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SESAME PRODUCTION AND UTILIZATION

PREPARED

BY

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I. BOTANICAL DESCRIPTION

- Sesame (*Sesamum indicum*) has early origin in East Africa and India (Bedigian, 1985; Nayar and Mehra, 1970). It is an erect, broadleaf annual crop belongs to Pedaliaceae plant family
- It is perhaps one of the older crops cultivated by man, having been grown in the near east and Africa for over 5,000 years for cooking and medicinal needs
- The ancient attributed near-mystical power to sesame. The oil was used in barter since it would preserve and store in the desert for years
- It grows to height of 20 to 60" depending on the variety and the growing conditions
- Some varieties are highly branched, while others are un branched or alternate (Fig. 1)
- The bell shaped white to pale rose flowers begin to develop in the leaf axil about 38 - 45 days after planting with 2 flowers /stem/day for about 35-40 days
- Multiple flowering is favored by opposite leaves
- Some varieties have 6 flowers/stem/day for 25 – days

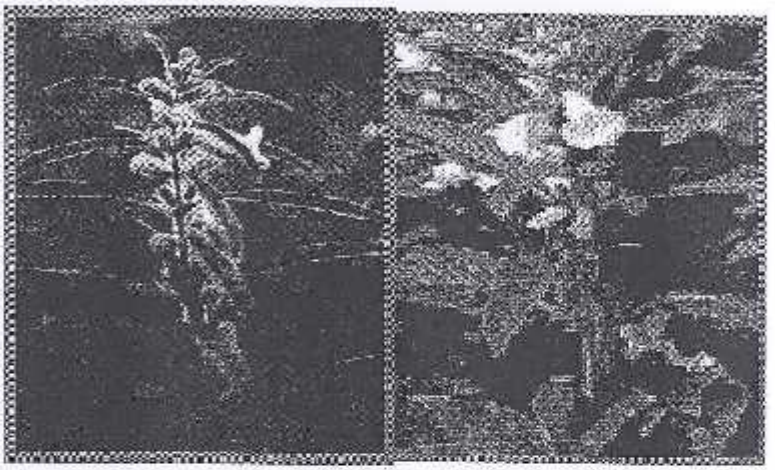

Fig. 1 Sesame Plant

- Sesame varieties grown in the U.S. will stop blooming based on heat units and availability of moisture and fertility. Higher heat will accelerate maturity
- In dry weather or under low fertility the plants will stop blooming sooner
- Sesame is normally self-pollinated, although cross pollination by insects is common
- It is highly drought resistant and grows best where cotton does well
- The fruit is a deeply grooved capsule (1 to 3" in length) with 8 rows of seed each capsule that contains 50 to 100 or more seeds
- The seeds mature 4 to 6 weeks after fertilization
- The growth of sesame is indeterminate, that is, the plant continues to produce leaves, flowers and capsules as long as the weather permits
- Most capsules split open at maturity but indehiscent capsules will not. Indehiscent, seamless, and shatter resistant lines will not have the seed drop out when the plant is inverted
- Depending on moisture, fertility, variety, and temperature, the first capsule is located 1 to 2.5 ft from the ground
- Sesame seeds are small (100,000 or 180,000 per pound of seeds or 220/g) (Martin et al., 1976) and vary in color (Fig. 2)
- One thousand seeds weigh about one ounce

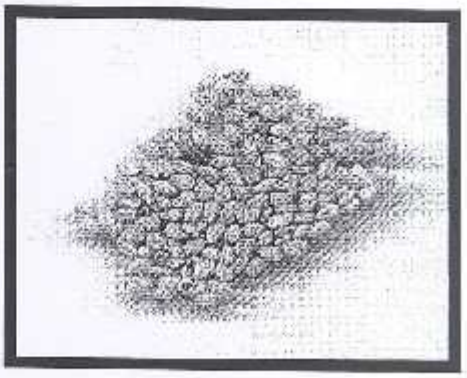

Fig 2. sesame seeds

- The lighter colored seeds are considered higher quality
- Seed color is genetically controlled and light-colored seed is preferred for confectionary uses

II. HISTORY AND OVERVIEW

- To day, world production is estimated to be over 15 million acre (6.2 million hectares, Table 1)
- Over 57% of the world production is in Asia. Most of the production is in India and Burma (Myanner)
- In Asia most of the sesame is consumed within 100 miles where it is grown since farmers grow very small plots for their extended families
- Africa grows 15% of the world's sesame, with Sudan, Uganda, and Nigeria being the key producers
- Latin America grows 4% of the total world production in Mexico, Guatemala, and Venezuela
- The U.S. usually imports about 40,000 metric tones annually, mostly from Guatemala, Mexico, and India
- Sesame ranks eights in the world production of edible oil seeds
- In U.S. the acreage of sesame in the late 1990s has varied from 20,000 to 40,000 acres, depending on prices of major agronomic crops, weather outlooks, early season weather damage to cotton and contract prices for sesame (which are tied to world prices)

Table 1. World Sesame Production and Imports to the U.S. in 1999

Region/country	Production (ha)	Production (M/T)	Imported to U.S. (M/T
Africa			
Sudan	1,459,000	220,000	1,000
Uganda	186,000	93,000	Nil
Nigeria	155,000	60,000	140
% of Total	**29**	**15**	**3**
Asia			
India	2,000,000	650,000	7,2000
China	67,700	550,000	350
Burma (Myanmar)	500,000	186,300	100
% Total	**51**	**57**	**20**
Latin America			
Mexico	58,000	32,700	7,100
Guatamala	50,000	43,200	11,500
Venuezela	46,000	23,500	4,800
% Total	**2**	**4**	**61**
World			
50 countries	**1,107,000**	**282,6000**	**5,810**
Totals	**6,228,000**	**2,427,000**	**38,000 (1.5%)**

- After production, over 80% of the land is rotated to other crops to reduce potential weed problems and to extend the biological benefits from sesame production to other crops
- Texas is the leading state in U.S. sesame production with substantial production in Oklahoma. Nominal acreage is planted in Arkansas and Missouri
- The majority of U.S. sesame is grown under natural rainfall; 10% or less receives supplemental irrigation
- U.S. yields range from 400 to 1,200 lbs per acre and affected by length of growing season, rainfall, weather, and plant stand
- Yields are substantially higher in other countries where sesame is a primary crop and the small hand-tended receive substantial rainfall and is hand harvested. The U.S. record for experimental yield was 2,500 lb per acre in fields near Yuma, Arizona
- For years the U.S. was totally dependent on imported sesame seed, since harvesting was labor intensive. Similar to soybeans, sesame became commercially feasible in the U.S. after shatter-resistant genotypes were developed, which made combine harvesting practical
- Genetic advances over the past ten years have produced superior lines with both single stemmed (uniculm), branched stemmed and shattering resistant lines
- Presently U.S. production is about 40,000 acres and is based primarily in Texas and Oklahoma
- The crop responds to 50 lb of nitrogen per acre, which enhance seed production and capsule fill
- After production, over 80% of the land is rotated to other crops to reduce potential weed problems and to extend the biological benefits from sesame production to other crops
- Texas is the leading state in U.S. sesame production with substantial production in Oklahoma
- Production in the U.S. during 1950 and 1960 was hampered by excessive shattering Problems. However, the shattering resistant types of sesame available to producers today greatly reduce these losses
- Diseases and insect problems appear minimal and relatively dry summer weather makes sesame production possible

III. USES

- Sesame oil is considered as "queen" of vegetable oil. Seeds have 50% oil and 25% protein and are used in baking, candy making. It is also used in paints, soaps, cosmetics, perfumes, pharmaceuticals, and insecticides
- The outstanding characteristics of sesame oil is its stability and keeping quality as well as resistance to rancidity
- The oil contains about 47% oleic and 39% linoleic acid
- Sesame oil and foods fried in sesame oil have a long shelf life because the oil contains an antioxidant called sesamol
- Sesame meal, left after the oil is pressed from the seed, is an excellent high –protein (34 to 50%) feed for poultry and livestock
- In most areas of the world, sesame is produced for its cooking oil and other direct food uses, with some direct consumption of the seed

- In the U.S. sesame seed is primarily used as a confectionary topping, in baked goods, or as a condiment
- Sesame seed imparts unique taste and textured features when included with baked products
- Sesame is rich in calcium and high in antioxidants and other healthful features

SESAME ANTIOXIDANTS

✓ Sesame has traditionally been valued as a health food throughout Asia and Middle East

✓ It is described in the ancient medical texts of India and China for preserving preventing health,disease, and promoting general well being

✓ Sesame is rich in natural antioxidant or lignans, which are both oil and water- soluble These antioxidant compounds preserve the stability of sesame and oil

✓ Furthermore, they are biologically active and provide a variety benefits upon ingestion These compounds are being investigated in both animal and human clinical studies as potential industrial antioxidants and nutraceutical and pharmaceutical ingredients (Namiki, 1995)

✓ The biological functions of sesame lignans Antioxidant content in sesame may be enhanced through traditional crop breeding

✓ Sesame breeding programs in the U.S., Korea, China, Thailand, and Japan consider antioxidants as one of the selection factors in the development of new varieties for the future

✓ Researchers have found sesame reduces nematode populations

IV. ENVIRONMENTAL REQUIREMENT

A. CLIMATE

✓ Commercial varieties of sesame require 90 to 120 days. Daytime temperatures of 77 to 80°F are optimal, below 68°F growth are reduced, and at 50°F germination and growth are inhibited

✓ Sesame is very drought tolerant due in part to an excessive root system. However, it requires adequate moisture for germination and early growth and a minimum rainfall of 20 to 26" per season is necessary for reasonable yields

✓ Moisture levels before planting and flowering have the greatest impact on yield

✓ Sesame is intolerant of water-logging

✓ Rainfall late in the season prolongs growth and increase shattering losses

✓ Wind can cause shattering at harvest and is cited as one reason for the failure of commercial sesame production in France

✓ Initiation of flowering is sensitive to photoperiod and varies among varieties

✓ The oil content of the seed tends to increase with increased photoperiod. Because protein content and oil are inversely proportional, seed with an increased oil content has a decreased protein content

B. SOIL

✓ Sesame is adaptable to many soil types, but thrives best on well-drained, fertile soils or medium texture

- ✓ Sesame prefers neutral to slightly alkaline pH, with moderate fertility. The optimum pH for growth ranges from 5.4 to 6.7
- ✓ Sesame has a very low salt tolerance and can not tolerate wet conditions

V. CULTURAL PRACTICES

A. SEEDBED PREPARATION

- ✓ Sesame requires a warm, moist, weed-free seedbed. Good drainage is important, because the plant is extremely susceptible to water logging at any stage of growth
- ✓ Since sesame is planted late, several generations of weeds can be killed by repeated shallow tillage before planting
- ✓ Medium textured soils are most favorable. Sesame does not like heavy clay soils or irrigation water containing high concentration of salt
- ✓ Raised beds are preferred to allow for good soil moisture while providing a method of keeping the moisture off the stems
- ✓ Generally the seed bed preparation used for cotton is satisfactory for sesame
- ✓ Sesame seeds need to be planted into good moisture and covered shallow. However, very limited success have occurred from watering up (furrow irrigation or pivot)
- ✓ Seed should be cleaned thoroughly and treated with one ounce of 75% Captan per 100 lb of seed to prevent damping off. This treatment is especially important for non shattering varieties. Because the seeds of the non shattering varieties spend more time in the soil before germination, they need more protection from fungal pathogens in the soil
- ✓ Always plant pure seeds of the same varieties and type. Mixing varieties results in stands uneven height maturity and seed quality

B. Planting Date:

- ✓ Planting is the most critical aspect of growing sesame
- ✓ A good rule of thumb is not to plant until at least a month after the last killing frost in the Spring. However, soil temperature is a better indicator of when to plant. For good germination plant after the soil temperature at the 8" depth at 8:00 a.m. averages 68^{O}F for ten days. Do not plant until all danger of cool weather is past
- ✓ In general sesame is planted 2 to 3 weeks later than cotton or grain sorghum
- ✓ In areas with long growing season and adequate summer rainfall or irrigation water, plant sesame in June or July
- ✓ A farmer can do nothing to improve yield on poor stands except replant
- ✓ In dry land production it is highly recommended that 15 to 50 gallons of water per acre be placed in the seed line to help insure uniform emergence in irregular soils
- ✓ If soil moisture is high, the gallons of water per acre in the seed lines has been successfully lowered to 10 gallons of water per acre

C. Row spacing

- ✓ A row spacing of 27 to 40" has shown to be adequate for sesame production
- ✓ Seldom is a drill used in Texas for planting purpose because of difficulty in getting a stand and having enough moisture
- ✓ In Oklahoma where producers are using modern drill with depth bands, thousands of acres have been successfully planted

- ✓ Problems with marginal moisture and drill without depth control are still a concern
- ✓ To get the desired distance drill rows that farmers will need to plug off portions of the planting unit

D. Seeding Rate

- ✓ Sesame seed is small and has less energy than larger seeded crop
- ✓ Sesame can be seeded with a row crop planter equipped with vegetable planter boxes
- ✓ Populations of 250,000 to 300,000 plants/acre in 18 to 30" rows have given the highest yields
- ✓ This is about 1lb/acre for 30" in rows
- ✓ Depth of planting varies with soil type and soil moisture from 1 to 2"
- ✓ Uniform depth and seed rate are essential for stand establishment resulting in maximum yield
- ✓ The planting rate should be increased if the seeds are:
  - planted deep
    soil moisture is limited
  - soil temperature is cool
  - soil is compacted, cloddy, or trash
- ✓ The planting rate should be reduced:
  - seed beds are well prepared
  - have adequate soil moisture
- ✓ Lift off packer wheels from planting line or put as little pressure on as possible
- ✓ Sesame seeds are too weak to break through much crust even a light one
- ✓ Scratching sometimes helps if timing is right
- ✓ Most of the time with a crust, a replant is required

E. VARIETIES AND GROWTH FEATURES

- ✓ Until 1985, sesame production in the U.S. centered around shattering-type varieties such as 'Baco' which produced lateral branches with numerous dehiscent pods which split open near maturity
- ✓ These shattering types were the only practical lines for commercial production since seed yields were 50% higher than those of non-shattering experimental lines
- ✓ These dehiscent lines were typically hand-cut or harvested with a binder and shocked for field drying before threshing
- ✓ Labor requirements and weather uncertainties precluded practical commercial production in the U.S.
- ✓ Higher yielding shatter resistant varieties, such as (Sesaco) 'S-17', 'S-23', 'S-24', 'S-25', and others with unique agronomic features were developed after years of breeding and selection by Deral G. Langham
- ✓ These varieties produces superior yields and are well adapted for mechanized harvest
- ✓ The crop may be cut with swather, allowed to field dry for two to three weeks, and then picked up with a combine header to be threshed or the crop may be harvested directly with a combine
- ✓ The high oil content and fragile seed coat require careful combine settings to avoid damage
- ✓ In the southwestern U.S. plants mature in 95 to 110 days and may be planted well after the usual planting dates for cotton
- ✓ The plant produces a deep tap root which improves soil properties and water penetration

- ✓ Over 85% of U.S. sesame is rotated annually with cotton and other crops
- ✓ In some years, sesame can be planted immediately after harvesting wheat and with some early harvests of sesame, wheat can be planted in the fall
- ✓ Sesame varieties vary in determinate growth habit but defoliate naturally well before a killing frost
- ✓ Harvest aid chemicals are not essential for timely harvest
- ✓ In subsequent rotational crops, volunteer sesame is easily controlled with mechanical, cultural, and herbicidal practices
- ✓ Sesame produces about one-third as much as sorghum under ideal conditions. However, it produces more than one-third as much as sorghum under poor growing conditions
- ✓ Another method of estimating sesame yields before planting is base on the fact that sesame produces approximately the same number of pounds of seed as cotton
- ✓ Shattering sesame for the homozygous indehiscent gene discovered by Derald. G. Langham in 1943
- ✓ Another type of closed sesame discovered gene discovered by Derald G. Langham in 1986 and is homzygous for the seamless gene
- ✓ The two types of non-shattering gene prevent the capsule from opening at dry down
- ✓ In the later years, modified genes were added that allowed commercial sesame to open slightly
- ✓ The indehiscent and seamless genes were abandoned for commercial sesame because even with the slight capsule opening, it was too difficult to get the seed out in the combine with extensive damage
- ✓ For instance, if cotton makes a bale/acre (1,350 lb of lint and seed/acre), sesame would make about 825 lb of seed/acre under the same conditions
- ✓ From 1998-2001, sesame yields ranged from 300 to 1,200 lb/acre in dry land acreage and 800 to 1,700lb/acre in semi-irrigated/irrigated production
- ✓ There is a great diversity within the several hundred varieties of sesame. However, the sesame varieties are usually divided into two types: Shattering and non shattering
- ✓ Shattering varieties- grown in the U.S. have been produced from the variety Kansas 10, or K 10
- ✓ The seeds of this un branched variety have high oil content over 50% but their bitter flavor limits their value on the whole-seed market
- ✓ Some shattering varieties grown in the U.S. include: Margo, Oro, Blanco, Dulce, and Ambia
- ✓ Non shattering varieties: have been developed to allow mechanical harvesting. Though these varieties usually contain somewhat less than 50% oil, their seed is used for oil production only. Some non shattering varieties include: Baco, Paloma, UCR3, SW-16 and SW-17
- ✓ Mechanical harvesting is more successful with varieties that have minimal branching and a height from the soil surface to the first capsule of about 12"

F. Seedling Establishment

- ✓ Sesame grows slowly at first and does not compete well with weeds
- ✓ Cultivate sesame to control weeds before rapid growth begins at 4 to 5 weeks after emergence (seedling height about 3 to 4 inches)
- ✓ Early cultivation causes seedlings to grow faster, possibly because of improved soil aeration
- ✓ If the soil becomes compacted by excessive rain, cultivation may be needed to aerate the soil

- ✓ Sesame plant color change from yellowish to green has been noted by several producers after plowing compacted soils, some indicated that color change was visible within six hours
- ✓ Areas with adequate rainfall for the production of dry land sorghum or cotton usually have enough moisture for sesame production
- ✓ Highest yields of sesame reported in the U.S. have been from experiments grown with irrigation in desert areas
- ✓ Sesame uses approximately 50% less water than cotton, 66% less water that grain sorghum and 75% less water than corn
- ✓ Stand establishment is the biggest challenge in profitable production of sesame
- ✓ Since seedlings lack the emergence vigor of larger-seeded agronomic crops, soil crusting can be a severe problems in stand establishment
- ✓ Seed bed preparation and shallow seed placement are essential to enhance emergence
- ✓ Seedlings are vulnerable to early-season weather adversities
- ✓ Rainfall or irrigation right after planting usually causes soil crusting and hamper seedling emergence

G. LENGTH OF GROWING SEASON

- ✓ Sesame is a long season crop, taking about 125 to 135 days from planting to maturity
- ✓ Sesame is of tropical origin, it performs best in areas where temperature remains high throughout the growing season
- ✓ Seed do not germinate well when soil temperature are below 70°F
- ✓ Plant growth is retarded by cool temperature after the stand is established
- ✓ Growth and fruiting are favored with average daily temperature in the range of 86 to 92°F
- ✓ Early literature indicated that capsule set is usually poor when temperatures exceed 105°F

Fertility requirements for sesame are similar to millet:

H. FERTILITY AND LIME REQUIREMENTS

- ✓ 80 lb N, 20 lb P_2O_5 and 20 lb K_2O and per acre
- ✓ The N recommendation is for soils with less than 2% organic matter. Reduce the N to 60 lb/acre for soil with 2% to 5% organic matter and 40 lb/acre if the soil has more than 5% organic matter
- ✓ The P_2O5 and K_2O recommendations are for soil testing in the "optimum" range
- ✓ The P_2O5 and K_2O and up to half of the recommended N could be applied in a band alongside the row at planting if desired
- ✓ A pH of 5.6 or above is satisfactory
- ✓ There is not likely to be a "starter" effect, however, if the crop is planted after soil temperature reaches 70°F as recommended. Sesame is not a poor-land crop
- ✓ Applying a balanced commercial fertilizer at planting time is required for satisfactory production on soils of low to moderate fertility
- ✓ Fertilizer rates and ratios are similar to those recommended for cotton on the same soil
- ✓ Side dressing with nitrogen bearing fertilizer may be necessary when growing plants are unthrifty and light green in color
- ✓ Sesame will require approximately 40 to 80 lb/acre on irrigated production and 25 to 60 lbs of nitrogen/acre on dry land production
- ✓ A large amount of the nitrogen is taken by the plant during flowering and the crop responds well to foliar feeding

✓ Apply phosphorous and potash according to the soil test. High phosphorous levels in saline soils may decrease sesame yield

Table 2. Nitrogen Requirement of Sesame Based on Available Moisture

Rainfall and Irrigation	Pounds of Nitrogen need/acre
Dry land < 28" of rainfall in soil profile	25 – 35 units of N
Dry land > 27" of rainfall in soil profile	30 – 60 units of N
Full irrigation, 12" additional water applied to full soil profile	60 - 80 units of N
Semi-irrigation, 6 – 8" of additional water applied to full soil	40 – 60 units of N

I. Water-Irrigation

- ✓ Sesame is one of the most drought tolerant crops in the world and should do well in areas of 16 to 18 " of annual precipitation
- ✓ It will respond to irrigation if applied properly
- ✓ It prefers fast, light irrigation (i.e., short runs or some slope)
- ✓ Excessive moisture is not beneficial and extended periods of rainfall and/or high humidity may cause leaf diseases
- ✓ Plants standing in water for more than a few hours may be killed
- ✓ Watering should be discontinued when flowering stops (70-80 days depending on variety)
- ✓ If a dry period occurs prior to planting plan on heavy pre-irrigation
- ✓ Follow with next irrigation 4 5 weeks later (watering up or watering back to help a poor stand seldom works). Two to three additional irrigation may be needed
- ✓ Application should be made every 7 to 12 days unless there is rain
- ✓ When the plant show leaf drop by 2:00 PM, the sesame will benefit from an application of water in the next few days (depending on soil texture)

VI. PEST MANAGEMENT

PEST PROBLEMS

- ✓ Several pests attack sesame with potential to limit economic production
- ✓ Some of these pests cause moderate to severe yield losses while others have been noted in the U.S. but are not severe problems
- ✓ However, some of these pests may help circumvent problems later as sesame production expands in the U.S.
- ✓ Historically, crop pests cause only normal damage in the each years of production but become more serious since pest populations tend to increase as crop acreage expands
- ✓ No pesticides are labeled for sesame production in the U.S.
- ✓ Sesame is a minor crop in the U.S. agriculture and agricultural chemical companies cannot justify developing new pesticides for small acreage crops
- ✓ However, a special program known as "IR-4 Minor Crop Pesticide Clearance Project" works with land grant universities, commodity groups, chemical registrants US EPA, USDA, and others to obtain pesticide tolerances and labels

1.0. WEED OVERVIEW

- ✓ Annual and perennial weeds are the most troublesome of all pests in U.S. production
- ✓ Weed control is essential to obtain good stands, reduce competition, and avoid quality/contamination problems
- ✓ Cultural controls are utilized to the maximum extent
- ✓ Since sesame is grown in rotation, chemical weed control in other crop helps reduce weed problems in sesame
- ✓ For example, "yellow" herbicides, such as trifluralin/Treflan and pendimethalin/Prowl, and post emergence herbicides such as glyphosate/Roundup in cotton help reduce troublesome weeds when sesame is planted the following year
- ✓ Another cultural practice is to prepare land for planting, let weeds germinate after a rain, and then harrow lightly or apply glyphosate to kill weeds that may emerge before planting sesame
- ✓ Presently there are no herbicides labeled for use in domestically produced sesame. However, weeds cause two problems in sesame: 1) weeds adversely impact sesame yields and 2) at harvest, weeds seeds contaminate sesame and are difficult to remove when processing the crop

1. 1. COMPETITIVE WEEDS

- ✓ Early-season weeds significantly reduce sesame yields. After planting, sesame is not highly competitive with weeds
- ✓ Annual weeds create a shade canopy and intercept sunlight above the crop
- ✓ Weeds have extensive root systems and extract moisture at the sacrifice of sesame seed production
- ✓ Even moderate infestation of annual weeds reduce sesame seed yields by 20 to 60%. As much as 10,000 acres of sesame have been discarded in some years because of weed infestation
- ✓ The availability of a soil-applied herbicide is extremely important in reducing weed seedlings when the crop is getting established
- ✓ Sesame typically grows 3 to 6 ft tall which creates a shade canopy and due to its height advantage, suppresses late season weeds
- ✓ Annual grasses, such as Texas panicum, southern crabgrass, and broad leaf signal grass grow faster than sesame under the warm, moist conditions commonly found at planting time
- ✓ This increased competition for moisture and nutrients can results in a substantial reduction in sesame growth and yield
- ✓ Some weeds, such as Palmer amaranth and other pigweed species, may grow as tall or taller than sesame. This early-season height advantage of some broadleaf weeds seriously reduces crop yields and interferes with mechanical harvesting
- ✓ The most competitive annual weeds that cause the greatest yield losses include pigweed or 'careless weed', cocklebur, annual sunflower, morning glory, and others. The presence of weeds at harvest increases the moisture content in seed and cause storage problems. Perennial weeds pose unique problems in sesame since these weeds have established root systems and are more competitive than the annual weeds
- ✓ Perennial weeds commonly found in sesame are similar to those that are most prevalent in cotton, peanuts, and sorghum

- ✓ With the use of glyphosate for perennial weed control in Roundup-Ready cotton, these weeds commonly occur in isolated areas within fields rather than field-wide infestation
- ✓ Tillage is not particularly effective due to the root system and growth johnsongrass, silverleaf nightshade 'whiteweed', and bermudagrass
- ✓ Broadleaf weeds can also be competitive early in the season due to their fast growth. Some have reported pigweed, devil's claw, and silver leaf nightshade have died while sesame has survived
- ✓ Some farmers have reported that sesame has suppressed silver leaf nightshade

1. 2. WEED CONTROL

Because of their slow early growth, sesame plants are poor competitors against weeds. Select fields with low weed densities

(i) Mechanical:

- ✓Cultivate sesame fields early and as close to the rows as possible
- ✓Shallow cultivations is recommended, because the fine, fibrous roots grow close to the surface and are easily damaged
- ✓ Early cultivation causes seedlings to grow faster, possibly as a result of improved soil aeration
- ✓Cultivate only as necessary to control weeds

(ii). Chemical:

- ✓Pre emergence herbicides alachlor (Lasso) and Trifluralin (Treflan) have been used successfully for weed control in sesame
- ✓Growers should check current labels for use of these or other products in their growing area

1.3. Major weeds and their control

- ✓ Herbicides, such as trifluralin (Treflan) are commonly used and incorporated prior to planting
- ✓ Rates of 0.75 ai/acre, 0.50 ai/acre, and 0.35 ai/acre are recommended for trifluralin on clay, silt, and sandy-loam soils, respectively
- ✓ Shallow cultivation may be an acceptable method of weed control
- ✓ Several shallow tillage operations kill early germinating weeds before planting, with between-the-row cultivation after emergence
- ✓ Keep field as clean as possible of Johnson grass, wild cucumber, sunflower, and ground cherry
- ✓ These seeds are difficult to clean out of sesame. Sesame delivered with these seeds are subject to price discounts
- ✓ Sesame is very sensitive to herbicide bands in cool or wet weather
- ✓ Sesame tolerates Dual, fusilade, Poast, select and some Prowl/Treflan
- ✓ Sesame does not tolerate Atrazine, Caparol, Paraquate, Pursuit, Roundup, Cadre, and 2-4D. In some years sesame can follow Cadre in peanuts, but in dry years there has been carry-over effects on sesame. There have been mixed results with wheat herbicides such as Amber, Gleen, Ally, Finesse, and Assert.
- ✓ Some farmers have planted after using these herbicides with results ranging from little effect to complete eradication of sesame

1. 4. CROP CONTAMINATION BY WEED SEEDS

- ✓ While weeds cause yield reductions in nearly all crops, an additional problem is created in sesame by cross contamination from weeds seed at harvest
- ✓ One of the desirable features of sesame is the attractiveness of the seed on consumer products
- ✓ The presence of weed seed creates a contamination problem that is not acceptable in the baking and consumer product industry
- ✓ For example, a single Johnson grass seed or any black object mixed with sesame seed is quickly mistaken for rat, excreta
- ✓ Historically, sesame from foreign countries has had problem with rat and insect, excreta
- ✓ Food processors continually inspect for any signs of etc –like materials on baked goods and other products
- ✓ Sesame seed contaminated with weed seed is purchased at a discount price, based on the type and the level of contamination. In some years, 20% of the field-run sesame samples must be discounted to off-set extra expense and losses incurred by weed seed contamination. When weed seeds are similar in size and density to sesame seed, extra processing is required to remove the contaminants
- ✓ Most weed seed and other foreign matter can be removed by mechanical screening and gravity/density and air separation. Pigweed seed are also small, dark and mistaken as undesirable foreign matter
- ✓ When weed seed is similar to the crop seed, these separation processes are less effective or may require additional steps or slower processing for removal
- ✓ Quality standards for whole sesame seed are higher than for seeds of other crops which re ground or milled to produce flour
- ✓ Some of the most common weed contaminates of sesame include johnsongrass, kochia, wild cucumber, and sunflower, and plus nightshaeds
- ✓ Johnson grass is the leading source of contamination since the seeds are similar in shape and size to sesame and shatter easily at harvest
- ✓ Until recently, the perennial grass was difficult to control in crop land. However, several soil applied herbicides used in other will control johnson grass seedlings
- ✓ The widespread use of glyphosate in roundup Ready cotton has helped to reduce johnson grass when sesame is grown the following year
- ✓ Johnson grass is a greater problem when sesame is planted after corn or sorghum, since this grassy weed is more prevalent in these crops
- ✓ Additionally johnson grass seed may be separated in the washing or dehulling process
- ✓ Dark seed that escapes all the above cleaning processes can be removed with sorters
- ✓ However, the presence dark weed seed in field-run sesame adds to cost, slow down processing, and creates quality concerns
- ✓ Kochia is a robust, annual broadleaf which grows 4 to 6 ft tall and is commonly found throughout the Great Plains states
- ✓ Kochia is highly competitive, interferes with mechanical harvesting, and produces bodacious quantities of seed which can contaminate sesame
- ✓ Kochia is prevalent in untilled or waste areas around fields but can be controlled by several herbicides cleared for use in other crops
- ✓ Weed control by sanitation, crop rotation, or avoidance strategies are commonly practiced to reduce kochia infestation in crop land

1.5.TILLAGE

- ✓ Tillage is practiced in 50% or more of the crop. Most growers cultivate one or two times and a portion of the acreage is hand hoed. Sweep cultivators, rotary hoes, and other implements break crushed soil and kill weeds between the rows
- ✓ However, early-season summer annual weeds such as pigweed must be controlled in the crop row to reduce crop losses
- ✓ Once sesame is established, cultivators can be used to throw soil into the row to cover small weeds
- ✓ Cultivation can also control early flushes of weeds after irrigation or rains but crop height limits tillage late
- ✓ Tillage cannot be practiced when sesame is drill-seeded in 12 inch rows

1.6. HERBICIDE DEVELOPMENT

- ✓ Several herbicides have been evaluated in sesame but there are no federally registered herbicides for sesame in the U.S.
- ✓ Herbicides trials have been conducted at Yoakaum, Texas, to identify possible chemicals that could be labeled with U.S. EPA
- ✓ Some history and background on herbicides studies is appropriate. In test plots, "yellow herbicides", such as trifluralin (Treflan) or pendimethalin (Prowl) have controlled weeds when incorporated lightly at planting. However, when trifluralin or pendimethalin have been incorporated to normal depths in soil for peanut or cotton production, severe stand reductions have been noted in sesame
- ✓ A federally –approved herbicide is important for the expansion of sesame in the U.S.
- ✓ Field and lab residue studies were initiated in 2000 through the IR-4 program to establish a tolerance for metolachor (Dual) and clethodim (Select)
- ✓ However, these chemicals are not registered and should not be applied in sesame until cleared by the U.S. EPA
- ✓ Residue trials are under way, which involve field work (at Weslaco), sample preparation (at College Station), chemical analysis and fulfillment of regulatory provision
- ✓ This work is conducted on complex Good Laboratory Practice standards defined by the U.S. EPA to assure quality and confidence in the data in the multi-step process
- ✓ This work with metolachlor and clethodim is coordinated with the registrants and U.S. EPA to gain a federal label for use in sesame in the U.S.
- ✓ Metolachlor was selected as the soil-applied herbicide since it has controlled small-seeded annual grasses and broadleaf weeds in research plots at 1.5 to 2.0 lb (*a.i.*) per acre without damaging the shallow-seed crop
- ✓ Since additional weeds problems occur after the crop is planned, a post emergence herbicide would be extremely useful for growers
- ✓ Clethodin (select) has been labeled for use in cotton and peanut and is very effective on several annual and perennial grasses (such as johnsongrass). Clethodim is more effective for IR-4 program. None of these herbicides are currently labeled for use in sesame and should not be used until federal approves are granted

Table 3. Summary of Weeds with Implications for Sesame Production in the Southern Western U.S.

Pest	Scientific Name	Impacts/Comments
Weeds-annual broadleaf		
Annual sunflower	*Helianthus spp.*	Early-season competition, mechanical harvest
Kochia	*Kochia scoparia*	Yield reduction, mechanical harvest, seed contamination
Morningglory	*Ipomoea spp.*	Early-season competition, mechanical harvest
Pigweed (careless weed)	*Amaranthus spp.*	Yield reduction, mechanical harvest, seed contamination
Wild cucumber	*Enchiocystis lobata*	Seed contamination
Annual Grasses		
Broadleaf signalgrass	*Brachiaria platyphylla*	Early –season competition
Southern crabgrass	*Digitaria ciliaris*	Early –season competition
Texas panicum	*Panicum texanum*	Early-season competition
Perennial Weeds		
Bermudagrass	*Cynodon dactylon*	Yield reduction
Johnsongrass	*Sorghum halepense*	Yield reduction, severe seed contamination
Silver nightshade	*Solonum elaeognifolium*	Yield reduction

2. 0. DISEASES OVERVIEW:

- ✓ Several pathogens attack sesame and can impose severe economic losses
- ✓ Plants diseases are not a significant problem since sesame is a relatively new crop on limited acreage in the U.S.
- ✓ However, as acreage and production increases, disease problem will become more prevalent and will need to be considered in future production and research programs
- ✓ There are many fungicides cleared for use in sesame
- ✓ The American Phytopatholigical Society maintains an inventory of plant disease (Farr et al. 1989) and includes records of pathogens observed on sesame
- ✓ Diseases of sesame include several fungal leaf spots, bacterial leaf blight, Fusarium wilt, stem and crown rots, and incidence of Phytophthora root rot (Table 4)

2.1. DISEASES AND THEIR CONTROL

- ✓ The most common diseases are leaf spot, leaf and stem blight, Fusarium wilt, charcoal rot, and root rot
- ✓ Some of the disease organism are carried on the seed. It is advisable to use disease-free seed and treat it with a fungicide before planting

2.2. SOIL-BORN PATHOGENS

- ✓ Genetically pure seed is produced, screened, and maintained for planting purposes but is not treated with a protective fungicide since treated seed cannot be used for other purposes
- ✓ Presently seedling diseases are minor since sesame is usually planted in warm soils
- ✓ Breeders are developing sesame that will germinate at lower temperature, but early planting may increase seedling diseases

2.3. FUSARIUM WILT

- ✓ Fusarium will has been noted in Georgia and Texas.
- ✓ Rhizoctonia spp. was observed on sesame in North Carolina.
- ✓ Both of these pathogens can attack seedlings, cause damping off, reduce crop stands in cool wet soils, and may attack the crop late in the growing season
- ✓ Sesame seedlings may emerge but seedling diseases may reduce stands 70 to 90%
- ✓ Some varieties are very susceptible to Fusarium but breeding lines have shown some resistance
- ✓ Fusarium may cause 80% yield loss with susceptible varieties
- ✓ After sesame seedlings are established, root damage can occur from Helminthosporium sesami and Thielaviopsis basicola
- ✓ These pathogens infect the vascular system and can reduce stands and cause premature death
- ✓ Aerial stem rot is present in Texas and probably persists in the southwestern state as well

2. 4. VERTICILLIUM WILT

- ✓ A major pest has occurred on sesame in New Mexico and at higher elevations in Texas
- ✓ This pathogens is commonly present in slightly acid to alkaline cotton field
- ✓ In some years a Verticillium wilt resulted in plant losses in sesame variety trials at Lubbock but did not appreciably affect yields (Brigham and Young, 1983)
- ✓ In western or semi-arid areas, verticillium wilt could be severe diseases in future years
- ✓ Crop rotations and sanitation are important control strategies

2. 5. PHYTOPHTORA ROOT AND CROWN ROT

- ✓ They can be a serious disease problem in sesame
- ✓ Infestation start in the root, spread to the crown area and move into the lower stem
- ✓ The fungus is soil-born and moves with surface water
- ✓ Phytophtora root rot is common in pepper and tomato field and could become a significant problem when sesame is grown in rotation
- ✓ Phytophtora root rot is far more severe when sesame is planted two or more years in the same field but lower when the plots are continually rotated to new land each year
- ✓ Trials with numerous fungicides and fumigants did not suppress Phytophtora root rot in sesame, which can result in a 10% yield loss with susceptible varieties

2. 6. FOLIAR DISEASES

- ✓ Several leafspot pathogens, including Alternaria sesame, Cercosceptora sesame, and Cercospora sesami, have been reported on sesame. They can be a serious disease problem in sesame in Florida , Georgia, Mississippi, North Carolina, and South Carolina
- ✓ Bacteria Leaf spot did not cause yield loss but could be a problem in periods of high rainfall
- ✓ Leaf spot organisms cause spotting on leaves and progresses to destroy leaf tissue
- ✓ Leaf blight was noted on sesame plants in Mississippi. Leaf blight appears as a scorched blotch on the leaf surface and appear very quickly
- ✓ Bacterial leaf blight may occur after rain or irrigation splashes soil on leaves and leaf surfaces are wet for two hours or longer
- ✓ If leaf blight is a potential problem, the management of irrigation water or scheduling may be advisable as alternative means to reduce the fungus
- ✓ Powdery mildew was noted in the Winter Garden late in the season on the more determinate types but did not severely limit yields

2. 7. NEMATODES

- ✓ Sesame has a deep tap root, which produces a natural biocide suppresses most nematodes
- ✓ Growers have noted a suppression of nematode population in rotational crops such as cotton, peanuts and other crops
- ✓ Researchers have documented the suppressions of several genera of root-knot nematodes in soil where sesame was grown (Starr and Black, 1995)
- ✓ Most sesame varieties are resistant to root knot nematodes
- ✓ There have been no reports of nematodes reducing yields in commercial sesame fields in the U.S. but problems have occurred in India
- ✓ Sesame exerts a biocidal control for nematodes and one way to suppress nematodes is alternate sesame with other crops
- ✓ This natural suppression may offer some practical biological control of nematodes in other crops
- ✓ Encapsulation or pelletization of sesame stalks, capsules, and seed are being researched as a potential nematocide
- ✓ Sesame pellets might be formulated and applied to soil to suppress nematodes in other fields
- ✓ Sesame residues probably suppress nematode reproduction but may not kill existing nematode in other fields
- ✓ Sesamin and sesamolin, the same antioxicants found in sesame seed, are also present in other parts of the plant

2. 8.CHARCOAL ROT:

- ✓ It was observed on sesame in Texas and California on young seedlings and in mid-season
- ✓ Charcoal rot attacks roots, crowns, and lower when sesame is planted after other susceptible crops
- ✓ The stem rots just above the soil line and results in severe stand reductions
- ✓ Early sesame breeders in Texas and Arizona worked on resistance to charcoal rot and it is rarely a problem

Table 4. Summary of Diseases Potential Pests, with Implications for Sesame Production in the Southern Western U.S.

Pest	Scientific Name	Impact/Comments
Diseases–soil borne		
Charcoal rot	*Macrophomina phaseolina*	Stand reduction
Cotton root rot	*Phymatorichum omnivorum*	Little impact noted
Phytophtora root & crown rot	*Phytophtora nicotianae*	Stand reduction
Verticilium wilt	*Verticillium albo-atrum*	Could be severe in future
Diseases - Seedling		
Fusarium wilt	*Fusarium spp.*	Damping off, stand loss
Seedling wilt	*Rhizoctonia spp.*	Damping off, stand loss
Aerial stem rot	*Helminthosporium sesami*	Root damage, stand loss
Root rot	*Thielaviopsis basicola*	Root damage, stand loss
Diseases Foliar		
Leafspot	*Alternaria Cercoseptoria, Cercospora Peseudomons*	Loss of leaf tissue
Leaf blight	*Cornespora cassiicola*	Loss of leaf tissue
Powdery mildew	*Leveillula taurica*	Late season loss of foliage

- ✓ Diseases do not cause much commercial damage on sesame, but they may increase when acreage increases
- ✓ Bacterial leaf spot is most likely to cause trouble
- ✓ Fusarium wilt can be a serious problem in South Texas on fields previously planted in sesame
- ✓ The current sesame varieties have tolerance to fusarium
- ✓ Farmers have planted sesame on field with serious cotton root rot problems and never seen the problem. However, there is a root rot (Phyophtora parasite) that does attack sesame
- ✓ Verticillium wilt also attack sesame

3. 0. INSECTS OVERVIEW

- ✓ Awareness of insect pests should be noted to reduce potential losses (Table 5)
- ✓ Bt (*Bacillus thuringiensis*) and neem (*Azadirachtin*) are cleared for use on sesame: Aluminium phosphid, HCN, and Diatect (pyrethrins and diatomaceous earth) have post harvest tolerance for insect control in storage
- ✓ Insect pests threaten most crop and cause economic losses as a result of foliar feeding or damage to seed or other harvestable portions of the plant
- ✓ In sesame, two pests have caused economic problems and two others have been observed feeding on sesame
- ✓ It should be noted that sesame acreage in the U.S. has been relatively low and massive insect problems have not yet developed into re-occurring problems

3. 1. INSECTS AND OTHER PREDATORS AND THEIR CONTROL

- ✓ Sesame plants are often attacked and damaged by aphids. Thrips will stunt seedlings and injure developing flower buds so that capsules do not set
- ✓ The gall midge (Asphondylia sesami Felt.) and various caterpillars have been important in some countries

- ✓ Green stink bugs, red spiders, grasshoppers, cut worms, army worm, and bollworms also attack sesame, but do not cause extensive damage
- ✓ Green peach aphid, (cotton aphid does not affect sesame), thrips, grasshoppers, cutworms, and white fly are the most common insects attacking sesame
- ✓ When these insects are bad, plants may not set sufficient capsules
- ✓ Grasshoppers generally do their damage to areas of the field adjacent to rangeland

3. 2. FOLIAR INSECT PESTS

- ✓ Aphids are more severe in sesame where pyrethroid insecticides have been applied in other crops and have reduced the natural enemies of aphids in sesame
- ✓ Aphids feed on new foliage near the top of the plant and can attack sesame nearly anytime and reduce plant growth
- ✓ Damage is caused by the loss of plant sap and reduced plant vigor
- ✓ Sesame has produced good yields in research plots when aphids were sprayed once (however the seed could not be sold since the chemical was not cleared)

3. 3. STORED INSECT PEST:

- ✓ Larva of several common stored product insects invade sesame seed
- ✓ Commonly recognized sanitation measures are practiced around storage facilities to reduce insect harborage
- ✓ As seed is placed into storage, inert diatocacious earth is added
- ✓ As larva feed on seed, silica from the finely ground diatoms destroys the gut and causes death
- ✓ Aluminum phosphide is not commonly used in sesame storage facilities or warehouses

3. 4. VERTEBRATE FEEDERS:

- ✓ At research stations, deer frequently feed peanuts, forage plants, and other crops. However, deer and other wildlife have not been attracted to sesame foliage
- ✓ In severe drought deer may nibble sesame, but do not like the muscilage on the leaves and will do little damage
- ✓ Cows, horses, and sheep will not eat sesame, but goats will feed on the foliage
- ✓ Field mice sometimes come out of a pasture into sesame but have not caused economic damage

Table 5. Summary of Insects with Implications for Sesame Production in the Southern Western U.S.

Pest	Scientific Name	Impacts/Comments
Insects		
Aphids	*Myzus spp.*	Attacks new foliage, reduce vigor
Silver whitefly	*Bemisia argentifolii*	Destroys lower foliage
Garden webworm	*Achyra rantalis*	Larva feed on foliage
Bollworm	*Heliocoverpa zea*	Larva feed foliage
Cabbage Looper	*Acrididae (several)*	Larva feed on foliage
Grasshopper	*Trichoplusia ni*	Destroys foliage

VII. HARVESTING

1.PREPARATION FOR HARVESTING

- ✓ At present, over 99% of the sesame in the world is harvested manually
- ✓ In general, the mature plants are cut, bundled, and shocked to dry
- ✓ In some area the shocks are left in the field. In other areas the bundles are moved to a shock fence (as in part of Africa) or to a threshing floor (as in parts of India)
- ✓ As plants dry, the capsules open and some of the seed can fall out on a threshing floor, the shocks can be moved every few days, and the seed collected. But if the capsules open in the field, the fallen seed is lost
- ✓ There is a limited amount of mechanization in some countries. In Venezuela, the fields are manually cut to open space for tractors. The plants are then cut with a binder, manually shocked, and then combined mechanically
- ✓ Some farmers manually pitch the shocks into the combine while others use an ingenious device to slam the shock into an auger that feeds it into the combine
- ✓ A limited amount of the crop area in Australia is combined directly after spraying the crop with Reglone to desiccate the plants, but there is still a tremendous amount of shattering and loss of seed
- ✓ Reglone was tried briefly in Venezuela, but abandoned because the yields are not superior to traditional methods and the quality of seed was not suitable for the market
- ✓ In Thailand and Korea, some innovative farmers cut the sesame plants with rice cutters, still shock the sesame, and move the sesame to stationary thresher
- ✓ Korea has a government support price for sesame far above the world price. As the result, Korean farmers invest much more time in their sesame field. It was determined that 1,255 man-hr/ha were used for growing sesame with all manual labor
- ✓ With some mechanization the hours were reduced to 247 hr ha^{-1}. In Venezuela the estimates are 7.65 hr ha^{-1}
- ✓ Sesame is ready for harvest when the stalk dries down where it will be cut
- ✓ For best yields, sesame must be harvested as soon as the crop is ready
- ✓ The present shattering resistance varieties of sesame will hold the seed through 6 weeks of rain
- ✓ The current problem is not with the shattering but rather with the deterioration of the plant which may result lodging
- ✓ Clean all harvest machinery and trucks for food crop

2. HARVESTING

- ✓ Sesame is ready for harvesting 90 to 150 days after planting
- ✓ In general, the un branched varieties mature earlier
- ✓ The crop must be harvested before the first killing frost to obtain high quality seeds
- ✓ At maturity, leaves and stems tend to change from green to yellow to red in color. The leaves will begin to fall off the plants
- ✓ The shattering and non shattering types require different harvesting techniques. Caution is recommended to minimize seed damage and loss
- ✓ Shattering sesame varieties are usually swathed green and placed upright in small shocks, about 8 bundles per shock
- ✓ Tighten the strings on the shocks in 2 or 3 days. In two weeks the crop will be ready to thresh

- ✓ Light rains during this time will not seriously damage seed
- ✓ Sesame should be threshed using a low cylinder speed (450 to 500 rpm)
- ✓ Screens may need to be adjust (1/8" round perforations) for the small seed size.
- ✓ Nonshattering types can be combined directly at low cylinder speed

3. HARVESTING EQUIPMENT

- ✓ Combine settings should allow for minimum seed damage
- ✓ Since sesame seed is 50% oil, high broken seed reduces the grade
- ✓ Slow cylinder speed with loose canvas are necessary for quality harvest
- ✓ Check the combine bin often to determine the number of broken seeds, a maximum of two broken seed per 100 is acceptable
- ✓ The rate of feeding, cylinder concave surface and speed, setting of cleaning sieve and air blast must be in "balance" to do an efficient job of threshing with excessive seed damage
- ✓ Most combines can do an excellent job when set up properly
- ✓ Small grain concaves and sieves usually clean well enough for good seed grades
- ✓ A5/32" punched hole bottom screen cleans (alfalfa screen look like they will work in the shop, but do not work well over time - they will plug
- ✓ "Screening in" the back of the platform saves additional seed while allowing operator visibility
- ✓ Modified air headers ands some Lynch (Heston) attachment work. Generally maize and Brittain fingers do more harm than good
- ✓ For tall (6ft or over) sesame or lodged crops a JD # 50 series all crop headers is recommended
- ✓ Protect seed from rain and drew in combine and trucks. Wet seed can heat up faster that most seed

VIII. DRYING AND STORAGE

1. DRYING AND STORAGE

- ✓ Sesame may be stored at room temperature for approximately 5 years with out loss of viability. Freezing temperature damage seed and make them less marketable
- ✓ For safe long–term store, sesame seed should be clean, have a moisture content no more than 6% and be stored at a relative humidity of approximately 50% and at a temperature less than 18°C
- ✓ Oil content (when seed are pressed for oil) and seed condition are important in the sesame industry
- ✓ Oil percentage of < 59% are not acceptable. Most sesame varieties today yield 50 to 55% oil
- ✓ Some sesame varieties are grey or brown in color and a specialized sesame, black in color, is sold in Japan, Korea, China, Vietnam, and Myanmar
- ✓ The black seed coat color is important since the color can bleed into the seed and the dehulling process will not remove the color
- ✓ Sortex machine are used to remove the dark seeds prior to use

IX. YIELD POTENTIAL AND PERFORMANCE RESULTS

- ✓ Domestically (U.S.) sesame is a relatively high risk crop
- ✓ Sesame yields is test plot average 1,000 to 1,500 lb/acre, though as much as 2,300 lb/acre have been produced under irrigation in California.Commercial yields are usually lower
- ✓ The introduction of the nonshattering characteristics in high-yielding, normally shattering varieties carried with it a reduction in yield and/or seed quality
- ✓ The development of higher-yielding non shattering varieties is necessary for sesame to compete with other crops
- ✓ Sesame yields are variable depending upon the growing environment, cultural practices, and cultivar (Table 6)
- ✓ Worldwide yields averaged about 340 kg/ha in 1986, however, as high as 2,250 kg/ha have been obtained in test plots in Texas (Brigham, 1985)
- ✓ Major contributing factor to low yields in Sesame is that the seed capsules shatter causing a loss of large amounts of seeds, particularly when the crop is machine harvest
- ✓ Sesaco Corporation in Yuma, Arizona, has developed semi-indehiscent commercial cultivar with yield ranging from 600 -1,600 kg/ha (Brigham, 1987)
- ✓ A panel of sesame experts met and summarized plant breeding objectives for sesame improvements (Ashri, 1987). These include:
  - Improved seed retention in the capsule
  - Increase oil content
  - Uniform maturity and
  - Diseases resistance

X. MECHANIZATION CONSIDERATION

1. Plant height
2. Height of the first capsule,
3. Branching
4. Lodging resistance
5. Weed control
6. Crop dry down
7. Capsule loss
8. Seed cleaning
9. Planting seed germination
10. Seedling emergence

Table 6. The Variability of Sesame Lines in Sesaco Nurseries, Uvalde Texas

Trait	Range
Plant height	67 – 245 cm
Height of the first capsule	25 - 150 cm
Capsule zone length	18 - 120 cm
Number of branches	0 -20
Height of first branch	2 – 135 cm
Number of nodes on main stem	4 – 65
Internode length at middle of capsule zone	1 – 11 cm
Main internode for whole capsule zone	1.9 – 8.0 cm
Leaf* size (5th node from base)	
blade length	11.7 - 31.0"
blade width	2.1 - 23.6"
petiole length	4.5 – 20.0"
Days to 50% flowers	28 – 98
Days to 90% flower termination	51 - 133
Flowering period	10 - 98 days
Days to physiological maturity (PM)	70 – 167
Days to first dry capsule (DC)	74 - 180
* *Generally one of the largest leaves on the plant*	
Swathing window (PM – DC)	14 - 28 days
Number of capsules per leaf axil	1 -7
Number of locules	2/4/6/8
Capsule length	1.3 -7.0 cm
Seed loss at dry down	0 -100 %
Seed weight/capsule	0.08 -0.48 g
Capsule weigh/capsule	0.07 – 0.37g
Capsule harvest index	36 – 72%
Seeds per capsule	30 - 120

1. Height of the plant

- ✓ When swathing sesame or indirect harvest, the plant should be short enough so that the reel pull in the plants rather than first pushing them out and then pulling them in
- ✓ The maximum height acceptable for all harvest implementation is 150 cm and lower plants are preferable

2. Height of the First Capsule

- ✓ Whether swathing or direct combining, the cutter bar should be below the lowest capsule
- ✓ In a laser leveled field the first capsule at 15 cm is adequate
- ✓ The capsule zone is defined as the plant height from the ground to the first capsule
- ✓ The longer the capsule zone, the higher the yield. However, if the capsule zone is increased by height or by lowering the first capsule, there are harvesting problems that compromise any increase in yield

3. **Branching**

- ✓ In the binder, it is preferable to have uniculm lines, but branches help in swathing and combining
- ✓ In both auger and belt swathers, branched plants will become intertwine and making easier to move the plants to the window
- ✓ In picking up the windows, the intertwining also helps in moving the plants into the combine
- ✓ In looking at harvested fields, it is simple to separate out the uniculm and branched field:.- the uniculm fields have more trash piles where the combine had to stop and back –up after plants went below the pick up attachment and blocked feeding from the window
- ✓ In direct harvest this same intertwining helps the header auger to move the plants to the feeder housing
- ✓ However, if there is too much branching, it is difficult to separate the crop at the edge of the header
- ✓ With too much intertwining, separating the crop can cause loss of capsules and/or shattering of seed
- ✓ Beeach and Imrie (2001) also prefer branching, their rational is related more to problems with cutting the thick stems of uniculm lines

4. Lodging resistance

- ✓ Every crop must be lodging resistant
- ✓ There are two directions for breeding for lodging resistance; Streng woody stems or thin stems that will bend in the wind
- ✓ The major objective is to keep the stems from breaking
- ✓ If they are too woody, they will break the teeth on the cutter bars, it will be difficult to pick them up with a pick-up attachment, and they will bridge over the auger in a header
- ✓ Woody stems are more susceptible to lodging and breaking in the first 40 days than wiry stems
- ✓ Later in the season, wiry stems are susceptible to lodging but seldom break

5. **Weed Control**

- ✓ One of the major obstacles to mechanizing sesame is the lack of registered herbicides
- ✓ It is a general chicken/egg problem- Major chemical companies do not develop herbicides for minor crops, and a crop cannot become a major crop without an herbicides
- ✓ The problem has become more important with the advent of "Roundup Ready" cotton
- ✓ In years past, in most of Texas and Oklahoma there were manual laborers to hoe the field
- ✓ These crews are now almost non-existent for use in sesame
- ✓ An obvious solution would be to develop "Roundup Ready" sesame
- ✓ However developing a GMO crop when the largest importers in the world are anti GMO is a risky endeavor, particularly since the Asian use sesame specifically for health
- ✓ Currently the US IR4 program is in the process of clearing two herbicides for sesame, and more work is in progress
- ✓ The IR4 program is designed to approve the use of chemicals on minor crop. In the meantime, the emphasis is on planting into clean fields and cultivating

6. Crop Dry down

- ✓ When sesame plants are cut at maturity there are a few drying issues
- ✓ In shock, the outer bundles dry earlier than the inner bundles
- ✓ In windows, the plants on the top of the window dry earlier than those near the ground

- ✓ Shorter plants dry faster than the older taller cultivars
- ✓ When sesame is harvested direct, the amount of time between physiological maturity and harvest is much longer than desired
- ✓ Without a frost, this can be as much as 60 days
- ✓ In Australia, Reglone is used to dry down the crop, but Beech and Imrie (2001) state that under certain conditions this does not work well
- ✓ In the U.S. the FDA might not approve the use of Reglone on a food crop
- ✓ Dry down is important in the U.S. because sesame is grown in the summer and harvested in the fall
- ✓ The longer the crop is in the field, the shorter and cooler the days, and there is often more rain
- ✓ If there is persist warm wet weather, mold can form on the plants, capsules and seed
- ✓ In Sesaco a tremendous amount of selection pressure has been applied to enlarge the swathing window which also extends the amount of time until complete dry down
- ✓ Breeding for large seed size has also led to longer dry down
- ✓ Taking dry down notes has also been complicated by root rots
- ✓ It is difficult to distinguish between plants drying from a root rot and natural dry down
- ✓ Recently, some lines with large seed, root rot tolerance and quick dry down have been identified, and hopefully, quick dry down can be improved through breeding without having to resort to desiccants
- ✓ Desiccants will require labeling, cause concern in the health food market, and increase the cost of growing sesame

7. Capsule Loss

- ✓ When leaving sesame for direct harvest, after the leaves drop there can be rubbing of stems and branches in the wind
- ✓ There are some lines, particularly triple capsule lines, where the capsules break off the plant
- ✓ In constant winds there have been as much as 70% loss
- ✓ A strong attachment of the capsule to the stem and the angle between the capsule and stem are important
- ✓ However, capsules that hug the stem do not break off readily (and are less susceptible to hail) but they dry down slowly

8. Seed Cleaning

- ✓ As with any seed, the higher the foreign matter content, the more difficult it is to clean
- ✓ Sesame has three plant parts that can be difficult to clean: petioles, pedicles, and nectarines
- ✓ The petiole problem has been solved through defoliation
- ✓ The pedicles that hold capsules to stem should not break off
- ✓ In single capsule per leaf axel lines, there are two nectarines
- ✓ These are smaller than seed and weigh less, but in quantity, they are difficult to remove
- ✓ Beech and Imries (2001) identified the same problem in Australia
- ✓ Breeding efforts continue to reduce the size of nectarines, and hopefully, one day there will be a mutation without nectarines
- ✓ The nectarines can also be eliminated by selecting by selecting lines with multiple capsules per leaf axil

9. Planting Seed Germination

- ✓ There was a direct correlation between seed damage and germination – the higher the damage the lower germination
- ✓ Initially the standard for planting seed were set at 70% germination because it was so difficult to develop planting seed with higher germination rate
- ✓ Even damaged seed has good germination after combining, but planting is 6-8 months after harvest
- ✓ In 1980s the germination rates varied between 65% and 80%, even with the rotary combines
- ✓ The primary problem was that swathing method of harvest was used. When the plants are on the ground, if there is a hard rain, the sand/dirt will splatter on to the plants
- ✓ This sand/dirt often will travel with the seed into the combine
- ✓ As the seed is moved through a series of augers, the sand/dirt acts as an abrasive and damages the seed coat
- ✓ Presently, with direct harvest methods the germination rates vary between 75% and 95%
- ✓ One of the critical aspects is harvesting at very low moisture. The ambient humidity at harvest is a large factor in getting the lowest moisture contents
- ✓ Tarping/untarping trucks at the appropriate time can also be a factor

10.Seedling Emergence:

- ✓ One of the most difficult problems in planting sesame is that the seeds are small and should be placed precisely in the soil
- ✓ They cannot be so deep that the cotyledons never reach the surface, and yet they cannot be so shallow that the moisture around the seed is lost
- ✓ Seed damage can be a factor in reducing the vigor of the seed
- ✓ At present, there is continual selection pressure to large seeds that will have more energy to push up the soil and emerge from deeper placement
- ✓ Modern equipment with depth control is essential for sesame planting
- ✓ One of the best insurance policies for a good stand is to plant more seeds than necessary
- ✓ Two adjacent seed can push through the soil better than a single seed

XI. ECONOMICS OF PRODUCTION AND MARKETS

- ✓ Currently sesame is being imported at a price of 43 cents/lb
- ✓ This relatively high price reflects a world wide shortage. Though the market for sesame is strong, domestic production awaits the development of high yielding non shattering varieties
- ✓ However, in 1978 and 1992 sesame was grown in Yuma Arizona where the night temperature were above 100°F and in 1990 there were 21 days the temperatures were above 129° F and no problem were encountered with capsule set in those high temperatures
- ✓ The plant will shed blooms if it is stressed for moisture
- ✓ If it has been stressed for moisture and is irrigated late, some varieties will shed blooms for several days
- ✓ Sesame varieties grown for commercially require 90 to 110 days from planting to reach physiological maturity
- ✓ Another 20 to 40 days are needed to allow the plant to dry down for harvest

- ✓ A good rule of thumb is not to plant until at least a month after the last killing frost in the spring
- ✓ However, soil temperature is a better indicator of when to plant
- ✓ For good germination plant after the soil temperature at the eight inch depth at 8:00a.m. averages 68^{O}F for ten days
- ✓ Late plantings mature in less time than early plantings, however, 95 days prior to 45 degree nights and 110 days prior to frost is needed to make full

XII. PROCESSING AND MARKETING

- ✓ Imported seed is usually dehulled before shipment where hand labor is involved in removing extraneous matter
- ✓ Imported seed is brokered by firms for the processing firms who produce baked or confectionary products
- ✓ Import brokers and warehouses are generally based on the east and west coasts of the U.S.
- ✓ Market demand in the U.S. for the whole seed has been stable for 20 years
- ✓ The sesame ingredient market is expected to increase several-fold over the next decade
- ✓ "Washed-natural seed" is prepared by passing seed through an agitated wash, followed by a continuous-flow drier
- ✓ This bright, dust free un-hulled seed makes up 30% of the domestic production and is 99.97% pure for the baked goods market
- ✓ Immature or off-sized seed are removed and salvaged for oil production
- ✓ A U.S. firm (Sesaco at Paris Texas) uses several mechanical and wet processing methods to produce food –grade sesame for the U.S. markets
- ✓ Field-run, unhulled seed is 70 to 95% pure
- ✓ The seeds is mechanically cleaned in a series of screening, de-stoning, and other processing steps to remove extraneous plant and foreign matter
- ✓ About 10% of this "cleaned natural seed" moves directly into food use as whole seed to be blended into flour for baked foods
- ✓ The remaining seed is cleaned further in either a washed or decortication/de-hulling wet processes
- ✓ At least two growers and two firms produce and process sesame in Texas for organic markets at premium process
- ✓ "De-hulled seed" is produced by a wet/chemical process to remove hulls
- ✓ The hulls surrounding the seed are removed in a wet process using caustic soda (a sodium hydroxide solution) to loosen and remove hulls from the seed
- ✓ The decorticated hulls are discarded
- ✓ The bare seed is then washed and dried to produce a premium confectionary product
- ✓ These de-hulled seed make up 50% of the U.S. market for use in specialty baked goods or added as a topping after buns, rolls, or crackers are baked
- ✓ Currently less than 10% of the total U.S. production into oil and flour

Table 6. Sesame Processing and Uses in the Domestic Food Market in the U.S.

Products	Processing	Seed & End Uses	% of U.S. Production
Field-run seed	Combine harvest	70 to 95% pure seed	100
Cleaned natural seed (hulls remaining	Seed is mechanically processed to remove extraneous plant & foreign matter	99.9 % pure. Whole & cracked seed used in flour mixes and for baked goods	10
Washed natural seed (hulls remaining)	Cleaned natural seed is wetted, agitated & then dried	99.7 % pure. Bright seed used for baked goods	30
De-hulled seed (hulls removed)	Cleaned natural seed treated to remove hulls color. Sorter removes dark seed	99.99 % pure seed. Confectionary & topping for baled goods	50
Oil & Flour	Cull and off-color seed are pressed for oil	Oil for salad dressing Meal for specialty flour	10

- ✓ Traditionally, these products were produced from cracked, off-sized, or otherwise cull seed that were separated during the preparation of premium grade seed for other uses
- ✓ Sesame contains 52 to 75% oil which is extracted in a multi-step press processes
- ✓ In contrast to most other oil seeds, (such as cottonseed or soybean), sesame oil is not extract with a solvent but rather with pressure in a mechanical expeller and is not heated
- ✓ This pure, virgin oil is preferred by food handlers. The oil is blended with other vegetable oils for salads and other food
- ✓ Another use for the sesame oil in the U.S. is a medical carrier in medical injections and in the cosmetics industry
- ✓ This oil is extracted from number one quality seed
- ✓ Oil for pharmaceutical uses in further refined
- ✓ Many cosmetics include sesame oil because of its antioxidant properties
- ✓ After oil extraction, the resultant meal contains 50 to 55% protein and is blended with other flours for food uses
- ✓ The flour is an emerging market with significant growth potential
- ✓ The antioxidants in sesame increase the shelf-life of the product baked with sesame flour
- ✓ Sesame Processing and Uses in the Domestic Food Market in the U.S.

XIII. CROP IMPROVEMENT

- ✓ Sesame yields are variable depending upon the growing environment, cultural practices, and cultivar
- ✓ Worldwide yields averaged about 340 kg/ha in 1986, however, as high as 2,250 kg ha^{-1} have been obtained in test plots in Texas (Brigham, 1985)
- ✓ major contributing factor to low yields in Sesame is that the seed capsules shatter causing a loss of large amounts of seeds, particularly when the crop is machine harvest
- ✓ Sesaco Corporation in Yuma, Arizona, has developed semi-indehiscent commercial cultivar with yield ranging from 600 -1,600 kg/ha (Brigham, 1987)
- ✓ A panel of sesame experts met and summarized plant breeding objectives for sesame improvements (Ashri, 1987). These include:
- ✓ Improved seed retention in the capsule
- ✓ Increase oil content
- ✓ Uniform maturity and
- ✓ Diseases resistance

XIV. APPROACH FOR CROP IMPROVEMENT

1. Mutation breeding
2. Tissue culture and genetic manipulation
3. Sesame plants can be regenerated from shoot apical meristems and hypocotyl segments and grown to maturity in less than four months. This provides an opportunity for genetic transformation using Agrobacterium as the vector
4. Conventional Breeding

A. Floral Characteristics

- ✓ Sesame flowers appear in clusters borne on short peduncles at the base of leaf axils
- ✓ Individual flowers have as small calyx divided into five segments 3 to 7 mm length (Fig. 1)
- ✓ The corolla is tubular, with an entire upper lip and a three-lobed lower lip, the middle one of which is larger than the two lobes
- ✓ The corolla tube is open at the distal end, generally curved downward, and measures 15 to 35 mm in length
- ✓ The calyx is usually green, but in rare cases is red-brown or slightly yellowish
- ✓ The corolla tube is light green and folded closed at the distil end while the flower is developing
- ✓ When the flower is fully extended, the corolla is usually pale white, but is sometimes rose or of greenish hue and in rare cases red-brown
- ✓ The sesame flower typically has four green-white stamens arranged in pairs, one pair shorter than other, attached to the upper lip of the corolla tube
- ✓ In some cases, a fifth stamen is present which is usually nonfunctional
- ✓ The anthers are white or yellow and 1 to 2 mm in length
- ✓ In male sterile types of sesame they remain green, closed and underdeveloped in size throughout anthesis
- ✓ Pollen grains are light yellow. In the common bicarpellate sesame, the style is cylindrical ending in a stigma with two hairy lobes (Fig. 3)
- ✓ Before, the flower opens, the four anthers are closed and are below the level of the stigma. About 2 hours before flower opening, the filaments start to elongate rapidly and as

the higher positioned two anthers reach the level of the stigma, they burst longitudinally and release their pollen at about the time the flower opens

- ✓ The second pair of anthers then burst in quick succession
- ✓ At about the same time, the two hairy lobes of the stigma separate and receive large quantities of pollen. Thus, pollination take place shortly before or shortly after flower opening
- ✓ The stigma is receptive 24 hours prior to flower opening, Therefore, thrips or other insects carrying pollen could contribute to natural cross-pollination if they entered prior tot eh time its own pollen becomes available for self pollination
- ✓ The probability for natural cross-pollination increase s on cloudy, cool, damp morning when pollen release is often delayed until 1 to 2 hours after flower after flowers open

B. Equipment Needed

- ✓ A pair of tweezers used to detach anthers and brush them against stigmas for crossing or selfing sesame
- ✓ In rare case a long sharp needle may be useful in splitting partially closed anthers and in straightening bent styles
- ✓ Soda straws are inserted over crossed flowers to eliminate unwanted cross pollinations
- ✓ Jeweller's tags are tied to those flowers to identify each cross
- ✓ Grocery type 212 x 35 cm brown paper bag secured to the plants by twistems, or staples are used for selfing sesame in the field

C. Preparation of the Female

- ✓ In its early stage of development, the sesame flower has a green corolla, which is thick and rigid
- ✓ As it enlarges and approaches the pollination stage, the corolla color changes progressively from green to white and its walls become thinner and softer
- ✓ A flower at proper stage of development for emasculation, the corolla tube is still closed, but its margins are not zipped together tightly
- ✓ It may have a greenish hue towards the base, but it is pale white towards the top
- ✓ Inside the corolla, the anthers are at about the height of the stigma;
- ✓ They are pale. white turgid, with a moist surface, but have not ruptured yet
- ✓ To emasculate sesame flowers, remove the entire corolla while it is still greenish and closed, instead of removing each anther individually
- ✓ In doing so, the stamens which are attached to the corolla is also removed
- ✓ Because the stigma is receptive a this stage of development, it is advisable to check each corolla that is removed to verify the anthers inside are still closed
- ✓ On rare Occasions, some anthers may burst open and release pollen prematurely
- ✓ This inspection is not time consuming and removes any suspicion of accidental self-pollinations which could ruin an entire experiment, if they remain unnoticed. The style and stigma are left intact to complete their development until the next morning when the cross is actually made
- ✓ A bright colored 8 x 16 mm jeweller's tag is tied loosely around each emasculated flower
- ✓ Tags help breeder to identify the emasculated flowers without wasting time
- ✓ If the female parent has three flowers per axil, the middle flower at each axil is emasculated while the two side flowers are removed with tweezers

- ✓ It is not necessary to protect emasculated flowers against accidental pollination in an insect-free greenhouse
- ✓ In the field, emasculated flowers are protected by inserting a 4 to 6 cm long piece of paper soda straw over the style

D. Pollination

- ✓ The distal end of this straw is either folded or stapled to block the entrance of pollinating insects
- ✓ In field plantings of sesame, flowers generally is determinate, with most flowers opening
- ✓ Perform emasculation in the late afternoon at 1600 to 1800 hours on the day before flowers are expected to open, and pollination early the next morning at 0700 to 0900 hours
- ✓ Flowers in the greenhouse is indeterminate, emasculations and pollinations may be made at the almost any time that pollen is available and female parent flowers are at the right stage
- ✓ The stigma is receptive at the time flowers are emasculated; thus, if pollen is available, crosses may be made at the same time as emasculations
- ✓ Open flowers of the predetermined male parent are cut off and placed in a plastic cup
- ✓ Open anthers covered with pollen are pinched from these flowers with tweezers and lightly brushed against the stigma of the emasculated flowers

E. Factors Affecting Efficiency

- ✓ Sesame cultivars differ in the number of days required to flowering
- ✓ Crossing between early and late flowering types can be accomplished by staggering planting dates
- ✓ Genetic markers are used to identify hybrid seeds or plants. There is a strong association between capsule indehiscence and leaf enations, i.e., leaf –like out growths
- ✓ Appearance of leaf enations on the leaves of 2 to 4 week-old seedlings has been used universally for early identification of dehiscent and indehiscent strains (Fig. 8)

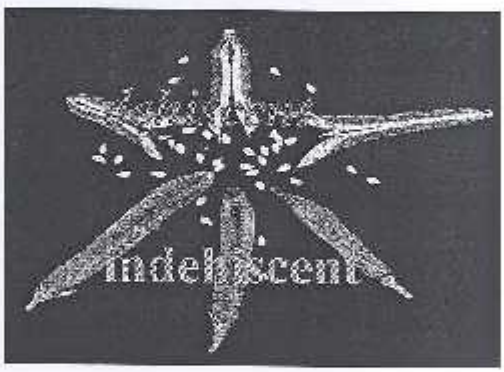

Fig 8. Sesame strain

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