (93.40), seeds per capsule (76.70), weight of capsule (0.410 g), seed weight per capsule (0.210 g) and seed yield per plant (5.40 g). Further, these results also indicated that increased seed yield and its components noticed in broader spacing and highest fertilizer levels (S_2xF_7) may be related to the less population pressure per unit area and also availability of balanced and adequate nutrients which might have stimulated better vegetative and reproductive growth. On the contrary, a treatment combination of S_1xF_7 recorded significantly maximum seed yield per ha (1178 kg/ha), which was followed by S_2xF_7, S_1xF_8 and S_1xF_6 as against S_2xF_1. On an average 60.90 per cent increase in seed yield was observed at S_1xF_7 followed by S_2xF_7 (42.35%), S_1xF_8 (47.95%) and S_2xF_8 (25.77%) as against S_2xF_1 treatment combination (732.70 kg/ha). Significantly maximum seed yield per ha noticed in narrow spacing under highest fertilizer level (S_1xF_7) may be perhaps ascribed to the 50 per cent more population density noticed in narrow spacing and sufficient nutrients availability as against wider spacing with lower fertilizer level (S_2xF_1).

These results are in corroborative with the findings of Malligawad (1994) in grain amaranthus, Patil *et al.* (1995) in dolichos bean and Anilkumar (2004) in fenugreek. Seed quality parameters revealed non-significant variations due to interaction between spacings and fertilizer levels except for 1000 seed weight, germination percentage and seedling dry weight (Table 10 to 12). In general, the S_2xF_7 treatment combination recorded consistently higher values for 1000 seed weight (3.97 g), germination (93.00%), shoot length (9.52 cm), root length (10.36 cm), seedling vigour index (1820), seedling dry weight (23.70 mg) with lower electrical conductivity of seed leachate (0.513 dSm^{-1}) which it was followed by S_2xF_8, S_2XF_6 and S_2XF_5 treatment combinations as against S_1xF_1 (3.29 g. 89.00%, 3.14 cm, 9.92 cm, 1644, 17.75 mg and 10.803 dSm^{-1} respectively). These results are in agreement with the findings of Malav and Yadav (1997) in coriander, Malligawad (1994) in grain amaranthus and Anilkumar (2004) in fenugreek.

5.2 Experiment II : Effect of mother plant nutrition on seed storability of sesame Cv. DS-5 under ambient condition

Seed storage is an essential component of seed production programme. As a biological entity, the viability and vigour of seeds in storage are influenced by several factors like storage temperature, relative humidity, seed moisture, storage pests, storage containers *etc.* apart from its genetic makeup. It is a natural phenomenon that seed loses its viability and vigour after harvest in storage and deteriorates variably due to both extrinsic and intrinsic factors. But, the complete control over seed deterioration is practically impossible but its rate of deterioration can be slowed down or arrested by different protection methods. Among several storage factors, initial seed quality is important to maintain the desired storage life and it can be maintained by providing adequate major and minor plant nutrients during crop growth period under field condition. The plant nutrients like Phosphorous, Potassium and Sulphur are known to increase fruit and seed setting, seed weight and other quality parameters but their influence on storability of seeds in field crops particularly sesame are scanty and inconclusive. Looking into these aspects, a laboratory experiment is conducted on effect of plant nutrients on storability of sesame seeds stored in cloth bags under ambient condition for six months. The results of this experiment are discussed here.

The storage period response:

The results of storage experiment revealed consistent and marked variations of both seed quantitative and qualitative parameters throughout six months storage irrespective of the plant nutrient treatments. Among seed quantitative parameters, seed infestation increased linearly and substantially from initial month (nil) to six month (16.93 %) over the nutrient treatments in entire storage period. Whereas, seed moisture content showed inconsistent and fluctuating increasing trend from 8.66 to 8.87 per cent over the storage period. This dynamic fluctuating moisture content due to ever changes in the weather conditions resulted in the substantial rise in the seed infestation (16.96%) during storage period. These results are in agreement with findings of Negalur (2000) in soybean, Channabasnagowda (2007) and Ambika Sharma (2012) in wheat

The substantial rise in seed infestation has resulted in the marked decline in seed qualitative parameters. Seed germination, root length, shoot length, seedling vigour index and seedling dry weight showed a linear and gradual decreasing trend (91.71 to 71.72%; 10.09 to 8.67 cm; 9.34 to 8.16 cm; 1780 to 1210; 21.18 to 15.42 $mg10^{-1}$, respectively), whereas, electrical conductivity (EC) of seed leachates increased reciprocally and sharply (0.69 to 1.54 dSm^{-1}) over the treatments in the entire storage period. This significant loss in seed quality parameters may be attributed to substantial rise in seed infestation due to dynamic changes in moisture content causing loss in germination and vigour index of seed with increase in EC value in storage. The similar findings were also confirmed by earlier workers like Kurdikere (1991) in maize, Channabasnagowda (2007) and Ambika Sharma (2012) in wheat

Plant nutrient treatment

The plant nutrient treatments revealed a substantial and gradual reduction in both seed quantitative and qualitative parameters throughout the six months storage period. The seeds harvested from F_7 (60:20:30 NPK + Sulphur @ 10 kg /ha) treatment recorded higher seed germination (76.50 %), shoot length (8.47 cm), root length (9.00 cm), seedling vigour index (1336) and seedling dry weight (18.37 mg) and the least seed infestation (8.24%) and EC value (1.46 dS m^{-1}). It was followed by F_8 (40:10: 20 NPK + Sulphur @ 15 kg /ha) and F_6 (50: 25:25 NPK + Sulphur @ 5 kg /ha) treatments. On the other hand, the seeds obtained from F_1 (40: 20: 20 NPK) treatment recorded least seed quality parameters (64.75%, 8.33 cm, 7.84 cm, 1047, 11.71 mg 10^{-1}, respectively) and higher seed infestation and EC values (23.08 % and 1.59 dSm^{-1}, respectively) at the end of six months storage period. The seeds of F_7 treatment retained better storability by showing more germination percentage and seedling vigour index and less seed infestation and EC value as against F_1 treatment and it may be attributed to the adequate availability of the essential plant nutrients like N, P and K including sulphur and these nutrients might have exerted their influence in enhancing seed weight and development leading to better storage potentiality of seeds under higher nutrient supplements as compared to those harvested from less supplement of plant nutrients (F_1 treatment). These finding have been confirmed by the workers like Dataram *et al*. (2001) in fenugreek, Raul *et al*. (2003) in mustard, Datta *et al*. (2005) in French bean and Jamal (2006) and Harura (2011) in sesame who reported superior seed quality parameters due to increased application of plant nutrients.

SUMMARY AND CONCLUSION

A field experiment was conducted to know the effect of spacing and fertilizer levels on crop growth, seed yield and quality in sesame (*Sesamum indicum* L.) Cv. DS-5 and a laboratory experiment was carried out to know the storability of sesame seeds. The results obtained from the present investigation are summarized in this chapter.

Experiment I: Effect of spacing and fertilizer levels on crop growth, seed yield and quality in sesame Cv. DS-5

The field experiment consisted of totally 16 treatments combinations of two spacings (S_1-30 x 15 cm and S_2-45xl5 cm) and eight fertilizer levels *viz.,* F_1 (40:20:20 kg NPK/ha), F_2 (50:20:20 kg NPK/ha), F_3 (50:25:25 kg NPK/ha), F_4 (50:30:30 kg NPK /ha), F_5 (60:30:30 kg NPK/ha, F_6 (50:25:25 kg NPK/ha+ sulphur @ 5 kg /ha), F_7 (60:20:30 kg NPK /ha + sulphur @ 10 kg /ha) and F_8 (40:10:20 kg NPK /ha + sulphur @ 15 kg /ha).. It was conducted in Randomized Block Design with factorial concept in three replications in *khari* season 2013 at Main Agricultural Research Station farm, University of Agricultural Sciences, Dharwad. The results of this field experiment are summarized here.

Due to spacings (S)

The results of this study revealed significant differences due to spacings for growth parameters like plant height, number of primary branches per plant at harvest except for 30 and 60 DAS irrespective of fertilizer levels. At harvest, plant height was significantly more (138.30 cm) in narrow spacing of 30 x 15 cm (S_1) than in wider spacing of 45x15 cm (S_2) (132.30 cm). Whereas, number of primary branches per plant at harvest were significantly more (5.57) in 45x15 cm (S_2) than in 30x15 cm (S_1) spacing (4.43).

Among the flowering parameters studied, the days to flower initiation and 50 per cent flowering did not differ significantly due to spacings, irrespective of fertilizer levels. However, all these parameters were numerically more (41.21, 49.05 days) in 45x15 cm (S_2) than in 30x15 cm (S_1) (39.03, 46.89 days, respectively).

Seed yield and its components like number of capsules per plant, seeds per capsule, seed weight per capsule (g), seed yield per plant (g) and seed yield per ha (kg) except capsule weight (g) and capsule length (cm) at harvest revealed marked variations due to spacings over fertilizer levels. On an average, significantly more number of capsules per plant (78.15), seeds per capsule (69.03), seed weight per capsule (0.205 g), seed yield per plant (31.37 g) were noticed in 45x 15 cm (S_2) over 30x15 cm (S_1) spacing (84.30, 65.75, 0.201 g and 31.07 g, respectively). Likewise, weight of capsule was numerically more (0.392 g) in S_2 over S_1 (0.384 g). Whereas, length of capsule was relatively more (3.15 cm) in S_1 over S_2 (3.10 cm). However, significantly more seed yield (872.90 kg/ha) were noticed in S_1 as against. S_2 spacing (859.30 kg/ha).

Irrespective of fertilizer levels, the statistical differences due to spacings were found to be significant for seed quality parameters like 1000 seed weight, seed germination percentage, shoot length, root length, seedling vigour index and seedling dry weight except electrical conductivity of seed leachates. All these seed quality parameters were significantly and consistently more (3.75 g, 91.63%, 9.30 cm, 10.10 cm, 1776, 21.20 mg, respectively) in 45x15 cm (S_2) spacing than in 30x15 cm (S_1) (3.70 g, 90.63%, 9.28 cm, 10.06 cm, 1678 and 20.66 mg, respectively). Whereas, it was numerically more (0.670 dSm^{-1}) electrical conductivity in S_1 spacing as against S_2 spacing (0.659 dSm^{-1}).

Due to fertilizer levels (F)

Irrespective of spacings adopted, the growth parameters *viz*., plant height, number of primary branches per plant differed significantly between fertilizer levels at different stages of crop growth period (30 DAS, 60 DAS and at harvest). At harvest, a fertilizer level of 60:20:30 kg NPK per ha + sulphur @ 10 kg per ha (F_7) recorded significantly the highest plant height (141.35 cm) and number of primary branches per plant (6.20) followed by F_8, F_6 and F_5 levels. However, they were significantly the lowest (131.30 cm, 4.55, respectively) in 40:20:20 kg NPK per ha (F_1) level. The flowering parameters like days to flower initiation and 50 per cent flowering varied significantly between the fertilizer levels over spacings. They were significantly highest in 60:30:30 kg NPK per ha (F_5) (42.40, 49.15 days, respectively) followed by F_7, F_6 and F_4 levels as against 40:20:20 kg NPK per ha (F_1)

(37.85, 46.00 days, respectively) level.

Significant variations for seed yield and its components were seen amongst the different fertilizer levels irrespective of spacings. A fertilizer level of 60:20:30 kg NPK per ha + sulphur @ 10 kg per ha (F_7) recorded significantly maximum number of capsules per plant (89.40), seeds per capsule (74.85), weight of capsule (0.404 g, length of capsule (3.55 cm), seed weight per capsule (0.208 g), seed yield per plant (32.66 g) and per ha (1060 kg/ha) followed by F_8, F_6 and F_5 levels. While, minimum in 40:20:20 kg NPK per ha (F_1) (67.15, 62.35, 0.344 g, 2.85 cm, 0.197 g, 28.81 g and 739.33 kg/ha, respectively).

1000 seed weight, germination percentage, shoot length, root length, seedling vigour index, seedling dry weight and electrical conductivity of seed leachate varied significantly due to fertilizer levels irrespective of spacings. The significantly highest quality parameters (3.91 g, 92.50%, 9.49 cm, 10.33 cm,1765 and 23.40 mg, respectively) were noticed in 60:20:30 kg NPK per ha + sulphur @ 10 kg per ha (F_7) followed by F_8, F_6 and F_5 whereas, the lowest (3.31 g, 89.50 %, 9.15 cm, 9.93 cm, 1687 and 17.83 mg, respectively) were recorded in 40:20:20 kg NPK per ha (F_1) except for electrical conductivity of seed leachate which was significantly the highest (0.796 dSm^{-1}) in F_1 and least (0.518 dSm^{-1}) in F_7 levels.

Due to spacing and fertilizer levels (SxF)

All growth parameters revealed non-significant variations due to interaction between spacings and fertilizer levels. At harvest, plant height was numerically more (145.00 cm) in S_1xF_7 over S_2xF_1 (127.70 cm). On the contrary, number of primary branches per plant were more (6.50) in S_2xF_7 as against S_1xF_1 interaction level (3.90).

The flowering parameters such as days to flower initiation, 50 per cent flowering did not reveal significant variations due to SxF interactions. However, they were numerically more (43.30, 50.30 days, respectively) in S_2xF_5 compared to S_1xF_1 interaction treatments (37.00, 45.30, days, respectively).

Seed yield and its components except for number of capsules per plant, number of seeds per capsule and seed yield per plant (g) seed yield per plant revealed marked variations due to interaction between spacings and fertilizer (SxF) levels. However, consistently more values for number of capsules per plant (89.40), number of seeds per capsules (76.70), seed yield per plant (5.40 g) were recorded in S_2xF_7 followed by S_2xF_7, S_2xF_6 and S_2xF_5 levels as against S_1xF_1 (64.30, 60.00, 3.63 g, respectively) interaction level. However, seed yield (1178.0 kg/ha) were significantly the highest in S_1xF_7 followed by S_1xF_8, S_1xF_6 and S_2xF_8 and lowest (732.7 kg/ha) in S_2xF_1 interaction.

The interaction between spacings and fertilizer levels did not show significant variations for seed quality parameters except for 1000 seed weight, germination percentage and seedling dry weight. In general, the consistently more values for 1000 seed weight (3.97 g), germination percentage (93.00%), shoot length (9.52 cm), root length (10.36 cm), seedling vigour index (1820) and seedling dry weight (23.70 mg) were recorded in S_2xF_7 followed by S_2xF_7, S_2xF_6 and S_2xF_5 as against in S_1xF_1 (3.29 g, 89.00%, 9.14 cm, 9.92 cm, 1644 and 17.75 mg, respectively) interaction treatments.

Experiment II : Effect of mother plant nutrition on seed storability of sesame Cv. DS-5 under ambient condition

A laboratory experiment was initiated under ambient condition for six months storage period ranging from November 2013 to April 2013 with eight nutrient treatments *viz.* 40:20:20 NPK kg/ha (F_1), 50:20:20 NPK kg/ha (F_2), 50:25:25 NPK kg/ha (Rd) (F_3), 50:30:30 NPK kg/ha (F_4), 60:30:30 NPK kg/ha (F_5), 50:25:25 NPK kg/ha + sulphur @ 5 kg/ha (F_6), 60:20:30 NPK kg/ha + sulphur @ 10 kg/ha (F_7) and 40:10:20 NPK kg/ha + sulphur @ 15 kg/ha. The laboratory experiment was conducted at Department of Seed Science and Technology, College of Agriculture, UAS, Dharwad in Completely Randomized Design (CRD) with three replications.

The seed quantitative parameters like 1000 seed weight decreased linearly with reciprocal rise in seed infestation (0.00 % to 16.93%) due to dynamic changes in the seed moisture content from initial month (8.56 %) to six month (8.75 %) storage irrespective of plant nutrient treatments.

The seed qualitative parameters like germination percentage(%), root length (cm), shoot length (cm), seedling vigour index and seedling dry weight (mg) showed a gradual declining trend from initial month (91.71 %, 10.09 cm, 9.34 cm, 1780 and 21.18 mg, respectively) to sixth month (71.92 %, 8.67 cm, 8.16 cm, 1210 and 15.42 mg, respectively) storage period. In the entire six month storage period, the seeds of F_7 treatment retained better storability by registering higher 1000 seed weight, germination percentage (76.50%), seedling vigour index (1336), seedling dry weight (18.37 mg) and least seed infestation (8.24%) and EC value (1.46 dS m^{-1}). Next superior storability was recorded in F_8 and F_6 treatments as against F_1 fertilizer level (64.75%, 1047, 11.71 mg, 23.08% and 1.59 dS m^{-1} respectively)

Conclusion

Based on the results of the field and laboratory experiments the following findings are of practical application.

i) 30x15 cm spacing recorded about 14.2 percent more seed yield over 45x15 cm (859.3 kg/ha) irrespective of fertilizer level.

ii) The best quality seeds in terms of test weight, seed germination and seed vigour may be obtained with 45x15 cm spacing.

iii) Irrespective of the spacings, F_7 (60:20:30 NPK kg/ha + sulphur @ 10 kg/ha) fertilizer level recorded 27.40 per cent more seed yield and best quality seeds followed by F_8 and F_6 as against F_1 (40:20:20 NPK kg/ha) fertilizer level.

iv) Seeds harvested from F_7 fertilizer level retained more seed storability by showing least seed infestation and higher 1000 seed weight, seed germination and seedling vigour index over F_1 fertilizer level throughout six month ambient storage period. Next better seed storability was retained in the seeds of F_8 and F_6.

Future line of work

i) There is a need to standardize seed production technology with respect to plant geometry, mother plant nutrition and dates of sowing in different varieties and agro-climatic regions.

ii) There is a need to study the effect of plant growth regulators and biofertilizers on seed yield and quality in different sesame varieties.

iii) Studies on storability of sesame varieties with respect to storage containers, chemical pesticides and botanicals are to be conducted in different agro-climatic locations.

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Appendix-I : Soil physical and chemical properties of the experimental site

Particulars	Values
A. Physical properties	
Clay (%)	32.70
Silt (%)	9.50
Fines sand (%)	31.24
Coarse sand (%)	26.56
B. Chemical properties	
Total N (kg/ha)	265.0
Available P2O5 (kg/ha)	10.8
Available K2O (kg/ha)	245.0
pH	6.7
Available Fe (ppm)	6.0
Available Zn (ppm)	0.6
Available Cu (ppm)	1.2
Available S (ppm)	25
Available Ca (ppm) (Exchangeable)	25

Appendix II : Monthly meteorological data during crop growth period (2013-14) and the average of 62 years (1950-2012) at the Main Agriculture Research Station, Dharwad

Month	Rainfall (mm)		Rainy days (2013)	Mean Temperature (^oC)				Relative humidity (%)	
				Maximum		Minimum			
	2013	1950-2012		2013	1950-2012	2013	1950-2012	2013	1950-2012
January	0.0	0.8	0	31.2	28.7	14.5	14.1	47	64.7
February	2.2	11.3	0	32.6	31.6	16.8	16.5	51	54.4
March	42.0	1.5	1	35.3	34.9	19.2	19.6	48	63.9
April	10.0	48.7	1	36.9	36.6	20.2	20.1	51	77.7
May	124.6	19.7	6	35.5	35.2	21.8	21.0	61	75.4
June	75.4	105.4	10	28.0	30.2	20.8	21.7	82	86.1
July	177.8	153.1	17	25.4	27.3	20.3	20.9	89	89.1
August	97.2	100.8	10	26.7	27.3	19.9	20.1	85	88.5
September	133.6	107.2	13	27.9	27.9	20.2	20.0	81	86.5
October	75.4	125.3	5	28.8	29.5	19.4	18.6	76	79.2
November	2.2	32.1	0	29.0	28.9	15.8	15.9	53	73.4
December	0.0	5.1	0	28.4	27.8	12.7	13.2	64	68.9
Total	**740.4**	**711.1**	**63**	**-**	**-**	**-**	**-**	**-**	**-**

`Appendix - III : **Price of inputs and out puts used for experimental crop as influenced by spacing and fertilizer levels in calculating cost of cultivation and net returns of sesame seed production**

	Particulars	Quantity	Rate (Rs.)	Total Price (Rs.)
1)	**Inputs**			
A	**Sowing**	4 kg/ha	80/ kg	320
B	**Fertilizer levels (F)***			
	F_1: 40:20:20 NPK kg/ha			2433
	F_2: 50:20:20 NPK kg/ha			2670
	F_3: 50:25:25 NPK kg/ha (RDF)		-	3110
	F_4: 50:30:30 NPK kg/ha			3531
	F_5: 60:30:30 NPK kg/ha			3672
	F_6: 50:25:25 NPK kg/ha + sulphur @ 5 kg/ha			3269
	F_7:60:20:30 NPK kg/ha + sulphur @ 10 kg/ha			3434
	$F_{8:}$ 40:10:20 NPK kg/ha + sulphur @ 15 kg/ha		.	2377
C	**Land preparation**			
	Tractor charges	1 plough	2000/ha	2000
	Equipment hire charges (Bullock pair)	2 pair	200 /day	400
D	**Sowing**			
	Bullock pair	2 pairs	200/day	400
	Equipment hire charges	I plough	200/day	200
	Leveling with bullock pair	2 harrow	200/day	400
	Men labour	4 No's	50/day	200
	Women labour	4 No's	35/day	140
E	**Intercultivation (2 times)**			
	Bullock pair	I pair	200/day	400
	Men labour	2 No's	50 /day	200
F	**Hand weeding (3 times) & spraying 4 times**			
	Women labour	45 No's	35/day	1575
	Man labour	16 No's	50/day	800
	Equipments hire charges (16 hours)	1 power spray	30/hr	480
G	**Plant protection**			
	Carbendezim	750 g/ha	100/100 g	750
	Monocrotophos	1 lit/ha	450/lit.	450
H.	**Irrigation (3 times)**			
	Men labour	6 No's	50/day	300
I	**Harvesting and Threshing**			
	Women labour	20 No's	35/day	750
J	**Cleaning, drying and packing**			
	Men labour	4 No's	50 /day	200
	Women labour	16 No's	3/day	560
			Total	12991

*** Note**

Fertilizer dose	Applied	Quantity applied	Rate (Rs.)	Total (Rs.)
40 kg /ha N	Urea	70 kg/ha .	10.80 /kg	756
50 kg /ha N	Urea	92 kg/ha	10.80 /kg	993
60 kg/ha N	Urea	105 kg/ha	10.80/kg	1134
20 kg /ha P	DAP	43 kg/ha	25.32/kg	1088
25 kg /ha P	DAP	54 kg/ha	25.32/kg	1367
30 kg/ha P	DAP	65 kg/ha	25.32 /kg	1645
10 kg/ha P	DAP	22 kg/ha	25.32/kg	557
20 kg/ha K	MOP	33 kg/ha	17.86 /kg	589
25 kg/ha K	MOP	42 kg/ha	17.86 /kg	750
30 kg/ha K	MOP	50 kg/ha	17.86/kg	893
5 kg/ha S	SSP	42 kg/ha	3.80/kg	159
10 kg/ha S	SSP	84 kg/ha	3.80/kg	319
15 kg/ha S	SSP	125 kg/ha	3.80/kg	475

Appendix- IV : Benefit cost ratio analysis of sesame experimental crop as influenced by spacing and fertilizer levels

No.	Treatments	Seed yield (kglha)	Gross Return (Rs./ha)	Cost of cultivation (Rs./ha)	Net returns (Rs/ha)	B:C ratio
A.	**Spacings (S)**					
1.	S_1-30x15cm	981	78480*	13617	.64863	4.76
2.	S_2-45x15cm	859	68720	13617	55103	4.04
B.	**Fertilizer levels (F)**					
3.	F_1: 40:20:20 NPK kg/ha	769.4	61552	12991	48561	3.74
4.	F_2: 50:20:20 NPK kg/ha	795.4	63660	13225	50435	3.81
5.	F_3: 50:25:25 NPK kg/ha (RDF)	871.4	69680	13665	56015	4.09
6.	F_4: 50:30:30 NPK kg/ha	907.4	72560	14086	58474	4.15
7.	F_5: 60:30:30 NPK kg/ha	918.4	73440	14227	59213	4.16
8.	F_6: 50:25:25 NPK kg/ha + sulphur @ 5 kg/ha	988.7	79040	13824	65216	4.71
9.	F_7:60:20:30 NPK kg/ha + sulphur @ 10 kg/ha	1110.0	88800	13989	74811	5.34
10.	$F_{8:}$ 40:10:20 NPK kg/ha + sulphur @ 15 kg/ha	1001.0	80008	12932	67076	5.18
C.	**Interaction (SxF)**					
11.	S_1xF_1	806.0	64480	12991	51489	3.96
12.	S_1xF_2	828.0	66240	13225	53015	4.01
13.	S_1xF_3	926.0	74080	13665	60415	4.42
14.	S_1xF_4	970.7	77656	14086	63514	4.50
15.	S_1xF_5	996.7	79736	14227	65453	4.60
16.	S_1xF_6	1061.0	84880	13824	71056	5.07
17.	S_1xF_7	1178.0	94240	13989	80257	5.74
18.	S_1xF_8	1083.0	86640	12932	73708	5.70
19.	S_2xF_1	732.7	58616	12991	45569	3.50
20.	S_2xF_2	762.7	61016	13225	47735	3.60
21.	S_2xF_3	816.7	65336	13665	51615	3.77
22.	S_2xF_4	844.7	67576	14086	53434	3.80
23.	S_2xF_5	840.7	67256	14227	5973	3.72
24.	S_2xF_6	916.0	73280	13824	59456	4.30
25.	S_2xF_7	1042.0	83360	13989	69371	4.95
26.	S_2xF_8	920.7	73600	12932	60668	4.70

* As per local market procurement price of Rs. 8000 / q

EFFECT OF SPACING AND MOTHER PLANT NUTRITION ON CROP GROWTH, SEED YIELD, QUALITY AND STORABILITY OF SESAME (*Sesamum indicum* L.)

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ABSTRACT

A field experiment was conducted during *kharif*, 2013 on the effect of two spacings *viz*., S_1- 30x15 cm, S_2- 45x15 cm and eight fertilizer levels *viz*., F_1 (40:20:20 kg NPK/ha), F_2 (50:20:20 kg NPK/ha), F_3 (50:25:25kg NPK/ha), F_4 (50:30:30 kg NPK /ha), F_5 (60:30:30 kg NPK/ha, F_6 (50:25:25 kg NPK/ha+ sulphur @ 5 kg /ha), F_7 (60:20:30 kg NPK/ha+sulphur @ 10 kg /ha) and F_8 (40:10:20 kg NPK/ha+sulphur @ 15 kg/ha) on crop growth, seed yield and quality of sesame cv DS-5. Among the two spacings, significantly more capsule number/plant (78.15), seed number/ capsule (69.03), capsule seed weight (0.205g), seed yield per plant (4.50g), seed oil (45.68%), 1000 seed weight (3.75g), seed germination (91.63%), seedling vigour index (1776) were noticed in 45x15 cm spacing (S_2). Whereas seed yield per ha (981.20 kg/ha), net returns (64,863 Rs./ha) and B:C ratio (4.80) were higher in $S_{1.}$ (30X15cm). Similarly F_7 fertilizer level recorded significantly higher seed yield per plant (5.40 g) and ha (1110 kg), net returns (74,811 Rs./ha), B:C ratio (5.35), 1000 seed weight (3.95g), seed germination (92.50%) and vigour parameters as compared to F_1 fertilizer level. Treatment combination of 30x15cm spacing and 60:20:30 kg NPK/ha+sulphur @ 10 kg/ha fertilizer level (S_1xF_7) recorded significantly higher seed yield per ha (1178kg/ha), net returns (80,251 Rs./ha) and B:C ratio.

A laboratory experiment was conducted under ambient condition for six months to study the seed storability of sesame cv DS-5 with eight fertilizer treatment as listed above. The results revealed that the seeds produced from 60:20:30 kg NPK/ha+sulphur @ 10 kg/ha fertilizer level (F_7) maintained higher seed germination (76.50%), vigour index (1336), and lower electrical conductivity (1.46 dSm^{-1}) and seed infestation (8.24%) at the end of six month of storage period as compared to control F_1 (40:20:20 kg NPK/ha) (64.75%, 1047, 1.59 dSm^{-1} and 23.08%, respectively).