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Cultivation technology of sesame seeds and its production in the world and in Egypt

Noureldin Sharaby^{1,2}, Andrey Butovchenko¹

¹Don State Technical University, sq. Gagarina, 1, Rostov-on-Don, 344010, Russia

²Agricultural Engineering Department, Faculty of Agriculture, Kafrelsheikh University, Egypt

E-mail: Noureldin_Sharaby@agr.kfs.edu.eg

Abstract. Sesame crop is one of the oldest oil producing crops around the world, which has a high ability to adapt to tropical and semi-tropical regions. Sesame seeds are widely involved in making healthy foods, which is increasingly in demand nowadays. Moreover, they have positive effects on human health because of their contain of nutrients, antioxidants, minerals, and vitamins. The purpose of this work is to give a general view of the sesame crop in terms of physical and chemical properties, which affect the design and work of agricultural machinery that used for sowing sesame seeds, as well as aims to give a global overview of available sesame cultivation technology and its development in different regions of the world to indicate the gaps and make future recommendations. The low cultivated area of the sesame seeds in many countries is caused by the low labor, which is a fundamental factor in addition to using the traditional methods of planting and sowing sesame seeds such as hand planting, and limited use of mechanically planting such as row planter until.

1. Introduction

Sesame (*Sesamum indicum* L.) has many different names, which vary from one country to another. It is known as benniseed, benne, gingelly, gengelin, tila, and sim-sim or semsemin in Africa, Southern United States, India, Brazil, Sanskrit, and Hebrew, respectively. It belongs to a Pedaliaceae family, it is the seeds of tropical annual *Sesamum indicum*. Sesame was discovered in its original home in Africa and then moved to both China and India, where it is considered one of the oldest and most important oil seeds known to mankind. Furthermore, it is distinguished with economically important and widely distributed overall the world, however, it is heavily grown in developing countries compared to developed countries. The sesame varieties spread throughout the Middle East are comparable to those found in Africa, where they are thought to have moved to it from Africa through Egypt. Sesame has been classified in different colors varies from white, yellow, red, brown, gray, to black [1].

Sesame seeds are used in various food and snack preparations as well as in salad dressing. The importance of the sesame crop in the whole world is increasing due to its a rich source of calcium, phosphorus, and protein, in addition, to being an economic oil. Sesame seeds contain the highest oil compared to any other oilseed to an extent of 50% and above. Most of the sesame seeds are used for oil production which is extensively used for cooking purposes and a small percentage is also used in cosmetics, perfumery industries, and pharmaceuticals, while the rest is used for edible purposes [2]. Sesame seeds are a rich source of protein such as soybeans, which makes them a high nutritional and healthy value [3]. In Egypt, most sesame crops are consumed mainly and directly in making food



rather than oil production. where it is cultivated in most of the Egyptian governorates and there is an increase in demand for cultivating sesame due to its low costs of production in addition to, it has a good economic return, especially for smallholder farmers. Therefore, in Egypt, the total cultivated area of sesame crop is increasing from around 11,264 ha during 1961 to about 36,907 ha by 2010[4].

1.1. Challenges to sesame production and low productivity

There are a number of constraints inhibiting the increase in the productivity of sesame crop, including:

- Research interest on sesame crop is much lower than other crops, such as corn and wheat, although sesame is a major export crop in many countries.
- The shortage of using modern technology in the cultivation and harvesting of sesame, such as planter and combines. Due to the low cost of farming, the majority of sesame farmers from the low-income class who do not have the ability to afford the modern technology in planting and harvesting sesame.
- Some sesame varieties with low production capacity are planted in some countries compared to other good varieties cultivated in other countries.
- Farmers depend on the traditional methods of sesame cultivation, such as hand planting or using traditional plowing system, which leads to the labor-intensive and increasing the cost of production, in addition to the inaccurate distribution of seeds along and between the rows.
- Irrigation water: even though the sesame crop is high drought-resistant, but due to the decrease in rainfall in the countries that depend on the cultivation of sesame on rainwater, in addition to a scarcity of irrigation water in the current period in many countries around the world, thus affecting the growth and development of sesame crop.

2. Physiochemical characteristics of sesame seeds

The physical and mechanical properties of sesame seeds can strongly influence their movements in agricultural machines. Therefore, they play a vital role in overcoming the problems related to the design and improving of various machines kinds such as sieve unit, cleaning, storage as well as they must be considered during the design and development of sewing machine. In reference [5], the researchers reported that the weight of thousands sesame seeds was recorded between 2.76 to 3.96 g/1000 seeds for 12 sesame species cultivated in Turkey, but the physical characteristics for some varieties of sesame seeds which are common and cultivated in Egypt such as Giza 32 and Shandawil 3 showed that the average of white colored sesame seeds was around 3.61 and 3.75 grams per 1000 seeds respectively, as the seeds were medium[1]. However, the physical characteristics of the sesame crop vary depending mainly on the varieties and cultural conditions from one country to another.

The chemical composition of sesame showed that the sesame seeds are significant source of calories, as they have a high level of oil varied from 44-57%, and between 18-25% for protein, whilst for carbohydrate and ash were around 13.5 % and 5% respectively[6,7]. The chemical composition of Egyptian sesame seeds varieties like Giza 32 and Shandawil 3 explained that their moisture, ash and total carbohydrates are 0.20-3.06%, 3.01-4.38%, and 4.33-11.59% respectively, while the crude values for both protein, fiber and oil were 18.92-23.18%, 6.75-7.34% and 56.49-59.97%, respectively[1].

In reference[8], the research was studied some sesame seeds samples in India for analyzing chemically and physically to evaluate some physiochemical characters of sesame seeds for that. He found that the values of physical and chemical properties include average weight of 2000 seeds (3.86 - 4.40g), true density (1286.57 to 1312.62 Kg m⁻³), moisture content (3.26%- 4.18%), carbohydrates (8.2% - 11.96%), Proteins (23.10% - 24.43%), crude fiber (5.58% - 6.16%), ash content (4.36% - 5.86%), crude fat (50.80% - 52.92%), Ca (1168.02 – 1222.65 mg/100g), Zn (4.21- 4.52mg/100g), and Fe (9.86 – 10.57 mg/100gm).

For some sesame seeds varieties in Ethiopia, such as Adi, Bawnji and T-85, the average weight of 1000 seed was varied from 2.74 - 3.16 g, while true density ranged from 1190.66 to 1215.58 kg m⁻³. Moreover, the values for moisture, crude protein, ash, fat, fiber, total carbohydrate were ranged: 3.17% - 3.96%, 22.58% - 24.27%, 4.46% - 6.19%, 50.88% - 52.67%, 5.60% - 6.26%, 8.3% - 11.69%,

while their contains form elements such as Ca, Zn and Fe for each 100g were 1172.08 - 1225.71 mg, 4.23 - 4.45 mg and 10.2 - 10.75 mg, respectively[9].

3. Global sesame production and trends

Sesame seeds can be cultivated on different soil types, but ideal soils for sesame cultivation should be characterized by good drainage, ventilation, and high fertility to achieve high production of seeds. The plant is usually 60 to 120cm. Sesame falls into the category of chilling-sensitive plants (0–15°C), along with crops such as rice, maize, soybean, cotton, and tomato. These plants are unable to enhance freezing tolerance when exposed to low temperature. For commercial sesame varieties, the optimum temperature ranges from 25°C to 27°C, while it requires 90–120 frost-free days to achieve optimal yields in cold regions [10].

The cultivable land used worldwide for sesame production has generally remained constant over the years, but in many countries, the crop has become marginalized because of higher remuneration from other crops and labor shortages pushing sesame to less fertile areas. It looks likely that sesame production might decrease in the future [11].

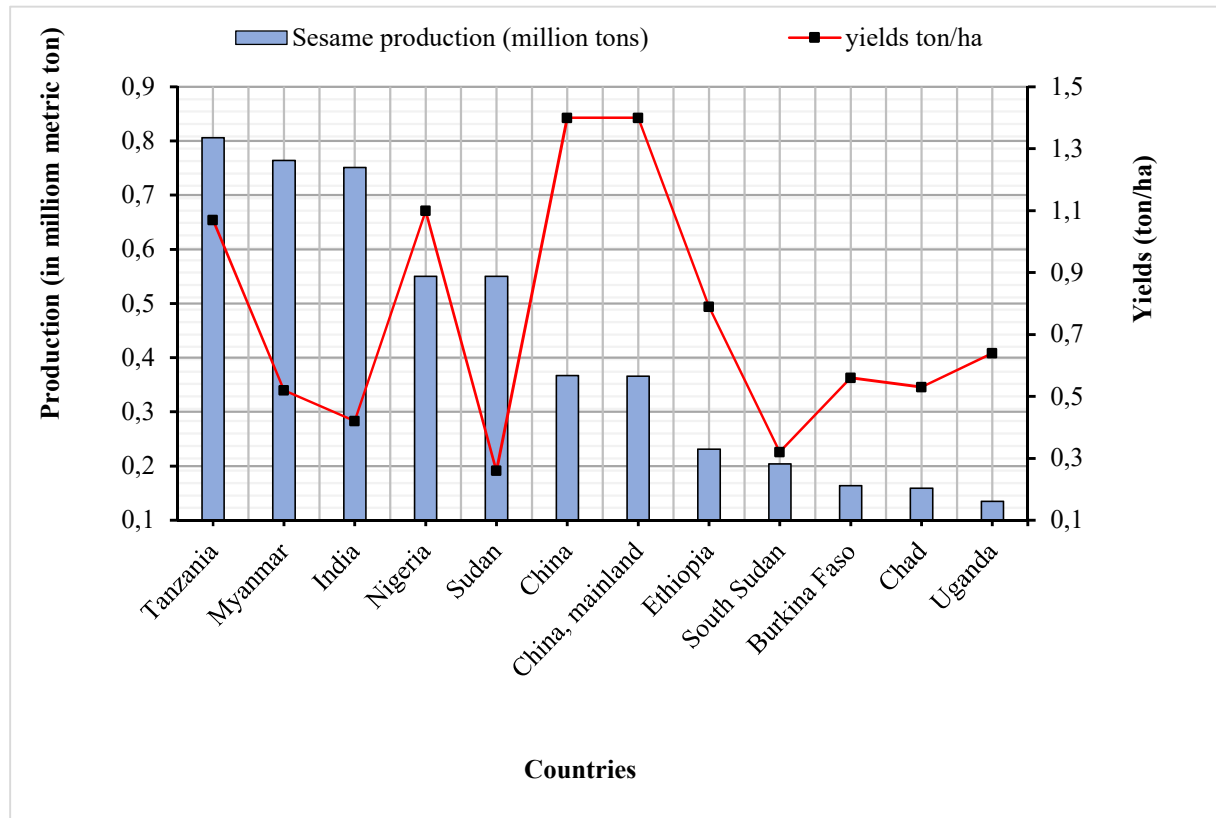
Global cultivated area of sesame crop in 2017 was around 10,245,246 ha, producing 5.90 million metric tons, which production increasing by 1.6 million cubic meters compared with yield production in 2013[12]. The topworld's leading countries for producing sesame crop in 2013 were Myanmar, India and China followed by Sudan, the United Republic of Tanzania (Tanzania), Ethiopia, Uganda, and Nigeria respectively. While in 2017, the largest producers of sesame seed were the Tanzania where its production rose compared to 2013, While Myanmar retreated to fourth place after it was the world's leading producers of sesame in 2013 followed by India, Nigeria, and Sudan respectively are shown in the figure 1. While in contrast, Japan is the largest sesame importer in the world due to sesame oil is an essential component in Japanese food, followed by China which is the world's second largest sesame importer, although it is one of the largest producers of sesame seeds. Moreover, there are others many major sesame importing countries such as the USA, the Netherlands, Turkey, Canada as well as France.

The production of sesame yields in developing countries is much higher than in developed countries, where sesame production in Asia and Africa represented more than 93% of global production. Asia produces half of the world's production of sesame crop, followed by Africa with an average yield of about 43%. Europe produces small quantities of sesame seeds and converts them into oil, showing that there is a higher demand for oil than for the seeds themselves, whereas the opposite applies in both Asia and Africa[10].

There is a major difference for production both sesame seeds and sesame oil from one region to another around the world, however, despite the rise of sesame production in Asia and Africa compared to Europe as showed in Table1[13]. But the average sesame yield per hectare in the European countries are the most productive. For example, Italy produces 7.2 metric tons per hectare. In contrast, some countries in African and Asian have a relatively low sesame yield such as Kenya which produces about 0.4 metric tons and Pakistan with production almost 1.2 metric tons of sesame seeds per hectare. The low cultivated area and production of the sesame seeds in numerous countries are due to some fundamental factor such as usually grown in less fertile soils, low labor and lack of nutrient management properly. Furthermore, using the traditional methods of sowing sesame seeds such as hand planting, and limited use of mechanically planting such as row planter is one of the major causes for low yields.

Table 1. The production output of sesame seed and oil in different reigion around the world.

Region	Sesame seed (millionton)	Sesame oil (million ton)	Total production (ton)
Asia	2.180	0.809	2.989
Africa	0.809	1,337	2.146
America	0.176	0.023	0.199
Australia	0	0.002	0.002
Europe	0.0014	0.031	0.0324

**Figure 1.** Top 12 world's leading countries for producing sesame crop in 2017, based on production output (in million metric tonnes),Source: <http://www.fao.org>.

3.1. Sesame production in Egypt

The total cultivated sesame area in Egypt has grown up from about 11,264 ha in 1961 to near 34000 ha by 2017, with an increase of around 300% during this period. In 2017, Egypt is the eighteen largest producers of sesame in the world, the sesame cultivated area was about 34000 ha which producing about 1.29 ton/ha and the total productions was 44000 ton. The average value of average of cultivated area and production for sesame seeds in Egypt between years 2010 to 2017 as illustrated in Figure 2, while the values for sesame yields were 1.25, 1.32, 1.30, 1.31, 1.37, 1.36, 1.38, 1.29 for years 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, respectively [12].

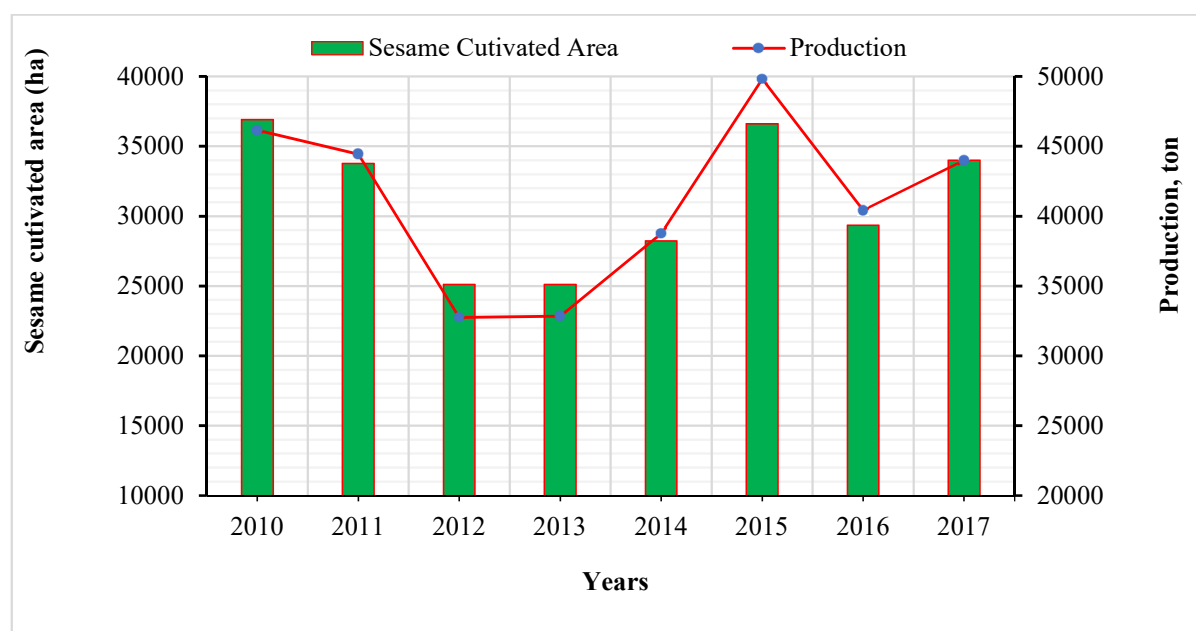


Figure 2. Average of cultivated area and production for sesame seeds in Egypt during the period from 2010 to 2017. Source: <http://www.fao.org>.

4. Sowing sesame methods

Sesame seeds are sown or planted manually via hand or mechanically using different methods, such as hand-operated seeder or tractor - operated seed drills as well as a precision planter (Figure 3). While precision sowing for sesame seeds is the best method between different sowing techniques compared with other methods, as it is used for accurately place single seeds or groups of seed almost equidistant apart along a furrow, however, using precision planting for sowing sesame seeds is still limited compared to other crops like cereals. The planting distance for sesame varies according to the seed varieties, for example, The recommended planting distance for sesame in Egypt is 10 -20 cm between plants in the same row and 40 – 60 cm between rows according to sesame varieties.

4.1. Handplanting

Sesame seeds are quite small and therefore difficult to plant it individually by hand, and thus they are often mixed with other substance such as sand, ash or soil, to boost the volume handled and to assist regular distribution. The commonly used mixture ratio which is used in broadcast sowing is 1: 3 for both seed and dry sand or earth respectively. However, as the latest field observations point out that a mixture of 1kg seed to 5kg soil was optimum and gives good stand establishment. The requirement seed rate varies according to the planting method. The research recommended seed rate per hectare for row ranges from 5 to 7 kg, while is between 7 to 10 kg per hectare for broadcast planting depends on the efficiency of the person in distributing the seeds equally [14].

Sesame hand planting adjusts leads to high population density in some area and empty space in another area. If the plant population is too high or groups of plants, seedlings are thinned to keep the distance between plants along the furrow within 10 cm by removing the weak or diseased plants. It is necessary to maintain the number of plants per meter in the range of 20 to 25 to attain the maximum yield, While in the case of empty spaces and gapping without seedlings between the plants along the furrow. They are replenished by re-sowing seeds in these gaps to replace the lost plants and then boost crop production. The hand-planting is the most common method of planting the sesame crop in Egypt as well as in most developing countries, that have the largest cultivation areas of sesame crop in the world.



Row hand planting under irrigation in Ethiopia



Broadcast hand planting in Tanzania



Row planter for sesame (SBN) support programme in Ethiopia



Pneumatic sesame row planter



NARDI row planter for sesame in ISSD programme in Ethiopia



Broad cast planting in Ethiopia

Figure 3. General types of sesame cultivation methods.

4.2. Mechanically planting

4.2.1. Mechanically by hand operator seeder/ Manual planter. The sesame hand operator planters may be simple as the various types of pushed or pulled seed drills. It can also be equipped with some parts to become more complex such as seed metering devices, furrow openers to put sesame seeds on the required depth in addition to the unit for covering and pressure seeds after planting as shown in figure 4. Before utilization of hand-operated planters, the farm needs to be prepared seed beds. Therefore, the farmers who prepare land using hand hoe, they use a manual planter with very limited indeed.



hand-operated seeder for sesame



Mechanically hand-operated seeder in Tanzania

Figure 4. Some types of manual planter machines.

4.2.2. Mechanically by tractor-operated drills. Nowadays, the sesame crop can be seeded using row planter either mounted on a tractor or pulled behind the tractor. Generally, planters may contain a

central hopper for whole rows or individual hopper for each row, which contain the seeds and transported them downwards to the seed metering device, and then the seeds fall into the seed delivery tube that conveys the seeds into the seedbed. The seed metering device aims to keep the seed spacing uniformity along the row and between rows, or is restricted to transfer seeds from the seed hopper and deposit it into the seed delivery tube, therefore, its performance affects the uniformity of seed distribution directly. The cultivation of sesame seeds using the row planter helps to maintain equal planting spacing within and between rows to enhance production and give high yield, with a soil cover of 2–5 cm. There is no widespread use of sesame seeds planter in many countries including Egypt, where there are few and limited in the form of partnerships programs between international and local organizations in some countries that producing sesame seeds as is the case in Ethiopia.

For example, one of the sesame crop development projects in Ethiopia is the programme on Integrated Seed Sector Development (ISSD), which aims to mainly at developing and promoting seeds production to provide seeds of superior varieties, and affordable and suitable for a larger number of farmers, thus contributing to the protection of food security and boost the economic development in Ethiopia in general. The programme is a joint effort between some local Ethiopian organizations represented in Bahir Dar University, Haramaya University, Hawassa University, Mekelle University, Oromia Seed Enterprise, the Ethiopian Seed Association, and Centre for Development Innovation of Wageningen UR as an international organization. The programme is funded by the Directorate General for International Cooperation through the Embassy of the Kingdom of the Netherlands in Addis Ababa. They worked with Rhea Composites (specialized in producing products for the agricultural sector) for developing prototypes and local made row sesame seeds planter for small-scale farmers (Figure 3)[15].

While for large-scale farmers, as in one of the sesame cultivation programs in northwest Ethiopia supported by the Sesame Business Network (SBN) in collaboration with some Ethiopian agricultural institutions such as Mamaye Agricultural Development PLC; Humera Agricultural Research Centre (HuARC); Rhea Composites and Ultimate Motors were testing and demonstration of tractor-mounted sesame row planters for NARDI precision row planter as illustrated in Figure 3. The programme is a joint effort of the Centre for Development Innovation of Wageningen UR, the Netherlands as a foreign organization with some local Ethiopian research centers, such as Agricultural Research Centre (GARC), Humera Agricultural Research Centre, Amhara and Tigray Regional Bureaus of Agriculture (BoA), Regional Agricultural Research Institutes, Bahir Dar University, Mekelle University [16].

5. Conclusion

Sesame seeds are an oily crop, which is distinguished by being edible and odorless. In addition, it is a good source of protein for man and livestock alike. With the current climate changes in the world and drought conditions in many regions of the world, especially in Africa, there is a demand to grow drought-resistant crops, including sesame. There is also an increasing demand for sesame in the global market as it enters as a major component in many healthy foods and is also a step in the right direction towards ensuring food security with increasing income generation, especially that sesame represents an important crop for export in many countries with the possibility of creating numerous jobs, especially in the in developing countries.

Sesame cultivation in rows is one of the most successful ways to enhance sesame yields and boost its quality. However, up until now, the utilization of row planter for planting sesame is still very limited compared to other crops, and unavailability in many sesame producing countries, Consequently, farmers tend to use the hand planting.

6. Recommendation and Future Prospects

Based on the research studies conducted on the sesame crop, it is necessary to overcome the challenges that stand in the way of increasing the sesame yield and quality, which were mentioned above. The sesame crop should be given more research interest like other crops, which is a major export crop in many countries. In addition, there is an interest in the utilization and development of

sowing or planting sesame seeds technologies on the rows while keeping the equal distances between the seeds along the row and between the rows using a precision seed planter, which saves time, costs, reduce the seeds used in agriculture as well as improving the sesame production. However, also the justification of row planter should be based on the local conditions of the countries producing sesame, which will enhance its utilization for planting sesame seeds compared to the importing planter, which does not conform to local conditions, especially in developing countries.

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