# GROWTH AND PRODUCTION OF SESAME

**Elly Kafiriti** and **Omari Mponda**
*Naliendele Agricultural Research Institute, Ministry of Agriculture Food Security and Co-operatives, Mtwara, Tanzania.*

**Keywords:** Broadcasting, capsules, drought resistance, intercropping, land clearing, low productivity, pest and diseases, plant residues, self pollination, water logging.

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**Summary**

Sesame is one of the most ancient oil crops known to mankind. It is grown as a rain fed crop throughout the tropics and subtropics. It is a short-day plant but also grows well in long-day areas. The crop thrives best on moderately fertile, well-drained soils with a pH ranging from 5.5 to 8.0 and is sensitive to salinity.

Sesame is cultivated both by smallholders and at larger industrial scales. Sesame propagation is by broadcasting or seed drilling in rows. Broadcasting seeds is the most common seeding method used by smallholder farmers. The seeds are often mixed with sand, soil or ash and then broadcast or drilled by hand in small furrows. Under large-scale production, the crop can be planted mechanically, with the equipment varying from small hand operated seeder units or animal-drawn drills to tractor-operated electronically controlled air seeders.

Whole or ground sesame seeds are used in various food preparations. Young leaves are used as a soup vegetable. However, most of the sesame in the world is consumed as oil. Sesame oil carries a premium relative to other cooking oils due to the presence of antioxidants. Oil is used in the manufacture of margarine and compound cooking fats. It is suitable for salads in combination with other edible oils.

The largest producers are India, China, Myanmar and Sudan. The largest consumers of sesame are China and India. Although the world production has kept increasing, it has not maintained the pace of an ever rising consumption, particularly in recent times.

## 1. Introduction

Sesame (*Sesamum indicum* L.) belongs to the family of Pedaliaceae, and is one of the most ancient crops and oilseeds known and used by mankind. It is also known as benniseed, gingelly, simsim, ajonjoli, sesamo and til. It was a major oilseed crop in the ancient world due to its easiness of extraction, great stability, and resistance to drought. Sesame was cultivated and domesticated on the Indian subcontinent during Harrapan and Anatolian eras (Bedigian and Van der Maesen, 2003). This is evidenced by the presence of archaeological remnants of the crop dating back to 5500 BC in the Harappa Valley in the Indian subcontinent (Weiss, 2000; Ashri, 2007). The Assyrian tablets depict how the gods ate bread and drank sesame wine together prior to battling and restore order to the universe.

Sesame is considered to have both nutritional and medicinal values. The seeds are used either decorticated or whole in sweets such as sesame bars and halva, in baked products, or milled to get high-grade edible oil or tahini, an oily paste (Bedigian, 2004). Tahini is widely used in foods in the Middle East. Sesame seed contains two lignans, sesamin and sesamolin. After roasting sesame seeds, sesamolin is converted to sesamol. Sesamol has been found to have anti-oxidative effects and to induce growth arrest and apoptosis in cancer cells. In recent times, the anti-photo-oxidant activity of sesamol for oil has been reported to be due to the scavenging of single singlet oxygen. Sesamol has a phenolic and a benzodioxide group in its molecular structure. The phenolic groups of molecules are generally responsible for the anti-oxidant activity of many natural products. On the other hand, benzodioxide derivatives are widely distributed in nature and have been shown to possess anti- tumor, anti-oxidant and many other biological activities.

It is noteworthy that in recent times sesame seeds have been found to contain immunoglobulin E (IgE) - mediated food allergens, with research reports from France (Agne *et al.* , 2003), Israel (Dalal *et al.*, 2002), Italy (Pastorello *et al.*, 2001) and the U.S. The more prevalence of sesame seed allergy is probably attributed to the wider and expanding use of sesame seed in baked products and fast foods.

## 2. Origin and Distribution

Discussion continues about the exact origin of sesame. It is often asserted that sesame has its origin in Africa and spread early through West Asia, China and Japan, which themselves became secondary centers of diversity. With the exception of *Sesamum prostratum* Retz., all the wild *Sesamum* species are found in Africa (Purseglove, 1977).

This variability and the importance of sesame in the economies of several African countries could further justify the African continent to be the ultimate centre of origin. However, Bedigian (2004) demonstrated that the crop was first domesticated in India, citing morphological and cytogenetic affinities between domesticated sesame and the south Indian native *S. mulayanum* Nair., as well as archeological evidence that it was cultivated at Harrapa in the Indus Valley between 2250 and 1750 BC. All these assertions make it difficult to say with certainty the exact origin of the crop.

Due to its relatively low productivity sesame ranks only ninth among the top thirteen oilseed crops, which make up 90% of the world production of edible oil.

## 3. Botany

The genus *Sesamum* is a member of Pedaliaceae family, which contains 16 genera and 60 species. The number of sesame species is not clear; however, about 40 species have been described, and 36 are mentioned in the *Index Kewensis.* Many occur in Africa (18 exclusively), 8 occur in the Indian – Ceylon region (5 exclusively). Almost all of the wild species are prevalent in Africa.

*Sesamum indicum,* as well as *S. capense* Burm. (*S. alatum* Thonn.) and *S. schenkii* Aschers, has a somatic number $2n = 26$. For *S. laciniatumthis is* $2n = 28$. For *S. angolens* and *S. prostratum* it is $2n = 32$. For *S. occidenale* and *S. radiatum* Schm & Thonn. it is $2n = 64$. *Ceratotheca sesamoides*, related to *Sesamum*, has $2n = 32$. Only *Sesamum indicum* is cultivated; however, a few other species: *S. angustifolium*, *S. calycinum*, *ssp. Baumii*, *S. malabaricum*, and S. *radiatum* are harvested and eaten occasionally, particularly during famine or food shortage (Ashri, 2007).

### 3.1. Cultivars and Classification

From the literature, *Sesame indicum* has a number of local cultivars. However, it is often claimed that the genus *Sesamum* has only one cultivated species *S. indicum* spp. *indicum*, and variable sesame *S. indicum* spp. o*rientale*. A range of collections of *Sesame* spp. and cultivars exist in the USA, India, Russia, China, Kenya, South Korea and to a lesser extent Japan, providing a valuable gene pool. South American collections resemble those from India and the Ethiopia-Eritrea area, and similar types occur in East Africa, where varieties usually are well branched and single flowered. The Indian regional cultivars can be broadly divided into early, little branched, few-flowered, and late, many-branched multi-flowered types.

During floral bud differentiation, sepals arise first, followed by petals and stamens. Then the carpels are initiated, forming a bi-carpelling, binocular superior ovary with several anatropous ovules. Flowers occur in leaf axils on the upper stem and branches, and the node number on the main shoot at which the first flower is produced is a characteristic of the cultivar and highly genetic.

Although sesame also grows well in long-day areas, it is generally considered a short-day plant. It flowers in about 45 days under 10-hour day length. Long-term selections in regions with different day length and light intensity have produced genotypes with different photoperiod requirements (Ashri, 2007). Some cultivars are day-neutral, such as the cultivar *Venezuela 51*. Depending on the cultivar, the crop matures in 75 to 150 days after sowing.

Sesame seeds contain 50-60 % oil and 19-25 % protein with antioxidants lignans such as sesamolin and sesamin, which prevent rancidity and give sesame oil a long shelf life. The lignin contents have useful physiological effects in human and animal health (Ashakumary *et al*., 1999). The principal unsaturated fatty acids are oleic and linoleic with about 40 % of each and about 14 % saturated acids.

The seeds are very rich in iron, magnesium, manganese, copper, and calcium (90 mg per tablespoon for un-hulled seeds, 10 mg for hulled), and contain vitamin $B_1$ (thiamine) and vitamin E (tocopherol). They contain lignans, including unique content of sesamin, which are phytoestrogens with antioxidant and anti-cancer properties. Among edible oils from six plants, sesame oil had the highest antioxidant content. Sesame seeds also contain phytosterols associated with reduced levels of blood cholesterol. The nutrients of sesame seeds are better absorbed if they are ground or pulverized before consumption, as in tahini (Bedigian, 2004).

### 3.2. Structure

*S. indicum* is an annual plant which, depending on the cultivar, varies in height from 0.5 to 2 m; however, varieties that are 1.0 to 1.4 m high are more common (Ashri, 2007). It has a large tap-root which can reach up to 990 cm in length and a dense surface mat of feeder roots, which makes it drought tolerant. However, under differing soil and moisture conditions, the plants may have a stronger tap root or a stronger group of fibrous roots. Roots of short-season single-stemmed cultivars have a more rapid rate of elongation than longer-season branched ones. Its erect stem is usually square with definite longitudinal furrows. However, cultivars with rectangular and wide, flat stems can also occur. Stem color can range from light green to almost purple but is most often dark green. The stem can be glabrous, slightly hairy or very hairy. Sesame varieties vary markedly in their branching pattern. Some cultivars have numerous branches; some have few (Table 1) whereas others have no branches. There is variation for the location of the branches - whether they grow from the base or higher up on the plant. The degree of branching is influenced by the environment and genetics.

| **Character** | **Year/nursery**[1] | **S25** | **S26** | **S28** | **S29** | **S32** |
|---|---|---|---|---|---|---|
| Branching style | All | Few | Many | Many | Few | Many |
| Number of capsules per leaf axil | All | 1 | 1 | 1 | 1 | 1 |
| Seed color | All | Buff | Buff | Buff | Buff | Buff |
| Yield (lbs/ac)[2] | 2005 UV | 1256 | 1613 | 1596 | 1601 | 1657 |
| | 2006 UV | 1470 | 1485 | 1560 | 1374 | 1735 |
| | 2007 UV | 835 | 1218 | 1274 | 936 | 1133 |
| | 2005 CP | 817 | 735 | 762 | 877 | 967 |
| | 2006 CP | 693 | | | 885 | 759 |
| | 2007 CP | 1105 | | | 1081 | 1188 |

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|---|---|---|---|---|---|---|
| Days to flowering | 2005-07 UV | 38 | 43 | 43 | 40 | 39 |
| | 2005-07 CP | 41 | 43 | 44 | 40 | 42 |
| Days to flower termination | 2005-07 UV | 76 | 84 | 84 | 81 | 81 |
| | 2005-07 CP | 80 | 78 | 78 | 78 | 77 |
| Days to physiological maturity | 2005-07 UV | 98 | 104 | 103 | 99 | 101 |
| | 2005-07 CP | 100 | 103 | 102 | 100 | 105 |
| Days to direct harvest | 2005-07 UV | 121 | 137 | 137 | 137 | 126 |
| | 2005-07 CP | 142 | 135 | 135 | 138 | 129 |
| Height of plant (ft) | 2005-07 UV | 4.3 | 5.2 | 4.9 | 4.7 | 5.1 |
| | 2005-07 CP | 4.4 | 4.7 | 4.5 | 4.1 | 4.4 |
| Height of first capsule (ft) | 2005-07 UV | 1.9 | 2.0 | 2.0 | 1.7 | 1.9 |
| | 2005-07 CP | 2.0 | 2.1 | 2.1 | 1.8 | 1.9 |
| Number of capsule nodes | 2005-07 UV | 28.0 | 30.3 | 27.6 | 28.7 | 26.7 |
| | 2005-07 CP | 24.7 | 25.3 | 24.3 | 25.0 | 24.3 |
| Average internode length within capsule zone (in) | 2005-07 UV | 2.7 | 3.3 | 3.2 | 3.2 | 3.5 |
| | 2005-07 CP | 2.9 | 3.2 | 3.2 | 2.9 | 3.3 |
| Capsule length (in) | 2001-2006 All | 1.12 | 0.88 | 0.89 | 1.10 | 0.84 |
| Seed weight per capsule (g) | 2001-2006 All | 0.212 | 0.234 | 0.229 | 0.232 | 0.227 |
| Shaker shatter resistance (%) | 2001-2006 All | 73.0 | 72.9 | 75.3 | 75.8 | 77.2 |
| Improved ND rating | 2005-07 All | 6.34 | 6.52 | 6. | 6.50 | 7.25 |
| Seed weight – 100 seeds (g) | 2001-2006 All | 0.305 | 0.331 | | 0.306 | 0.313 |
| Seeds per pound | 2001-2006 All | 145,525 | 136,858 | | 141,121 | 145,192 |
| Composite kill rating | 2005-07 UV | 5.15 | 5.83 | | 6.18 | 5.87 |
| | 2005-07 CP | 7.40 | 6.86 | | 7.03 | 6.56 |

1. Data is from two nurseries: UV = Uvalde, Texas, and CP = Caprock in Lorenzo, Texas

2. These yields are taken in research nurseries and should only be used as an indication of potential. The yields are replicated extrapolations from cutting 10 ft of sesame in a representative part of the field. The yields change under different planting dates, weather patterns, moisture/fertility, and farmer practices.

Table 1. Variability of sesame lines in Sesaco nurseries, Uvalde, Texas (Courtesy D. Langham, 2008, and www.sesaco.net)

The first true leaves are normally small and entire, and then they increase in size. The fourth or fifth leaves are the largest; they are flat and sometimes tri-lobed. The leaves are very variable, hairy on both sides, margins ciliate, estipulate. The lower leaves are opposite, broad and palmate lobed or palmate compound. Higher up on the plant they are alternately arranged, narrow and lanceolate and measure 3.0 to 17.5cm in length and 1.0 to 1.7cm in width. The petiole is about 1.0 to 1.5cm long. Leaf color varies and, depending on the variety, is lighter green or dark gray – green; in some cases there is a reddish anthocyanin pigmentation, expressed in the petioles and the stems.

Figure 1. Sesame crop showing numerous flowers. (Courtesy Langham, 2008).

Sesame flowers have five petals with the lower petal being longer, forming what is known as the lip. The lip is folded over the top of the flower keeping it closed to around sunrise; when it opens it forms a running strip for bees (Langham, 2007). Flowers are produced in the leaf axils, each axil bearing up to 3 white, yellow, pink or purple flowers. Plants have usually numerous flowers (Fig. 1), whose fruit is a capsule containing a number of small oleaginous seeds. The fruits are erect capsules, which form from flowers in the leaf axil about 4 – 6 nodes pairs to the top of the plant. Some germplasm lines, particularly from China, have been found to have 5 capsules per leaf axil in many nodes; two lines were found to have 7 capsules per leaf axil (Langham, 2007).

The capsules vary in length from 2 to 7 cm long (Fig. 2), they may be square or oblong with a shorter or longer tapered apex (beak). They are usually bi-carpellate or tetra-carpellate, and in each carpel there are two locules. The number of capsules per plant depends on the variety and the environment. In Egypt, some cultivars have about 180 capsules per plant while in Tanzania the number of capsules per plant is about 40 only. Each capsule has about 70 seeds.

There are dehiscent, non-dehiscent, seamless and indehiscent sesame varieties. Most sesame is produced with dehiscent cultivars. As soon as the capsules on dehiscent cultivars are mature, they split from the top downwards over about two-thirds of their length and shed their seeds which, if not timely harvested, leads to yield losses. The seeds are very small, 3 x 1.5 mm, ovate, smooth or reticulate, and they have no endosperm. One thousand seeds weigh 2 to 4g. The seed color can be white, yellow, grey, brown, chocolate or black. Seeds germinate usually within 5 days after sowing.

There is dormancy and the seeds remain viable for at least one year. There are also dormant cultivars but most will germinate without dormancy. Cases of seed remaining viable for 30 years when maintained in bottles in a warehouse that can reach more than $50^{o}$ C have been reported.

Figure 2. Sesame plants with capsules in leaf axils. (Source: Naliendele Agricultural Research Institute, Mtwara, Tanzania).

### 3.3. Pollination and Propagation

Sesame is considered a self-pollinated crop; but this is mainly because pollinating insects prefer flowers of other species if available (Ashri, 2007). Where insect activity is high, out-crossing can reach high levels, but cross-pollination is under 1 % when sesame is surrounded by other flowering crops. In Moreno, California, as high as 68 % out-crossing was registered in fields where sesame was the only flowering plant in a semi arid area with minimal other vegetation.

Although sesame also grows well in long-day areas, generally it is a short-day plant and normally will flower in 42 to 45 days depending on the cultivar. However, long term selections in regions with varying day length and light intensity have produced genotypes with different photoperiod requirements. In areas where sesame is grown in two or three seasons per year (for example India and Myanmar), cultivars varying in photoperiod responses have been developed (Ashri, 2007) and many have become adapted to local light periods. Considerable variation in growth and yield frequently occurs when cultivars are introduced in areas with similar day length but different rainfall or temperature patterns.

The flowers normally open at dawn between 5 and 7 a.m. and the pollen is shed shortly after remaining viable for about 24 hours. On cloudy or cool days, the flowers may open 3 hours after sunrise. As the flowers open, the bifid stigma separates and becomes receptive and is copiously covered with pollen from the stamens. Anthers open longitudinally and release pollen after the flowers open; the interval depending on the cultivar. The stigma is receptive one day before the flower opens and remains receptive for two more days unless fertilized. Under natural conditions pollen stays viable for about 24 hours. Temperatures below 15$^{o}$ C or above 40$^{o}$ C lead to pollen sterility, reduced fertilization and lower seed set, although there are exceptions. Langham (2007) reports sesame growing in Arizona where the day temperatures during the reproductive phase are seldom below 40$^{o}$ C and often reach 50$^{o}$ C.

Sesame propagation is by broadcasting or seed drilling in rows. Broadcasting seeds is the most common seeding method used by smallholder farmers. The seeds are often mixed with sand, soil or ash and then broadcast or drilled by hand in small furrows spaced at 50 cm apart as is the case in Tanzania. This makes distribution of the seed evenly, thus reducing the number of seedlings lost during thinning. Elsewhere, for example in Guatemala, Paraguay, Thailand and parts of India where sesame is planted by hand, and thus not broadcast, farmers poke a hole with an implement similar to a broomstick, and then put in 3-5 seeds, and cover. Where the crop is grown under large-scale production conditions, sesame can be planted mechanically. Commercial farmers in the US fields grow the crop with planters ranging from row planters to drills.

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**Biographical Sketch**

**Elly Kafiriti** holds an M.Sc. in Agronomy (1986) and a Ph.D. in Biological Sciences (2004). He is currently Principal Agronomist with the Oilseeds Research Program at Naliendele Agricultural Research Institute, Tanzania; and Zonal Director for Research and Development in Southern Tanzania, since January 2011. Additionally, he is a part time lecturer with the Open University of Tanzania and a member of the Cashew Research Steering Committee that reviews and approves cashew research activities and the budgets to implement them.

His research work has been mainly on sesame and groundnut agronomy, focusing on the development of appropriate technologies for increased production, and on participatory research with rice farmers in irrigated fields in south eastern Tanzania, specifically in identifying suitable rice varieties, determining appropriate and economic rice nitrogen fertilizer rates, land suitability for irrigated rice, and validating the benefits of bunds in rain fed lowland rice production.

Elly Kafiriti is author or co-author of more than 20 peer reviewed papers published in national and international journals, a number of pamphlets, fliers, booklets and video films; and a chapter in Crop Production in Tropical Africa (edited by R. H. Raemaekers)

**Omari Mponda** is Principal Breeder with the Oilseeds Research Program at Naliendele Agricultural Research Institute, Tanzania. He has a M.Sc. in plant genetics and crop breeding from Kishinev Agricultural University, Moldova (1983) and a Ph.D. on sesame flea beetles from the University of East Anglia, UK (1996). He currently coordinates several international research projects on sesame and groundnuts in collaboration with ICRISAT.

As Oilseeds breeder Dr. Mponda has been actively involved in developing new improved sesame and groundnut varieties resistant to biotic and abiotic stress, and released five improved sesame and seven improved groundnut varieties now widely grown in Tanzania. He is a member of the Research Crop Working Group on Oil Producing Plants in the SADC Plant Genetic Resources Center (SPGRC) in Zambia and a member of the Oleaginous Seeds Technical Committee, Tanzania Bureau of Standards, Tanzania. He also served as Regional Board Member of the Vocational Education and Training Authority (VETA) for the South East Zone from 2002 to 2008.

Omari Mponda is author/co-author of more than 20 peer reviewed papers published in national and international journals, a number of leaflets, booklets and video films.